PROCEEDINGS OF THE FIFTH WORKSHOP ON

SUSTAINABLE HORTICULTURAL PRODUCTION IN THE TROPICS

23RD TO 26TH NOVEMBER 2005

AGRICULTURAL RESOURCES CENTRE, EGERTON UNIVERSITY

P. O. BOX 536, EGERTON, KENYA

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Agriculture and Technology

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Institute of Plant Diseases and Plant Protection,
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PREFACE

The horticultural subsector of Agriculture is important in foreign exchange earning, food security assurance, industrial raw materials provision, wealth and employment opportunities creation, as well as landscape beautification in many tropical countries. These benefits are in line with a number of the United Nation's Millennium Development Goals. In Kenya, horticulture is currently the second leading foreign exchange earner after tea. However, in most tropical countries the vast potential of horticulture remains untapped and production activities border on not being sustainable. These two scenarios gave impetus to this workshop on Sustainable Horticultural Production in the Tropics to redress the deficiencies in tropical horticulture.

For tropical horticulture to remain competitive in global markets, it must recognise and respond to demands of safe food and environment. Risk factors during growing of horticultural crops include pest attack and pesticide residues on produce. Pest attack reduces plant health, whereas organic crop production alleviates dangers posed by synthetic pesticides used in pest management. Therefore, appropriate technologies need to deviced and disseminated to help farmers in the tropics produce healthy and high quality crops organically.

The first workshop under the topic of sustainable horticulture was held from 3rd to 6th October 2001 at JKUAT, Juja-Kenya. It emphasised export crops, biotechnology and African indigenous vegetables. The second workshop was held at the same venue from 6th to 9th August 2002 to address reduced pesticide and efficient water and nutrient use in horticultural crop production. The third workshop was held at Maseno University, Maseno-Kenya from 26th to 29th November 2003, focusing on African indigenous vegetables. The fourth workshop was held from 24th to 26th November 2004 at Moi University, Eldoret-Kenya to address organic farming of horticultural crops in the tropics.

In line with previous workshops, the theme of the fifth workshop held at Egerton University, Egerton-Kenya from 23rd to 26th November 2005 was 'Plant Health in Organic Horticultural Production Systems in the Tropics'. The first two days spent on plenary, poster and exhibit presentations, as well as convening of the Annual General Meeting for the Horticultural Association of Kenya that has emerged as the umbrella body for sustenance of this series of workshops. During this fifth workshop each plenary session was boosted by inclusion of an opening 20-minute keynote lecture summarizing core issues under each subtheme. The keynote lectures were then followed by 10-minute oral presentations. At the end of each session consolidated discussion of all presentations was held. Subsequently, deliberations of working groups formed previously were postponed to a future date. Poster presentations and exhibitions of industrial products were held during break out sessions. The field trips on the third and fourth days took participants to five horticultural production and processing sites in Nakuru District of Kenya.

The subthemes for the fifth workshop were: Disease management for plant health; Insect pest management for plant health; Appropriate technology and cropping systems for plant health; Economic, environmental and socio-cultural issues in plant health; Indigenous crops; Quality aspects of crops for export; and Genetic resources of horticultural crops and plant biotechnology. Copies of these proceedings and information on this workshop is published at: http://www.gartenbau.uni-hannover.de/gem/SVePiT/index_svepit.

The workshop organizers thank all the participants who made the workshop a success and the authors who presented papers that enabled publishing of these proceedings. Profound gratitude goes to DAAD for the much needed financial support. We thank the Acting Vice Chancellor of Egerton University, Prof. E. M. Wathuta for officially opening the workshop, and Prof. L. S. Wamocho for timely closing remarks. The long-standing collaboration with the Institute of Biological Production Systems and Institute of Plant Diseases and Plant Protection, Leibniz Universität Hannover, Germany has made these workshops a great success. Special thanks go to the Horticultural Association of Kenya for its pivotal contribution in planning of the workshops. We are indebted to the chairpersons and rapporteurs of sessions, the master of ceremony and receptionists for their tireless hardwork. Our acknowledgement cannot be complete without recognizing the enabling environment accorded by Egerton University, support provided by JKUAT and HCDA, and the uniting leadership received from Prof. S. G. Agong, the DVC (APD) of JKUAT. All the rest who supported the planning and holding of the workshop either directly or indirectly are gratefully acknowledged.

THANK YOU ALL!

OFFICIAL OPENING SPEECH

Prof. E. M. Wathuta, Acting Vice Chancellor, Egerton University, During the Official Opening of the Fifth Workshop on Sustainable Horticultural Production in the Tropics, Held from 23rd to 26th Nov. 2005 at Egerton University, Njoro, Kenya.

Acknowledgement

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Team Leader, Leibniz Universität Hannover, Prof. Hartmut Stuetzel

Horticultural Industry Representatives and Stakeholders

Distinguished Guests, Participants, Staff, Ladies and Gentlemen

Workshop Theme

I am greatly honoured to welcome you here today for this Fifth Workshop on Sustainable Horticultural Production in the Tropics. This year's theme is 'Plant Health in Organic Horticultural Production Systems in the Tropics'. This is one of the most crucial issues in organic crop production, since producers in the tropics are challenged to reduce pesticide inputs, to meet consumer-safety demands, but still keep crops healthy. Besides, insect pests and diseases cause poor health and loses in crop production, reduce quality of produce, and increase costs of production. On the other hand, control of plant diseases and insect pests is successful, effective, and economical when all pertinent information is considered.

In recent years, awareness and interest in organic farming has been on the increase worldwide due to rising market demand and concern about side effects of chemicals to the environment. Use of natural pesticides is not new to farmers; *Tephrosia vogelii*, *Neuratanenia mitis*, pyrethrum powder, tobacco extracts, tobacco dust, chillies, black pepper, pine leaf ash, fresh and dry cow dung are some of those commonly used. Other non-chemical pest control measures such as biological and cultural practices are also applied though not adequately. However, most of the practices rely on farmer's indigenous knowledge, whereas most of the research conducted in the tropics is not conclusive. Thus, there are few scientific recommendations on the types, methods and rates of application for the common natural pesticides.

To increase productivity of organic crops, there is a need to improve research to provide scientific verification of farmer's experiences. Particular emphasis should be placed on dissemination of technical information already available in different research and training institutions to organic producers. The purpose of this workshop is, thus, to provide you with a forum for sharing and learning from research findings that different groups have developed in an attempt to realise the theme of this workshop, and then convey them to horticultural practitioners.

Organisation

I note that the workshop has been organised by the Horticultural Association of Kenya (HAK) and its collaborators. The Association was founded in 1997 and registered in November 2001. Its objectives are diverse and laudable. They include: promotion of horticultural science in Kenya; sustainable and environment-friendly horticultural production; exchange of scientific information and technology through conferencing and publication; capacity building; professionalism in horticulture; formation of local branches; affiliation to and co-operation with regional and international professional organizations; utilization of local expertise and resources; and solicitation of funds for support of the Association.

National Horticultural Performance

Horticulture is currently the fastest growing sub-sector in the agricultural industry. Its growth rate has ranged from 10 to 20% annually in production, exports and earnings over the last 5 years. It is, thus, a major gross domestic product contributor and second foreign exchange earner after tea through the 50% export earnings it realises.

Ladies and gentlemen, horticultural exports constitute only 4% of the total production, while 96% is consumed locally; thus immensely contributing to food security creation. Fruits and vegetables cater for about 11% of the urban household food consumption in Kenya. The growth of the subsector has seen exported horticultural produce rise from 1,400 tonnes in 1968 to over 133,000 tonnes in 2004, earning KES 40 billion, out of 4.4 tonnes, equivalent to KES 82 billion gross production and earnings, respectively.

The major export markets absorbing Kenyan horticultural produce are the European Union Countries, which take 80% of total exports. Kenya is the leading exporter to the EU, by contributing 25% of imports. Other markets for Kenyan produce are: The Middle East, South Africa, Norway, USA, Canada, and Japan. These destinations need to be protected through all-round efficient and high quality performance. Ladies and gentlemen, in job creation, the subsector employs 80% of the population either directly or indirectly. Small-scale producers are important in the subsector, with their population approximating 1.8 million in the domestic market, and their contribution to exports reaching 60% of the total. The private sector has also contributed to the steady growth in the subsector, as the Government provided structural and macroeconomic reforms.

Constraints to Horticultural Growth

The most common constraints to exploitation of the full potential of the subsector include:

1) Poor infrastructure and road network, as well as adverse weather
2) Declining productivity on farms and high perishability of produce
3) External market competition from African, Caribbean & Pacific countries
4) Tedious and stringent external market regulations
5) High freight and tax charges, disease and insect pest incidences
6) Inadequate pest-free seeds, planting materials and rootstocks
7) Lack of farm inputs and credit facilities

Strategies For Sustainable Growth

For Kenya to maintain its leading position it must maintain its competitive edge through:

1) Research intensification
2) Value addition to produce
3) Compliance with regulations
4) Diversification of products, markets and extension services
5) Intensification of market intelligence
6) Enhancement of produce quality
7) Improvement of infrastructure and crops

I believe authors in this year's workshop have aptly captured these strategies ready for sharing and dissemination. I, therefore, congratulate the workshop planners for this achievement and urge them to keep up. Ladies and gentlemen, I now declare this workshop officially opened.

Thank you!

KEY NOTE ADDRESS

Plant Health in Organic Horticultural Production Systems in the Tropics

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Definitions

The terms "organic" agriculture and horticulture are sometimes used without a clear definition regarding their differential properties in comparison to "conventional" production. Although there is no clear scientific definition, since 1991 there is at least a fairly clear political description of what is considered organic plant production by EU authorities. The framework of organic production in Europe is given by EU regulation 2092/91 which emphasizes the need for prevention through agronomic means since the range of permitted substances for direct intervention is restricted. In essence, organic production is now defined by the restriction to a limited number of substances, which may be used as inputs. In its Annex II the regulation contains positive lists of these substances (Tables 1-5).

Table 1: Substances permitted for use in plant protection by EU regulation 2092/91

Name	Description; compositional requirements; conditions for use
Azadirachtin extracted from *Azadirachta indica* (Neem tree)	Insecticide; need recognised by the inspection body or inspection authority
Beeswax	Pruning agent
Gelatine	Insecticide
Hydrolysed proteins	Attractant; only in authorized applications in combination with other appropriate products of this Annex II, part B.
Lecithin	Fungicide
Plant oils (e.g. mint oil, pine oil, caraway oil).	Insecticide, acaricide, fungicide and sprout inhibitor.
Pyrethrins extracted from *Chrysanthemum cinerariaefolium*	Insecticide; Need recognised by the inspection body or inspection authority
Quassia extracted from *Quassia amara*.	Insecticide, repellent
Rotenone extracted from *Derris spp.*, *Lonchocarpus spp.* and *Terphrosia spp.*	Insecticide; need recognized by the inspection body or inspection authority.

Table 2: Microorganisms permitted for biological pest control by EU regulation 2092/91

Name	Description; compositional requirements; conditions for use
Microorganisms (bacteria, viruses and fungi) e.g. *Bacillus thuringensis, Granulosis virus,* etc.	only products not genetically modified in the meaning of Directive 90/220/EEC

Table 3: Substances permitted for use in traps and/or dispensers for biological pest control by EU regulation 2092/91

Name	Description; composition requirements; conditions for use
Diammonium phosphate	Attractant; only in traps
Metaldehyde	Molluscicide; only in traps containing a repellent to higher animal species; only during a period expiring March 2006
Pheromones	Attractant; sexual behaviour disrupter; only in traps and dispensers
Pyrethroids (only deltamethrin or lambdacyhalothrin)	Insecticide; only in traps with specific attractants; only against *Batrocera oleae* and *Ceratitis capitata wied;* need recognized by the inspection body or inspection authority

Table 4: Preparations to be surface-spread between cultivated plants in organic farming by EU regulation 2092/91

Name	Description; compositional requirements; conditions for use
Iron (III) orthophosphate	Molluscicide

Table 5: Other subtances from traditional permitted for use in organic farming by EU regulation 2092/91

Name	Description; compositional requirements; conditions for use
Copper in the form of copper hydroxide, copper oxychloride, (tribasic) copper sulphate, cuprous oxide	Fungicide until 31 December 2005 up to a maximum of 8 kg copper per hectare per year, and from 1 January 2006 up to 6 kg copper per ha per year
Ethylene	Degreening bananas
Fatty acid potassium salt (soft soap)	Insecticide
Potassium alum (Kalinite)	Prevention of ripening of bananas
Lime sulphur (Calcium polysulphide)	Fungicide, insecticide, acaricide; need recognised by the inspection body or inspection authority.
Paraffin oil	Insecticide, acaricide
Mineral oils	Insecticide, fungicide; only in fruit trees, vines, olive trees and tropical crops (e.g. bananas); need recognized by the inspection body/authority
Potassium permanganate	Fungicide, bactericide; only fruit trees, olive trees, vines.
Quartz sand	Repellent
Sulphur	Fungicide, acaricide, repellent

Agronomic principles

These restrictions preclude the use of many powerful agrochemicals, fertilizers as well as pesticides, limiting the possibilities for direct intervention by e.g. readily available mineral fertilizers which can be used to more or less instantaneously accelerate growth, or synthetic fungicides which can be used immediately control the spread of a fungal disease. Therefore, organic farming has to rely much more on self-regulating forces and prevention, mainly through the proper use of agronomic means like

- Crop rotation
- Cultivar selection
- Tillage
- Mulching
- Weed control
- Irrigation
- Fertilizer application

Thereby, organic farming is much more a systems management than a short-term intervention policy. It therefore requires more systems thinking than conventional farming. One important systems approach is the concept of plant health management instead of short-term interventions in the form of simple disease control.

Aspects of plant health

In the triangle between the plant, pests/diseases and their antagonists a number of possibilities for interference exist (Figure 1).

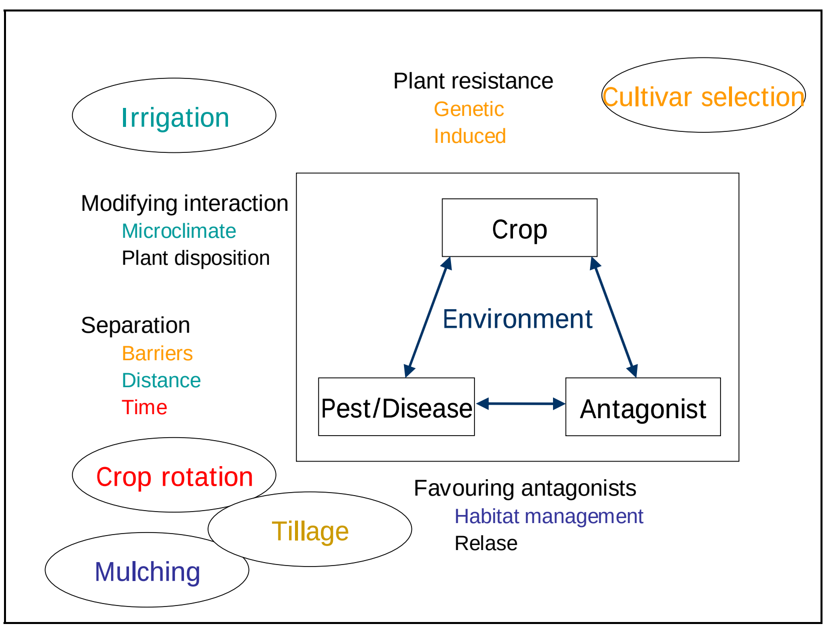

Figure 1: Aspects of plant health

The susceptibility of the crop can be influenced by targeted use of genetic plant resistance through the choice of an appropriate cultivar. It is always important to ask questions like

- Which pests and diseases are prevalent?
- Are there resistances available?
- Do resistant varieties have agronomic disadvantages?
- Do I need pure cultivar crops?

Induced resistance can develop after a visible or latent infection with a disease. It is also one mechanism contributing to the disease-suppressing action of mixed crops. Examples of positive effects of mixed crops on pests are listed below:

- *Allium* species with leaf crops → aphids
- *Allium* species with carrots → carrot fly
- Beans with potatoes → Mexican bean beetle
- Potatoes with flax → Colorado potato beetle
- *Apiaceae* with legumes or Brassicas → predatory wasps
- Thyme with *Brassicas* → cabbage butterfly

The interaction between plants and pests can be modified for example by adjusting the microclimate or the disposition of the plant. An important aspect of disease control is the separation of pest and diseases in a temporal (e.g. crop rotation) or spatial (e.g. regionalisation) sense. Antagonists can be favoured through proper habitat management, e.g. with mulches, through banker plants etc. Antagonists can also be released, which is more common in protected production than in the open field.

All the means proposed above have also other effect than the ones for which they are used. For example, planting a mulch crop to promote beneficial insects may create improved conditions for fungal diseases. Therefore, it must be carefully analysed whether positive or negative aspects of an agronomic measure prevail.

The list of options is by far not exhaustive. However, it makes clear that organic framing deals with a complex set of components and interactions. It is systems management rather than action and reaction.

Feedback

Question: ***Is the high cost of organically produced horticultural produce not a hindrance to accessibility and volume of consumption for an average consumer?***

Answer: Determination of this would require a cost comparative study. On one side, the more expensive organic products preclude the very poor population from consumption. On the other side organic production creates increased income for the farming community.

Question: ***Your presentation has not alluded to risk of allelochemical interference in multiple cropping systems?***

Answer: To vigorously test for allelopathic effects in the field situation is very difficult. Therefore, many reports on "allelopathic" effect may be questionable. Therefore, I have not included this topic in the keynote address presentation.

Question: ***Thank you for the very interesting presentation. You have mentioned that there is a list of acceptable products that are allowed for crop protection for organic farming under EU regulations. Would local plant extracts or other substances be allowed for application and what are the procedures for this approach?***

Answer: The EU regulation has a "positive list". All products not contained in this list are not allowed. This is to make sure that the intentions of the EU regulation are not cancelled through the back door.

Questions: ***How do the unique climatic conditions and small land sizes affect adoption of organic farming in the tropics in general? How can these be addressed with respect to pest management and nutrient recycling on farms?***

Answers: ***The warm climate means faster degradation, but also higher productivity. This degradation results in short and faster cycles in the tropics compared to temperate climates. Small land sizes give good possibility for utilising crops with different resistances, such as intercropping situation on a higher scale.***

Question: ***I have had a chance to visit farmers in Siaya, who practice minimal or no tillage crop rotation. They use hyacinth bean and canavalia to protect the soil and actually after a year they have realised good yields. My worry is the hardpans that develop. What can be done about them?***

Answer: It is important to enhance biological tillage mainly through plant roots and earthworms. The gradual buildup of organic matter additionally improves soil structure.

Question: ***In your presentation you showed that intercropping has an advantage in terms of disease and insect pest control. Are these studies accompanied with sustainability of intercropping using LER?***

Answer: Intercropping requires a careful choice of the intercropped species with respect to the objective and the conditions. But usually one gets a Land Equivalent Ratio greater than 1 in intercropping.

ORAL PAPERS

Biological Control of Bean Diseases Using Microorganisms

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Abstract

Although the commercial use of biological control agents for plant disease control is not yet a reality in Africa, it has tremendous potential for application to reduce the losses due to plant diseases. Biological control agents, such as species of *Trichoderma*, *Fusarium* and *Aspergillus*, have shown their effectiveness in reducing damage, at least in research station trials. Specifically *Trichoderma* spp. have successfully been used in experiments as biological control agents of various crops in Africa, although beans (*Phaseolus vulgaris*) are not mentioned in the 2003 overview by Bandyopadhyay and Cardwell. In the talk, some examples to control diseases of beans with microorganisms, especially *T. harzianum*, will be discussed. The examples will include soil-borne diseases (the most frequent application), but also leaf diseases. *Rhizoctonia* root rot caused by *Rhizoctonia solani* is a widely distributed bean disease, which can be controlled by *Trichoderma* species. In greenhouse experiments, the effects of soil moisture and sowing depth on bean root rot and its control by *T. harzianum* were studied, showing that the antagonist protected bean seedlings from pre-emergence damping-off, reduced disease severity and increased plant growth in the presence of *R. solani*, especially in moist soil. Bean rust, caused by *Uromyces appendiculatus*, is a chronic, yield-limiting leaf disease of beans worldwide. There is experimental evidence that bean rust can be controlled by bacterial strains. Our results of leaf disc assays and culture filtrate experiments indicate that control of bean rust by *T. harzianum* is possible, probably due to the production of antibiotic metabolites, which inhibited normal germ tube development. Although the experimental examples are showing the potential of microorganisms in plant disease control, much more work is needed to demonstrate the efficacy of biological control agents not only in the laboratory but also in the field. In the future, microbial antagonists will be a valuable component in integrated management programmes.

Key words: Bean, biological control, diseases, microorganisms

Feedback

Question: *How was* Rhizoctonia *applied in the potted plant experiment?*

Answer: It was grown on rice husks and incorporated in the potting media.

Question *Was the* Trichoderma *applied as spore suspension in water?*

Answer: Spore suspension with no co-fomulants.

Question: *Did you establish whether* Trichoderma *from different companies were indeed different strains or just different concentrations?*

Answer: The *Trichoderma* strains were actually different because the material was extracted from the different company products. The same concentration was used for all trials.

Question: *Is it possible to combine different* Trichoderma *strains to get positive effect on different diseases?*

Answer: Yes. The most effective system will be to spray a mixture, because there won't be a 'universal' strain.

Question: *Conditions that favour growth and good performance of* T. harzanium *(high leaf humidity) can also cause occurrence of other pathogens such as the one causing leaf mold. How can you avoid this?*

Answer: In case the pathogen and the antagonistic microinjections have the same ecological requirements, biological control may be difficult or impossible. Additional other control measures are then needed.

Resistance Expression to Stem Canker Pathogen in a Local Brassica Species

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Abstract

An assessment was made to investigate the incidence of fungal pathogens in *Brassica* crops in and around Chepkoilel in Uasin Gishu District. Each experiment consisted of five randomized blocks, which were further subdivided into sub-plots measuring 6m x 17m in five sites. The study indicated that most of the *Brassica* species that are grown have a high susceptibility to fungal pathogens, which are responsible for a substantial amount of losses incurred in the farmers' fields. The assessment further indicated that stem canker was the most prevalent fungal disease. *Leptosphaeria maculans*, the causal pathogen was used in re-inoculating the host. It was possible to re-isolate the pathogen from the inoculated host. Through pathogenicity tests, two local *Brassica* varieties were identified to have some resistance to the pathogen. All test plants were raised in pots using sterilized soil with no fertilizers added and maintained in a glasshouse. Intraspecific hybridization within *B. oleracea* was done to transfer resistance genes to two susceptible cultivars. The segregating F_2 progeny indicated that two and three genes were involved in determining resistance, while segregating backcrosses confirmed the three genes.

Key words: Blackleg, *Brassica* species, disease, pathogen, resistance, stem canker

Introduction

Breeding and selection has increased the range of *Brassica* species that has made it possible for them to be grown in other climatic regions including the high altitudes of the tropics. *B. napus*, an allotetraploid of the parental species *B. rapa* and *B. oleracea*, probably originated recently through spontaneous crossing of its two parents (Mc Naughton, 1976a). *Brassica rapa* consists of a large number of morphological forms, which interbreed and hence are considered subspecies (Oost, 1986). The oilseed forms were domesticated from the wild types (ssp. *Rapa*) in Afghanistan and in the Mediterranean (Mc Naughton, 1976b, Prakash and Hinata, 1980). Fodder cultivars and turnips (ssp. *rapifera*) could probably have originated from the wild type (Zeven and de Wet, 1982) and the leafy forms are likely to have originated from Oleiferous varieties introduced into China (Prakash and Hinata, 1980). In *B. oleracea*, the cultivated forms probably originated from a variety of wild species.

Most of the *Brassica* crops grown in Kenya are utilized as vegetables. Kale (*Brassica oleracea* var. *acephala*) is the most popular leafy vegetable in Kenya as well as in several other parts of East Africa (Chweya, 1984). The majority of the population utilizes the kales as green vegetables. Cabbage is the next popular variety used by many people as a vegetable crop. The other *Brassica* species utilized in smaller quantities include cauliflower, broccoli, Brussels sprouts, turnips, etc. A range of fungal pathogens affects the cultivated Brassica crops. The species of *B. rapa* including the wild *Brassica* species are known to posses resistance genes against most pathogens.

This study aimed to introduce genes for resistance to stem canker pathogen on the popular *Brassica* species from resistant species. This was done through intraspecific hybridization within *B. oleracea*. The study also aimed at investigating the inheritance of resistance to the pathogen. The work was undertaken with the realization that problems exist in the growing of Brassica crops by the farming community in Kenya and that: fungal pathogenic infection is one of the main causes of low yields; little is known concerning the main fungal pathogens; control of the diseases is hampered by lack of information concerning resistance; and highly susceptible species are currently in use.

Materials and Methods

Field collection of diseased material was done at the Chepkoilel Campus, Moi University. Chepkoilel Campus site has an altitude of 2180m above sea level. Procured seeds of different varieties were raised in the nursery. Seeds of six varieties were selected which included *Brassica oleracea* L. var. *capitata* (Cabbage-C.M., Golden Acre, Drumhead), *B. oleracea* L. var. *acepala* DC (kale, collards, 1000 headed). The seeds were sown thinly and covered lightly with good loam soil.

Incidence of disease on the crop was recorded as either presence (+) or absence (-). Disease severity was determined using six score categories, i.e., 0=0%, 1=1%, 2=5%, 3=10%, 4=25% and 5>50% plant area infected (Jones, 1987; Sutherland et al., 1996). Disease assessment was done at weekly intervals throughout the growing season. Seedlings at two-leafed stage were transplanted from the nursery to the field plots for re-inoculation with the pathogen. The field plots were prepared in a randomized complete block design. The field plot was divided into blocks each with five plots. The plots were subdivided into subplots measuring 6 m x 17 m, each with 280 plants, planted in ten single rows, with a spacing of 60cm x 60cm. Each variety was transplanted into two plots. Two weeks after transplanting, the seedlings were inoculated. The second set of plots was left uninoculated to act as controls. Records were made on symptoms development and were compared with that of uninoculated plants. The disease severity was assessed visually on a 0 to 5 scale based on symptoms development. A particular host variety was considered susceptible if it had more than 50% plant area infected; resistant if there were no observable symptoms or partially resistant if 1 to 25% plant area was infected.

Intraspecific Crosses

The resistant *B. oleracea* var. *capitata* L. and *B. oleracea* var. *acephala* were used in reciprocal crosses. Seeds of the parental material were sown in 9cm diameter plastic pots. At the seedling stage, they were transferred and re-potted in larger pots containing fresh soil. Two lines of *B. oleracea* var. *acephala* DC, Collards and Kale were used as the female parents while three of *B. oleracea* var. *capitata* (CCM, CGE and CGA) were used as the male parents in the crosses. Buds were emasculated just before opening. During emasculation, all the open flowers were removed from the inflorescence, thereby eliminating accidental self-pollination of emasculated flowers and preventing accidental harvest of selfed seeds. The underdeveloped buds were left on the plant and emasculated when about to open. Anthers were removed with forceps and emasculating scissors, as described by Nieuwhof (1969). The six undehisced anthers were removed with forceps and discarded. Petals and sepals were left intact in order to protect the stigma.

As soon as the plants started flowering, they were covered with perforated cellophane bags in order to isolate them from stray pollen. Before pollinations, the fingers were moistened with 70% ethanol to kill any stray pollen. Forceps and other pollination aids were also decontaminated to kill live pollen. All open flowers were discarded. Just-about-to-open buds of the female parent plants were emasculated through removing the anthers and leaving the stigma intact. The anthers containing abundant pollen were taken from the male parent plant and then dusted onto the mature stigma of the emasculated bud. The pollinated plants were again covered with perforated cellophane bags until the seeds were able to set. Once the seeds had sufficiently dried up, the cellophane bags were removed and the seeds harvested. The harvested seeds were kept in small envelopes, labeled and stored in the fridge at 4^oC until required.

The F_1 seeds were sown in sterilized soil packed in polythene bags. After germination and at two-leafed stage, the seedlings were thinned to 3 seedlings per bag. The remaining seedlings were inoculated with the suspension of the pathogen. A total of 150 seedlings were inoculated and a similar number were left un-inoculated to act as control. After a period of six weeks, both the inoculated and un-inoculated plants were removed and examined for symptoms development.

The F_1 seeds obtained from intraspecific crosses were sown in plastic pots. At the seedling stage, they were repotted in large pots. All the buds about to open on the female F_1 parent plants were emasculated and the anthers containing abundant pollen were taken from the male parent plant represented by the F_1 plants and then dusted onto the stigma of the emasculated buds of *B. oleracea* var. *acephala* DC plants. After pollination, the plants were re-bagged to avoid any stray pollen reaching them and then tagged and labeled to indicate the two parents crossed together. In the development of the F_2, the F_1 plants were simply covered with the perforated cellophane bags. The covered plants were regularly shaken to ensure that pollen comes in contact with the stigma.

The F_2 population and the backcrosses were screen using the pathogen. 250 seedlings of each of the F_2 and backcrosses were transplanted into plastic pots and then inoculated with 2ml suspension of the pathogen as described earlier. A similar number of plants were left un-inoculated to act as control. The plants were scored for symptoms development six weeks after inoculation. The inoculated plants were scored as described earlier. The scores obtained were then used in calculating the observed genetic ratios. X^2 values were calculated using the formula: $X^2=\sum(O-E)^2/E$, where O is the observed number and E the expected number.

The probability of obtaining the observed genetic ratios was determined to check whether any significant difference exist in the obtained genetic ratios from those of the expected representing 1,2 and 3 gene models. This was in turn used in determining the number of genes involved in the resistance.

Results and Discussion

Assessment of *Leptophaeria maculans* shows the most susceptible varieties to be Drumhead (16.8%), Cabbage-C.M. (10.7%) and Collards (9.1%). The varieties, which were less susceptible, include Cabbage G.A. (8.4%), kale-M.S. (8.1%) and cabbage-G.E. (6.5%).

The results indicated that disease severity was high in *B. oleracea* var. *capitata* L. (Cabbage–CM) and in *B. oleracea* var. *acephala* DC. (Kales and Collards). While the cabbage showed 25% plant area infected, kale was highly susceptible with 50% of the plant area infected. *B. oleracea* var. *capitata* L. showed some resistance as indicated by the drumhead, cabbage-GE and Cabbage GA. This variety was found useful particularly in utilizing the resistance genes in order to incorporate in the susceptible kale varieties.

Table 1: Severity of Stem Canker in different Brassica species

Variety	Number of plants	Score category	% Area infected
Cabbage-C.M.	30	4	25
Drumhead	47	3	10
Collards	22	5	50
Cabbage-G.E.	15	3	10
Kale-M.S.	17	5	50
Cabbage-G.A.	13	3	10

Table 2: Resistant/susceptible F_1 hybrids from intraspecific crosses

Female x Male	Inoculated	Resistant	Susceptible
Collards x CCM	250	218	32
Collards x CGE	250	247	3
Collards x CGA	250	244	6
Kale x CCM	250	226	24
Kale x CGE	250	247	3
Kale x CGA	250	249	1

Table 3 (a): Resistance/susceptibility in F_2 population

Test Plants (F_2)	Inoculated	Resistant	Susceptible
Collards x CCM	250	212	38
Collards x CGE	250	245	5
Collards x CGA	250	240	10
Kale x CCM	250	222	28
Kale x CGE	250	240	10
Kale x CGA	250	243	7

Table 3 (b): Resistance/susceptibility in backcross population

Test plants (Backcrosses)	Inoculated	Resistant	Susceptible
Collards x (Collards x CCM)	250	198	52
Collards x (Collards x CGE)	250	222	28
Collards x (Collards x CGA)	250	235	15
Kale x (Kale x CCM)	250	176	74
Collards x (Kale x CCM)	250	238	12
Collards x (Kale x CCM)	250	228	22

The crosses within the different lines of *B. oleracea* were fertile. Most of the buds that were emasculated developed healthy pods with viable seeds. In all crosses, the seed set per pod was good and seeds formed were normal and well developed. It was apparent that variation in seed quality depended mainly on the female parent. All non-inoculated plants remained healthy. In the inoculated F_1 hybrids plants, symptoms development was observed to a small extend from the crosses between the parental lines (Collards x CCM) and (Kale x CCM) where symptoms were observed on 32 and 24 plants respectively out of 250 inoculated plants. In all other crosses, insignificant number of plants (Less than 6) out of 250 inoculated showed symptoms development (Table 2). It therefore shows that all the F_1 hybrids except those derived from the crosses Collards x CCM and Kale x CCM were completely resistant to the pathogen. The F_1 hybrids derived from crosses with the cultivar CCM that was initially partially resistant indicated susceptibility.

Table 4(a): X^2 values for F_2 determined using different gene models

F_2	Model	Expected	X^2	Probability	Remarks [z]
Collards x CCM	1 gene	3:1	3.2	0.05<P<0.1	S
	2 genes	15:1	2.14	0.5>P>0.1	NS
	3 genes	63:	4.6	P<0.05	S
Collard x CGE	1 gene	3:1	17.633	P>P0.005	S
	2 genes	15:1	0.479	0.1<P<05	NS
	3 genes	63:1	0.004	0.5<P< 0.9	NS
Collards x CGA	1 gene	3:1	14.7	P<0.005	S
	2 genes	15:1	0.135	0.5<P<0.9	NS
	3 genes	63:1	0.146	0.5<P<0.9	NS
Kale x CCM	1 gene	3:1	6.348	P<0.1	S
	2 genes	15:1	0.656	0.1<P<0.5	NS
	3 genes	63:1	2.341	0.1<P<0.5	NS
Kale x CGE	1 gene	3:1	14.7	P<0.005	S
	2 genes	15:1	0.134	0.5<P<0.9	NS
	3 genes	63:1	0.146	0.5<P<0.9	NS
Kale x CGA	1 gene	3:1	16.428	P<0.005	S
	2 genes	15:1	0.316	0.5<P<0.9	NS
	3 genes	63:1	0.037	0.5<P<0.9	NS

[z]*NS = Not Significant; S= Significant*

Table 4(b): X^2 values for backcross population determined using different gene models

Backcross	Model	Expected	X^2	Probability (p)	Remarks[z]
Collards x (Collards x CCM)	1 gene	1:1	42.632	P<0.005	S
	2 genes	3:1	0.588	0.1<P<0.5	NS
	3 genes	7:1	1.968	0.1<P<0.5	NS
Collards x (Collards x CGE)	1 gene	1:1	75.272	P<0.005	S
	2 genes	3:1	6.348	P<0.01	S
	3 genes	7:1	0.048	0.5<P0.9	SN
Collards x (Collards x CGA)	1 gene	1:1	96.8	P<0.005	S
	2 genes	3:1	12.033	P<0.005	S
	3 genes	7:1	1.207	0.1<P<0.5	NS
Kale x (Kale x CCM)	1 gene	1:1	20.808	P<0.005	S
	2 genes	3:1	0.705	0.1<P<0.5	NS
	3 genes	7:1	8.355	P<0.005	S
Kale x (Kale x CGE)	1 gene	1:1	102.15	P<0.005	S
	2 genes	3:1	13.601	P<0.005	S
	3 genes	7:1	1.694	0.1<P<0.5	NS
Kale x (Kale x CGA)	1 gene	1:1	84.872	P<0.005	S
	2 genes	3:1	8.748	P<0.005	S
	3 genes	7:1	0.391	0.5<P<0.9	NS

[z]*NS = Not Significant; S = Significant*

When segregating F_2 progeny and backcross population were examined by the X^2 test for consistency with 1,2 and 3 gene models, mostly the 63:1 and 15:1 ratios were not significantly different (greater than 0.1) in the F_2 progeny (Table 4a), indicating that two and three genes are involved. In the backcrosses, only the 7:1 ratio was not significant thereby confirming that three genes are mostly involved.

Conclusions

The objective of this work was met in that the most prevalent and destructive fungal pathogens on *Brassica* species were identified. Resistance genes to the pathogen *Leptosphaeria maculans*, was transferred through intraspecific hybridization within *Brassica oleracea* varieties. The number of genes involved in this kind of resistance has also been determined. Through tissue culture, interspecific hybridization can be accomplished leading to development of synthetic hybrids from crosses between *B. oleracea* var. *acephala* and a wild cultivar of *B. rapa*. The synthetics developed can be used in future to incorporate the resistance genes in the susceptible cultivars through backcrossing hence retrogressing into the susceptible cultivated forms.

Recommendations

The resistance genes introduced in the susceptible cultivars of *B. oleracea* var. *acephala* through intraspecific crosses should be able to improve yield by at least 25% and therefore *B. oleracea* var. *acephala* should be adopted for planting in areas where pressure from different pathogenic isolates is less.

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Feedback

Question: ***Provide an indication on the yield levels between the original parental lines of** Brassica **and the resistant synthetic hybrids.***

Answer: The yield level of the synthetic hybrids was approximately 25% higher than in the original lines that were susceptible.

Current Characteristics of Cassava Mosaic Disease in 'Post-Epidemic' Areas Increase the Range of Possible Management Options

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Abstract

Cassava mosaic disease (CMD) is the most important biotic constraint to cassava production in western Kenya and the most important disease of cassava in Africa. Surveys were carried out in 2003 and 2004 in western Kenya using Siaya District as a case study to document the current characteristics of cassava mosaic disease (CMD) 'post-epidemic' areas. Data were recorded on CMD incidence and severity index, number of adult whiteflies, and cassava varieties. Farmers were interviewed on their understanding of the disease and their knowledge and practice of management interventions. Results indicated that cassava cultivation was being re-established, but local varieties predominated and had high CMD incidences. Adhiambolera was the most common variety encountered with an average incidence of 82% in 2003 and 73% in 2004. By contrast, the CMD resistant variety Migyera had a low mean incidence of 28% in 2003. The overall incidence for both years was 71% with 61% as a result of cutting infection and 10% as a result of whitefly infection. In 2003 the total incidence was 72% and average severity was 2.7 while in 2004 the incidence was 71% and the severity 2.6. There were significant ($P \leq 0.05$) severity variations in each division during the two years except in Karemo and Ukwala. The abundance of whiteflies was generally low averaging 1 in 2003 and 16 in 2004. Farm management using phytosanitation was very little, as evidenced by 29% selection and 15% roguing. Occurrence of greater than 25% CMD-free plants in 2004, moderate CMD severity and limited spread provide an opportunity for the use of phytosanitation as a CMD control measure that can be immediately used by farmers with their own varieties.

Key words: Cassava mosaic disease, epidemic, *Manihot esculenta*

Introduction

Cassava, *Manihot esculenta* Crantz, is a major staple food crop in Africa. In western Kenya, it is mainly grown and consumed by resource-poor, food-insecure traditional farmers on a subsistence basis. Cassava production in East and Central Africa has been devastated by a pandemic of severe CMD (Thresh et al., 1994) that is caused by cassava mosaic geminiviruses (CMGs), spread by either the whitefly (*Bemisia tabaci*) or infected cuttings. This unprecedented severe disease is associated with an emergent recombinant begomoviral species known as *East African cassava mosaic virus*-Uganda (EACMV-UG), in the family *Geminiviridae* and the genus *Begomovirus*. The current CMD pandemic spread from Uganda and was first reported in western Kenya at Malaba and Busia towns in the mid 1990's (Gibson, 1996; Legg 1999). The disease has since spread to most districts in Western and Nyanza Provinces, leading to massive economic losses and destabilised food security.

As the epidemic spread, a reduction in CMD inoculum pressure was observed where the epidemic had passed. This arose from the reduction in the area of cassava cultivated as a result of the epidemic, more frequent cultivation of somewhat tolerant local varieties, increased prevalence of improved resistant varieties (Otim-Nape et al., 2000; Otim-Nape et al., 2001; Sseruwagi et al., 2004a), and emergence of less virulent virus strains (Owor et al., 2004a). These scenarios led to the use of the term 'post-epidemic' to describe the current status of CMD in Uganda, parts of western Kenya and other areas in East and Central Africa (Sseruwagi et al., 2004a). Subsequently, dynamics of the CMD epidemic have been described and defined in a series of zones (Legg, 1999). According to the understanding at that time, the 'post-epidemic' zone of recovery was characterised as having low incidence of less than 30% and low severity of less than 3.0, while the nature of CMD infection was mostly cutting-borne. Abundance of the whitefly vector was moderate, while cassava cultivation was being re-established (Otim-Nape et al., 1997; Sseruwagi et al., 1998).

Management efforts for CMD have focused mainly on multiplication and dissemination of CMD-resistant varieties with a great deal of success (Otim-Nape et al., 2000). However, the pace of the pandemic-spread exceeds the pace of implementation of these measures (Legg and Fauquet, 2004). The rapid spread of CMD in epidemic zones has rendered management options utilising local varieties that are largely susceptible ineffective and unfeasible (Legg, 1999). The situation in 'post-epidemic' areas is different, however, and offers opportunities for alternative means of management. Of particular interest is the potential for the use of phytosanitation measures. Use of this approach would avoid undue reliance on resistant varieties (Thresh, 2003). This paper reports the results of studies undertaken in a 'post-epidemic' District of western Kenya, which characterized the 'post-epidemic' condition, investigated farmers' CMD knowledge and control practice and determined the most appropriate control approach.

Materials and Methods

Survey area and procedure

Two surveys were conducted in divisions of Siaya District in August 2003 and March 2004. The size of divisions, importance of cassava and frequency of occurrence in the different areas varied. Consequently, the number of fields sampled per division varied. Sixty fields were sampled and 35 farmers interviewed in 2003, while in 2004, 55 fields were sampled and 139 farmers interviewed. Fields were sampled at intervals of 4 to 10 km along main roads and alongside paths within villages, depending on availability of suitable cassava fields, aged between 3 to 6 months after planting (Sseruwagi et al., 2004b). Thirty plants, selected at regular intervals along two diagonals in the form of an x-shape, were assessed in each field (Otim-Nape, 1993). Farmers provided information on cassava varieties and age of plants grown. The approximate field size, intercrops and number of nearby cassava plots (visible from the sampled plot) were recorded. Coordinates for each site sampled were determined using a Global Positioning System handset.

Variables assessed

Symptom severity was scored using the scale of 1 to 5 described by Hahn et al. (1980). Cassava mosaic disease infection was categorized as due to diseased cuttings, current season infection by whitefly vectors, or none [healthy]. The type of infection was expressed as a percentage of total samples collected per field. Population of adult whiteflies was assessed on each plant sampled by counting adult whiteflies on the youngest five expanded apical leaves of the tallest shoot.

Cassava mosaic geminivirus diagnostics

An approximately 1-cm^2 portion of a newly emerged leaf showing CMD symptoms was collected from the uppermost shoot of a plant, selected to represent the general disease situation in the field visited. Whole plant DNA was extracted from the leaf portion using a protocol modified from that of Dellaporta et al. (1983). Near full-length fragments of DNA-A were amplified using universal primers. These fragments were then digested using the restriction enzymes *Eco*RV and *Mlu*I, following the restriction fragment length polymorphism approach of Okao-Okuja et al. (2004) for characterizing CMG variability. Specific primers for ACMV and EACMV's were used to confirm identity of the various CMG's (Zhou et al., 1997; Okao-Okuja et al., 2004).

Interview data

Farmers in Siaya were interviewed on awareness of CMD pandemic, CMD management practices such as phytosanitary measures (roguing and choice of CMD-free planting material), identity and sources of CMD-resistant cassava varieties. The gender of the farmer and person sourcing planting material, as well as the proportion of each farm planted with cassava, were recorded. Farmers were asked to explain reasons for intercropping, adoption of cassava-varietal mixtures, and their preferred mode of harvesting cassava.

Data Analysis

The frequency distribution of total CMD incidence in fields assessed in the different regions was calculated and compared using the Mann-Whitney Wilcoxon test. To determine the effect of multiple infections, whitefly incidence values were transformed and presented as multiple infection units (MIU) (Gregory, 1948). Transformation was done using the formula: $Y = log_e (1/(1-C-W)) - log_e (1/(1-C))$, where W refers to proportion of plants with whitefly-borne CMD, 1 is equivalent to 100% CMD-infected, and C refers to proportion of plants with cutting-borne CMD. When calculating mean severity score, the presumably healthy, symptomless score-1 plants were omitted. Number of plants within each severity score for each division was subjected to Chi-square analysis to make comparisons among divisions in a given year (season), as well as between seasons 1 and 2 for a given division. Averages of interview data were calculated for the different responses and converted to percentages, where appropriate. The interview data were then subjected to descriptive-statistics analysis.

Results

Varieties on farms

Local CMD-susceptible landraces in varietal mixtures predominated (Tables 1 and 2). One CMD-resistant variety Migyera (TMS 30572) was encountered in seven fields in 2003 but not in 2004 (Table 2).

Migyera was present in parts of Ukwala, Ugunja and Yala that border Western Province. Ukwala and Uranga areas, occupied by the Samia, who interact with Ugandans, had several Ugandan local varieties, including Ebwanatereka, Nambamnana and Nyauganda. In Wagai, there was no improved variety and the area generally had little cassava. Adhiambolera was the most common variety, occurring in 35% and 40% of the fields sampled in 2003 and 2004, respectively. Farmers' preferred variety varied with division (Table 1).

Table 1: Common varieties planted by farmers interviewed in 2003 and 2004

Division	**Variety**[z]
Boro	Adhiambolera, Oyombo, *Migyera*, Nyamasumbi, Kamis
Karemo	Oyombo, Nyamasumbi, Nyanek, Adhiambolera
Ugunja	Adhiambolera, Nyanthaga, Chongedongo, Rateng, Nyadai, Migyera
Ukwala	Nyadai, *Migyera*, Adhiambolera, Liech gumbo, Matuja, Nyauganda,
Uranga	Nambamnana, Ebwanatereka, Kamis, Nyauganda, Jumamit, Oyombo,
Wagai	Adhiambolera, Kamis, Oyombo, Rateng
Yala	Adhiambolera, Nyanthaga, *Migyera*, Nylon, Kamis

[z] *Improved CMD-resistant variety written in italics.*

Table 2.: Varieties, incidence of CMD (%), and number of adult *B. tabaci* [z]

2003			
Variety	Fields	**CMD**	**Whiteflies**
Adhiambolera	21	83	1.3
Kamis	2	98	0.4
Liech gumbo	2	58	1.3
Matuja	2	78	0.4
Migyera	7	28	0.9
Nyamasumbi	6	87	0.3
Oyombo	4	81	0.4
Ebwanatereka	2	66	1.4
2004			
Variety	Fields	CMD	Whiteflies
Adhiambolera	22	73	16.5
Bukalasa 8	2	68	8.1
Jumamit	3	66	68.3
Kamis	3	92	35.1
Nambamnana	2	98	77
Nyadai	2	61	5.2
Nyakendu	2	100	17.8
Nyamasumbi	2	100	16
Nyauganda	2	96	32.3
Rateng	3	70	10.8

[z] *Improved CMD-resistant variety written in italics.*

Disease incidence, infection type, and adult whitefly population

Cassava mosaic disease incidence in the region was moderate to high. The overall mean incidence for all fields sampled was 72% in 2003 and 71% in 2004. The greatest proportion of fields in both years fell within the 91% to 100% disease incidence category (Figure 1).

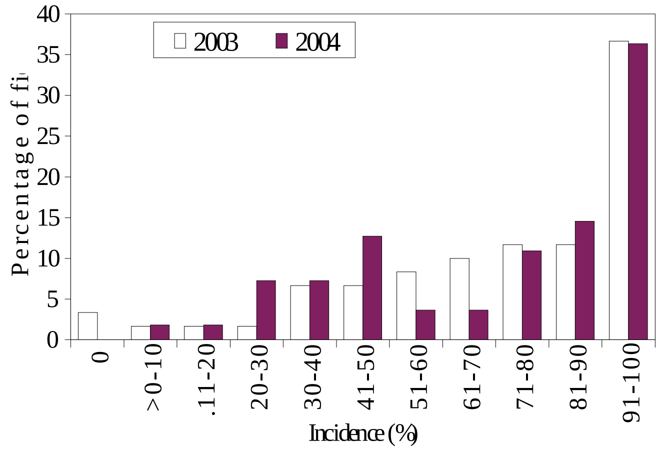

Figure 1: **Frequency (%) of CMD incidences in Siaya District during 2003 and 2004**

The proportion of the total incidence that was cutting-borne was high, ranging from 90% to 100% regardless of the division. Infection in all the divisions, except Ugunja and Ukwala, was higher in 2004 than in 2003 (Table 3). Abundance of whiteflies on cassava in Siaya was generally low and averaged 3 in 2003 and 17 in 2004 (Table 3).

Table 3: **Incidence of CMD and *B. tabaci* abundance on cassava in Siaya**

2003			**Variable assessed [z]**		
Division	**Fields**	**TI (%)**	**C (%)**	**W (%)[t]**	**Whiteflies**
Boro	9	79	69	10 (37)	0.5
Karemo	7	71	60	11 (33)	0.4
Ugunja	16	69	47	22 (55)	1.0
Ukwala	8	73	59	15 (44)	2.4
Uranga	5	67	47	20 (46)	1.0
Wagai	7	83	75	8 (37)	0.6
Yala	8	68	52	16 (40)	0.7
Total	60	72	57	15	2.2
2004					
Boro	10	86a	84	2 (16)	33.3
Karemo	7	89a	89	0 (0)	10.8
Ugunja	14	45b	35	10 (17)	15.1
Ukwala	7	55b	42	12 (24)	4.1
Uranga	10	88a	80	8 (51)	47.2
Wagai	2	95a	95	0 (0)	3.5
Yala	5	91a	87	4.0 (36)	4.2
Total	55	71	65	5	16.4

[z]TI = total incidence, C = cutting infection, W = whitefly infection, Whiteflies = mean adult whiteflies on top five leaves. Values followed by no letter or the same letter within TI columns of each year are not significantly different at $P \leq 0.05$ *(Mann-Whitney Wilcoxon statistic). Values in parenthesis refer to percentages expressed as multiple infection units (Gregory 1948).*

Disease (symptom) severity

Cassava mosaic disease severity of affected plants ranged from 2.0 to 3.0, with most affected fields showing mild to moderate symptoms. The average symptom severity score was 2.6 in 2003 and 2.5 in 2004. There were significant differences in severity scores between divisions in each year and also in each division during the two years. The highest score of 2.9 was recorded in Yala during 2003, while the lowest score of 2.5 resulted in Wagai during 2004. Except for Karemo and Ukwala that maintained their severity levels the rest of the districts experienced increased severity (Table 4).

Table 4: Plants under different severity categories in Siaya divisions

		Severity score category [z,y]					Avg.		
Division	**Year**	**1**	**2**	**3**	**4**	**5**	**score**	χ^2	**Significance**
Boro	2003	58	62	142	8	0	2.7		
Boro	2004	41	104	152	3	0	2.6	8.6	**
Karemo	2003	61	52	94	3	0	2.7		
Karemo	2004	23	67	117	3	0	2.7	0.1	NS
Ugunja	2003	147	141	176	16	0	2.6		
Ugunja	2004	230	102	77	11	0	2.5	7.4	*
Ukwala	2003	64	83	77	16	0	2.6		
Ukwala	2004	95	56	52	6	1	2.6	2.7	NS
Uranga	2003	50	35	63	2	0	2.7		
Uranga	2004	36	140	89	26	9	2.6	29.0	***
Wagai	2003	36	54	116	4	0	2.7		
Wagai	2004	3	28	29	0	0	2.5	7.0	*
Yala	2003	76	45	87	29	3	2.9		
Yala	2004	14	47	83	6	0	2.7	23	***
Total	2003	492	472	755	78	3	2.7		
Total	2004	442	544	599	55	10	2.6		

[z] *χ^2 indicates Chi-square value.*

[y] *NS, *, **, *** indicate not significant, significant at P = 0.05, P = 0.01, P = 0.001, respectively.*

Virus types in CMD-affected plants in Siaya

Leaf samples were collected only in 2004. Of the 27 positive leaf samples, 24 (89%) had EACMV-UG in all the divisions. ACMV was present in only two fields in Boro division, whereas one mixed infection of ACMV and EACMV-UG was observed in Yala division.

Farmers' knowledge

Most farmers interviewed (98%) were aware that there was a problem with their cassava crops, but they did not know that the problem was due to CMD. When asked leading questions, most farmers positively identified CMD and gave the years when they first noticed its damaging effects. The greatest proportion of farmers noticed CMD between 1997 and 2001. Most farmers (84%) did little to control CMD when they first noticed it; instead they abandoned cassava production when the damaging effects of the disease intensified. About 16% of farmers interviewed had made an attempt to control CMD by improving crop husbandry practices through weeding, spraying with ash, fertilizer application, rotation and change of variety. However, none of them tried chemical control. Of the farmers interviewed in both years, 67% stopped growing cassava as a result of CMD. Of these, 62% in 2003 and 43% in 2004 switched to or increased cultivation of sweet potato, maize and sorghum. Other alternative crops taken up included millet, beans and groundnuts. Almost all of the farmers interviewed (98%) had some cassava in their farms, but in most cases less than a quarter of the land in these farms was planted with cassava (Figure 2).

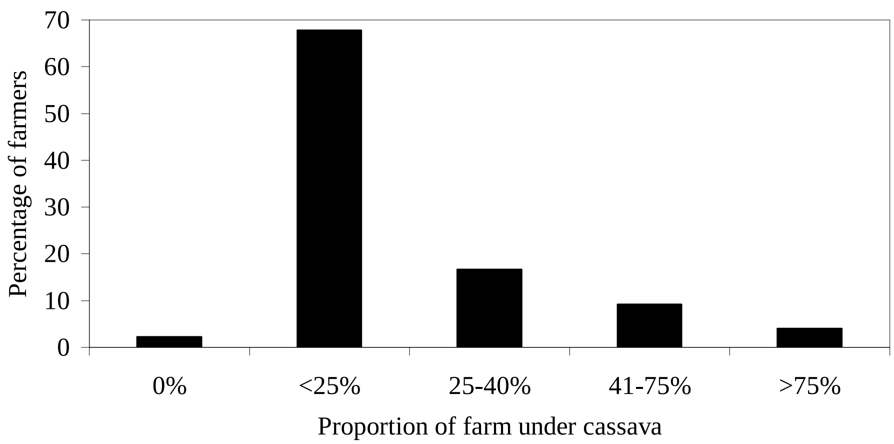

Figure 2: Proportion of farms planted with cassava

Material sourcing, labour and management interventions

Farmers in Siaya District mainly share planting materials amongst themselves. The most common sources were relatives, fellow farmers or recycling of previous season's planting material (Figure 3). In Uranga division, planting material was commonly sourced from relatives based in Uganda. Very few farmers obtained planting materials directly from the Kenya Agricultural Institute (KARI) or the Ministry of Agriculture (MoA) extension centres.

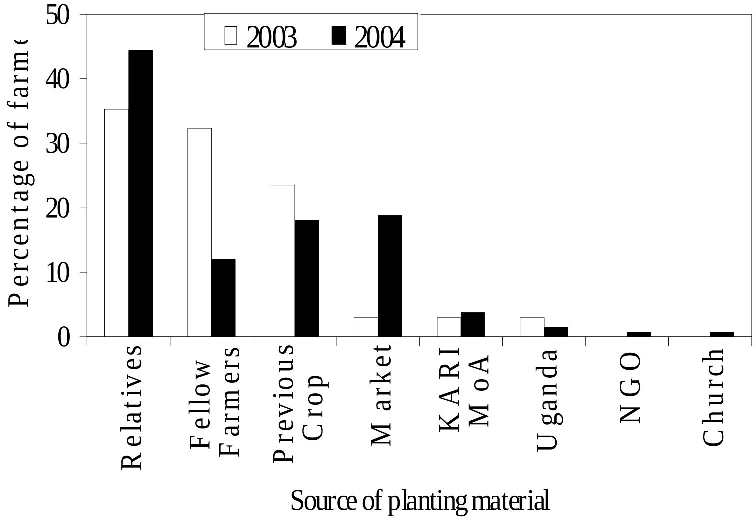

Figure 3: **Source of planting materials during 2003 and 2004**

This survey showed that women were most heavily involved in sourcing planting materials (60%), either on their own or with assistance from men (12%). Women were more involved in working on the farm (56%), where they performed weeding and maintenance of cassava. Even where other family members did maintenance, women performed 100% of the harvesting tasks.

About 71% of the farmers interviewed were not aware of the beneficial effects of choice of "clean" planting material and hence did not practise it. Those who opted to select (29%) did it based on the absence of disease, large stem size, high yields and node number. Only 15% of the farmers interviewed practiced roguing in their cassava fields. About 37% practiced roguing as they weeded, 51% practiced roguing between 1 and 4 months after planting (MAP), 4% practiced roguing at anytime, and 4% practiced roguing at harvest time. Most farmers were not aware of the work done by KARI and other collaborators in multiplication of CMD-resistant varieties. Of the farmers interviewed in 2003, only 25.7% were aware, although none had planted the CMD-resistant varieties. About 48.2% of those interviewed in 2004 were aware and 40.3% of them had planted them. Principal sources of information about CMD-resistant varieties were KARI and MoA (23% in 2003 and 32% in 2004) and chiefs' meetings (barazas) (15% in 2003 and 24% in 2004). Farmers generally claimed to have limited or no access to resistant varieties, but stated that although the chiefs and agricultural officers had mentioned them, they had not provided enough planting material of those varieties.

Discussion

Cassava mosaic disease continues to be a serious constraint to cassava production in Kenya, as elsewhere in the cassava-growing regions of Africa. Continued use of CMD-susceptible varieties and the high incidence of CMD in cuttings used for new plantings sustain CMD in Siaya District in western Kenya, where the main mode of transmission is through infected cuttings. Local cassava landraces predominate in Siaya, an observation that is comparable with data from Uganda, indicating a resurgence of local varieties in 'post-epidemic' areas (Owor, 2004a).

Incidence of CMD was consistently high through most of Siaya and changed little from 2003 to 2004. Similarly, symptom severity was moderate in both years and most infection was cutting-derived. These characteristics define the 'post-epidemic' condition and contrast strongly with epidemic conditions described elsewhere (Legg and Ogwal, 1998; Otim-Nape et al., 2000). The 'post-epidemic' condition in Siaya contrasts with previous descriptions, however, where incidences are said to be lower (Legg, 1999). This is a consequence of the fact that in Siaya in 2003 and 2004, resistant varieties had yet to become established. Two 'post-epidemic' states can therefore be usefully defined: an 'early post-epidemic' state, in which CMD-resistant materials have yet to be introduced and incidence is greater than 50%, and a 'late post-epidemic' state in which CMD-resistant varieties are becoming frequent and incidence is less than 50%. Siaya falls clearly in the former, whilst many parts of Uganda are in the latter (J. Legg, unpublished data).

The low to moderate severities of CMD symptoms recorded suggest that farmers were able to make selections both from amongst their varieties, choosing the most tolerant, and from within plants, selecting the most vigorous for planting the subsequent crop. It is significant that almost all of the diseased plants from which viruses were diagnosed were infected by EACMV-UG alone. This contrasts with the epidemic 'front' situation in which frequent mixed infections lead to very severe symptoms (Harrison et al., 1997; Legg et al., 2001). It also provides further indirect evidence for the selection by farmers of mildly diseased single virus-infected plants. Symptom severity reduction is normally enhanced further when farmers choose planting materials infected with mild strains of EACMV-UG that seem to provide a form of cross protection against severe strains of the same virus (Owor et al., 2004b). Both mild and severe strains of CMGs have been reported (Pita et al., 2001), with mild strains causing less yield loss than severe strains (Owor et al., 2004a). In 'post-epidemic' areas the current continued presence of less severe EACMV-UG in local varieties suggests that they are mild strains. Owor et al. (2004a), have given experimental evidence that explains the benefit farmers in 'post-epidemic' areas can continue to exploit from the continued cultivation of infected local varieties as a result of mild strain cross protection.

During the second survey in Siaya district (March 2004), just before the rainy season, whiteflies were much more abundant than they had been in the first survey in August 2003. It is likely that the higher temperatures in March were more conducive to whitefly population increase; whitefly populations typically peak during periods of high temperature (Dengel, 1981; Fishpool et al., 1995). However, despite the increase in whitefly population at the time of the 2004 survey, there was still limited CMD spread by whiteflies. This is partly due to the fact that whitefly-induced symptoms observed in the field at the time of the surveys were from infections of at least one month or more before sampling, given the incubation period (Fauquet and Fargette, 1990). In general, the whitefly data indicated that populations were moderate in Siaya's early 'post-epidemic' situation. Associated with this outcome was the current season infection by the vector that was also moderate to low. The slow CMD spread by whiteflies in this early 'post-epidemic' zone makes it an area with great potential for phytosanitation that could involve selection of CMD-free or mildly diseased stems of local varieties. However, recent evidence from Uganda and elsewhere shows great increases in whitefly populations in late 'post-epidemic' situations (Legg et al., 2003), suggesting that this potential may not be sustained, although this may depend on the relative proportions of CMD-resistant varieties to local landraces. Increases in the proportion of resistant material over time will reduce inoculum pressure and may facilitate continued effective use of phytosanitation even where whitefly populations increase.

The greatest proportion of farmers noticed CMD between 1997 and 2001, which is in agreement with previous findings as being the peak-period of pandemic spread in western Kenya (Legg and Ogwal 1998; Obiero et al., 2004). Farmers are not using the traditional approach of cultivating and recycling planting materials from their own farms, but have been forced by the epidemic to look for external sources such as neighbours and relatives, with women being most involved in this activity. Farmers generally lack knowledge and awareness on improved CMD-resistant varieties, and continue to grow local varieties that are CMD-susceptible. Only a small proportion of farmers in Siaya District have heard of resistant varieties and an even smaller proportion has planted them. This proportion increased in 2004 probably because the campaign to pass on information has been succeeding progressively over the years (Obiero et al., 2004). Continued growing of susceptible varieties is probably because of positive attributes other than CMD-resistance, or unavailability of resistant varieties. Local susceptible varieties are possibly preferred because of their 'sweetness' and good boiling (cooking) properties. These varieties are long-term and can store well in the ground, allowing piecemeal harvesting, beginning at 9 months and continuing for up to two years or even longer, after planting.

Farmers have played a key role in management of CMD in 'post-epidemic' areas. The role and contribution of local varieties in the current recovery and re-establishment of cassava production is very important (Otim-Nape et al., 2000; Thresh 2003). The situation suggests that management efforts should place greater emphasis on farmer training in management options, particularly targeting women. During the 5-10 years that it takes to introduce, evaluate and multiply adequate quantities of farmer-preferred CMD-resistant varieties, significant impacts in CMD management can nevertheless be achieved with local landraces. Efficient cropping practices, phytosanitation and mild strain cross protection should be promoted for these landraces in 'post-epidemic' areas. In addition to reducing the impact of CMD on the local landraces, such measures could also enhance the overall management effort through allowing the more direct targeting of scarce resistant variety planting material to the areas most recently affected by the epidemic.

Acknowledgements

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Feedback

Question: ***Whiteflies are mobile. How did you estimate the number on the top five leaves?***

Answer: Using the method described by Sseruwwagi et al. (2004) and Legg et al. (1995). The leaves are turned early in the morning or late afternoon when whiteflies are fairly sedentary. The leaves are turned gently and the whiteflies on the leaflet are counted. An estimate is then made for the entire leaf. The procedure is repeated for all the top five leaves.

Question: ***Were there major differences between seasons in pest infestation? If so what control measure is suitable?***

Answer: This study did show differences in whitefly vector population dynamics in the different seasons, but not in pest infestation. Thus, the moderate whitefly population led to reduced infection in post-epidemic areas. Therefore, phytosanitation such as selection of clean planting material is suitable since new infections are slow and by the time a plant possibly gets infected tuberisation will have occurred and economic yields even with local CMD susceptible varieties can be achieved.

Question: ***How many farmers were sampled and what criteria were used to select them?***

Answer: In 2003, they were 35, whereas in 2004 they were 139. They were selected randomly, as long as they had been cassava farmers.

Question: ***In your presentation of results, you indicated that 67% of the farmers had abandoned growing cassava and yet you also state that 98% of the interviewed farmers grow cassava. Please clarify.***

Answer: Approximately, 98% of the farmers had cassava in their farms at the time of the survey. The 67% that abandoned cassava production did so much earlier between 1997 and 2001 when the epidemic was at its peak. Thus, they were included in the 98% upon resuming cassava growing.

Questions: ***What was achieved by weeding? Was there any disease incidence reduction that was observed where weeding was done? Are there weeds that are carry CMD?***

Answers: Nothing, weeding did not reduce the disease incidence due to CMD. Farmers had no idea what could help control CMD and therefore tried anything they thought could work. This is why training of farmers is very important on the disease causes, dissemination and possible management practices.

Question: ***Highlight briefly on the original source of cassava planting material.***

Answer: Original source of planting material were: IITA quarantine station at KARI-Alupe for resistant varieties. The colonialist government provided older varieties. They are currently considered indigenous and have been given local names.

Questions: ***Elaborate on the diagonal transect sampling procedure and the average plot size as well as plant spacing across the fields.***

Answer: In each field, the diagonal transect was selected depending on the size of the field. If big every subsequent plant was noted in order to cover the whole diagonal. If few, every plant was considered to obtain 15. Plant spacing in farmers' fields is not the standard 1 m x 1 m. Therefore, this was not taken into consideration and 30 plants were selected regardless of plant spacing.

Question: ***What is the reason that you have localised disease symptoms in whitefly-transmitted disease unlike in cutting-transmitted disease?***

Answer: The cuttings come infected, unlike whitefly-transmitted virus and hence symptoms appear early during growth in the latter case.

Nematodes: Major Pests of Tuberose (*Polianthes tuberosa* L.) Produced by Small-scale Growers in Kenya

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Abstract

Tuberose is one of the cutflowers grown in Kenya that has planting material that is both inexpensive and easily available. However, a survey carried out indicates that growers have experienced pest problems, in particular nematodes as one of the major constraints in growing tuberose. Most of the growers consider nematodes as a major pest, and lack cheap effective control methods, leading to abandonment of the enterprise. Root-knot nematodes, *Meloidogyne* spp., have been identified as those affecting tuberose. *Meloidogyne* species commonly occur in many fields and attack a variety of horticultural crops in medium to high altitude areas, with distinct hot and dry periods for growwing tuberose. Unfortunately, nematode infestation in tuberose bulbs ready for planting was found to be very high, more than 70%. Though farmers report use of appropriate nematicides, the problem persists, indicating a problem in rates or application methods of the nematicides. The nematicides used for nematode control are no longer available because of health and environmental hazards associated with their use. Those nematicides that remain on the market are less effective and continue to increase in cost, while farm revenues decrease. This information will be taken into account when developing cultivation guidelines and recommendations for tuberose growing in Kenya, as it is one of the few cutflowers accessible to resource-poor small-scale growers.

Key words. Cutflower, Meloidogyne, nematodes, *Polianthes tuberosa*

Feeddback

Question: ***Why are farmers not using crop rotation to avoid root knot nematode buildup?***

Answer: The farmers cultivate small farms; an average holding is less than two acres. Even if they were to rotate they would not have enough land to move to, as the latent time for egg masses is three years. It would require new areas to plant every two years. The second reason is that farmers do not know whether the nematode species is host-specific or polyphagous. Choosing a rotation programme would be based on knowledge of these aspects.

Question: ***Farmers have mentioned bulb rot in tuberose as a major concern. Did you encounter this during your survey of remedies? Could it also be contributing to the low tuberose production in Kenya?***

Answer: No. I did not encounter this condition or disease. However, if bulb rot is present then it could contribute to low tuberose production in Kenya.

Question: ***What is the effect on quality of the flower taking into account the fact that this is a root infection?***

Answer: The ability of the plant to absorb mineral nutrients and water is reduced, causing reduced vigour. The plant then becomes vulnerable to other pests due to a weakened health status and flower quality declines.

Questions: ***What could be the role of planting material in the spread of nematodes in tuberose production? How could this be addressed?***

Answers: Planting material plays a major role in spreading nematodes. Infected bulbs will definitely spread the nematodes to the new farm or planting site. Control is by creating awareness so that new farmers buy clean planting materials and any material bought should be treated with nematicides before planting.

Question: ***Were you able to establish reasons for the decline in production?***

Answer: The farmers have given many reasons but a complete analysis of data has not been done to give the complete picture. Price fluctuations have contributed to farmers opting to grow other flowers such as Arabicum, which has a stable price.

Question ***How did the farmers know that plants were attacked by nematodes?***

Answer: After uprooting the bulbs for curing, swellings (knots) on roots were noticed.

Insect Pest Management for Plant Health: Population Dynamics of Thrips in Pure and Mixed Cropping

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Abstract

In the 19th century trade in plant products has dramatically increased leading to the spread of insect pests to areas where they were previously not reported. The population build up of pests in the new frontier has led to the development of pest epidemics in some regions, which has culminated in restrictions on movement of plant materials across borders. Various regulatory bodies have been formed that offer phytosanitary certificates to

facilitate movement of only clean plant materials. Today, plant health authorities worldwide face a collective challenge in developing and adopting risk assessment and risk management systems and practices that are consistent with the need for these phytosanitary measures. The phytosanitary requirements have caused dilemma in balancing the need for vigorous plant protection programmes and for international trade in plant products. However, in the 20th century market-driven demand for blemish-free plant products and with the advent of synthetic pesticides, farming communities all over the world resorted to prophylactic pesticide application to ensure marketability of their produce. This greatly reduced pest damage but not pest movement across borders. The intensive pesticide usage and development of more potent insecticides have resulted in major environmental pollutions and direct toxicity to humans, non-target insects and other mammals. Enlightened consumers of the 21st century started to demand low pesticide usage on plant materials. The demand has led to restriction of the usage of certain pesticides, and an array of approaches that aim at reducing pesticide usage has been devised. Use of biological control agents, pesticides derived from natural sources, and complete abstinence from synthetic inputs have resulted in organic farming where insect pest populations are naturally checked.

Key words: Insect pest, plant health

Feedback

Question: ***Is farmscaping and systems managing the same?***

Answer: Yes, farmscaping is multisystem for pest management that includes management of biocontrols, landscape plants and other agents.

Effects of Capsicum Extracts (Capsaicin) on Aphid Infestation on Cowpea (*Vigna unguiculata*)

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Abstract

Cowpea (*Vigna unguiculata* L.) is among the most important vegetables in Kenya. People prefer it because of its high nutrient content. It is also a good vegetable during dry seasons when all the other vegetables are not available. Cowpea aphid (*Aphis craccivora* Koch.) is among the most troublesome pests of cowpea and a big problem to farmers, and hence the need to control it. There has been great pressure to reduce the use of chemicals in pest control. Alternative measures are therefore being sought and these include botanical insecticides. This research was set up to study the effects of hot pepper (*Capsicum frutescens* L.) extracts (capsaicin) in control of cowpea aphid (*A. craccivora*). The research was conducted at Maseno University Horticultural farm between June and August 2005. The experiment was carried out on nine plots, each measuring 2.5m x 2.5m, and comprising of three treatments, replicated three times. One treatment served as the control. The second and third treatments were sprayed once and twice, respectively with hot pepper extracts at an interval of three weeks. The reason for splitting the applications was to find out the potency of the active ingredients on the plant leaves. Randomized complete block design was used. Data were collected on four parameters, namely number of aphids, plant height, number of leaves, and fresh weight to correlate the effects of aphid with plant growth and development. The data collected were subjected to analysis of variance (ANOVA) and significance tests at 5% level. Where there was significant F-value, Duncan's New

Multiple-Range Test (DNMRT) was used to separate the treatment means. The results obtained indicated that capsaicin and other capsaicinoids indeed possess insecticidal effects against cowpea aphid. Capsaicin also proved to have a potency of two to three weeks, which can be enhanced by use of a surfactant. These extracts therefore can also be said to possess repellent and anti-feed effects. The level of efficiency of these extracts in control of aphids was unexpectedly low and this was attributed to low dosage of alkaloids (capsaicin and capsaicinoids) in the spray water.

Key words: Aphid, capsaicin, cowpea, *Vigna unguiculata*

Introduction

Cowpea (*Vigna unguiculata* L.) is believed to have originated from tropical Africa (Tindall, 1983). It is a member of the Leguminosae family and an annual with erect, climbing or creeping habit. The trifoliate leaves have a glabrous petiole, measuring 5 to 15 cm long. The inflorescences are axillary and have two or four white to yellow or purple petals. The pods, which are 10 to 15 cm long, contain 8 to 20 rounded or kidney-shaped smooth or wrinkled seeds, ranging in colour from white to black depending on the cultivar (Kroll, 1997).

Cowpea is infested by a range of pests; one of its key pests being aphids (Blackman and Eastop, 1984). Several species of aphids that infest cowpea include cowpea aphid (*Aphis craccivora* Koch.), bean aphid (*Aphis fabae* Theobald), cotton aphid (*Aphis gossypii* Glover) and violet aphid (*Myzus omatus* Laing). The most troublesome is *A. craccivora,* which is a black aphid with a shiny back and its immatures are lightly dusted with wax.

There have been many approaches to pest control in horticultural crops, which include use of insecticides, cultural practices, biological control and use of organic insecticides. The use of hot pepper (*Capsicum frutescens* L.) in treatment of human ailments and the pungency in its fruits that deters pod-damaging pests has attracted research to investigate its effects on control of insect pests of other plants. The compound behind the pungency of hot pepper is a crystalline alkaloid genetically called Capsaicin.

It is produced by the glands at the junction of placenta and the pod wall and spreads unevenly throughout the inside of the pod, concentrating mostly in the placental tissue. It is slightly soluble in water but very soluble in alcoholics and oils (Spath and Darling, 1930). This research was done to investigate the effects of this compound on control of aphid infestation in cowpea.

Statement of the Problem

Aphids have continued to be a big menace in the production of cowpea and other crops. With restricted remedial measures to the use of chemical pesticides which leave high toxic residues level in edible crops, kill non target organisms and pollute the environment, alternative control measures are being sought. These include botanical pesticides for which hot pepper extracts (Capsaicin) is a potential candidate.

Research Justification

Chemical control measures have been in the use for many years but consumers are now becoming more and more particular about the quality, safety and reliability of fresh products they buy. Even in the international market, there is the EUREPGAP protocol whose guidelines aim at producing products that are safe, environmental friendly, socially acceptable and of high quality. One of their requirements is the application of proper crop protection strategies in order to reduce the use of chemicals. Hot pepper is locally available and cheap, has no phytotoxicity or toxic residues. It is gentle to the operator and has a selective insecticidal spectrum. This creates interests in research on its effectiveness.

Objectives

The two objectives of this study were to investigate the effects of hot pepper (*Capsicum frutescens* L.) extracts on control of Aphids *(Aphis craccivora*, Koch) infestation in cowpea (*Vigna unguiculata* L.), and find out the potency of hot pepper extracts as botanical insecticide on leaves of cowpea.

Materials and Methods

A germination test was set up within the pretext of laboratory where cowpea seeds were placed on Petri dishes lined with wetted filter paper. This treatment was replicated thrice. In the field, nine (9) plots measuring 2.5 m x 2.5 m were well prepared. D.A.P. fertilizer was applied at a rate of 200 kg/ha after which the seeds of cowpea were planted at a spacing of 60 cm x 15 cm. No manure was applied. Watering was done from the day of planting throughout the course of crop growth as dictated by the weather conditions. Subsequent cultural practices including weeding, thinning and top dressing with C.A.N. were provided as required.

Fully ripe, dry hot pepper pods of habanelo variety were ground into fine powder using a grinder and stored well in an airtight container awaiting application. After seedling emergency, the percentage germination was scored and the results recorded. No introduction of aphids was done, rather infestation occurred naturally. Pest sampling was always done before application of the extracts.

Data Collection and Analysis

The data was collected for aphid number, plant height, leaf number and fresh weight. The first sampling was done two weeks after planting and subsequent sampling was done weekly for six consecutive weeks.

The data collected was subjected to analysis of variance (ANOVA) at 5% level of significance to test for the significant difference between the treatments.

Results and Discussion

Results for germination tests showed 98% germination. The average germination percentage was equal in treatment E_0 and E_2. Treatment E_1 showed a relatively lower germination percentage of 82.38% (Table 1).

Table 1: Percentage germination in the field

Treatments	Block 1	Block 2	Block 3	Mean
T_1 (E_0)	96.88	87.50	93.75	92.71
T_2 (E_1)	90.63	78.13	78.13	82.38
T_3 (E_2)	96.88	96.88	84.38	92.71

Table 2: Mean number of aphids on cowpea leaves

Treatment	Time (Weeks)					
	1	2	3	4	5	6
E0 (Control)	21.7	18.0	21.3	48.0	15.0	3.7
E1 (Treated once)	18.0	3.3	8.0	21.0	9.3	3.7
E2 (Treated twice)	16.3	5.0	8.0	26.7	5.3	0.7
F test	NS	NS	*	NS	NS	NS
DNMRT	-	-	9.94	-	-	-

*NS= Not significant; *= Significant at P = 0.05, according to the Duncan's New Multiple-Range Test (DNMRT)*

Significant results were obtained only in the third week of sampling (2nd week after application of extracts). However, the aphid number decreased after extracts application and remained relatively low in the treated plots as compared to the untreated (control) plots (Table 2). The insignificance in the results was attributed to low concentration of capsaicin and capsaicinoids in the solution due to their low solubility in water. Capsaicin and capsaicinoids are slightly soluble in water but soluble in oils and alcoholics (Spath and Darling, 1930). Another attribute could be low potency of the extracts on the leaves of cowpea because no surfactant was used. In addition, the rates used could have been low. There were, however, significant results in the third week of sampling. This implies that hot pepper extracts has some insecticidal effects against cowpea aphid (*Aphis craccirora*). This is in conformity with the findings of Greenville-Reynolds Industry (1995) in Pennsylvania, manufacturers of "Hot Pepper Wax". This product has proved effective against pests including white flies, spider mites, cabbage loopers, lace bugs and some other soft-bodied insects (Greenville-Reynolds, 1995). Though aphids are not mentioned among the above, they fit in the class of soft-bodied insects.

Table 3: Mean plant height (in cm) of cowpea plants treated with hot pepper extracts against aphids

Treatment	Time (Weeks)					
	1	2	3	4	5	6
E0 (Control)	7.2	9.3	11.2	13.6	15.3	16.4
E1 (Treated once)	6.8	9.4	11.6	14.2	15.8	17.3
E2 (Treated twice)	7.2	10.7	12.8	14.9	16.1	17.4
F test	NS	*	*	NS	NS	*
DNMRT	-	0.88	0.99	-	-	0.77

There was significant difference among treatments on plant height in the 2nd, 3rd and 6th weeks of sampling. The plant height increased by the weeks as the plants grew but the untreated plants remained relatively shorter throughout the experimental period (Table 3). This implies that the difference in plant height occurred immediately after first treatment (application of extracts) and a week after the second application of the extracts. In addition, the treated plants were relatively taller than the untreated ones throughout the experimental period. These results indicate that even a low infestation of aphids causes reduced growth to the host plant. The results are in consistent with the literature, which says that aphids damage the host crop resulting in loss of vigour and causing stunted growth and short shoots (Gratwick, 1992). Separation of the means showed no significant difference between treatments E_0 (control) and E_1. This was attributed to several factors. First, there was high thrip (*T. tabaci*) infestation in the whole field which out-competed the target pest and contributed to retardation of plant growth. Heavy attack by thrips leads to stunting of plants (Gratwick, 1992). Initial plant height in E_1 was also shorter (6.8cm) compared to E_0 (7.2 cm).

Table 4: Average number of leaves on cowpea plants treated with hot pepper extracts against aphids

Treatment	Wk1 (2/07/05)	Wk2 (9/07)	Wk3 (16/07)	Wk4 (23/07)	Wk5 (30/07)	Wk6 (6/08)
E0 (Control)	2.0	4.0	5.0	10.0	18.3	20.7
E1 (Treated once)	2.0	4.0	5.0	10.3	18.3	21.0
E2 (Treated twice)	2.0	3.7	5.0	11.0	18.7	21.3
F test	NS	NS	NS	NS	NS	NS

There was no significant difference on leaf number among treatments throughout the experimental period. The leaf number increased with plant growth although the leaves appeared distorted especially in the untreated plots (Table 4). Gratwick (1992) found that aphids reduce plant vigour by sucking sap from the plant resulting in stunted growth. By extension, therefore, one can say that aphids reduce the rate of leaf emergence and development. The reason for insignificant difference among treatments was attributed to low level of infestation right from the beginning of the experiment.

There was no significant difference on fresh weight among the treatments although the results showed higher fresh weight on treated plants relative to untreated plants (Table 5). This conflicts the literature, which says that aphids suck sap from the plant resulting in reduced fresh weight and eventual wilting of the crop (Gratwick, 1992).

Table 5: Fresh weight of cowpea plants taken in the final (6th) week (6/08/2005) of experiment

Treatment	Fresh weight (g)
E_0 (Control)	30.8
E_1 (Treated once)	31.6
E_2 (Treated twice)	33.5
F test	NS

However, there was slight difference among the three treatments although this difference was statistically insignificant. These differences are in line with the literature because the fresh weight was found to be inversely proportional to the number of aphids. The slight insignificant differences among treatments were attributed to high infestation of thrips in the field, which by their action of sucking the sap from the plants reduced the fresh weight in all the plants (treated and untreated). Another reason could be due to low concentration of capsaicin and capsaicinoids resulting in reduced efficiency in control of aphids. In addition, the level of infestation right from the beginning of the experiment was low.

Conclusions

The active ingredient in hot pepper capsaicin, backed by other capsaicinoids is effective in control of aphids though the magnitude of effect is low in raw extracts. The heat produced by these alkaloids is highly insecticidal especially if the right concentration can be obtained. The potency is also good, covering a week or two but this can be increased by use of a surfactant such as soap, oil, or wax. If a surfactant is used, the mode of action may be widened to include anti-feed and repellence effects.

Recommendations

Treatment three (extracts applied twice at an interval of three weeks) was recommended, although the results were interfered with by heavy rainfall that occurred towards the end of this research. Further research is necessary to come up with a good extraction procedure that yields a high content of capsaicin and other capsaicinoids through use of alcoholic compounds such as ethanol as well as oils.

Hot pepper extracts should be tested on a wide range of species of aphids for various crops as this particular research was performed on cowpea aphid (*Aphis craccivora*) only. Similar experiment/research should be done using soap, white oil or bee wax or any other substance that can act as a surfactant to enhance adherence of the active ingredients on plant leaves after spraying to increase the potency and hence the efficiency. The mode of action of capsaicin against aphids may include toxicity, anti-feed and repellency. Understanding this mode is important for its proper usage. Further research is therefore required in this area.

Prevailing weather and climatic conditions greatly influence the activities of insects in the field. This research should therefore be repeated during a different season or in a different agro-ecological zone.

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Feedback

Question: What is the logic in use of capsicum in control of aphids?

Answer: The research was targeting peasant farmers who can afford to grow capsicums butt are unable to buy chemicals. Capsaicin is environment-friendly, has no toxic residue, and does not kill non-targets.

Question: How many times do you need to control 1 ha of cowpeas, considering the quality standard requirement?

Answer: Peasant farmers cannot afford large hectarages. Commercial products are being produced using capsicum, which are more effective than this raw product and a small quantity can control aphids in a wide hectarage of land.

Question: Is it justifiable to use capsicum to fully control the aphids, considering the fact that one or two aphids can spread the virus, which will affect the crop?

Answer: Capsicum can reduce the level of aphids tremendously, even if it won't wipe away all the aphids, and the amount of chemicals used.

Question: Do we need to produce capsicum for export or for control of aphids?

Answer: Both export market and aphid control are important. The quality does not matter in the capsicums used for aphid control. Capsicums that are rejected for export can be used in aphid control.

Development of Tomato Hybrids (*Lycopersicon esculentum* X *L. hirsutum*) Resistant to Tobacco Spider Mite (*Tetranychus* evansi)

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Abstract

The provision of locally adapted, high yielding and good quality tomato varieties resistant to tobacco spider mite remains an important obligation in tomato breeding programmes. In Kenya, several tobacco spider mite-tolerant tomato accessions have been identified. However, their quality and yield are below acceptable levels. The general objective of this study was therefore to initiate inter-specific tomato crosses (*Lycopersicon esculentum* Mill. X *L. hirsutum* C.H. Mull) and establish the mode of inheritance of resistance to tobacco spider mite (*Tetranychus evansi* Baker and Pritchard). Furthermore, the successful rate of incorporation of the tobacco spider mite tolerance into the widely grown Money Maker and Cal J varieties is pivotal in the provision of a sustainable tobacco spider mite-tolerant tomato variety. The specific objectives included determination of developmental characteristics of *T. evansi,* as influenced by the parental and hybrid tomato lines. The experiments were carried out at the International Centre of Insect Physiology and Ecology (ICIPE) and at the Jomo Kenyatta University of Agriculture and Technology (JKUAT). Plant characteristics such as trichome type and density, mite fecundity and survival rates on parental and hybrid lines were determined. Phytochemicals were detected using gas chromatography. Cross breeding programme was commenced to stabilize tolerance, reduce damage, increase yield, and minimize use of pesticides.

Key words: Hybrids, *Lycopersicon esculentum*, L. hirsutum, resistance, spider mite, *Tetranychus evansi*, tomato

Introduction

Tomato cultivation is considered a high-risk crop, because of pests and diseases, requiring intensive use of pesticides, especially in tropical countries. Current levels of cultivar resistance are not high enough to permit a significant decrease in the amount of pesticides applied. However, varietal resistance can become an important tool in an integrated pest management program aimed at reducing the chemical pesticide sprays and allowing for smaller environmental impact (Maluf et al., 2001)

Pest attack in tomato including that by spider mites can cause serious damage and reduction in yield. *T. evansi* is the most serious dry season pest of tomatoes in eastern and southern Africa. It was found for the first time in Kenya in 2001 and can cause total crop loss in hot and dry conditions (Knapp et al., 2003). It is due to this problem that a solution has to be found on how to control the spider mites. Until recently, the most important spider mite species attacking tomatoes in Kenya was *Tetranychus urticae* Koch. Recently, it was observed that *T. evansi* is also present (Knapp et al., 2003).

The genus *Lycopersicon* is characterized by great diversity within and among its nine species. Arthropod resistance has been studied intensively in *Lycopersicon esculentum* Mill, *Lycopersicon hirsutum* Humb and Bonpl and *Lycopersicon pennelli* (Corr) D'Arcy. Of these, the highest levels of resistance to the greatest number of arthropods are found in *L. hirsutum*. Arthropod resistance has been associated with a diverse array of traits, including physical and chemical properties of trichomes, constitutively expressed and wound induced chemical defenses associated with leaf lamellar exudates (Kennedy, 2003). Seven types of trichomes do exist in Lycopersicon species, types I, II, III, IV, V, VI and VII. Types I, IV, VI and VII are referred to as glandular, they posses heads at their tips that release secretions on touch, while types II, III and V are non-glandular, they do not posses heads at their tips. Glandular trichomes are associated with arthropod resistance (Luckwill, 1943). Type VI glandular trichomes of *L. hirsutum* contain high levels of two methyl ketones; the 13-carbon 2-tridecanone and the 11-carbon 2 undecanone that are toxic to two-spotted mite *Tetranychus urticae* Koch. A high negative correlation was found between the 2 tridecanone and average distance travelled by *Tetranychus urticae* and *T. ludeni* Zacher on tomato leaves of *L. hirsutum* (PI 134417), *L. esculentum* and their respective F1 and F2 hybrids (Aina et al., 1972; Weston et al., 1989; Gonçalves et al., 1998)

The glandular trichomes also physically impair movement of pests and this leads to reduced growth and development of the pest, hence reducing the population (Farrar and Kennedy, 1991). Type IV trichomes are also associated with high levels of resistance to mites (Snyder and Carter, 1985). Simmons et al (2004) reported a positive relationship between type IV trichomes and mortality of *Myzus persicae* Sulz on *L. hirsutum* f. *glabratum* Mull. Resende et al (2002) reported that indirect selection for high levels acylsugars associated with type IV trichomes in leaflets of *L. pennellii* (Corr) D'Arcy x *L. esculentum* hybrids led to correlated increases in the levels of mite repellency. Type IV trichomes have been found to be abundant, and highly correlated to zingiberene content in *L. hirsutum* f. *hirsutum* Dunal (PI 127826), and its F2 hybrids with *L. esculentum* 'TOM-556' which repells*T. evansi* (Maluf et al., 2001).

The provision of locally adapted tobacco spider mite resistant, high yielding and good quality tomato varieties remains an important obligation in tomato breeding programmes. In Kenya several tobacco spider mite tolerant tomato accessions have been identified. However, quality and yield are below acceptable levels.

The objective of this study was to initiate inter-specific tomato crosses (*Lycopersicon esculentum* Mill X *Lycopersicon hirsutum* C.H. Mull) and establish the mode of inheritance of resistance or tolerance to tobacco spider mite (*Tetranychus evansi* Baker and Pritchard). Furthermore, the successful rate of incorporation of the tobacco spider mite tolerance into the widely grown

"Money Mmaker" variety is pivotal in the fulfillment of provision of a sustainable tobacco spider mite tolerant tomato variety.

Materials and Methods

Plant materials

The wild species, *L. hirsutum f. glabratum* accession 439 was used as male plant (pollen donor), the cultivated variety *L. esculentum* 'Money Maker' as the female plant to produce F1 hybrid seed. The plants were established in the ratio of 1:4, male to female respectively. The F1 was pollen donor to 'Money Maker' to produce BC1 seed; F1 was selfed to produce F2 seed.

Seeds for 'Money Maker' were sourced from East Africa Seed Company, while those of *L. hirsutum* accession 439 (L06222) where provided to ICIPE from AVRDC – (Taiwan). The plants were raised in 3kg pots in media of soil, manure and sand in the ratio of 3:2:1 respectively. Plants were subjected to standard cultural practices that included watering, weeding and top dressing.

Mites

The mites used in the tests were sourced from a colony reared at ICIPE under controlled conditions of 25^{o} C and a relative humidity of 50-70%, 12 hours light and 12 hours dark conditions on 'Money Maker'/Cal J tomato plants.

Trichome type and density

The number and type trichomes on the abaxial side of leaves of *L. hirsutum*, 'Money Maker', F_1, F_2, and BC_1 were counted with aid of a dissecting microscope fitted with a square grid. Six leaflets were randomly selected from 10 plants per accession between the 2nd and 6th leaf from bottom. The leaflets were plucked from the second pair of proximal leaf end. Fifteen squares with an area of $0.11mm^2$ were randomly selected on each leaflet and trichomes counted, then the trichome density per mm^2 was calculated. Plants used were seven weeks old from sowing

Development time from egg to adult

Small Petri dishes (60-mm diameter) were loaded half with cotton wool and kept wet by adding water. Twenty leaf discs with a diameter of 25 mm each from the selected lines were prepared using a leaf disc cutter. The leaf discs were placed in individual Petri dishes, the underside facing up.

Twenty female mites were be taken from the colony, put on each one leaflet for each tomato line separately and left for 2 hours to allow egg laying. Afterwards, one egg was transferred to each respective leaf disc. Petri dishes containing leaf discs were then placed in an open rectangular dish (32 × 22 × 6) cm with wire gauze and put in an incubator.

The leaf discs were checked after every 24 hours with the aid of a dissecting microscope and development time from egg to larva, protonymph, deutonymph and adult, as well as adult survival and sex noted. Cotton wool was kept wet by adding clean water to restrict mites on the leaf and keep the leaf discs fresh. Leaf discs were changed after every four days to produce fresh leaves for mites to feed on. This experiment was repeated twice. The experiment was carried out in an incubator set at 25^{o}C and 60% relative humidity (Helle and Sabelis, 1985).

Fecundity and longevity studies

Leaf discs for the selected lines were prepared as in development studies above. One female deutonymph and two males were placed on each leaf disc. The Petri dishes were placed in rectangular dishes and put in the incubator. Males were removed 24 hours after the female had emerged. The number of eggs was counted after every 48 hours until the mite died, noting whether it died on the leaf disc or outside. The cotton wool was kept wet and leaf discs changed after every four days (Helle and Sabelis, 1985).

Data Analysis

Data were collected, assembled and initially processed using Microsoft Excel. Analysis of variance (ANOVA) was done using the General linear model (GLM) procedure analysis of variance (ANOVA) of SAS 2001. Means were separated with separation of means test following the procedures of Tukey's Studentized Range (HSD) Test

Results

Trichome type and density

Glandular trichomes type I, type IV, type VI and VII were present on the abaxial (lower) leaf surface of *L. hirsutum* accession 439. Non- glandular trichomes type III was present but type II and type V were absent. Type VI trichomes bore a round glandular head (Table 1). In 'Money Maker', glandular trichomes type I, type VI and type VII were present, but type IV was absent. Non- glandular trichomes types III and V were present, but type II was absent. Type VI trichomes bore a four lobed glandular head as opposed to that of accession 439 that was round. (Table 1).

Table 1: Trichome type, accession and density per mm2 leaf area on the abaxial surface of tomato leaves of the tested accessions [z]

Trichome type	439	'Money Maker'	F1 hybrid	F2 hybrid	BC1 hybrid
I	0.20±0.14b	0.91±0.20ab	0.10±0.10ab	0.10±0.10b	1.82±0.41a
II	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
III	0.10±0.10b	0.81±0.27ab	0.51±0.30ab	0.00±0.00b	0.30±0.17a
IV	17.58±1.51a	0.00±0.00d	7.07±1.02b	4.14±0.66bc	2.32±0.51cd
V	0.00±0.00d	28.38±1.84a	16.57±1.79c	18.99±1.89bc	23.54±1.75ab
VI	4.85±0.54a	5.15±0.66a	3.94±0.54a	4.34±0.60a	4.04±0.54a
VII	1.31±0.34a	0.51±0.22ab	0.10±0.10b	1.01±0.30ab	0.71±0.26ab

[z] *Values in the table are mean ± standard error. Means with same letter notation within rows for same surface are not significantly different (Tukey test, P>0.05)*

Glandular trichome types I, IV, VI and VII were present in the F1 hybrid. Non-glandular trichome types III and V were present, but type II was absent. Type VI trichomes were a mixture of round and lobed glandular heads (Table 1). In the F2 hybrid, glandular trichomes types I, IV, VI and VII were present. Non- glandular type V was present, but type II was absent. Type VI trichomes were a mixture of round and slightly lobed heads (Table 1).

Glandular trichomes type I, IV, VI and VII were present on both leaf surfaces of the BC1 hybrid. Non- glandular trichomes types III and V were present on both leaf surfaces, but type II was absent. Type VI trichomes were a mixture of round and slightly lobed glandular heads (Table 1). There were significant differences (P<0.05) between the tested accessions in the density of trichomes. Type I, trichome density was significantly different (P<0.05) between BC1, F1, 'Money Maker' and F2 and 439. Type III, trichome density was significantly different (P<0.05) between BC1 and F2 and 439. Type IV, trichome density was significantly different (P<0.05) between 439 and F1, F2, BC1 and 'Money Maker', F1 and F2, BC1 and 'Money Maker', F2 and BC1 and 'Money Maker'. Type V, trichome density was significantly different (P<0.05) between 'Money Maker' and BC1, F2, F1 and 439, BC1 and F2, F1 and 439, 439 and F1andF2. Type VI trichome density was not significantly different between all accessions, 'Money Maker', 439, F2, BC1 and F1. Type VII trichome density was significantly different between 439 and F1 (Table 1).

Developmental time from egg to adult of *T. evansi*

Developmental stages were five, egg, larvae, protonymph, deutonymph and adult in all accessions. There was significant difference (P<0.05) in egg hatching period, duration of larval stage, protonymph stage, and deutonymph stage and as well as adult survival among accessions (Table 2).

The mortality rate of egg and larva stages was highest in 439 with 50% and 80% respectively, but and lowest in 'Money Maker' with 5% and 15.8% respectively. Protonymph mortality rate was highest in the F1 hybrid (87.5%) and lowest in 'Money Maker' (18.7%). Deutonymph mortality rate was highest in 439 (100%) and lowest in F1 (0%).

Table 2. Duration of stages *T. evansi* on different accessions [z]

	Egg		Larva		Protonymph	
Acc	**n**	**Duration**	**n**	**Duration**	**n**	**Duration**
439	40	5.2±0.28a	20	1.6±0.29b	4	0.3±0.14c
MM	40	3.9±0.17b	38	2.7±0.24ab	32	1.7±0.15a
F1	40	5.0±0.22a	29	2.8±0.37ab	8	0.6±0.19bc
F2	40	5.2±0.31a	29	2.4±0.29ab	15	1.2±0.25ab
BC1	40	4.4±0.20ab	34	3.1±0.33a	16	1.3±0.25ab
	Deutonymph		**Adult**		**Sex (M)**	**Sex (F)**
Acc	**n**	**Duration**	**n**	**Duration**		
439	1	0.05±0.05c	0	0.0±0.00b	-	-
MM	26	1.2±0.18a	22	7.5±1.48a	8	14
F1	1	0.08±0.08c	1	0.3±0.30b	-	1
F2	10	0.5±0.13bc	7	1.5±0.58b	4	3
BC1	11	0.6±0.16b	7	1.7±0.62b	1	6

[z] *Means with the same letter within columns are NS different. (Tukey test P>0.05). HE = Hatched eggs, S = survived, L = larva, P = protonymph, D = deutonymph, F = Female, M = Male, MM = 'Money Maker'.*

Fecundity and longevity of *T. evansi*

Fecundity studies were to determine number of eggs laid in the accessions 439, F1, F2 and, BC1 and 'Money Maker' till the mite dies. There was significant difference ($P<0.05$) in all accessions in eggs laid per day (Table 3).

There was significant difference between 'Money Maker' and BC1, F1, F2 and 439, but there was no significance between BC1 and F1, F1 and F2, F2 and 439 in mean total eggs laid per female mite (Table 3). Highest total number of eggs laid by an individual female mite was 160 eggs in 'Money Maker'.

Longevity studies were to determine number of days a female mite can live from newly hatched deutonymph until the mite dies. There was significant difference among accessions in mite longevity (Table 3).

Discussion

Glandular and non-glandular trichomes of types I, III, IV, V, VII and VII, glandular and non-glandular were identified and counted on the abaxial surface of parent plants and hybrids. Type II trichomes were absent on both parents; type IV were absent on 'Money Maker' and type V were absent on accession 439 (L06222) (Table 1). Luckwill (1943) reported that tomato species *L. hirsutum* and *L. esculentum* do not possess type II, and that the former lacks type V while the latter lacks type IV trichomes. Type II trichomes, according to Luckwill are found in *L. pimpinellifolium* (Jusl) Mill, *L. pissisi* Phil and *L. glandulosum* C.H. Mull.

Table 3: Accession, fecundity per day, fecundity per mite and longevity in days in of *T. evansi* on different accessions

Accession[z]	Eggs/day	Eggs/mite	Longevity days
439	0.0±0.00d	0.0±0.00d	5.1±0.31b
F2	0.8±0.14cd	5.3±1.75cd	6.9±0.58b
F1	1.2±0.15c	13.4±3.38bc	10.8±0.76a
BC1	2.8±0.23b	22.3±3.04b	8.1±0.62ab
'Money Maker'	3.7±0.23a	46.4±5.87a	12.6±1.06a

[z] *Values are means ± S.E. Means with same letter notation within columns are not significantly different (Tukey test, P>0.05).*

Hybrids possessed all trichome types that were present on parent plants, they had both type IV and V that were absent on 'Money Maker' and accession 439 respectively. Snyder and Carter (1984) reported that F1 hybrids of *L. hirsutum* and *L. esculentum* possessed all trichome types on parent plants; they concluded that trichome characteristics are inherited from both parents.

The density of glandular trichome type IV was significantly higher on accession 439, while the non- glandular type V trichomes were found in significantly higher numbers on 'Money Maker' and hybrids (Table 1); these findings are similar to those of Simmons *et al* (2005) and Luckwill (1943), who reported abundant type IV trichomes on *L. hirsutum* and abundant type V trichomes on *L. esculentum*. There was no significant difference in type VI trichome density in accession 439, 'Money Maker' and their hybrids (Table 1); this suggests that its association with resistance to arthropods in *L. hirsutum* is chemical rather than physical. Type VI glandular trichomes of *L. hirsutum* contain high levels of two methyl ketones; the 13-carbon 2-tridecanone and the 11-carbon 2 undecanone that are toxic to two-spotted mite, *T. urticae* Koch. A high negative correlation was found between the 2 tridecanone content and average distance traveled by *T. urticae* and *T. ludeni* Zacher on tomato leaves of *L. hirsutum* (PI 134417), *L. esculentum* and their respective F1 and F2 hybrids (Aina et al., 1972; Weston et al., 1989; Gonçalves et al., 1998). Snyder and Carter (1984, 1985) found that mite survival was lower in *L. hirsutum* species that possessed fewer type VI trichomes compared to *L. esculentum*; they concluded that trichome type IV could be responsible for the high levels of resistance in the wild species.

There is a positive relationship between the density of type IV trichomes and mortality of mites and peach aphid *M. persicae* Sulz, but not type VI (Snyder and Carter, 1985; Simmons et al., 2004). Type IV trichomes in *L. pennelli* are known to contain acylsugars that are responsible for high levels of resistance to *T. evansi* (Goffreda *et al* 1990; Resende et al., 2002), in *L. hirsutum* f *hirsutum* they are known to contain the sesquiterpene zingeberene responsible for high levels of resistance to *T. evansi* (Maluf et al., 2001), but no literature was available on what they contain in *L. hirsutum* f *glabratum* to which accession 439 (L06222) belongs.

Type I, III and VII trichomes were sparse accession 439 and 'Money Maker', though Luckwill (1943) observed abundance of type I and III in *L. esculentum*. Trichomes grouping into glandular (I, IV, VI, VII) and non-glandular (III, V) revealed that the former are significantly denser on accession 439, while the latter are significantly denser on 'Money Maker'. This is similar to the findings of Luckwill (1943) who attributed host plant resistance to glandular trichomes. Rasmy et al., (1985) reported that mite oviposition is deterred by high density of glandular trichomes on *L. hirsutum* f *glabratum* and *S. sarachoides* Sendter compared to *L. esculentum* that had lower density of the trichomes. Glandular trichomes are also known to be responsible for the reluctance of potato tuber moth to oviposit on foliage of *S. berthaultii* Hawkes (Malakar et al., 1999). Several allellochemicals present in wild *Lycopersicon* taxa have been associated with pest resistance. Toxic methyl ketones such as 2-tridecanone are found in glandular trichomes present on the leaf surface of *L. hirsutum* f *glabratum* (Williams et al., 1980; Carter et al., 1989; Maluf et al., 1997) found in glandular trichomes present on leaf surface (Carter et al., 1989) and are associated with moderately high to high heritability values (Maluf et al., 1997).

The total period from egg to adult in 'Money Maker' was 9.5 days. Silva (1954) reported that the life from egg to adult on tomato leaves ranged from 6.5 to 11.5 days. Meyer (1996) reported that the life cycle is as short as 9 to 12 days resulting to 24-30 generations in a year.

The difference in time taken for eggs to hatch and larva that completed the cycle indicated that development and population increase of *T. evansi* depends on host type.

In this case 'Money Maker' is a more suitable host compared to accession 439 and hybrids because it had the shortest egg period and 58% of the larvae reached the adult stage. Host plants can exert profound effects on the biology of spider mites including *T. evansi* (Jeppson et al., 1975) Qureshi et al (1969) reported that the ratio of male to female was about 1:10, while Moutia (1958) reported that the sex ratio on tomato plants in the field was 1:3.3. The short life cycle and high ratio of female to male indicate that on suitable host and favourable climatic conditions *T. evansi* can reproduce rapidly and cause severe crop losses.

Fecundity studies were to determine no of eggs laid in the accessions 439, F1, F2, BC1 and 'Money Maker' till the mite dies. There was significant difference ($P<0.05$) in all accessions in eggs laid per day (Table 3). No mite laid eggs in accession 439, while in 'Money Maker' an average of 46 eggs/mite were obtained. Majority of the eggs were laid within the first fourteen days from emergency, peak fecundity varied in accessions (Fig. 1). Meyer (1996) reported that that oviposition begins a day after emergency and female reach maximum egg laying capacity on the fourth day after which oviposition decreases.

Longevity studies were to determine number of days a female mite can live from newly hatched deutonymph until the mite dies. There was significant difference among accessions in longevity. Longevity was least in accession 439 (5.1 days) and highest in 'Money Maker' (12.6 days), the hybrids were intermediate. This clearly shows that the resistant accession 439 has a negative influence on mite survival and this trait can be inherited (Table 3).

Conclusions

The developmental characteristics, fecundity and longevity studies of *T. evansi* on *L. hirsutum* accession 439, *L. esculentum* variety 'Money Maker' and their F1, F2 and BC1 hybrids reveal that accession 439 is resistant, 'Money Maker' is susceptible but the hybrids are intermediate in response to *T. evansi*. Trichome types are inherited by hybrids from both parents, though the non- glandular type V seems to be inherited more dominantly than the glandular type VI. The trichome type that seems to be associated with resistance is IV since it is the most dominant in accession 439.

This study reveals that the mite resistance in *L. hirsutum* is inherited by *L. esculentum* and therefore can be utilized to improve tomato production by breeding mite resistant varieties; this will minimize pesticides application hence lowering production cost and reducing their negative effect on the environment and human health.

Recommendations

Further studies need to be done to establish the role of trichome type IV in resistance to mites in *L. hirsutum* f. *glabratum*; it contains acylsugars in *L. pennelli* and a sesquiterpene zingiberene in *L. hirsutum* f. *hirsutum*.

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Feedback

Question: ***What is the population of mite economic injury level like?***

Answer: Mite injury on plants is estimated using scores depending on the visible damage caused on the leaf. Mites cause whitish-yellow stipples on leaves; the extent of the stipples is used to score the damage as follows: Score 1 = less than 10% leaf damage. Score 2 = 10 to 20% leaf damage Score 3 = 20 to 50% leaf damage. Score 4 = 50 to 70% leaf damage Score 5 = 70 to 100% leaf damage Score 2 and above mans the damage will affect crop performance.

Question: ***What is the science behind the use of trichome in control of*** *Tetranychus evans?*

Answer: Glandular trichome types I, IV, VI and VII are known to release secretions on touch that are sticky and toxic. The secretions immobilize mites or kill them. Glandular trichomes are few in *L. esculentum*, which has high non-glandular trichomes that do not secrete exudates. The glandular trichomes are abundant in *L. hirsutum* and are the reason for high resistance to insect pests in this species. Transfer of these attributes to *L. esculentum* will minimize mite damage on tomato.

Question: ***Does breeding for high density of trichomes have any relevance for fungal diseases affecting tomato, owing to possible reduction in evapotranspiration on the leaf surface?***

Answer: *L. esculentum* has trichomes I, III, V, VI and VII with type V being the dominant type. It does not secrete any exudates and has no glandular head. *L. hirsutum* has trichomes I, III, IV, VI and VII with type IV being dominant. It secretes exudates that are toxic to pests. The aim is to incorporate type IV trichomes into *L. esculentum* and reduce the density of trichome V. Study reveals that between trichome IV and V, if one is in high density the other will be lower. So basically the number of trichomes will not increase but type IV will replace type V.

Impact of Onion Thrips (*Thrips tabaci* Lind.) Infestation on Dry Matter Partitioning and Onion Bulb Yield

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Abstract

Growth and yield of bulb onion are subject to significant stress by injuries caused by sap feeding thrips, mainly *Thrips tabaci* Lindeman. The current study was undertaken to characterize the growth rate of onion leaves and bulbs by comparing plants grown in plots infested by thrips (unprotected) with those from non-infested (protected) plots in nine field trials conducted in Kenya during 2000 and 2001. The overall leaf growth rate (0.11g plant^{-1} day^{-1}) was greatest in the protected plots during 42 to 56 days after transplanting (DAT), while this same period experienced the greatest reduction in dry matter partitioning into leaves (0.04 g plant^{-1} day^{-1}) due to thrip infestation. Leaves constituted less than 20%, while bulbs constituted about 80% of the total dry matter. The increase in bulb dry weight was significantly reduced by thrip infestation from 56 DAT onwards and the extent of reduction reached a peak at 98 DAT. Bulb yield reduction due to thrip infestation ranged from 18 to 60%. Overall, significant negative relationship of thrip infestation with the onion bulb yield occurred at 56 DAT. The study has pointed out critical growth stages at which thrip infestation showed significant relationship with final bulb yield and confirmed the negative effect of thrip infestation on dry matter partitioning, final bulb yield, and bulb quality.

Key words: bulb onion, dry-matter partitioning, *Thrips tabaci*, yield reduction.

Introduction

In the onion crop, larvae and adults of thrips, *Thrips tabaci*, pierce individual leaf cells and suck the cell contents through a feeding tube formed by paired maxillary stylets (Mound, 1971; Chisholm and Lewis, 1984). As a result of the thrips injury, the plants are weakened, growth retarded and resistance to common exogenous factors such as drought reduced. Most importantly, thrips infestation has been associated with substantial yield losses in onion. In addition to yield reduction, thrips infestation has been reported to affect the quality of onion bulbs (Zaman, 1990). In Kenya, thrips have been reported as an important onion production constraint (Kimani and Mbatia, 1993) but no attempts have been made to quantify the losses due to thrips infestation. Knowledge on the physiological impact of thrips infestation on plants is also scarce (Evans, 1972; Sandras and Wilson, 1998). Such information would provide an insight into thrips interaction with yield formation and help improve decision making on timing of thrips control interventions in onion. Field trials were therefore conducted to determine the response of the onion crop to thrips infestation as manifest in the dry-matter partitioning and yield loss.

Materials and Methods

Experimental sites and onion crop establishment

Nine field trials were conducted at two sites at the Kenya Agricultural Research Institute (KARI) Mwea-Tebere and Kiboko farms. The Mwea-Tebere farm is situated approximately 100 kilometers (km) North East of Nairobi at an altitude 1158m above sea level (asl), latitude 0^{o} 37′ S and longitude 37^{o} 20′E, while Kiboko is situated approximately 150 km South East of Nairobi at an altitude of 960m a.s.l., latitude 2^{o} 30′ S and longitude 37^{o} 50′ E (KARI, 2000).

Onion crop establishment

Seeds of onion cultivar Red Creole were sown in nursery beds using the standard onion production practices (Anon., 1989). The seedlings were transplanted in the field at a spacing of 30cm between the rows and 10 cm within the rows after about six weeks from sowing. During transplanting, Diammonium Phosphate (D.A.P) fertilizer was applied into shallow furrows at the rate of 200kg ha^{-1}. Later, the onions were top dressed with Calcium Ammonium Nitrate (C.A.N), at the rate of 300kg ha^{-1} after one month. The crop was kept weed free through hand weeding and furrow irrigation applied when necessary to avoid drought stress. The trial consisted of two randomised complete blocks replicated six times. The technique adopted was to use insecticides for keeping one set of plots from thrips infestation (protected) while in the other set of plots, thrips infestation was not controlled (unprotected) (Jotwani *et al*., 1971). Thrips protection was done using fortnightly foliar application of insecticide Polytrin® (Profenofos 400g/l and Cypermethrin 40g/l mixture) at the recommended rate (1litre ha^{-1}) using a knapsack sprayer at 100ml per 20litres of water.

Data Collection

Thrips density per plant was estimated from whole plant by cutting and bagging method (Freuler and Fischer, 1984). From each plot, 10 plants were selected through stratified random sampling, avoiding the border rows (Dent, 1991). Thrips extraction from the onion plants was carried out in the laboratory, using 70% alcohol (Bullock, 1963). A vacuum suction pump was used to filter thrips, which were then counted under a dissecting microscope. To assess the dry matter formation, leaves and bulbs from ten randomly selected plants per plot were cut off and placed in brown paper bags for transportation to the laboratory. The bulbs were sliced longitudinally to ensure thorough drying (Tei *et al*., 1996). The leaves and bulbs were oven dried for four days at 70^{0}C after which, they were weighed in an electronic balance. The weight of leaves and bulb was recorded for each sample plant.

To assess the final bulb yield, the onion crop was harvested when more than 50 percent of the leaf bundles had lodged. The tops and roots were cut off and bulbs air-dried for seven days.

Yield was calculated from the mean weight of bulbs harvested from a net plot, consisting of four middle rows per plot and extrapolated into tons per hectare. The bulbs from each net plot were sorted in three grades based on the bulb diameter (Grade 1=>5 cm, Grade 2=≤ 5 >3 cm and Grade 3=≤3 cm) (Nguthi *et al*., 1994).

Data Analysis

Density of thrips (thrips numbers plant^{-1}) were log transformed (n′=log $_{10}$ (n+1) during analysis. Analysis of variance (ANOVA/GLM), were performed to compare the test variables among the treatments and means separated using Student-Newman-Keuls (SNK) multiple range test (SAS, 2000). Regression analysis was performed to determine the relationship between the assessed variables. The mean growth rate (G) was calculated as described by Petr *et al*. (1988) as follows: *G= w2-w1/t2-t1.* Where *w1* and *w2* are respective dry weights found at two consecutive sampling occasions *t1* and *t2*.

Results

Effects of thrips infestation on onion dry matter partitioning during the crop development

In the thrips protected plots, the maximum leaf growth rate (0.11 g day^{-1}plant^{-1}) was observed from 42-56 days after transplanting (DAT) (Table 1) while a lower growth rate (0.04 g day^{-1}plant^{-1}) was observed in the thrips infested (unprotected) plots at this stage. Increase in leaf growth ceased after 70DAT and remained so, in both the protected and unprotected plots while bulb growth increased drastically from 56DAT and continued until the last sampling date (98DAT) in both protected and unprotected plots. Overall, the rate of dry matter increase was lower in the thrips infested plots.

Table 1: Overall leaf and bulb growth rate during the onion crop development in the thrips protected and unprotected plots, among nine field trials in Kenya, during 2000 and 2001

Onion plant age (*DAT)	Leaf growth rate (g plant^{-1} day^{-1})		Bulb growth rate (g bulb^{-1} day^{-1})	
	Protected	Unprotected	Protected	Unprotected
14-28	0.04	0.03	0.01	0.01
28-42	0.10	0.09	0.10	0.07
42-56	0.11	0.04	0.09	0.09
56-70	0.08	0.07	0.28	0.17
70-84	-0.02	-0.01	0.53	0.32
84-98	-0.06	-0.05	0.60	0.22

**DAT: Days after transplanting.*

The relationship between dry weight partitioning in the leaf and in the bulb, with the onion crop growth was highly significant and best described by a third degree polynomial pattern (Fig. 1). Dry matter partitioning within the onion leaves showed that about 20% of the final leaf dry-matter was formed during the first 28 DAT, while only about 2% of the bulb dry-matter had been formed at this stage. Maximum leaves dry weight was reached during 70-84DAT after which, no further dry matter was partitioned to the leaves. In contrast, rapid dry- matter increase was observed in the bulbs during 70DAT to 98DAT constituting about 70% of the total dry- matter formed (Fig. 1). Difference in dry matter formation in bulbs between the protected and unprotected plots was apparent from 56DAT. The most significant bulb dry- matter formation was observed during 84-98 DAT, which contributed to about 40% of the final dry matter in the protected plots, while in the unprotected plots, about 10% of the bulb dry- matter was formed during the same period. By the last sampling date (98 DAT) about 50% reduction in the bulb dry matter was observed due to thrips infestation, while in leaves dry-matter was about 30% (Fig. 1).

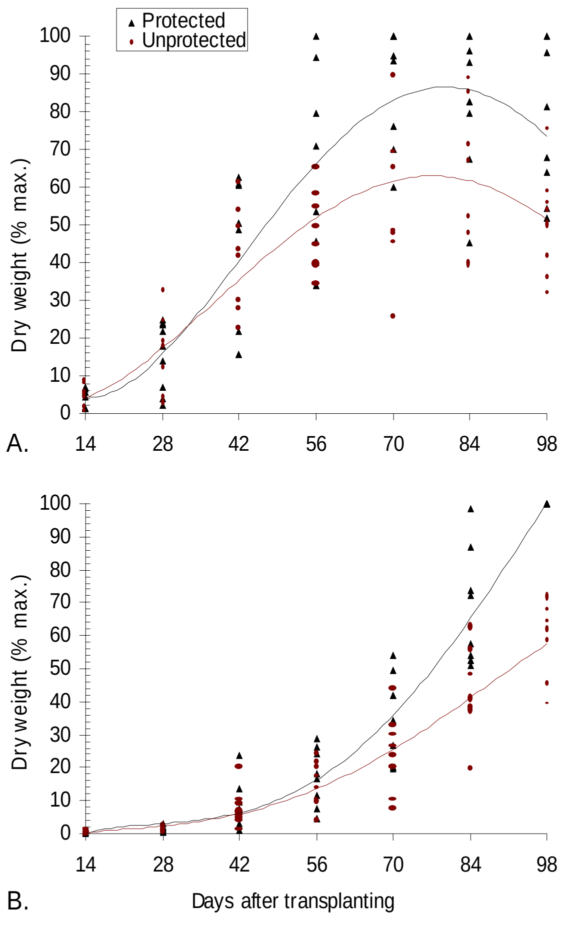

Figure 1: The partitioning of final dry weight of leaves (A) and bulbs (B) during the onion plant growth in the protected and unprotected plots during the onion crop growth in nine field trials grown in Kenya.

Dry matter partitioning between the onion leaves and bulbs in the protected and unprotected plots during the plant development established a polynomial type of relationship for the plant dry weight, leaves and bulbs respectively. During the first month (28 DAT), the fraction of dry matter partitioned to the leaves was about 90% of the total amount of the dry matter produced (leaves and bulbs). A switch in dry-matter partitioning from leaves to the bulb occurred from 56 DAT onwards resulting in steady increase in bulb dry matter until the last sampling date (98 DAT). In the onion plant, the leaves constituted less than 20% of the dry matter, while the bulbs comprised about 80% of the total assimilates (Fig. 2).

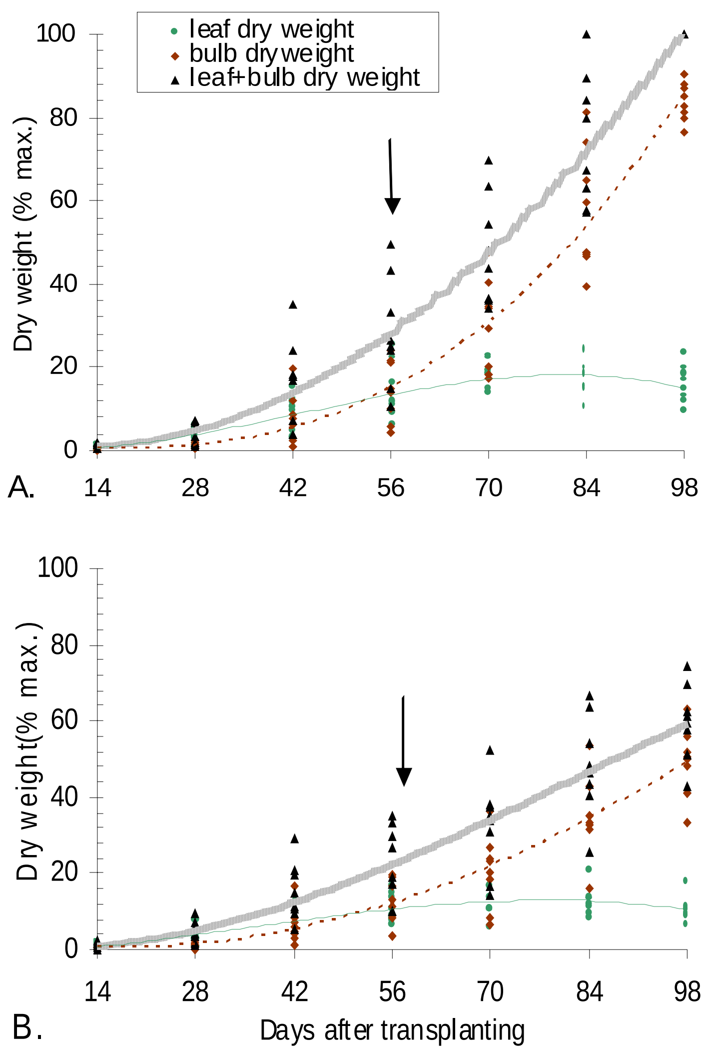

Figure 2: Dry matter partitioning from the final dry weight (leaves and bulb) to the leaves and bulbs in the protected (A) and unprotected plants (B) during the onion crop growth in nine field trials conducted in Kenya.

The effect of thrips infestation on the onion bulb yield and quality

There were significant differences observed in onion bulb yield between the protected and unprotected plots in the nine field trials (F=14.16; d.f=1, 80; P=0.0003) (Fig. 3). The protected plots yielded an average 44 tons ha^{-1} compared with 30 tons ha^{-1} in the thrips infested (unprotected) onion plots. The difference in the yield of superior quality bulbs was significant between the protected and unprotected plots ($F=26.41$; d.f=1, 80; $P<0.0001$). Among the protected plots, 61.3 % of the bulbs were of superior quality (Grade 1), while only 36.6% of the onions were Grade 1 in the unprotected plots.

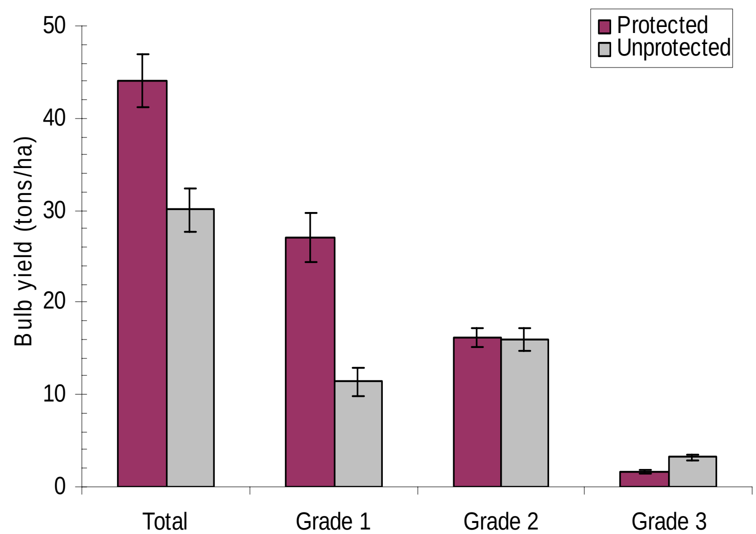

Figure 3: The overall total yield (tons ha^{-1}) and yield of superior (Grade 1), medium (Grade 2) and small (Grade 3) bulbs in thrips infested (unprotected) and protected plots. Pooled means for nine field trials grown in Kenya.

Onion bulb yields in each of the nine planting seasons (Table 2) showed significant differences between the protected and unprotected plots, except in the ninth trial, which had very low (17.9 thrips plant^{-1}) seasonal thrips numbers. The percentage avoidable yield loss due to thrips infestation ranged from 17.8% to 60.0%. Multiple regression of the yield loss against thrips numbers for the different sampling dates (Table 3) showed that thrips infestation at 56DAT best predicted yield loss in onion ($R^2=0.7110$, $P=0.0043$).

Table 2: Onion bulb yields (tonnes ha^{-1}) in the protected and unprotected plots in nine onion field trials in Kenya

Field trials	Protected	Unprotected	F	d.f	P	Yield loss %
1	68.85±2.35Aa (0.9±0.1)	42.72±0.57Bb (63.2±1.6)	116.7	110	<0.0001	37.95
2	41.69±2.09Ab (0.3±0.0)	31.67±1.10Bc (21.7±1.0)	18.1	110	0.002	24.04
3	29.71±1.32Acd (0.4±0.1)	20.70±1.31Bd (26.3±0.8)	23.4	110	0.001	30.3
4	24.17±2.77Ad (0.3±0.1)	17.69±0.58Bde (22.1±0.6)	5.23	110	0.045	26.81
5	25.87±1.68Ad (0.9±0.1)	10.34±2.08Bf (29.58±1.4)	33.8	1 6	0.001	60.04
6	64.35±3.22Aa (2.3±0.2)	52.87±2.79Ba (19.1±0.9)	7.3	1 6	0.036	17.84
7	36.74±3.59Abc (1.0±0.1)	14.98±0.91Be (38.4±2.5)	34.6	14	0.004	59.24
8	73.27±2.45Aa (1.4±0.1)	53.46±2.02Ba (21.2±1.3)	38.9	14	0.003	27.04
9	42.78±4.52Ab (1.1±0.3)	32.16±3.21Ac (17.9±1.7)	3.7	14	0.13	24.82
F	97.53	53.56				
d.f	8, 32	8, 32				
P	<0.0001	<0.0001				

Within a column, means (± s.e) marked by the same lower case letter are not significantly different (P<0.05) by SNK test and means marked by the same upper case letter within a row are not significantly different (P<0.05) by Scheffes test. Values in parenthesis are mean thrips (± s.e) per plant.

Table 3: Regression of yield (dependent variable) on thrips numbers (independent variable) at different onion growth stages for nine onion field trials planted at Mwea-Tebere and Kiboko in Kenya.

Onion plant age	Y-intercept ± s.e	Slope ± s.e	R^2	P
14DAT	33.19±6.413	0.31454±1.027	0.0132	0.7683
21DAT	29.81± 8.257	0.72268 ± 1.034	0.0652	0.5073
28DAT	30.54±10.047	0.354±0.810	0.0264	0.6760
35DAT	36.88±7.464	-0.118±0.231	0.0359	0.6253
42DAT	33.18±7.853	0.025±0.135	0.0049	0.8574
49DAT	24.73±8.763	0.225±0.172	0.1966	0.2320
56DAT	20.78±4.378	0.269±0.065	0.7110	*0.0043
63DAT	27.14±8.306	0.190±0.176	0.1423	0.3169
70DAT	29.196±8.874	0.139±0.196	0.0666	0.5026
77DAT	22.932±10.055	0.311±0.242	0.1918	0.2385
84DAT	30.642±10.975	0.128±0.342	0.0198	0.7180
91DAT	32.29±12.617	0.073±0.426	0.0041	0.8695
98DAT	30.21±11.666	0.129±0.333	0.0212	0.7088
105DAT	24.787±21.738	0.425±0.766	0.0715	0.6084

**Significant at P=0.05, n=9; DAT- days after transplanting*

Discussion

In the present study, the relative dry matter accumulation between leaf and bulb in relation to thrips infestation in onion was characterized over nine trials. It was observed that the protected onion crops tended to allocate about 20 percent of the total dry matter to leaves, while the rest was partitioned to the bulbs. The leaf dry matter showed a negative increase during the later growth stages (70-98DAT) of the onion crop, which coincided with substantial increase in bulb dry weight. This conforms to observations by Brewster *et al.* (1986), who had indicated that at later stages of the onion growth, there was net loss in leaf dry weight, suggesting that photosynthates were translocated to the bulbs, thus avoiding their loss as senescent leaf material. Onion plant is apparently able to balance between loss of dry matter due to thrips infestation and the associated yield loss of bulbs. As against the overall 50 percent reduction in the bulb dry weight due to thrips infestation, final bulb yield reduction in the trials was only 14%. Sandras and Wilson (1998) reported such compensation in cotton, where thrip infestation caused about 40% dry weight reduction but only 11% final yield loss. This compensation counters the potential of thrips to act as a sink for the cell sap (Evans, 1972).

The criticality of crop growth stages and the effects of thrip infestation on yield formation were also observed in the current studies. Marked reduction in the bulb growth rate due to thrips infestation was observed during 56 DAT onwards, the last period (98 DAT) showing the maximum reduction. The thrips infestation also showed a significant positive relationship with bulb yield reduction at 56 DAT. The studies have also shown that thrips infestation levels, especially at 56 DAT, significantly affected the dry matter partitioning, in diverting bulb development. Since bulbs depend on leaves for their supply of carbohydrates and other minerals, the bulb development is expected to be limited when carbohydrate production in leaves is restricted as a result of tissue puncturing, draining of cell contents and collapse of cell walls caused by the thrips feeding. In this way, thrips interfered with the distribution of photosynthates between the plant organs resulting in bulb yield reduction.

Bulb yield reduction ranged between 18 and 60% among the unprotected plots in the nine field trials. Trials carried out recently at the International Centre of Insect Physiology and Ecology, (ICIPE), Kenya, estimated yield losses ranging from 38 to 54% (K. Ampong-Nyarko and S. Sithanantham, unpubl.). Estimates by other researchers indicate a wide range in yield losses due to *T. tabaci* infestation in onions. In Indonesia, onion yield loss has been reported to range from 12 to 50% (Dibiyantoro, 1997), while in Quebec (Canada) heavy infestation by onion thrips resulted in yield losses of 43% and 34.5% in 1988 and 1989, respectively (Fournier *et al.*, 1995). In the present study, significant yield losses were recorded from all the crop seasons, except one crop season with the least seasonal thrips numbers (17.9 thrips $plant^{-1}$). Furthermore, lower yield losses were observed in some cases with higher thrips numbers. It was therefore evident that onion plant yield response to thrips injury was not limited to thrips alone, but other exogenous factors also.

Edelson et al. (1989), observed lower yield of onions in a trial even though the seasonal number of thrips was lower than in a previous season. The yield variability was attributed to the differences in weather factors. Similarly Fournier et al. (1995) attributed the differences in yield response of onions between seasons due to variations in precipitation. In the present study, the onion plants were irrigated when necessary and were unlikely to experience distinct levels of water stress. However, climatic factors such as rainfall, temperature and relative humidity as well as inherent soil nutrient status in the two trial sites may have influenced the thrips population abundance and onion plant development trend, resulting in the observed variability in yield as also observed by Harding (1961) and Lewis (1997).

In addition to reduction in the total bulb yield, thrips infestation was shown to reduce the quality of the bulbs. In the unprotected plots, grade 1 (superior quality) onions constituted only 37% of the total bulb yield, while in the protected plots, 61% of the onion yield was superior quality bulbs.

In conclusion, the present study has established that thrips adversely interfere with yield formation through deviation of photosynthates into the insect gut resulting in reduction of the final bulb yield and quality. The magnitude of yield loss though related to increase in thrips numbers is also dependent upon other exogenous factors that were not quantified in the present studies.

Acknowledgements

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Effects of coloured mulch on aphids and/or *Lepidoptera* in lettuce and broccoli

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Abstract

The effects of the change of light quality caused by the use of coloured mulch material on infestation with aphids and/or *Lepidoptera* were tested in lettuce and broccoli crops. As material silver (aluminium coated), blue, green, red, black and white polypropylen fleece was used. A bare soil acted as 'control'. The abundance of aphids in lettuce and as a strong tendency in broccoli was reduced due to the UV-reflecting mulch colour silver and white. The occurrence of cabbage flies was reduced in all mulch colours except blue and green. The yield of broccoli was higher in the highly reflecting silver material. No clear influence of the mulch material was found for the yield of lettuce. As a negative effect the abundance of caterpillars of different cabbage pests seemed to be higher in the UV-reflecting mulch colours silver, white and red. To make a decision for the use of these materials additional costs for material and labour, the risk for the occurrence of specific pests and the market situation have to be considered.

Key words: Aphids, *Lepidoptera,* mulch, lettuce, brocccoli

Introduction and hypotheses

Mulch material is used in vegetable production to reduce weed growth and evaporation, to warm up the soil especially in early spring (transparent or black), or to reduce soil temperature during phases with high radiation in summer (white). The reflexion is important, too. Light is mainly understood as energy source for plants via photosynthesis, but light might also be an information carrier. Plants show growth reactions in relation to light quality (wavelengths => photomorphogenesis) (Kasperbauer 1992) and insects also change their behavior under different light qualities (Kolb and Scherer 1982; Greer and Dole 2003).

Humans have three light receptors (419 nm blue/violett, 531 nm green, 558 nm orange/red). Some insects (all butterflies, flies, bees) are also trichromatic, but their reception maxima are different from the human ones (Briscoe and Chittka 2001; Menzel and Backhaus 1991). For aphids the absorption pattern is not clear. Some authors assume a dichromatic receptor system (Burrows et al. 1983). In effect insects have a different light perception compared to humans - they ‚see different'.

Looking at light as an information carrier it should also be possible to use different mulch colours and their reflective properties to irritate insects to find a host. Besides there could be also effects on plant development and finally yield.

Material and methods

As modified factor the colour of the mulch material was used (silver, blue, green, red, black, white and bare soil as 'control'). The material was a polypropylen-fleece with 70 g m^{-2}. As crops lettuce and broccoli were used.

There have been different planting dates in 2003 and 2004 in several locations around Hannover, Germany (Winzlar, Herrenhausen and Ruthe). The experiments were carried out in an organic production system. Consequently no pesticides and only organic fertilizers were used (100 and 200 kg N ha^{-1} for lettuce and broccoli, respectively). Irrigation was done according to crop requirement.

Results and Discussion

Aphids in lettuce

Accept for one intermediate harvest there had been significant differences in the number of alate aphids in lettuce (experiment Herrenhausen, data not shown), with a low number of alate aphids in the silver mulch treatment (app. 2 aphids $plant^{-1}$) and a high number in the green (app. 10 aphids $plant^{-1}$). This agrees with the total number of aphids resulting in around 50 aphids $plant^{-1}$ in silver mulch and around 350 aphids $plant^{-1}$ in green mulch. Bare soil and black mulch show intermediate abundances (Fig. 1).

With the reflective silver material the number of aphids was reduced significantly. It has to be stated that even in this treatment more than 50 aphids per plant were found. This may be acceptable for consumers with a preference for organically produced vegetables, but for the standard market there would be difficulties to sell such a produce.

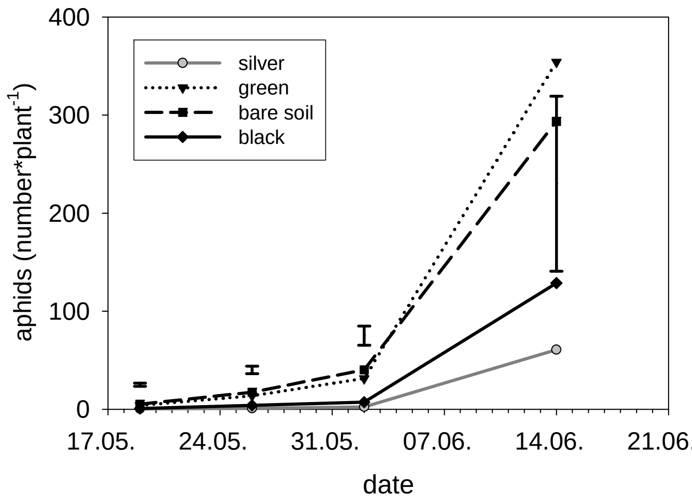

Figure 1: Abundance of aphids in lettuce (Herrenhausen 2004, bars represent least significant difference, lsd-test, n= 4, p= 0.05)

Aphids in broccoli

Also for broccoli silver and additionally white mulch showed reduced aphid infestation. This was significant for alate aphids in comparison to blue and green mulch, but for unwinged aphids this can only be stated as a tendency due to big standard deviations (Fig. 2).

It could also be observed that the number of antagonists (larvae of hoverflies, ladybirds) was higher in the treatments with a higher number of aphids (data not shown). This effect is possibly caused by a coevolutive mechanism (Grez and Prado 2000), or in the sense of the 'friend or foe hypothesis' (Finch and Collier 2000). For broccoli around 20 aphids plant^{-1} are no problem for the marketability.

Cabbage fly in broccoli

Beside the positive effect of reducing the number of aphids, there was also a significant effect on plant loss caused by cabbage flies. This was true for all mulch material except dark blue and green (Fig. 3). An explanation could be that the mulch is a physical barrier for the egg deposition of the cabbage fly at the stem basis of the plant (Skinner and Finch 1986).

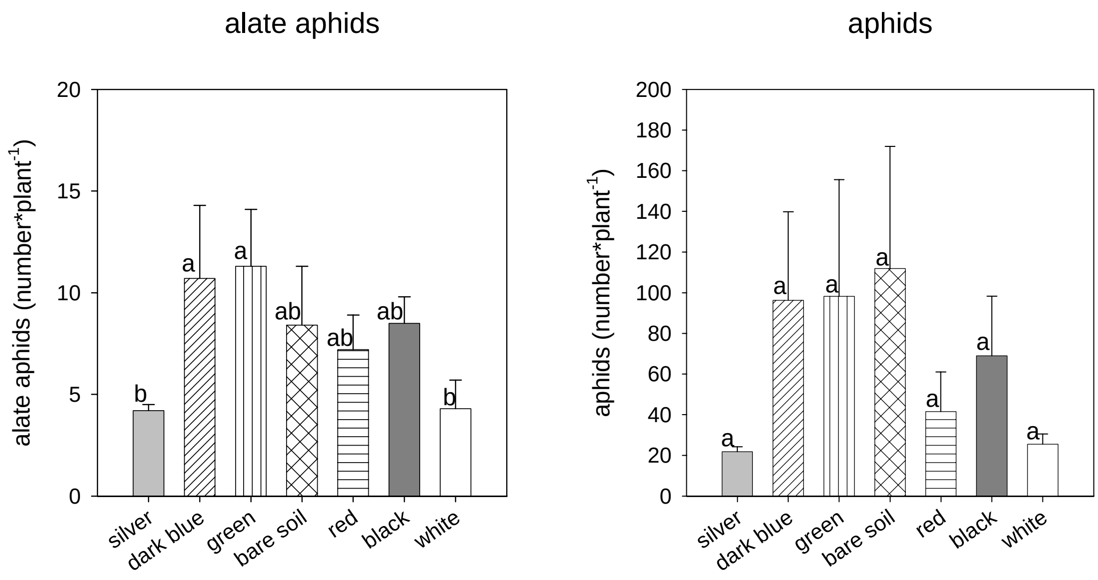

Figure 2: Abundance of aphids in broccoli (Herrenhausen, 7 weeks after planting, bars represent standard deviation, Tukey-test, n= 3, p= 0.05)

Caterpillars in broccoli

On the one hand it could be shown that aphids were reduced by UV-reflecting mulch material. On the other hand more caterpillars were found with these material (Fig. 4), but as incidence grouped over different species this effect is not significant. At least there seems to be the tendency that caterpillars show an inverse host finding reaction compared to aphids. Nevertheless for all treatments most of the time the incidence of caterpillars was higher than the corresponding threshold values (25% up to 8-12 leaves, 50% up to head formation, 5% during head growth). This means using coloured mulch additional strategies against caterpillars are necessary or it might be even counterproductive.

Lettuce and broccoli yield

For lettuce no clear influence of the mulch material on the yield was found (data not shown). If the four planting dates of broccoli are averaged, the plants with silver mulch show a higher yield than with the other treatments. But a significant higher yield can only be stated between silver and red as well as between silver and black mulch (Fig. 5).

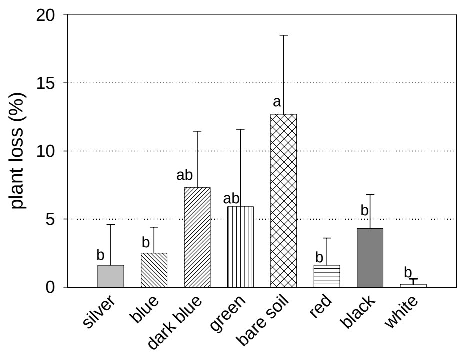

Figure 3: **Percentage of plant loss in broccoli caused by cabbage fly (Herrenhausen 2003, set 1, bars represent standard deviation, Tukey-test, n= 4, p= 0.05)**

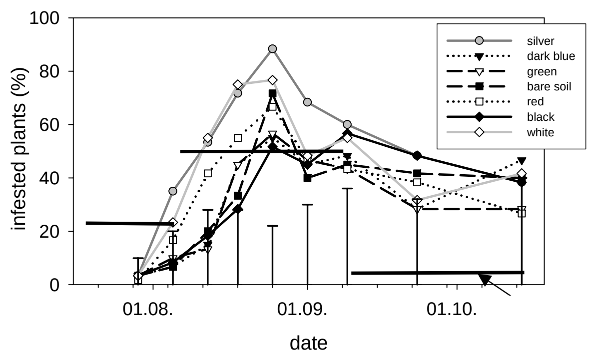

Figure 4: **Incidence of caterpillars in broccoli (Winzlar 2003, *Mamestra brassicae, Pieris rapae & brassicae, Autographa gamma, Evergestis forficalis*, bars represent least significant difference, lsd-test, n= 5, p= 0.05)**

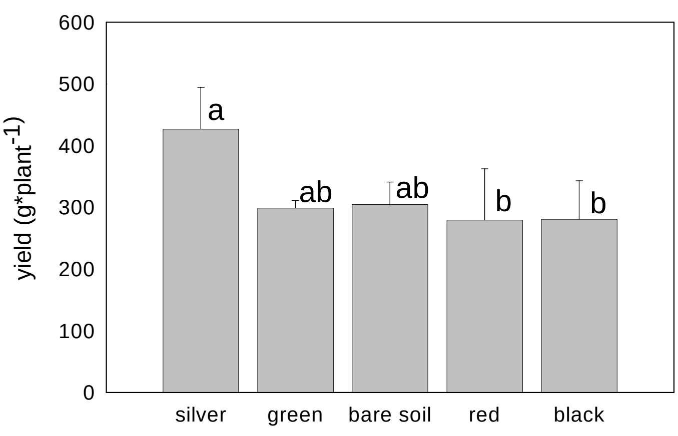

Figure 5: **Mean yield from four planting dates for broccoli (bars represent standard deviation, Tukey-test, p= 0.05)**

Conclusion and Recommendations

If thinking about using mulch in vegetable production, first the financial aspect should be considered. Depending on prices for the produce it has to be calculated, if the costs of about 0.40 € m^{-2} mulch (if used only one time) is economically reasonable. Additionally there are higher labour costs for the handling of the material, but probably less to spend for weeding.

Regardless the costs there are some positive aspects for the plants in general (no competition with weeds, adequate soil temperature and less evaporation). As shown here also a reduced aphid and cabbage fly population was possible with UV-reflective mulch material. On the other hand there was a tendency to more caterpillars of different cabbage pests in these treatments. The decision of using reflective mulch material is only possible by taking all mentioned aspects into account. There is also the possibility to combine the use of mulch with other biological pest control strategies as for example *Bacillus thuringiensis* to counteract the negative effects regarding caterpillars.

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Feedback

Question: ***What other factors could affect aphid movement. For example, how did you control wind and the other factors in your study?***

Answer: The most important other factor is wind. The wind direction was measured only at location "Harrenhausen". There, it could be shown that the wind mostly came from the west/southwest direction. The experiments were blocked in east-west direction. One experiment additionally was laid out in Latin square design.

Question: ***Silver mulch seemingly gave the highest absolute yields. Could you comment on the quality of the produce?***

Answer: The quality was marketable as long as the number of aphids did not exceed the maximum number accepted by the market. The maximum changes, depending on the market situation. If low produce amount is on the market, some aphids are accepted. If there is a high amount of produce on the market no aphids are accepted.

Question: ***If silver background was not effective in all pests, then what is the best and universal solution to the problem of pests?***

Answer: Mulch use can only be one measure in producing organic vegetables. To be successful a combination of measures has to be used in the production chain.

Question: ***What was the perceived effect of temperature on plant growth under the silver mulch where there seemed to be better production of lettuce?***

Answer: Temperature was: 16.3^{o}C under silver mulch, 16.9^{o}C under bare soil, 16.7^{o}C under dark blue, 16.9^{o}C under green, 16.6^{o}C under red, 16.9^{o}C under black and 16.6^{o}C under white. The temperature was measured 10 cm under the soil surface. Temperature sum over whole growing period was 1253^{o}C under silver and 1303^{o}C under bare soil.

Use of Horticultural Mineral Oil for Pest Management

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Abstract

Pests are among the major constraints to crop production worldwide. For a long time farmers have relied heavily on conventional chemical pesticides to manage pests. The use of pesticides was supported by extensive research on pesticides by scientists and development of new products by agrochemical companies. The need to seek alternative management options has been occasioned by numerous negative impacts of chemical pesticides including: pest resurgence, development of resistance to pesticides, environmental degradation, and human exposure to pesticides. Petroleum spray oils are substances that have been investigated as alternatives to conventional pesticides. Their usage includes direct application for control of pests, combination with pesticides to improve efficacy, and formulation of entomopathogenic fungi to overcome the problem of UV radiation degradation and low relative humidity in the field. Improvement in refining has resulted in less phytotoxicity and greater efficacy. Petroleum spray oils are acceptable within organic farming systems and hence the greater potential for their utilization in pest management.

Key words: organic farming, petroleum spray oils

Introduction

Insecticides have been until recently the main strategy for managing insect pests. The limitations of insecticides for pest management include selection for resistance in pest populations, destruction of beneficial species, resurgence of treated populations, outbreak of secondary pests, residues in feeds, foods and water, and hazards to humans and the environment (Luckmann and Metcalf, 1994). There is overwhelming evidence that reliance on single strategy for pest management is unlikely to effectively manage insect pests and may be destructive to the ecosystem. It is therefore becoming more common to integrate strategies in the best manner possible. This has been termed integrated pest management (IPM).

One important principle of IPM is the utilization of natural factors to control pests with application of curative strategies only when and if the pest population rises beyond the economic threshold level. In such programs, the key factors limiting the pest population are natural enemies. Of these natural enemies, parasitoids and predators play important roles of maintaining the population below damaging level. Chemical insecticides are usually the choice strategy when the economic threshold is reached. Since chemical insecticides have been shown to destroy natural enemies, benign products are preferred. Petroleum spray oils are considered biorational for pest management and are allowed in organic farming systems.

The Webster's New World College Dictionary defines the term oil as "any of various kinds of greasy combustible substances obtained from, animal, vegetable and mineral sources; oils are liquid at ordinary temperatures and soluble in certain organic solvents as ether but not in water." On the account of this definition, three oil groups based on origin are: vegetable oil (from plants), animal oil (from animals) and mineral oil/petroleum oil (from minerals). In this paper, only petroleum oils are discussed.

Horticultural mineral oils have also been referred to as petroleum spray oils, white, summer, superior, horticultural or narrow-range oil. Lack of standardized terminology made it very difficult to compare work done with oils. Horticultural mineral oil (HMO) was proposed as the preferred name for the highly refined narrow range oils used in pest management during a workshop held in Sydney Australia in 1999.

Properties of Horticultural mineral oils

Hamilton (1993) discussed the structure and general properties of oils. Hodgkinson's (Unpublished) and the proceedings of the international conference on oil held in Sydney, Australia (Beattie *et al.,* 2002) provided some more recent reviews of the same subject. Important properties of HMO include: chemical composition, paraffin content, molecular weight/carbon number and unsulfonated residue (USR). HMO consists of a mixture of hydrocarbons with straight chains and ring molecules. The main molecules are: paraffins (straight saturated chain molecules), napthenes (straight unsaturated chain molecules), olefins (saturated molecules with rings) and aromatics (unsaturated molecules with rings) (Figure 1).

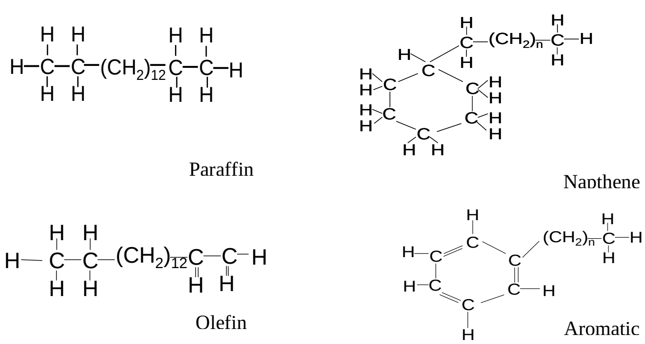

Figure 1: Major constituents of a horticultural mineral oil

Paraffin content (Paraffinicity) is the percentage of paraffin molecules within oil. A minimum of 60% paraffinicity is essential for pesticidal activity. Un-sulfonated residue (USR) is a measure of the level of saturation of the molecules in the oil. It is estimated in terms of the oil fraction that does not react with concentrated sulfuric acid. Ideal oils should have not less than 92% USR value. Molecular weight or carbon number refers to the size of the molecule within the oil. It is measured in terms of the number of carbon atoms within the constituent molecules. The molecular size influences both the pesticidal efficacy as well as phytotoxicity (Figure 2).

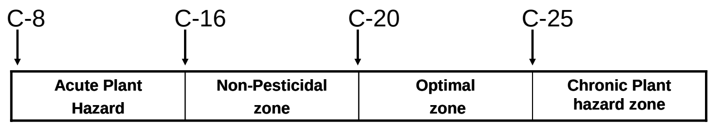

Figure 2. Relationship between molecular size of horticultural mineral oil and pesticidal/phytotoxic effects of the oil

Distillation temperature determines the molecular size profile. The difference between temperature at which 10% oil and 90% distils at 10 mm Hg is referred to as range. Narrow range oils must not exceed 44.4°C.

Utilization of HMO in pest management

Mineral oils have a long history in crop protection. Oils were used in 1880's as dormant sprays and in early 1900's to control scales in orchards. Application was limited to dormant vegetation due to phytotoxicity. New oils are highly refined, lighter in weight, with fewer impurities and have sunscreens; they are hence less phytotoxic. Currently, there is widespread and very successful use of HMOs in orchards (e.g. citrus) in Australia and China. They may also be used in management of fungal diseases, formulation of entomopathogens, storage of fungi, reduction in the spread of viruses and as spray additives. Oils have been shown to affect several fungi (Table 1) and hence may be used to manage fungal diseases.

Herron *et al*. (1995), demonstrated toxicity of petroleum spray oils (Caltex Lovis, Ampol D-C Tron and Sunspray ultrafine) to selected stages of various citrus pests and green peach aphid. The susceptibility varied greatly depending on the species and stage of the insects tested. In another study three petroleum spray oils: Lovis (C21; Caltex oil; Australia); D-C Tron NR (C23; Ampol limited; Australia); and Guangdong oil (C27; Luoding Biochemical Plant; China) applied at the rate of 500mL/100 litre of water gave comparable control of citrus leaf miner, *Phyllocnisti citrella* to that of the conventional insecticides, cartap and methomyl (Rae *et al*. 1996a).

Table 1: Example of pathogens susceptible to HMOs

Disease	Host	Remark	Reference
Powdery mildew (*S. pannosa*)	Roses	0.3-0.5 % (v/v) PSO provided curative control	Nicetic et al. 1999
Powdery mildew *Leveilula taurica*)	Tomato	0.5 and 1 % (v/v) PSO prevented establishment of the disease	Nicetic et al. 1999
Powdery mildew (*S. fuginea*)	Cucumber	0.5 % oil reduced infection over 6 weeks	Goodwin, et al. 1999
Powdery mildew (*Uncinula necator*)	Grapes	Stylet oil controlled this disease when used at 14-day interval	Northover, 1999
Powdery mildew (*Podosphaerella clandestine*)	Cherry	Oil used to control this disease in orchards and nurseries	Grove and Boal, 1999

A combination of abamectin at (1.5 g a.i. with petroleum spray oil (500mL/100litres) provided complete control of this pest (Rae *et al*. 1996b). Examples arthropod pests susceptible to oils are given in Table 2. HMO control arthropod pests in various ways including: mortality, repellency (Larew and Locke, 1990), oviposition interference, inhibition of development and reduced attachment of eggs to plants (Schroeder and Green, 1983) and ovicidal (Zidan *et. al*., 1987; Rae *et al.* 1997; Riedl *et al*. 1995).

Table 2: Examples of arthropod pests susceptible to HMOs

Pest tested	**Oil tested**
Eggs	
Two spotted mite eggs	Caltex Lovis and Ampol D-C Tron NR
First instar	
Chinese wax scale, pink wax scale, white wax scale, Black scale	Caltex Lovis, Caltex Lovis, Caltex Lovis Caltex Lovis, Caltex Lovis
Red scale, Citrophilous mealy bugs, Brown leaf hoppers	Caltex Lovis, Caltex Lovis, Caltex Lovis Ampol Dc Tron NR,
Greenhouse thrips (prepupae)	Caltex Lovis
Adults	
Greenhouse and Tomato thrips	Caltex Lovis+/- Ampol DC Tron NR
Adults:	
Citrophilous mealy bugs and Green peach aphid	Caltex Lovis, Total Citrole, Caltex Lovis and Ampol DC Tron NR
Adults:	
Black citrus aphids and Cotton/tobacco white flies	Caltex Lovis, Caltex Lovis and Ampol DC Tron NR
Adults:	
Citrus and European red mite	Caltex Lovis +/- Ampol DC Tron NR
Adults:	
Two spotted mite	Caltex Lovis and Ampol DC Tron NR
Adults:	
Broad mite and Tomato rosette mite	Ampol DC Tron NR for both

The practice of formulating microbial insecticides in oil is common. On an operational scale in China, conidia of *Beauveria bassiana* were formulated with crude petroleum extracts *in situ* and sprayed onto the forest caterpillar, *Dendrolimus* sp. using a rotary cage atomiser (Price *et al*., 1997). An oil-based formulation of *Beauveria bassiana* was sprayed on a rangeland grasshopper from air using Cessna Ag Tuck (Price *et al*., 1997). Trials of this nature indicate the possibility of integrating oils with insect pathogens as well as utilization of equipment designed for chemical application with insect pathogens. Dry conidia of *M. flavivoride* in paraffinic oil were effective against brown locust, *Locustana pardarlina* South Africa (Price *et al*., 1997).

Green muscles, an oil-based formulation of *M. flavoviride* conidia worked against *Locustana pardalina* in ground-based trials (Price *et al*., 1997). According to Inglis *et al.* (2002), oil formulation increase adhesion of propagules to the insect integument, enhance spread of inoculum over the insect body, enhance penetration of the insect cuticle, protect propagules from ultraviolet radiation, and enhance infection under conditions of low humidity. There is also the potential of oil penetrating deep into the insect body (Taverner, *et al.* 1998; 2002) thereby further boosting the infection process. The protection of entomopathogens against ultraviolet radiation degradation by oil has been reported (Inglis *et al.* 1995).

In a laboratory study, we found that HMO could enhance longevity in storage of spores of *Metarhizium anisopliae* (Table 3). We also found that the fungus accumulated more mycelia in oil-enriched broth than in broth alone (Table 4) and protected the fungus against UV radiation (Table 5). This study demonstrated the safety of the HMO to the entomopathogenic fungus making it possible to develop oil-based formulation of the fungus.

Table 3: Germination of *M. anisopliae* spores after short-term storage

Formulation	Germination (%)					
	Initial	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Tween	53.44a	4.01a	0.00a	0.00a	0.00a	0.00a
Oil w/o sunscreen	81.59b	80.29b	77.81b	77.20b	58.88b	46.08b
Oil with sunscreen	81.08b	80.30b	78.49b	76.44b	58.07b	46.17b

z Means followed by the same letter down the column are not significantly different according to DMRT (α=5%)

Table 4: Growth of *Metarhizium anisopliae* FI-1248 in broth with or without oil

Formulation	Weight of mycelia (g) z	
	Fresh	**Dry**
Broth alone	8.46a	1.56a
Oil enriched broth	22.38b	3.84b

z Means followed by the same letter down the column are not significantly different according to DMRT (α=5%)

Table 5: Post-UV exposure germination of *M. anisopliae* FI-1248 spores

Formulation	Germination (%)					
	0 hrs	**2 hrs**	**4 hrs**	**6 hrs**	**10 hrs**	**20 hrs**
UVC						
Dry	78.95a	4.49a	1.96a	-	-	-
Tween	32.76b	6.47a	4.69a	-	-	-
Oil	83.94a	17.2a	5.78b	-	-	-
Screen	83.69a	55.92b	53.75b	-	-	-
UVAB						
Tween	47.17a	-	-	4.69a	2.95a	11.74a
Oil	83.69b	-	-	0.20a	0.22a	0.00b
Screen	89.71b	-	-	59.95b	0.00a	0.00b

[z] *Means followed by the same letter down the column are not significantly different according to DMRT (α=5%)*

Stylet oils are used to prevent the spread of viruses by insect vectors. The oils clog the stylets of the virus-vectoring insects. As spray additives, HMOs are combined with conventional pesticides to improve attachment and penetration of pesticides into the host. The oil also reduces evaporation and hence increases the life of spray droplets. Hamilton (1993) pointed out that the '*UK Pesticide guide*' lists 15 adjuvants for agrochemicals, which contain either a refined mineral oil or a vegetable oil.

Limitation of HMOs

Phytotoxicity is the injury to plants by oils and is the greatest limitation to the utilization of HMOs. Phytotoxicity could be acute or chronic where acute phytotoxicity manifests as blemishes on the plant surfaces mainly the leaves while chronic phytotoxicity manifests as reduced growth and yield. The causes of phytotoxicity and possible remedial measures are given in Table 6.

Table 6: Causes of phytotoxicity in HMOs and remedial measures

Cause	Measure
Unsaturated molecules	Removal or saturation of unsaturated molecules
Degradation	Protection of oil against UV degradation
Molecular size	Use of narrow range oils

Conclusions

Horticultural Mineral oils (HMO) are diverse. They have been used for a long time in pest management. There is wide scope for use of HMO in pest management including: control of fungal diseases, control of arthropod pests, formulation of entomopathogenic fungi, control of the spread of viruses and as spray additives. The phytotoxicity associated with HMO is a limitation that can be minimized through use of narrow range highly refined oils and incorporation of in HMOS.

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Feedback

Comment: ***It appears that control by oil may be due to the effect on the condition for infection rather than direct effect on the pathogen. For example, the presence of oil on a plant surface may reduce the moisture on the host surface, thereby preventing germination of spores and infection by the pathogen.***

Answer: Indeed this is true. Oils could form a barrier between the fungus and the host plant. However, there is also potential for direct toxicity to the fungus. More research in this direction may be necessary to clarify the nature of the effect, as the mechanisms are still unclear.

Chemical Suitability of Some Organic Materials Available in Kenya as Components of Potting Substrates

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Abstract

Production of quality nursery potted seedlings requires a proliferous root system that enables adequate acquisition of water, air and soil nutrients and this depends on the quality of substrates used. Soil has always been used as a nursery and pot substrate but it has problems, including aeration, drainage, non-uniformity and chemical suitability. Therefore development of alternative potting substrates with optimal chemical properties is necessary. The main objective of the current study was to evaluate chemical suitability of forest soil, compost, pine bark, and rice husk as alternative components of potting substrates. The experiment was conducted at Maseno University, between February and December 2004. Materials including pine bark (PB), rice husk (RH), forest soil (FS) and compost soil (CS) were collected and formulated into 10 media treatments, namely T1 (100% FS), T2 (75% CS: 25% PB), T3 (50% CS: 50% PB), T4 (25% CS: 75% PB), T5 (75% CS: 25% RH), T6 (50% CS: 50% RH), T7 (25% CS: 75% RH), T8 (100% CS), T9 (100% PB) and T10 (100% RH). These were filled in polythene bags and arranged in a CRD with four replications. The media chemical properties, including macronutrients, micronutrients, cation exchange capacity (CEC), pH, and electrical conductivity (EC) were evaluated. Data obtained were subjected to analysis of variance to determine whether the treatment effects were significant at 5%, 1%, and 0.1% levels. Separation of means using Duncan Multiple Range Test was done where treatment effects were significant. The levels of macronutrients and micronutrients were significantly ($P \leq 0.05$) higher in substrate formulations of 75% CS and 50% CS formulated with either PB or RH than in the control. The pH was significantly ($P \leq 0.05$) different and generally acidic in all the substrates. Substrate formulations of 75% CS and 50% CS formulated with either PB or RH had CEC and EC within the optimal ranges. The substrate formulations 75% CS: 25% PB, 50% CS: 50% PB, 75% CS: 25% RH, and 50% CS: 50% RH had chemical properties within the optimal ranges and are recommended as pot substrates. These media will provide alternative potting substrates with superior or similar chemical qualities to soil and better utilization of agricultural and industrial wastes. Physical suitability of these substrate formulations will be evaluated.

Key words: Organic wastes, potting media, potting substrates

Introduction

The development of horticulture industry in Kenya has taken place at a rapid pace (Mulandi, 1998). The volume of horticultural export and the number of horticultural nurseries, which have mushroomed all over the country, verify this. From a technical point of view, this development and the increase of production intensity has set new demands for high quality inputs including growing media/ substrate. Suitable plant development depends to a large extent on the substrate used (Jaenicke, 1999). Peat is the dominant bulk material in most substrates (Nappi and Barberis, 1993). It is not locally available in Kenya and therefore, has to be imported at high costs.

The use of peat-based substrates in Kenya is confined to big or established horticultural enterprises whose products are meant for external trade. However, most horticultural enterprises producing seedlings of vegetables, fruit trees, trees for landscaping, environmental protection and conservation, research nurseries, floriculture, ornamentals, and other users, use substrates made of a mixture of topsoil, organic supplements and sand in varied proportions in containers or use a bed prepared on the soil (Jaenicke, 1999). These types of growing media/substrates are limited in quality in terms of aeration, drainage and diseases and negatively affect the development of plant roots (Aguila, 1988 and Reinikainen, 1993). Mining the soil also affect its quality for use for other economic and beneficial activities (Kuepper and Katherine, 2002).

This therefore calls for an urgent need for the development of more cost effective and good quality substrates from locally available alternatives including composted urban and agricultural wastes for quality nursery production. Therefore the main objective of this study was to chemically characterize formulated substrates from forest soil, pine bark, compost and rice husk.

Materials and Methods

Location of study and source of materials

This was a pot experiment carried out under a net shade situated in the demonstration farm of Department of Horticulture, Maseno University, Maseno, Kenya. The materials used in the study included; Compost, pine bark, rice husk and Flame violets. Compost was prepared from farmyard manure mixed with grass clippings in the demonstration farm of Department of Horticulture, Maseno University, Maseno, Kenya. Compost was prepared according to International Society of Horticultural Science (ISHS) standards (Gabriel and Verndonck, 1992). Pine bark was obtained from Webuye Paper Mills and was cut into smaller sizes of 1 cm to 2 cm sizes. Rice husk was obtained from Ahero rice farmers, Ahero, Kenya, Forest soil was obtained from a commercial ornamental plant nursery in Kisumu, Kenya.

Experimental design and layout

All the substrate formulations were sterilized by solarisation, a practice normally used by the small nurseries operators (Jaenicke, 1999). The composted manure was mixed with the pine bark, rice husk and forest soil in different proportions using a drum and a peddle mixer. These constituted the media to be used in the experiment. These were arranged in a Completely Randomized Block Design with four replications and ten treatments. Ten media were used which constituted the treatments (Table 1). Forest soil was used as the control. This is the standard growth media used by local nurseries operators. 100 g of each of the prepared media was sampled and placed in polythene paper bags and labeled for laboratory chemical analyses.

Table 1: Treatments used in the experiments

Substrate	Composition	Abbreviation	Composition (%)
T-1	Forest soil (Control)	(FS)	100
T-2	Compost: Pine bark	(CS: PB)	75:25
T-3	Compost: Pine bark	(CS: PB)	50:50
T-4	Compost: Pine bark	(CS: PB)	25: 75
T-5	Compost: Rice husk	(CS: RH)	75:25
T-6	Compost: Rice husk	(C: RH)	50:50
T-7	Compost: Rice husk	(CS: RH)	25: 75
T-8	Compost	(CS)	100
T-9	Pine bark	(PB)	100
T-10	Rice husk	(RH)	100

Chemical characterization.

Chemical properties determined included pH, electrical conductivity, cation exchange capacity, macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Na, Fe, Al, Mn, Cu, Pb, Mo, B, Zn).

The pH of the substrates was determined by potentiametric methods according to Tan, (1996). Electrical conductivity was determined from the mixture used to estimate the pH by filtering the filtrate through Whatman paper and using electrical conductivity meter (Rowell, 1994).

The mineral elements potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), aluminium (Al) and molybdenum (Mo) were extracted using ammonium acetate according to Rowell, (1994) and Tan, (1996). The nutrient elements, manganese (Mn), copper (Cu), zinc (Zn) and iron (Fe) were determined according to Rowell, (1994) and Tan, (1996). According to this method, these nutrient elements were extracted using ethylenediamineteraaceticacid (EDTA). Phosphorous (P) was determined by Olsen method as described by Tan, (1996). Sulphur was determined by turbidimetric method as described by Tan, (1996). The cation exchange capacity (CEC) was determined by ammonium acetate as described by Tan, (1996).

Nitrate nitrogen (NO_3-N) was extracted by potassium chloride (KCl) method (Rowell, 1994). The data obtained was subjected to analysis of variance (ANOVA) to determine if the treatment effects were significant at 5%, 1% and 0.1% level. Separation of means was done using the Duncan Multiple Range Test (DMRT) at 5% level. Correlation analyses were also done to determine associations between treatments and response variables.

Results

pH

Table 3 shows the pH was significantly (P≤0.05) affected by the substrate formulations. Substrates 75% CS: 25% RH and 50% CS: 50% RH had significantly higher pH than substrates 100% PB, 100% RH and the control (Table 3). Substrates 100%RH and 100% PB had significantly (P≤0.05) lower pH (4.2 and 4.4 respectively) (Table 3).

The substrates 75% CS: 25% RH and 50% CS: 50% RH had the highest and similar value of the pH, though they were not significantly (P>0.05) different from the other substrates, except, 100% RH and 100% PB (Table 3). The pH of all the substrates tended to be acidic (Table 3).

Nitrogen (N)

The substrate formulations significantly (P≤0.05) affected the nitrogen content (Table 2). Substrates 75% CS: 25% RH, 50% CS: 50% RH and 100% CS had significantly (P≤0.05) higher nitrogen contents than all other substrates (Table 2). The rest of the other substrates were not significantly (P≤0.05) different (Table 2). Generally the nitrogen concentration was observed to increase with the increase in the amount of the compost (Table 2).

Potassium (K)

The K content was significantly (P≤0.05) affected by the substrate formulations (Table 2). The potassium content in substrate 100% CS was significantly (P≤0.05) higher than that of all other substrates except substrates 75% CS: 25% RH, 50%C: 50% PB and 75%C: 25% PB (Table 2). Potassium levels in substrates 100% CS was also significantly higher than in substrates 25% CS: 75% PB, 50% CS: 50% RH, 25% CS: 75% RH, 100% PB and 100% RH (Table 2).

Table 2: Macronutrients content, CEC and EC of the formulated substrates

	Mineral nutrients (g kg^{-1})						CEC	EC
Formulation [z]	N	K	P	Mg	Ca	S	(Meq/100cc)	(ms/cm)
100%FS	14.1a	5.1a	4.8a	3.6a	8.7a	3.3b	12.4bc	2.8c
75%CS: 25%PB	16.2a-c	5.7ab	5.9b	4.0a	12.5cd	2.0a	17.7d	1.6b
50%CS: 50%PB	15.7ab	5.7ab	5.3ab	4.0a	12.2cd	2.0a	15.3c	1.5b
25%CS: 75%PB	15.9ab	5.2a	5.7b	3.9a	1.6bc	2.0a	10.7b	1.5b
75%CS: 25%RH	17.1bc	5.8ab	6.0b	4.1a	11.8bc	2.7b	18.2d	1.7b
50%CS: 50%RH	17.4bc	5.1a	6.1b	4.4ab	12.3cd	2.0a	14.7c	1.8b
25%CS: 75%RH	16.1a-c	5.0a	5.2a	4.3ab	10.1b	1.9a	10.9b	1.7b
100%CS	17.6bc	6.1b	5.7a	4.6ab	12.8d	2.6b	21.1e	3.1cd
100%PB	14.9ab	4.9a	4.5a	3.4a	7.7a	1.3a	1.8a	0.6a
100%RH	14.4a	5.0a	4.4a	3.5a	8.0a	1.4a	1.1a	0.4a

[z] *Mean separation within columns was done by DMRT at 5%. Means followed by the same letter are not significantly different at the 5% level.*

Table 3: Micronutrients content in the formulated substrates in experiment

	Mineral nutrients (g kg^{-1})				(mg kg^{-1})			
Formulation [z]	Fe	Mn	Na	Cu	Zn	Mo	Pb	pH
100%FS	13.8bc	1.7b	4.6b	0.3b	0.9bc	5.8b	15.5b	5.8b
75%C: 25%PB	10.0a	0.3a	3.1a	0.2a	0.5b	2.8a	14.3ab	6.2bc
50%C: 50%PB	9.9a	0.2a	3.2a	0.1a	0.5b	3.8ab	12.3a	6.4bc
25%C: 75%PB	11.0ab	0.1a	3.2a	0.2a	0.4ab	4.8ab	12.3a	6.1bc
75%C: 25%RH	10.7a	0.9a	3.0a	0.2a	0.5b	4.3ab	14.3ab	6.8c
50%C: 50%RH	10.2a	0.1a	3.0a	0.1a	0.5b	2.3a	13.3ab	6.8c
25%C: 75%RH	10.9ab	0.1a	3.0a	0.1a	0.4ab	2.0a	13.8ab	6.2bc
100%C	11.1b	1.0ab	4.0b	0.2a	0.6b	5.0ab	15.8b	6.3bc
100%PB	9.3a	0.1a	2.6a	0.1a	0.2a	1.6a	11.3a	4.4a
100%RH	8.9a	0.1a	2.4a	0.1a	0.3 a	1.7a	12.3a	4.2a

[z] Mean separation within columns was done by DMRT at 5%. Means followed by the same letter are not significantly different at the 5% level.

Phosphorous (P)

The substrate formulations significantly (P≤0.05) affected the P contents (Table 2). Substrates 75% CS: 25% RH, 50% CS: 50% RH and 25% CS: 75% PB had significantly higher phosphorous content than all the other substrates except for substrates 50% CS: 50% PB (Table 2). All the substrates had significantly (P≤0.05) higher phosphorous levels than the control (100% FS) except 100% PB and 100% RH (Table 2). Phosphorous levels in the control substrate (100% FS) was not significantly (P>0.05) different from substrate 25% CS: 75% RH, 50% CS: 50% PB, 100% CS, 100% RH and 100% PB but was significantly (P≤0.05) different from all the other substrates (Table 2). The 50% CS: 50% RH substrate had the highest phosphorous level of 6.1 g/kg while the 100% FS had the lowest P level of 4.8 g/kg (Table 2).

Magnesium (Mg)

The magnesium concentration was significantly (P≤0.05) affected by the substrate formulations used in the experiment (Table 2). Substrates 50% CS: 50% RH and 100% CS were not significantly (P>0.05) different (Table 2). Similarly they were significantly (P≤0.05) higher than all the other substrates. The rest of the substrates were not significantly (P>0.05) different amongst themselves (Table 2). The 100% FS (Control) substrate had the lowest magnesium level of 3.6 g/kg (Table 2).

Calcium (Ca)

The Ca content was significantly (P≤0.05) affected by the substrate formulations (Table 2). Substrate 100% CS had significantly (P≤0.05) higher Ca than all the substrates though it was not significantly (P>0.05) different from substrates for 75% CS: 25% PB, 50% CS: 50% RH and

50% CS: 50% PB (Table 2). The 100% CS substrate had the highest calcium level of 12.8 g/kg while the 100% FS had the lowest calcium level (8.7 g/kg) (Table 2).

Sulphur (S)

The substrate formulations significantly (P≤0.05) affected Sulphur content (Table 2). The S levels in the substrates 100% CS, 100% FS and 75% CS: 25% RH were not significantly (P>0.05) different (Table 2). Similarly these substrates had significantly (P≤0.05) higher Ca contents than the rest of the other substrates (Table 2). Substrate 100% CS had the highest level of S of 2.6 g/kg while 25% CS: 75% RH substrate had the lowest S level (Table 2).

Iron (Fe)

The substrate formulations had a significant (P≤0.05) effect on the Fe contents (Table 3). Most of the substrates had significantly (P≤0.05) lower iron contents than the control (Table 3). The control (100% FS) substrate had significantly (P≤0.05) higher iron content than most other substrates. Iron levels in substrates 100% CS, 25% CS: 75% RH, 25% CS: 75% PB and 100% FS were not significantly (P>0.05) different. Similarly the iron level in all other substrates was not significantly (P>0.05) different (Table 3). The 75% CS: 25% PB substrate had the lowest iron content of 9.9 g/kg (Table 3).

Manganese (Mn)

The Mn content was significantly (P≤0.05) affected by the substrate formulations (Table 3). The manganese contents in all the substrates were significantly lower than the control except 100% CS (Table 3). The control had the highest manganese content than the rest of the substrates. Manganese contents in the rest of the substrates were not significantly different (Table 3).

Sodium (Na)

The substrate formulations significantly (P≤0.05) affected the Na content (Table 3). The sodium contents in the substrates were significantly (P≤0.05) lower than the control except for substrate100% CS (Table 3). The rest of the substrates were not significantly different in their sodium content (Table 3).

Molybdenum (Mo)

The substrate formulations had a significant (P≤0.05) effect on the Mo contents (Table 3). Molybdenum in substrate 100% FS was significantly (P≤0.05) higher from substrates 50% CS: 50% RH, 25% CS: 75% RH, 75% CS: 25% PB, 100% PB and 100% RH, but was not significantly

(P≤0.05) different from substrates 50% CS: 50% PB, 25% CS: 75% PB, 75% CS: 25% RH and 100% CS (Table 3).

Lead (Pb)

The substrate formulations had a significant (P≤0.05) effect on the Pb contents (Table 3). Lead in substrates 25% CS: 75% PB, 50% CS: 50% PB, 100% PB and 100% RH was significantly (P≤0.05) different from lead content in substrates 100% FS and 100% CS (Table 3). The lead in all the other substrates was not significantly (P>0.05) different (Table 3). The 100% CS substrate had significantly higher lead than the other substrates (Table 3).

Copper (Cu)

The substrate formulations significantly (P≤0.05) affected the Cu content (Table 3). All the substrates had significantly (P≤0.05) lower Cu contents as compared to the control (Table 3).

Zinc (Zn)

The substrate formulations significantly (P≤0.05) affected the Zn contents (Table 3). Substrates 25% CS: 75% RH, 25% CS: 75% PB and the control were not significantly (P>0.05) different. Similarly they had significantly (P≤0.05) higher Zn contents than the rest of the other substrates (Table 3).

Cation Exchange Capacity (CEC)

The CEC was significantly (P≤0.05) affected by the substrate formulations as shown in Table 2. The CEC of the 100% PB substrate was not significantly (P>0.05) different from 100%RH, but they were significantly lower than all the other substrates (Table 2). All the substrates had CEC levels higher than the control (100% FS), except, substrates 25% CS: 75% PB, 100% PB and 100% RH (Table 2). The 100% CS substrate had significantly (P≤0.05) higher CEC (21.1me/100cc) than the other substrates (Table 2).

Electrical Conductivity (EC)

The electrical conductivity was significantly (P≤0.05) affected by the substrate formulations as shown in Table 2. The 100% CS and 100% FS substrate had significantly higher electrical conductivity than all the other substrates which were not significantly (P>0.05) different except substrates 100% PB and 100% RH (Table 2). All the substrates had their electrical conductivity lower than that of the control except the substrate 100%C. The substrates 100% PB and 100% RH had the lowest electrical conductivity values (0.6mS/cm and 0.4mS/cm respectively) as compared to the other substrates (Table 2). The electrical conductivity determination in experiment II showed a slight increase in all the substrates (Table 2).

Discussion

pH

The pH was significantly (P≤0.05) affected by the substrate formulations in the experiment (Table 3). These results are in agreement with (Nelson, 1991). The pH of the substrate formulations controls the nutrients availability to the plant roots (Nelson, 1991). According to Blom (1983), most plants grow best in a slightly acidic pH ranges of 6.2-6.8 in soil based substrate formulations and 5.4-6.0 in soil-less media. Generally all the substrate formulations had pH levels below 6.8 depicting the acidic nature of most of the substrate formulations in experiments (Table 3).

The pine bark and rice husk are acidic in nature owing to their composition (Nelson, 1991). Pine bark contains chemical substances, which are acidic while rice husk has its outer covering composed of silica materials making it acidic. Very low pH values could result in toxic concentrations of ions such as Al, Zn and copper while pH above 7.5 can result in chemical binding (Nappi and Barberis, 1993). All these lead to nutrients unavailability to the plants causing stunted growth. DeBoodt and Verndonck (1972) reported that optimum pH of container substrates differs with plant species but most plants can tolerate a pH of 5.0 to 6.5, provided that the physical environment of the substrate is well controlled.

Electrical Conductivity (EC)

The substrate formulations significantly (P≤0.05) affected the electrical conductivity in the experiments (Tables 5 and 8). These results were in agreement with Lemaire et al., (1985) and Eames, (1977), who reported poor plant growth in substrate formulations with excessively high EC above 3.5mS/cm. Electrical conductivity values below 3.5mS/cm are generally considered optimal for support of the plant growth in container production systems (Milks et al., 1989). The electrical conductivity which is a measure of soluble salts concentrations in the substrate formulations was generally low in all the substrate formulations except in substrate 100% CS (Table 2). The control (100% FS) and 100% CS substrate formulations had higher EC values in the experiment (Table 2). The 100% FS and 100% CS substrate formulations showed a slightly higher content of both the macronutrients and the micronutrients (Tables 2 and 3). This could possibly explain their higher EC values as compared to the other substrate formulations. According to Milks et al., (1989), EC measured shortly after planting are higher as compared to the EC values measured in the course of growth, provided the salt additions to the substrate formulations are controlled.

In the course of growth of container plants, changes in the substrate occur which affect the physical qualities of the substrate formulations. These may have negatively affected the drainage of the substrate formulations leading to waterlogging causing higher salt concentrations (Jespersen, 1993). As a result of this, the nutrients released from the compost and salts, which may have been contained in the irrigation water, were not drained away, causing salt build up and consequently higher EC. Excessively high EC values are detrimental for container plant production (Chong et al., 1991). Contrary report from Chong *et al.* (1991), indicated that some plant species in container substrate formulations can tolerate EC values in excess of 8mS/cm. Therefore a well controlled irrigation programme and frequent EC measurements of the substrate formulations are among the possible methods for maintaining the EC in the required ranges for the given production system.

Macronutrients and Micronutrients

The macronutrients and the micronutrients were significantly ($P \leq 0.05$) affected by the substrate formulations in the experiments (Tables 2 and 3). These results are in agreement with the work done Chong *et al*. (1991). Macronutrients and micronutrients are vital components of any root substrate for successful plant growth (Chong et al., 1991). The substrate analyses showed higher levels of nearly all the plant nutrients. The nitrogen and calcium were present in almost similar concentrations. Potassium and phosphorous similarly had almost equal concentrations (Table 2). All the micronutrients were present in very low concentrations except iron (Table 3).

According to Milks *et al.* (1989) all the elements with the exception of Mo and Cu were within the recommended ranges of the root substrate. Generally the nutrients concentrations in the substrate formulations used in the study were within the optimal levels (Tables 2 and 3). The mineral nutrients have specific and essential functions within the plant metabolism, though some of these functions may be loosely correlated to either quantity of requirement or physiochemical properties (Marschner, 1995). These mineral nutrients function as constituents of organic structure, activator of enzyme reactions or as charge carriers and osmoregulators in the plant system (Marschner, 1995). Nutrients supply to the plants roots is depended on the water availability in the root substrate for dissolution of the nutrients before absorption (Nelson, 1991).

Cation Exchange Capacity (CEC)

The CEC was significantly ($P \leq 0.05$) affected by the substrate formulations in the experiments (Table 2). These results are in agreement with Tisdale et al., (1993) and Nelson (1991), who reported that rice husk and pine bark and other non-composted materials do not hold nutrients well and as a result they have low CEC of as below as 1.6me/100cc. The cation exchange capacity (CEC) is a measure of the magnitude of the fixed negative electrical charges, which are essential in electrically attracting and holding nutrients, so that they are not washed away by heavy irrigation (Nelson, 1991). According to Nelson, (1991), CEC level of 6 - 15me/100cc is considered optimal for container root substrate, though higher CEC values are desirable. Substrate formulations of 25% CS: 75% PB and 25% CS: 75% RH had their CEC values lower below 6me/100cc, similar to the CEC of substrate formulations 100% PB and 100% RH (Tables 5 and 8). Similarly substrate formulations 25% CS: 75% PB and 25%C: 75% RH had lower CEC values than that recommended (Table 2).

These electrically held nutrients are available to the plants for growth and development. Hence a higher CEC level is desirable (Nelson, 1991). The irrigation water washed away some of the nutrients, while some were fixed making them unavailable to the plants (Mastalerz, 1977). Optimal CEC is achieved by fertilization, which ensures replacement of the nutrients in the substrate formulations. The nutrients availability to the plants entirely depends on the physical environment of the substrate formulations that promote the active root growth and development. Lower CEC value indicates little or no capacity of the substrate formulations to supply nutrients and hence complete plant failure due to nutrient deficiency. Compost has a high CEC and serves as a good reservoir of nutrients. In addition it is a good source of macronutrients and micronutrients (Nelson, 1991).

Conclusion

The substrate formulations which incorporated 75% CS: 25% PB, 50% CS: 50% PB, 75% CS: 25% RH and 50% CS: 50% RH had their chemical qualities within the optimal ranges.

Recommendations

The substrates formulations of 75% CS: 25% PB, 50% CS: 50% PB, 75% CS: 25% RH and 50% CS: 50% RH are recommended for use in nursery and pot plants production due to their optimal chemical qualities. The physical qualities and stability of the pine bark and rice husk to microbial decomposition during pot and nursery production should be evaluated.

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Utilisation of Organic Resources in the Management of Banana Nematodes

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Abstract

Plant parasitic nematodes are among the most devastating causes of yield decline in Kenyan bananas. Nematodes can cause yield losses of up to 70% per crop cycle, depending on the variety grown. Despite the widespread use of tissue-cultured planting materials, banana production is still threatened by the possibility of early nematode infestations because most farms are heavily infested with these parasites. A controlled experiment was conducted to evaluate the efficacy of four organic amendments (poultry manure, farmyard manure, *Tithonia diversifolia,* and *Tagetes minuta*) in the suppression of banana nematodes in tissue-cultured plantlets of *Musa* AAA cv. Grande Naine. The plants were inoculated with a mixed population of lesion nematodes, *Pratylenchus goodeyi* and spiral nematodes, *Helicotylenchus multicinctus*, at the rate of 1000 nematodes per plant. The amendments were applied at the rate of 5% (w/w) per plant. Significant (*P*<0.05) reductions were detected in the soil nematode populations of all amended soils. Population reductions of 96%, 88%, 76% and 71% were achieved with poultry manure, farmyard manure, *Tithonia diversifolia* and *Tagetes minuta,* respectively, compared with the control. Poultry manure had the strongest influence on nematode populations and plant growth. The results indicate that field infestation of clean plants may be mitigated through the use of organic resources that are readily available in most farms. These resources, which are acceptable management options, present an ideal crop and pest management tool for smallholder farmers because they can be used to effectively suppress parasitic nematodes, as well as assure economic and environmental sustainability.

Key words: Banana, manure, *Musa*, nematodes, *Tithonia diversifolia*, *Tagetes minuta*

Introduction

Banana (*Musa* spp) is ranked as the most important fruit crop in Kenya. It occupies about 2% of the total arable land, from which an average of 1,082,210 metric tons of fruits are harvested annually (Rutherford and Lamboll, 1998; MOARD, 2002). Banana is a useful source of dietary carbohydrates for a large proportion of the Kenyan population, besides being a major source of income and a reliable source of livestock feed for many farmers. It is grown countrywide from sea level to elevations as high as 1800 meters above sea level mainly in small farm holdings averaging 0.3 hectares (Qaim, 1999). Banana productivity in the country is severely constrained by invasions of insect pests, fungal diseases and parasitic nematodes. Plant parasitic nematodes are among the most damaging pests of bananas and are known to cause losses of as high as 70% per crop cycle (Karamura, 1993). The introduction of banana tissue culture technology was intended to *inter alia* mitigate the adverse effects of these pests. However, despite the widespread application of this technology banana production still faces the danger of early nematode infestations because important plant parasitic nematode species are endemic in most soils in Kenya (Seshu-Reddy et al., 1997).

The control of nematodes has traditionally been achieved with the use of nematicides. However, these chemicals are highly toxic and expensive especially for small-scale farmers who often lack the resources and the skills to safely apply them. Moreover, nematicides are among the most environmentally damaging of all pesticides. Emerging evidence also indicates that carbofuran, the most commonly used banana nematicide in Kenya, is becoming increasingly ineffective in other crops at the recommended lethal dose (Miano, 1999). Arising from these concerns is the need to develop sustainable alternatives for nematode management. Organic soil amendments have been found to be effective in the suppression of nematodes in many crops, with other beneficial effects on plant productivity. They therefore present a viable option for nematode control especially in smallholder banana farming. Several plant materials with potential to suppress parasitic nematode populations are found in most cropping systems in Kenya where they grow either as food and feed crops or thrive spontaneously as weeds. Many types of domestic animals are also reared in most farms, making different types of animal manure available for crop fertilization. Their potential usefulness in providing sustainable sources of essential plant nutrients and managing existing pest problems in these cropping systems makes them cost-effective, sustainable and ecologically viable plant resources. The objective of this study was to determine the effectiveness of some commonly available plant resources in the suppression of banana parasitic nematodes when incorporated as soil amendments.

Materials and Methods

Amendment preparation and application

The trial was conducted in a greenhouse at the National Horticultural Research Centre–Thika. Tissue culture derived plants of the cultivar 'Grande Naine' were established in 8x12x12 polyethylene sleeves containing 5000g of steam-sterilized potting mixture comprising forest soil, cattle manure and ballast mixed in the ratio of 4:2:1 (v/v), respectively. Farmyard manure, poultry manure, *Tithonia diversifolia* and *Tagetes minuta* were applied as soil amendments at the rate of 5% (w/w) when the plants attained a height of 200mm by incorporating them in the top 10 cm of the soil. The farmyard manure comprised a well-composted mixture of cattle manure and vegetative matter (banana pseudostems, napier and maize stalks), while the poultry manure was obtained from a commercial deep litter poultryrearing unit. This manure was cured for 6 weeks before application. The amendments of plant origin were harvested, chopped and sun-dried for 6 weeks before application. Carbofuran 5% (Furadan 5G ®) was applied as a check at the recommended rate of 17.5 grams per plant to provide comparative efficacy data on nematode control. A control treatment was included in which the soil was not amended but the soil in the top 10cm was loosened. The trial was laid out in a randomized complete block design (RCBD) with twelve replications, comprising one plant per replicate.

Inoculum preparation and application

Plants were inoculated using a nematode suspension comprising a mixed population of *P. goodeyi and H. multicinctus* extracted from heavily infested banana roots. The suspension was applied at the rate of 1000 nematodes per sleeve by pouring it into three 10 cm-deep indentations made around the plants. The control treatment involved the application of water only, which was applied in the same manner as the nematode suspension. Light watering was observed during the ensuing week to avoid the washing down of inoculum. The plants were grown for 90 days after inoculation during which they were watered regularly as the need arose. The trial was terminated at the expiry of this period.

Data collection and analysis

Plant response to nematode infestation was determined using the percentage root lesion index and the corm necrosis index. The first index was determined as the percentage of necrotic cortical tissue of 5 randomly selected functional primary roots. Corm necrosis was determined by scoring corm damage on a scale of 0-4 according to a scheme developed by Speijer and De Waele (1997) where 0 = no lesions, 1 = one small lesion, 2 = several small lesions, 3 = one large lesion and 4 = several large lesions). In addition, nematodes were extracted from 200 cm^3 of soil and 100 grams of macerated root samples using the modified Baermann funnel technique (Hooper, 1990) and counted in 5ml aliquots drawn from a known volume of nematode suspension. All nematode count data were subjected to a $\log_{10}(n + 1)$ transformation before statistical analysis. All data were then subjected to analysis of variance (ANOVA) using the generalized linear model procedure of the statistical analysis system (SAS) for means. The means were transformed back to the actual means after the statistical analysis. Where significant treatment differences were detected, the means were separated using the Student-Newman-Keuls' (S-N-K) test at $P<0.05$.

Results

Influence of soil amendments on nematode populations

All the amended soils had significantly ($p<0.05$) lower nematode populations than the control at the end of the trial. The lowest nematode populations were recorded in soils amended with poultry manure, farmyard manure and carbofuran, respectively. Soils amended with Tagetes minuta and Tithonia diversifolia had significantly higher nematode densities than those treated with carbofuran and the manure-based amendments. No significant differences were detected among the soil amendments as they affected root nematode densities and in the incidence of root and corm necrosis. The damage levels were generally very low for all treatments and never exceeded 24% and 1.1, respectively. The results are shown in table 1.

Influence of soil amendments on plant performance

Plants grown in soils amended with poultry manure had significantly ($P<0.05$) taller plants than those growing under the control and other amendments.

Table 1: Effect of soil amendments on root and soil nematode populations and nematode-induced damage

	Mean number of nematodes		Disease index	
Amendment	**Roots (100 g)**	**Soil (200 cc)**	**Root necrosis (%)**	**Corm necrosis**
Untreated control	61a	6531a	23.98a	1.08a
Carbofuran 5G	58a	389c	22.99a	1.08a
Farmyard manure	51a	324c	17.11a	0.67a
Poultry manure	44a	232c	15.82a	0.42a
Tagetes minuta	48a	1898b	20.15a	0.33a
T. diversifolia	49a	1913b	23.85a	0.25a
C.V. (%)	39.53	12.63	20.34	32

[Z]Means followed by the same letter within a column are NS different ($P<0.05$).

Soils amended with Tagetes minuta and Tithonia diversifolia produced plants that were had significantly taller than those growing in the control, carbofuran and farmyard manure amended soils. A similar influence was observed on plant girth and also on leaf number. Plants growing in soils amended with poultry manure and Tithonia diversifolia resulted in plants with significantly more leaves than the control and manure-based treatments. Plants growing on soils treated with the two amendments had significantly heavier shoots and roots compared with the control. The results are summarized in Table 2.

Table 2: Effect of soil amendments on plant growth

Amendment	Plant height (cm)	Girth (cm)	Leaves	Shoot weight (g)	Root weight (g)
Untreated control	40.58c	4.14b	9b	74.18b	292.41c
Carbofuran 5G	42.17c	4.13b	9b	75.66b	310.00b
Farmyard manure	39.58c	4.06b	9b	76.98b	345.91bc
Poultry manure	48.17a	4.72a	10a	97.50a	437.20a
Tagetes minuta	45.33b	4.53a	9b	87.95ab	377.04ab
T. diversifolia	47.33ab	4.52a	10a	88.91ab	401.50ab
C.V. (%)	6.00	6.22	6.89	16.57	22.94

[Z]Means followed by the same letter within a column are NS different (P<0.05).

Discussion

The results show that the amendments effectively suppressed the proliferation of nematode populations, resulting in the reduction of harmful inoculum and the eventual damage to banana roots. Farmyard manure, carbofuran and poultry manure were the best treatments in this regard. The suppression of nematodes through organic soil amendments has been reported elsewhere (Bridge, 1996; Siddiqui and Alam (1997); Miano, 1999; Acharya, 2000; Nanguma and Fawole (2001); Sundararaju and Kumar, 2003). These results are therefore in consonance with the results of these authors and serve to demonstrate that some of the organic resources available readily in many banana-based cropping systems in Kenya may be gainfully used for the suppression of parasitic nematodes and improvement of crop productivity. The results also suggest that the amendments may, where available, substitute for the nematicide since carbofuran did not seem to offer any significant advantage over the amendments in this trial. The results, however, show that the organic amendments did not differ significantly in their potential to prevent the destruction of banana roots by parasitic nematodes. This trend is consistent with the lack of significant differences in the levels of root parasitisation among the amendments tested. The lack of appreciable differences may be due to a combination of low levels of nematode inoculum and a short period of exposure of the hosts to the nematodes, considering of the advanced age of the host plants in this trial. It is expected that higher inoculum or a longer period would have elicited better responses.

Conclusions and Recommendations

Parasitic nematodes are endemic in many banana farms in Kenya and the suppression of these pests is necessary for improved crop productivity. A wide range of weeds and crop plants which grow abundantly in many cropping systems as well as animal manure provide viable and sustainable low cost options for the management of these pests. These resources are also useful in the restoration of soil fertility. The amendments may be incorporated in the planting hole during orchard establishment followed by periodic applications to the growing crop for sustained nematode suppression and plant nutrition. Farmers should therefore be sensitized on the value of these resources and encouraged to apply them to enhance crop performance and productivity.

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Feedback

Question: ***Did you perform price comparison of the organic materials or cost-benefit analysis for the materials to provide evidence that would encourage farmers in adoption?***

Answer: No

Question: ***What is the availability of the materials in Kenya like?***

Answer: Poultry manure is available commercially; farmyard manure is available on most small-scale farms, whereas *Tithonia diversifolia* and *Tegetes minuta* are commonly found on farms in western Kenya.

Marketing Kenyan Horticultural Crops: Opportunities and Constraints

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Abstract

Rules in the marketplace have changed and become very dynamic. Consumer preferences are increasingly becoming more complex than they were in the past. There is an increasing demand for quality. In recent years, quality has become a multi-faceted and evolving concept, including aspects of performance such as shelf life and freshness, and also conditions of production such as the environment and social responsibility; in essence product safety and services. The minimum requirement for a product to be considered quality is compliance with regulations in the above-mentioned categories. This development has led to a situation whereby Kenyan growers focus on differentiating themselves from competitors and swaying the perception of their products from that of 'commodity' to that of 'high-value crop'. This transition has its challenges, including poor infrastructure, lack of market access and product diversification, just to mention but a few.

Key words: Horticulture, market, quality

Introduction

The horticulture industry, which has been the fastest expanding sub sector of Kenyan agricultural sub-sector, is currently the second leading foreign exchange earner after tea (Economic survey, 2005). The value of fresh and processed horticultural export has shown a steady increase from KES 13.8 billion in 1997 to 22.7 b in 2003. The total acreage under cultivation in 2003 was 375,101ha, (220,000ha vegetables, 151,345 ha fruits, 1,798 ha flowers &

1,994 ha herbs and spices), whereas in 2002, it was 245,919ha (98,908 ha vegetables, 143,312 ha fruits, 2098 ha flowers & 1606 ha herbs and spices).

Over 95% of all horticultural production is consumed domestically, either on-farm or through domestic markets, the export market consumes about 4% of all horticultural production. Table 1 below shows the volumes in tons and value in KES of fruit, vegetables and cut flowers exported from Kenya from 1995 – 2004. Looking at the trend it shows that the volume has doubled over the years, with the value increasing by approximately 13 times.

The main destination for Kenyan exports is the European Union (Table 2). The UK and Holland have been the main market taking over 30% of total exports from 1995 – 2000. The other destinations include South Africa, Norway, USA, Canada, Saudia Arabia, Sweden, Italy, Djibouti and Japan.

Table 1: Export volume and value for fresh fruits, vegetables and cut flowers from Kenya 1995-2004

	Fruits		Vegetables		Cutflowers		Total	
Year	Volume	Value	Volume	Value	Volume	Value	Volume	Value
1995	13,865.0	617.3	29,373.0	3,642.3	75,364.3	6,464.5	32,126.3	2,204.8
1996	16,869.4	769.5	35,212.3	4,366.3	84,823.7	7,713.0	32,742.0	2,577.1
1997	17,450.0	805.1	35,850.0	4,887.8	84,180.0	8,809.0	30,880.0	3,116.2
1998	11,350.0	819.5	30,220.0	4,856.9	78,370.0	9,728.7	36,800.0	4,052.2
1999	15,595.0	1,256.0	36,992.0	7,235.0	98,964.0	14,204.0	46,377.0	5,713.0
2000	15,415.8	1,098.0	38,756.7	7,165.6	99,211.2	13,557.0	45,038.7	5,293.4
2001	22,595.5	1,559.8	41,396.0	10,626.9	98,762.3	20,221.2	34,770.9	8,034.5
2002	22,482.3	1,461.6	52,106.7	14,792.3	121,068.4	26,725.1	46,479.5	10,471.2
2003	23,575.5	1,752.7	60,982.9	16,495.5	133,232.5	28,839.6	48,674.2	10,591.4
2004	20,089.7	1,803.0	88,243.9	18,719.9	166,135.1	32,590.8	57,801.5	12,067.9

Source: HCDA statistics

Table 2: Main export markets (countries) for fresh horticultural produce as a percentage of total volume

	1995	1996	1997	1998	1999	2000
UK	35.6	33	38	31	30.9	31
Holland	29.5	27	31	31.8	33.6	34
France	16.8	12	13	15.2	15.4	14.9
Germany	8.8	7	7	6.5	4.6	5.2
Other destinations	9.2	21.1	11.1	15.6	15.5	7.2

Source: HCDA statistics

Competitor Analysis

The market for horticultural products is getting competitive (Table 3). One of the main constraints of the Kenyan products is quality. Quality in the recent past has gained a whole new meaning and has become a multi–faceted and evolving concept, including not only aspects of performance such as shelf life and freshness, but also conditions of production such as the environment and social responsibility or in essence product safety and services. Take the case of fruits and vegetables whereby the focus is on Maximum Residue Levels (MRLs) of pesticides on the produce. The need to ensure that exports do not exceed MRLs has led to an increasing emphasis on the traceability of horticultural production; exporters want to be able to trace production back to the specific farm from which it came to ensure quality and safe production and handling procedures (Dolan and Humphrey, 2000; Jaffee 2003).

Quality and Eco-certification

Quality systems can be split in two clusters. Product certification focuses on the characteristics with which the end product must comply (such as schedules of specification) Quality management systems focus on the process the company must follow to grow and market that product (examples are codes of practice and quality assurances). Within these two clusters are various other initiatives that place more emphasis on a particular component of quality, depending on the philosophy or objective of the initiative.

Market access is improved by attaining the quality control according to the compliance specifications this is ascertained by the concerned companies receiving an official recognised quality certification from the auditing organization. For example in floriculture the most widely known product eco label is the *Milieu* Program *Sierteelt* (MPS) in Holland and *Vlaams Milieuplan Sierteelt* (VMS) in Belgium. These labels ensure access to the auctions in both countries. Here in Kenya, The Fresh produce Exporters Association of Kenya (FPEAK) and the Kenya Flower Council (KFC) have developed codes of practises that are benchmarked to the MPS, EUREPGAP and VMS just to mention but a few these allows the producers affiliated to these associations access markets in several countries in the world.

The levels shown in Figure 1 refer to the following: **Level 1:** Meeting the phytosanitary, documentation or quality regulations of your government and your market; this is the key access point. A set of these rules should be made available to your sales/export team. **Level 2:** This level includes what European growers call Good Agricultural Practises (GAP); these should be practises that can be recommendation for level 1 growers to improve. **Level 3:** Product certification schemes such as MPS, KFC, FPEAK or many other certification programmes in developing countries are found on the third level. Most of these include compliance to various regulations, as well as adhering to most GAP principles. **Level 4:**

Quality management is a more global approach to quality, which can cover all the above-mentioned approaches. It includes product specifications, although these can be defined outside of an (International Standards Organisation) ISO procedure.

Table 3: A summary of selected product competitor analysis

Product	Main competitor	Kenya marketing constraints	Possible solutions
French beans	Senegal, Burkina Faso, Mali, India, Zimbabwe	Quality/variety Higher freight cost	Better husbandry/ cool chain New Varieties Lower freight costs
Asian vegetables	West Indies, Gambia, Zambia, India	International supply Quality/variety High air freight cost	Growing schedules Technical input
Snow peas	Guatemala, Zimbabwe	Quality problems in May–Sept & Nov.	Growing under cover during wet months Better seed
Fresh pineapples	Ghana, Ivory Coast, Costa Rica	Limited availability Poor sea freight facilities	Process fresh at source Lower freight costs
Mangoes	South Africa, Gambia, Ghana, Costa Rica, Puerto Rico, Mexico	Poor husbandry and post harvest handling Wrong varieties & Poor facilities for sea freight	Poor logistics Technical assistance on husbandry and handling
Avocadoes	South Africa, Israel, Spain, USA, Mexico	Fuerte not preferred variety Poor sea freight facilities Poor pre and post harvest handling	Hass is the preferred variety Poor logistics Preferential air freights rates in June August
Strawberries	Israel, Spain, Holland, USA	Variety sweetness Long growing period Distance to market	Newer Varieties Highly efficient cool transportation chain
Passion fruits	Zimbabwe	No major market	Process at source
Melons	Spain, Brazil, Israel, South Africa	Quality /climate control Cost of air freight	Sea freight Technical input

Source: Adapted from HCDA reports

Organic produce

The global market for certified organic produce is now estimated at US$25 billion (2003). Kenya's main export market has risen by 30% each year since 1985. Customers at Sainsbury's, the UK's second largest supermarket chain, willingly pay a 25% premium for organic products the company's fastest growing line. An estimated 20 million hectares of farmland are now devoted to organic production worldwide (Scully, 2003). Only an internationally accepted, certified organic label assures this exclusive market. Certification is a laborious, time-consuming and expensive.

For instance 'Uganda's certification market is dominated at present by European firms, whose inspectors must be flown in to assess farmers' compliance to standards on behalf of their home markets. The cost of this services ranges from US$1,000–2,000 for a single farm, and US$8,000-12,000 for a group of up to 6,000 farmers much of which goes to cover inspector's overseas travel and accommodation. The whole process can take up to one year for a farmer who has never used chemicals and as long as four years for land where chemicals had been used in the recent past or where a farmer's current practises deviate in any way from accepted standards. Since average income in Uganda is US$280 and certification must be renewed annually at the same high cost, getting certified is no small task.

Figure 1. Demands of the four levels of quality and eco-labels control. Source: Marie–Françoise Petitjean (2001)

According to the director of National Organic Agricultural Movement of Uganda (NOGAMU) there are 37,000 certified organic farmers. The success is due to a project Export promotion of organic products from Africa (EPOPA) funded by SIDA. It provides technical assistance to develop the companies' capacity to obtain organic certified and covering some of the initial project costs' (Adapted from Scully, 2003).

The issue has now become knowing what quality means, as well as knowing how to choose the most suitable approach to create a long lasting marketing technique that will return on investment. There are several opportunities and challenges that arise due to the dynamic nature of the horticultural markets.

Opportunities available for horticultural producers

The Kenya producers have the advantage of the agro-climatic conditions that are ideal, thus ensuring high quality produce. In addition the country has the institutional capacity to address issue concerning certification, there are already two internationally recognised associations namely Kenya Flower Council and the Fresh Producers Exporters of Kenya catering that provide a marketing label for their members. The Government through the ministry of Agriculture has being training farmers on Good Agricultural Practises (GAP) and EUREPGAP regulations for instance, in 2004 Kirinyaga District - Central Province, 60 groups were trained on GAP and 9 groups on EUREPGAP this trend can be extrapolated to all other districts involved in horticulture. As concerns organic farming the country is a host to four reputable institutions for organic farming namely Kenya Institute of Organic Farming (KIOF), SACDEP, Baraka Agricultural College and Manor House Agricultural Centre.

Challenges facing horticultural producers

The challenges facing horticultural producers are several, the marketing of horticultural produce as highlighted is moving towards a direction that the consumers are willing to pay for quality which is assured by the producers subscribing to certain certification programmes. Certification is not a cheap exercise however; producers are left no option other than to subscribe to one or several labels. Other challenges include:

- Competition
- Poor and inadequate rural infrastructure esp. Feeder roads, electricity, pre–cooling and storage facilities for small holder farmers
- Access to markets and information on new varieties, market demands, certification requirements, timely market information
- Regulatory constraints
- Access to adequate and reasonably priced credit
- Cost of farm inputs
- Erratic dollar exchange rates
- Unavailability of good quality seed and appropriate technology esp. for the smallholders

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Feedback

Question: ***You mentioned that hectarage under flowers declined in 2003 due to small-scale growers being pushed out of production. What is the reason why?***

Answer: Flower production by small-scale farmers is highly dependent on market prices during the previous year. Production thus increases or decreases depending on the return received. Most small-scale farmers do not subscribe to a label. Labels have in the recent past become very important in marketing of flowers.

Question: ***Elaborate on the quality management ISO certification. Who are responsible for the certification?***

Answer: ISO certification is a company and process certification scheme guaranteeing that the different steps in the manufacturing (producing) of a product follow written procedures to anticipate and reduce the risk of quality losses. ISO9002 offers customers internationally recognised quality assurance. Reputable firms contracted by the ISO audit the certification process.

Survey of the Current Status of Weed Control and Herbicide Usage by the Small-Scale Commercial Vegetable Farmers in Kenya.

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Abstract

Vegetable production in Kenya is an enterprise that has grown very rapidly in the last ten years due to increased demand for vegetables for both the local and export markets. The increased demand has resulted in expansion of the hectarage planted to vegetables and this has resulted in labour shortage due to both the increased hectarage and rural to urban migration of potential casual labour especially the youth. This has led to inadequate supply of labour for weed control and especially at the critical period. The objectives of this survey were therefore to find out the problems that the farmers experience in their bid to control weeds, and also find out what weeds they considered to be a major problem. The survey was carried out in Kabete, Lari, and Kinangop divisions in areas where smallholder farmers do intensive vegetable farming for commercial purposes. The farmers were randomly selected and the interviews conducted on their farms, based on the Participatory Rural Appraisal (PRA) methodology. The survey results showed that farmers who previously relied only on manual labour for weed control were now increasingly using herbicides for weed control. The adoption of herbicide technology by these small-holder farmers was out of their own initiative, either due to labour shortage or because one had a special weed problem that had proved difficult to manage by other methods. From the information obtained it was clear that locally generated data and information on herbicide use by the small-scale farmers in Kenya, is lacking for most, if not all vegetable crops. There is also a need to develop other methods of weed control based on an IPM programme.

Key words: Herbicides, vegetable farmers, weeds, IPM

Introduction and Background Information

Vegetable production in the tropics has for a long time been a backyard garden operation where the farmers produced just enough for the family (Williams *et al.*, 1991). It was mainly traditional vegetables that were grown and these did not have a wide appeal apart from the village market. With the increase in urban populations there developed a ready market for vegetables in the urban centres. Due to the increased demand for vegetables, most farmers started growing more than the traditional vegetables commercially albeit on a very small scale. In addition to the local market, the export market has expanded very fast with such organisations as the government's Horticultural Crops Development Authority in addition to other enterprising individuals, being involved in the export of quality vegetables.

As a result of the increasing demand for vegetables for both the export and local markets in Kenya, most smallholder farmers have now expanded and diversified, their vegetable production, and this has resulted in an increase in the hectarage planted to vegetables. The vegetables most widely grown for cash are Kales, French beans, onions, cabbages and tomato, (see Table 1 data presented for three crops only).

These vegetables are grown intensively under a range of climatic and soil conditions in Kenya. French beans are grown mainly for the export market with only a small percentage consumed locally. Onions and tomatoes, cabbages, kales are grown mainly for the local market where demand often exceeds supply.

Table 1: Total recorded hectarage, yield and value of French beans, onion, and tomato in Kenya 1989-1993

Crop	Year	Hectarage	Total Yield (Tonnes)	Value K£X1000
French Bean[1]	1989	1347	5192	2077
	1990	1731	5889	2945
	1991	2420	13147	6570
	1992	3440	11862	5165
	1993	3579	12596	10086
Onion	1989[2]	1855	16349	1812
	1990	3535	38414	12485
	1991	4321	83172	24952
	1992	3170	34721	13888
	1993	3839	41291	18581
Tomato	1989	5685	99298	14895
	1990	10459	155918	23388
	1991	8370	138014	27603
	1992	7973	112306	28076
	1993	8740	156869	109808

Source: Compiled from the available data of The Ministry of Agriculture and Livestock Development Annual Reports. French bean data is from Central Province only. [2]The 1989 data for onions from Central province only.

As vegetable production has continued to increase and the hectarage under cropping expanded, labour supply has decreased due to urban migration by the educated youth. The youth move to the urban centres in search of better paying jobs or to do small trading rather than work in the fields where the pay is not very enticing. This has put a strain on vegetable production and especially in the area of weed control, which most farmers had continued to do manually because there are now fewer labourers to hire. The cost of hired labour has therefore gone up and it is critically short during the peak labour requirement periods when some farmers are still sowing and others are weeding their first crop.

However, the farmers having realised that vegetables are a high value cash crop have considered other methods of weed control rather than limit the area planted to vegetables. This has resulted in the small-scale commercial vegetable farmers turning to the use of herbicides. There is, however, very little or no technical information, on suitable herbicides to use, apart from the information given by the stockist who in most cases is not a trained agriculturist, and is relying on information on labels. In most cases the label information was not generated in Kenya.

Reasons for Lack of Information

The lack of technical information is due to the fact that the number of persons trained in weed research is very low in tropical countries as noted by Akobundu (1996). This is because there has been very little attention paid to weed research, especially in vegetable production in Kenya, just as in many other developing countries, compared to the developed countries where weed control is no longer a human struggle with weeds (Akobundu, 1996), because modern technologies are employed to combat weeds. Another reason as noted by Zimdahl (1994) is the public image of weed science. It is of concern and a source of frustration and discouragement to weed scientists in the developing countries that the public seldom appreciates that weed control, traditionally relegated to women and children, should be considered a science. This explains why weed research was ignored early on while other disciplines of crop protection such as plant pathology and entomology were developed and expanded in Kenya.

With little or no information on herbicide use in vegetables in Kenya, weed control in these crops continues to be drudgery where no alternatives are available. In those crops in which the farmers have identified herbicides that they can use, and having realised their potential for weed control, the farmers are increasingly adopting the use of these herbicides (Table 2).

Objectives

The primary objectives of this project were to explore the problems that the small-scale farmers encountered in their bid to control weeds, and specifically obtain information on their attitude to herbicide use and explore why they use or do not use herbicides.

Methodology

This survey was done in Kabete and Lari divisions in areas where very intensive commercial vegetable growing is practiced and all the farmers are small-holder, owning between 1.5-2.5 ha, and where vegetable production takes anywhere from 0.5-2 ha. Some farmers can grow vegetables throughout the year using irrigation water from the streams in the area during the dry season. Another vegetable growing area visited was Kinangop where the land sizes are bigger than in Kabete and Lari, but the area planted to vegetables is still small.

The farmers were randomly selected and the interviews were conducted on the farm based on the participatory rural appraisal (PRA) methodology where the farmer was encouraged to do most of the talking. The farmer therefore narrated his/her problems as far as vegetable production was concerned and thus the information obtained was not only on herbicide use but also on insecticides, fungicides and fertilisers.

Results and Discussion

The results obtained in the survey are summarised in Table 2. Most of the farmers grow the same range of crops with very few variations and they say that the market is very big and only the supply is limited. It was interesting to find that most of the farmers interviewed used herbicides. These were mainly linuron (Afalon) and metribuzin (Sencor) on coriander (dania) and carrots though one farmer said he used pendimethalin (Stomp) on cabbage crops.

Table 2: Summary of small-scale commercial vegetable farmers interviewed on herbicide usage in Kenya (Kabete and Lari areas).

Location	Farm size (ha)	Crops grown	Weeding cost/day/person (KES)	Herbicides and crops on which used
Kahuho	2	Kales, tomato, cabbage, carrots, lettuce, spinach, onion, coriander	100 in lettuce 60 in others	Afalon in coriander, onions, carrots. Sencor in tomato
Kahuho	1.6	Kale, tomato, cabbage, spinach, green pepper, onion, lettuce, coriander	60	Afalon in coriander, onions, carrots. Sencor in tomato. Stomp in cabbage
Ruku	1.2	Celery, parsley, spring onions, green pepper spinach, cauliflower	60	None on crops Gramoxone in fallow land
Ruku	2.4	Celery, cabbage, kale. Cauliflower, spinach	100	Afalon in coriander
Kibichiku	2	Celery, parsley, spring onion, green pepper spinach, cauliflower	60	None on crops Gramoxone in fallow land
Nyathuna	2.4	Parsley, lettuce, leek, cabbage, coriander, tomato, carrot, onion, spinach	70	Afalon in coriander, carrots
Nyathuna	2	Tomato, kale, spinach	70	none
Gikuni	1.6	Cabbage, kale, tomato	75	Sencor in tomato
Lari	2.4	Cabbage, kale, tomato, carrots	45	Afalon in carrots

Asked how they learnt about these herbicides the farmers said it was from other farmers who have been using the products or from salesmen who visit their farms or from the stockist from where they bought pesticides. When asked why they chose to use herbicides, most of those interviewed said it was due to the high cost of labour and because it is also very difficult to weed in carrots and coriander. They therefore started to seek information on possible chemicals for controlling weeds in these crops and luckily Afalon and Sencor were very available.

At the time of these visits those farmers who grow lettuce were very anxious for any information about herbicides to use in their lettuce crop. They said that even though lettuce fetches a lot of money, the area planted to the crop was being decreased, because weeding lettuce was a big problem and most workers did not want to do it, because weeding in lettuce is a very slow job that has to be done early and using a machete in a squatting position. Those who agreed demanded Ksh. 100/= per day (equivalent to $1.80).

The farmers said that herbicides had helped them expand the area planted to coriander and carrots. When asked how they measure the herbicide the farmers said that they use a tablespoon to measure the powders and according to them one tablespoonful was enough for one 20L knapsack sprayer.

All the farmers interviewed said that they were ready to use herbicides even in other crops if these were available. Only one farmer said he would not use herbicides because he does not understand them and he had heard that some herbicides "damage" the soil and nothing will ever grow where they were applied. Another farmer said she had used Sencor (metribuzin) and it damaged the area she had applied it to and nothing would grow there for a long time. But given the proper advice she was ready to use herbicides again.

The weeds occurring in these farmers' fields were mainly annual broadleaved weeds such as Stellaria media, Galinsoga parviflora, Commelina benghalensis, Oxalis latifolia, Tagetes minuta, Bidens pilosa and Portulaca oleracea Sedges namely- Cyperus esculentus and C. rotundus, were also a problem.

In Kinangop the farmers were growing potatoes, carrots, cabbages, kales and peas all under rain-fed conditions. Here the labourers were demanding Kshs 60-70 per day and it took four people up to a week to hand-weed 0.4hectare at a total cost of between Kshs1200-1400 per weeding (equivalent to $21.6-25.2). The farmers said they often did 3 to 4 weedings before each crop matured and was ready to harvest, and for cabbage this was three months. It therefore cost the farmer between Kshs3600 and Kshs 5600 per crop ($65-$100 per crop).

However the farmers here are not well informed on the economics of their farming systems and they therefore did not know whether they made a profit or a loss in their farming practises. It was evident from the information gathered that controlling weeds cost them a lot compared to their other inputs.

The farmers said the most troublesome weeds were *Stellaria media, Galinsoga parviflora,* and *Schkuhria pinnata.* These weeds were a problem because they did not die off after weeding and this being a constantly wet area the weeds re-established soon after weeding thus necessitating more weeding. These farmers only used one herbicide and this was only in carrots. The herbicide was confirmed to be linuron, bought at the local shops where they purchased other farm inputs and no advice was given on how to use the herbicide because the stockists were only local traders with no technical know-how.

On method of use the farmers said they bought just "enough" to treat the area the farmer wanted to plant and the chemical was therefore dispensed without a label into any suitable container. They had learned the use of this herbicide from other farmers who had used it before. One said her measure was 5 tablespoonfuls for a 20-litre knapsack sprayer, which was a very big variation from the information obtained from the Kabete farmer who said they used one tablespoonful per 20L knapsack sprayer. As these farmers had no technical information on how to use the herbicides they were applying, they just used any amount as long it controlled the weeds and did not damage their crops. Sometimes this was with harmful results to the soil, as was stated earlier by the lady who had used metribuzin. This is the reason why we need to intervene and give guidance even to the use of other methods that do not use chemicals to avoid environmental damage.

Conclusions

It was clear from the interviews conducted at the Kabete area and Kinangop, that locally generated data and information on herbicide use for the smallholder farmers is seriously lacking for most, if not all, vegetable crops.

On the use of other methods of weed control it was found out that mulching is rarely if ever used as a method of weed control because the farmers use any mulch material as feed or bedding for their animals especially now when there is an increase in cows being reared under zero-grazing methods. Cover crops are not used as a means of weed control because the vegetable crops are short season crops that mature in 3 to 4 months and therefore the use of cover crops would be unsuitable.

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Feedback

Questions: ***What is your opinion on use of some selected green manure to control weeds? How about sod culture and its usefulness in fruit crops?***

Answers: Green manure can be used in perennial crops. In vegetable crops it is not possible since these are short season crops. Sod culture can be used in fruit crops as long as it is kept low either through mowing, slashing or other practices.

Question: ***Would there be any chemical residues in carrots where the farmers are using herbicides to control weeds?***

Answer: There should not be since these herbicides are applied pre-emergence and this means that by the time the crop matures the herbicide has dissipated. It was also with this in mind that we developed the bioassay method of testing for residues in the soil. The method does not require any laboratory testing and the farmers can be trained on how to do it through farmer field schools.

Adaptation of Spiderplant and African night shades to Water Deficit and Nitrogen Stress

P.W. Masinde

Abstract

Spiderplant (*Gynandropsis gynandra* (L.) Briq.) and African nightshade (*Solanum* spp.) are important leafy vegetable crops consumed by various rural communities in Kenya. They are important sources of nutrients and have medicinal value. Unreliable rainfall, intermittent droughts and the need for production during dry season necessitate irrigation for successful commercialization of these crops. However, there is only scanty information on the water management of these crops. Moreover, understanding the adaptation of these crops to drought is crucial in devising water management strategies that will maximize production at minimal irrigation costs. The application of nitrogen to increase yield in leafy vegetables is an important agronomic practice. The leaf nitrogen content correlates well with the leaf chlorophyll content, hence N deficiency leads to reduced photosynthesis resulting in lower biomass accumulation. This review considers the mechanisms of adaptation to water deficit and nitrogen stress in both spiderplant and African nightshade and relates them to productivity of these crops. Generally, water deficit causes reduction of plant leaf area and specific leaf area (SLA). Both Spiderplant and African nightshade showed only limited osmotic adjustment (OA) in the range of 0.10-0.33 MPa. Under nitrogen stress, both African nightshades and spiderplant respond by reduction of leaf area, dry matter production but maintained relatively high leaf nitrogen content on leaf area basis. These results suggest that both African nightshade and spiderplant respond to limited water and nitrogen by drastic reduction in leaf area in an effort to maintain a high plant water status and high leaf nitrogen content.

Key words: Leaf area development, osmotic adjustment, leaf nitrogen, leaf to stem ratio, *Solanum sarrachoides*, *Solanum villosum*

General Introduction

Spiderplant (*Gynandropsis gynandra* (L.) Briq.) and African nightshade (various *Solanum* species) are important traditional leafy vegetables grown and consumed in Kenya. They are popular in the Kenyan retail markets as shown by recent surveys. These vegetables have already entered the supermarkets, offering the urban dwellers access to these crops on one hand, while offering a reliable market for growers on the other hand. Besides, they are also consumed in various African countries (Chweya and Eyzaguirre, 1999) hence are potential export crops. This calls for field-scale production of these vegetables in order to meet the increasing demand.

These vegetables are good sources of nutrients such as vitamin A, vitamin C, as well as minerals, especially micronutrients such as Fe (Mwajumwa et al., 1991). Besides, these vegetables provide variety in the family diet and help to ensure household food security. Spiderplant and African nightshade are also used for medicinal purposes (Edmonds and Chweya, 1997; Kokwaro, 1993). However, they also contain anti-nutrients such as glucosinolates and nitrates, and phenolic compounds and oxalates, which give the crops an astringent taste (Edmonds and Chweya, 1997).

Growers of spiderplant and African nightshade obtain low yields of 1.5-3.0 tons/ha (MOALD&M, 1995; 1998), compared to potential yields of 20-30 tons/ha (Chweya and Mnzava, 1997; Edmonds and Chweya, 1997). The main reasons for the low yields are poor agronomic practices, which include lack of fertilizer use, irrigation and improved varieties. Production of these crops is mainly rainfed. The rainfall is erratic and hence exposes the crops to episodes of drought. Irrigation is therefore necessary to maximize the leaf yields and nutrient content for successful commercialization of these crops. This calls for efficient water management practices considering that water is scarce and the costs of irrigation are high.

Water stress affects various plant processes with the main ones being leaf area development, dry matter partitioning, water relations and transpiration. The rapid commercialisation of African nightshade and spiderplant has not been backed by sufficient amount of research especially in the area of fertilizer use. The application of nitrogen to increase yield in leafy vegetables is an important agronomic practice. It is known that nitrogen deficiency exerts its effects on plant growth through reduced leaf area index and hence low light interception and low dry matter production (Jones 1992). The current commercial farmers have no proper guidelines on the amount of nitrogen to apply. It is possible that growers may apply excessive N to realise high leaf yield and presumable high economic returns. This can lead to environmental contamination as well as nitrate accumulation in the vegetables, thereby posing health hazards to consumers (Wright and Davison 1964, Taiz and Zeiger 1998).

Influence of Water Deficit and Nitrogen stress on Leaf Area Development of Spiderplant and African Nightshades

What happens to the leaf area development of spiderplant and African nightshades when they are exposed to water defecits? Generally, plants that have drought avoidance mechanisms, experience a reduction in leaf area development, which reduces plant water use rate and hence conserves water during periods of drought (Jones, 1992; Ludlow and Muchow, 1990). In spiderplant, it has been shown that plants under severe water deficit had only 17-18 % of the leaf area of plants under well watered conditions (Fig 1.). This drastic reduction in leaf area was attributed to reduced leaf number and reduced leaf expansion. The specific leaf area (SLA) was significantly lower in plants under severe water deficit. This was mainly due to these plants having smaller and thicker leaves. Similar results were observed in African nightshades with plants under severe water deficit having 12-26 % of the leaf area of well watered plants, and a significant reduction in SLA under severe water deficit (Fig 2.). The number of leaves per plant is a function of leaf appearance rate, branch formation, leaf number per branch, plant height as well as leaf senescence rate. Under water deficit leaf number, leaf appearance rate, branch number and plant height reduce while leaf senescence is accelerated (Belaygue et al., 1996). The extent of reduction of leaf appearance rate depends on the timing and duration of the stress period (Belaygue et al., 1996).

The reduction of individual leaf area involves inhibition of expansive growth of the leaf. Expansive growth results from cell division and enlargement, which involves extensibility of the cell wall under turgor pressure (Pugnaire et al., 1999). Under limited water supply, turgor pressure reduces and growth depends on the rate of water supply (Jones, 1992). In this way, water deficits or other environmental factors such as air humidity that reduce turgor pressure also reduce expansive growth (Turner, 1997; Serpe and Mathews, 2000).

Leaf expansion in a drying soil can be reduced before any measurable decline in leaf water status in some crops (Dodd et al., 2002). This has been attributed to a non-hydraulic signal produced when roots are growing in a drying or compacted soil, which act to inhibit leaf expansion (Roberts et al., 2002). The hormone ABA is known to play a major role in this signal, but other hormones, ions and growth inhibitors are known to be involved (Munns, 1992; Davies et al., 2002b). Leaf expansion can also be inhibited by other environmental factors that reduce plant water status, for instance, high evaporative demand (Tardieu et al., 2000; Salah and Tardieu, 1996; Van Volkenburgh, 1999).

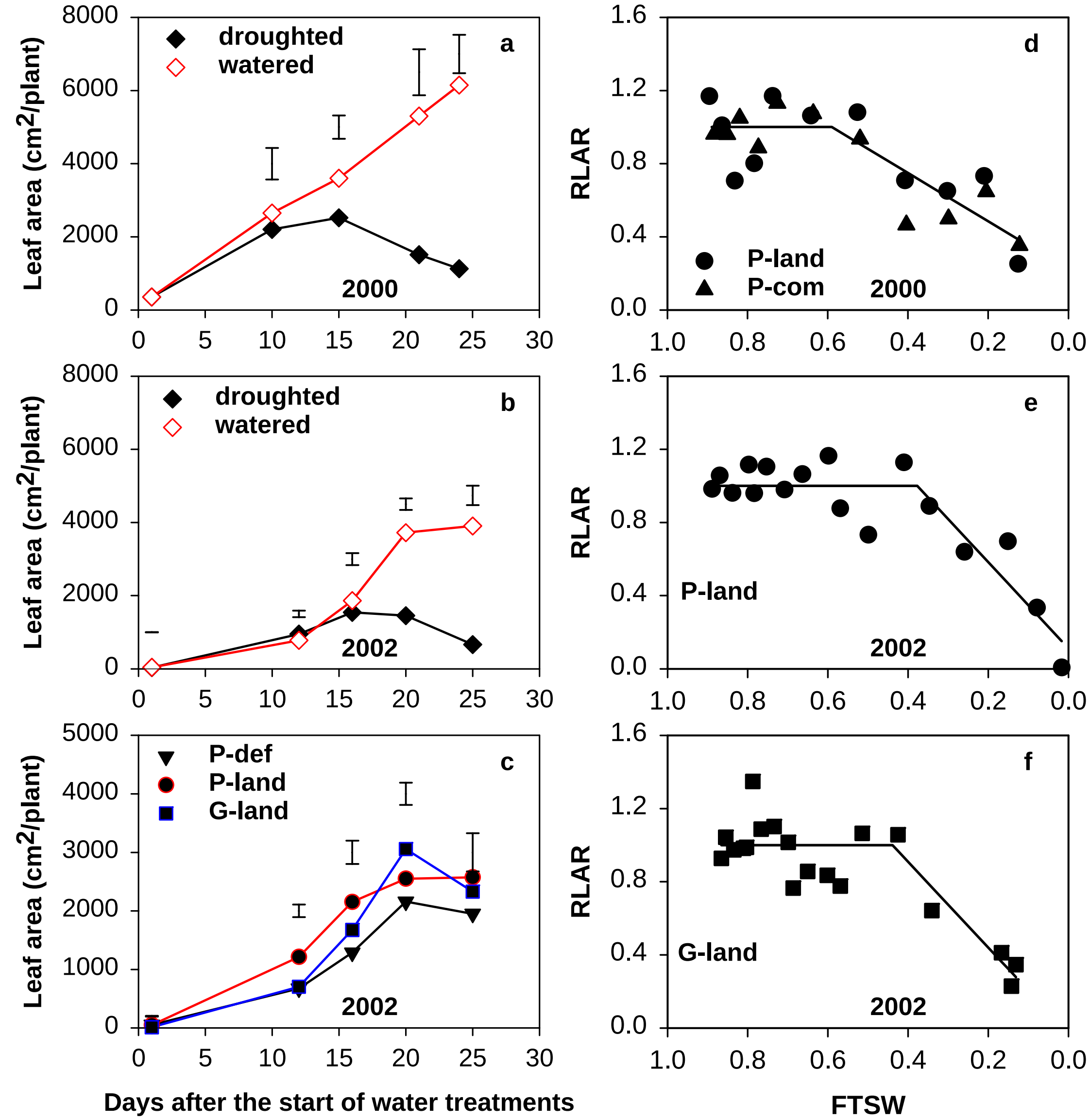


Fig. 1. Plant leaf area of spiderplant grown in the glasshouse as influenced by water levels (a, b) and genotypes (c) and relative leaf appearance rate (RLAR) as a function of fraction of transpirable soil water (FTSW) for spiderplant genotypes (d-f) in 2000 and 2002. Vertical bars show $LSD_{0.05}$. Lines in d, e and f show plateau regression functions.

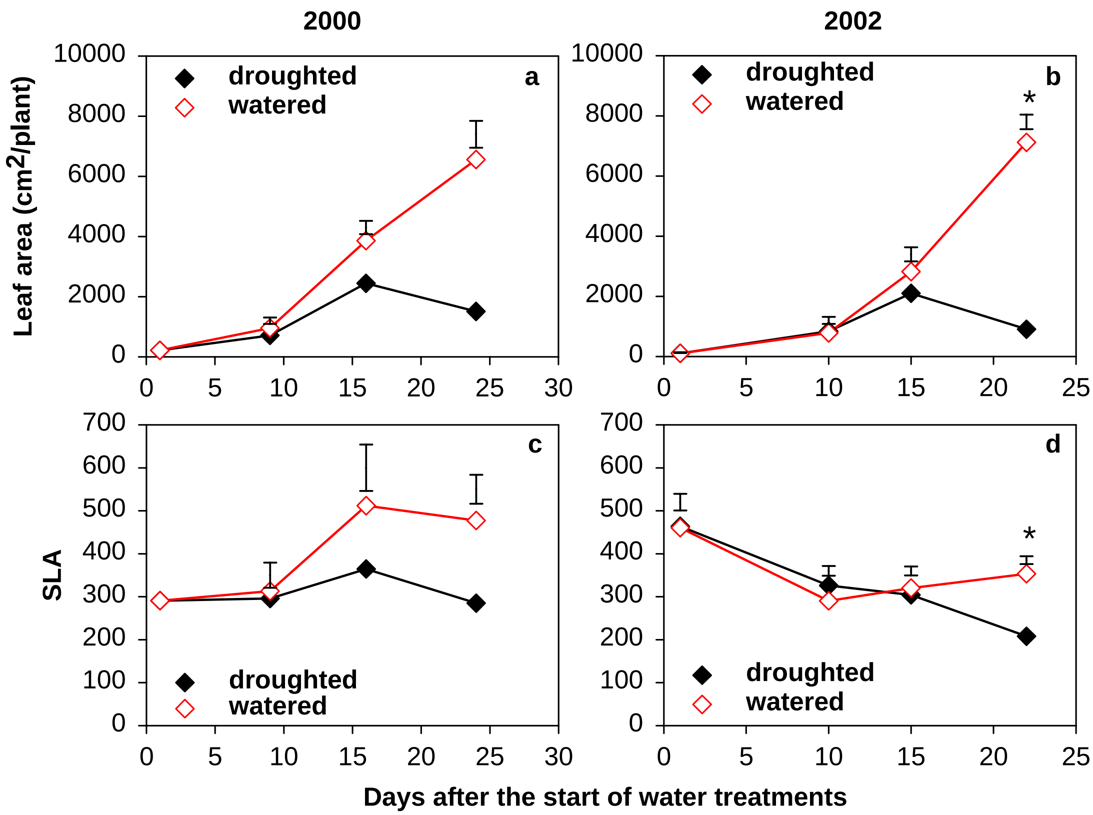


Fig. 2. Plant leaf area (a, b) and SLA (c, d) of African nightshade grown in the glasshouse as influenced by water levels (means across genotypes) in 2000 and 2002. Vertical bars show $LSD_{0.05}$.

Spiderplant and African nightshades similarly experienced drastic reduction in their leaf areas when faced with nitrogen stress. Leaf area was 2-3 times and 5-8 times higher in plants supplied with sufficient nitrogen as compared to those with no nitrogen supply for spiderplant and African nightshade, respectively (Figs. 3 and 4.). On a leaf area basis, there were no significant differences in leaf nitrogen content between plants supplied with nitrogen and those not supplied for spiderplant (Table 1). In African nightshade, these differences were significant only in the young plants. In mature plants, the differences were minimal (Table 2). These results suggest that spiderplant and African nightshade under nitrogen stress tried to maintain a high leaf nitrogen concentration. This was probably through reduction in leaf growth. By reducing leaf area under limited nitrogen supply plants may be able to maintain a high leaf nitrogen concentration as has been shown in potato (*Solanum tuberosum* L.) (Vos and van der Putten 1998). Another strategy plants use in response to limited nitrogen supply is to maintain a high leaf area, but adapt the leaf nitrogen concentration to nitrogen availability as demonstrated in maize (*Zea mays* L.) (Vos et al. 2005).

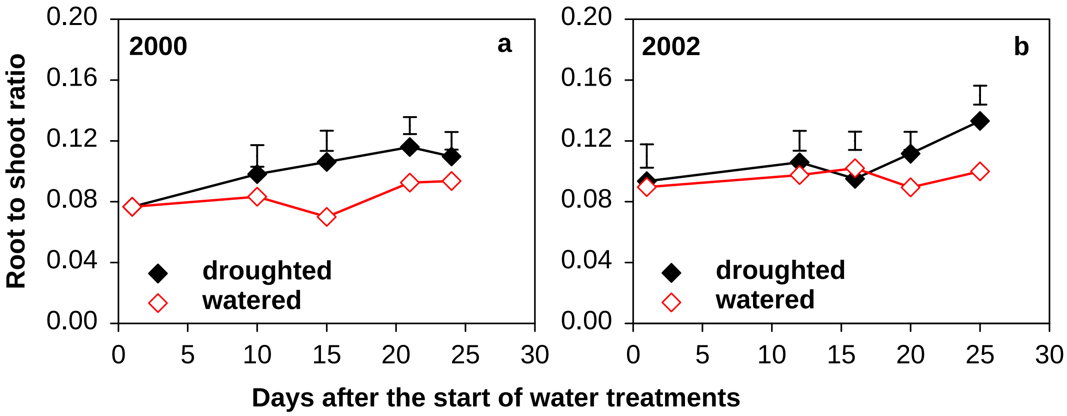
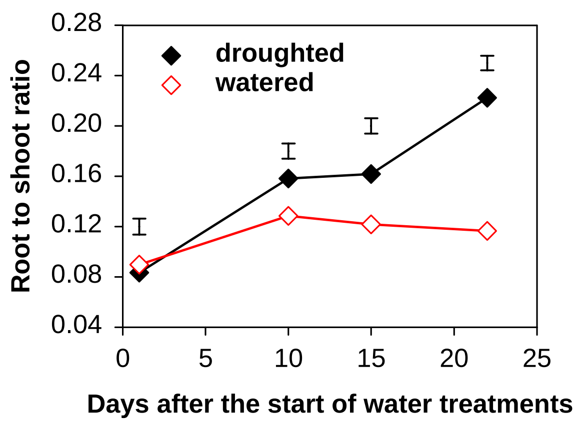


Fig. 3 **The root to shoot ratio of spiderplant grown in the glasshouse under droughted and watered conditions (means across genotypes) in 2000 (a) and**



2002 (b). Vertical bars show $LSD_{0.05}$.

Fig. 4. **The root to shoot ratio of African nightshade grown in the glasshouse under droughted and watered conditions (means across genotypes) in 2002. Vertical bars show $LSD_{0.05}$.**

The application of nitrogen to increase yield in leafy vegetables is an important agronomic practice. It is known that nitrogen deficiency exerts its effects on plant growth through reduced leaf area index and hence low light interception and low dry matter production (Jones 1992). The leaf nitrogen content correlates well with the leaf chlorophyll content, hence N deficiency leads to reduced photosynthesis resulting in lower biomass accumulation (Zhao et al. 2005). It has been shown that the maximum canopy photosynthesis in maize (*Zea mays* L.), rice (*Oryza sativa* L.) and cauliflower (*Brassica oleracea* L. *botrytis*) was correlated to leaf nitrogen concentration (Vos et al. 2005, Shiratsuchi et al. 2005, Alt et al. 2000, Kage et al. 2001).

Table 1. **The influence of nitrogen application on N content (N g/m²) in blades spiderplant grown in greenhouse at JKUAT June-December, 2004.**

N treatment	Days after planting			
	50	**61**	**66**	**71**
0	2.56a	2.53a	2.18a	2.39a
1.04	2.14a	2.17a	2.24a	2.37a
2.08	2.60a	2.78a	2.45a	2.50a
3.12	2.26a	3.08a	2.80a	2.53a
LSD	0.53	0.70	0.70	0.29

Means followed by the same letter down the column are not significantly different ($P \leq 0.05$).

Table 2. **The influence of nitrogen application on N content (N g/m²) in blades of African nightshade grown in the field at JKUAT in 2001**

N treatment	Days after transplanting					
	1	**8**	**15**	**22**	**29**	**45**
0	1.89a	1.48a	1.72a	2.09a	2.00a	1.41ab
2.6	0.68a	2.18b	2.21b	2.09a	1.94a	1.23a
5.2	0.69a	2.31c	2.21b	2.19a	2.14a	1.64b
LSD	0.63	0.03	0.38	0.25	0.69	0.24

Influence of Water Deficit on Dry Matter Partitioning Spiderplant and African Nightshades

The edible part of these crops is the leaf. It is therefore important to understand the influence of water deficit on the allocation of biomass between the root and shoot, and more specifically between the stems and leaves. Water deficits are known to influence dry matter partitioning (Jones, 1992). In both spiderplant and African nightshade, there was an increase in root to shoot ratio under severe stress (Figs. 5 and 6). This increase was mainly due to differential sensitivity of the root and shoot biomass production to drought. At maximum stress, the root biomass reduced by 28-32% as compared to 42-45% for shoot biomass in the case of spiderplant. Similarly, relatively larger reductions of biomass production were observed in shoots than roots in African nightshades, which resulted in higher root to shoot ratio under drought. This differential sensitivity has also been reported in crops such as wheat (Blum and Sullivan, 1997), cowpea (Sangakkara, 1998) and beans (Boutraa and Sanders, 2001). Many studies indicate that relatively more dry matter is partitioned to the root as compared to the shoot in plants facing drought (Li et al., 1994; Arora and Mohan, 2001; Lehto and Grace, 1994; Wilson, 1988; Wien, 1997). Increase in root to shoot ratio under drought has also been attributed to the fact that shoot growth is more sensitive to increasing soil moisture stress than root growth (Kramer and Boyer, 1995) as has been shown in cowpea (Sangakkara, 1998), French beans (Sangakkara et al., 1996a, b), soybean (Huch et al., 1986) and various C_4 grasses (Fernandez et al., 2002).

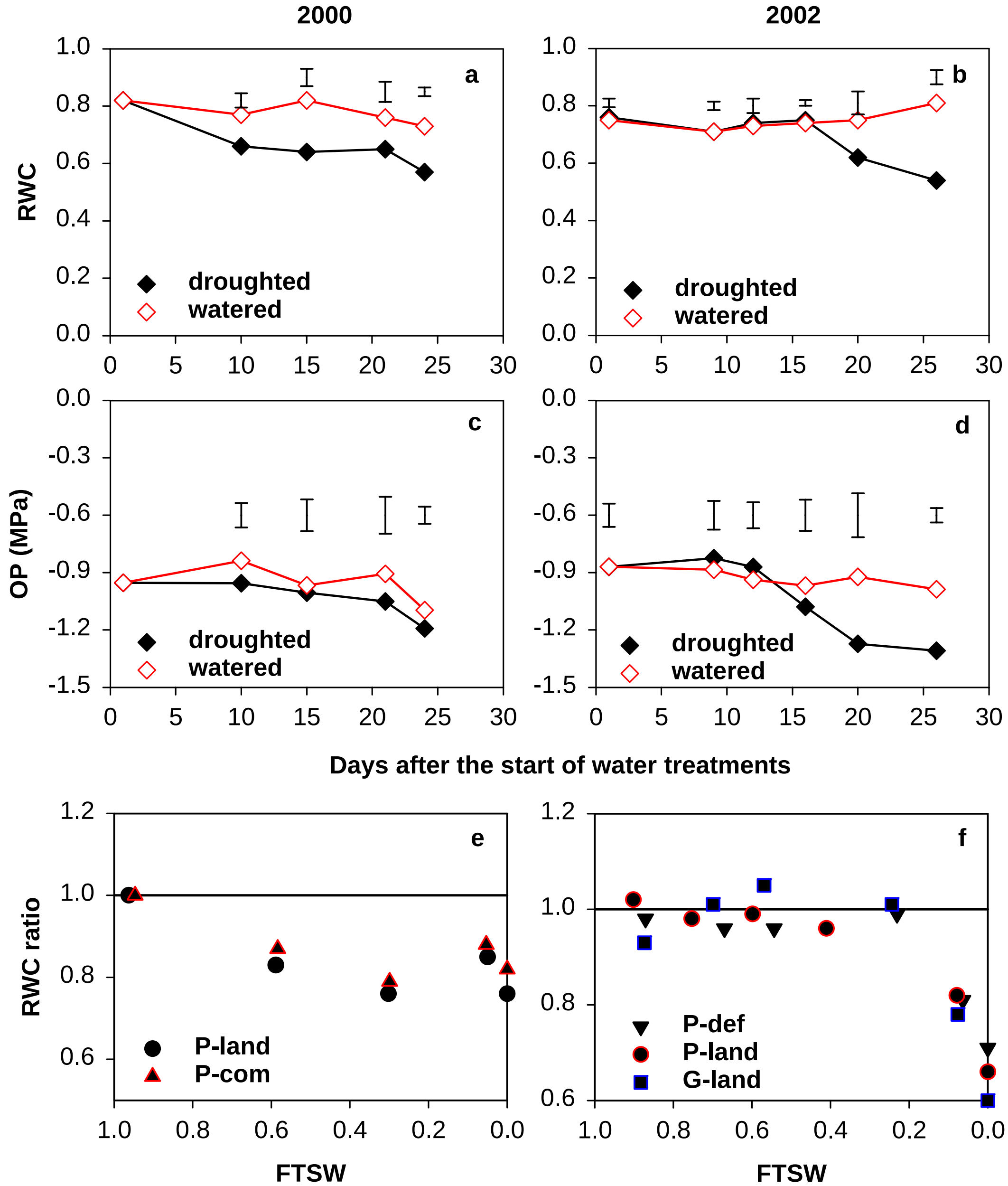


Fig. 5. **The relative water content (RWC) and osmotic potential at full turgor (OP) of spiderplant grown under droughted and watered conditions (a-d) and the scatter diagrams of the ratio of RWC of drought to watered plants as functions of FTSW for spiderplant genotypes (e, f). Vertical bars show $LSD_{0.05}$.**

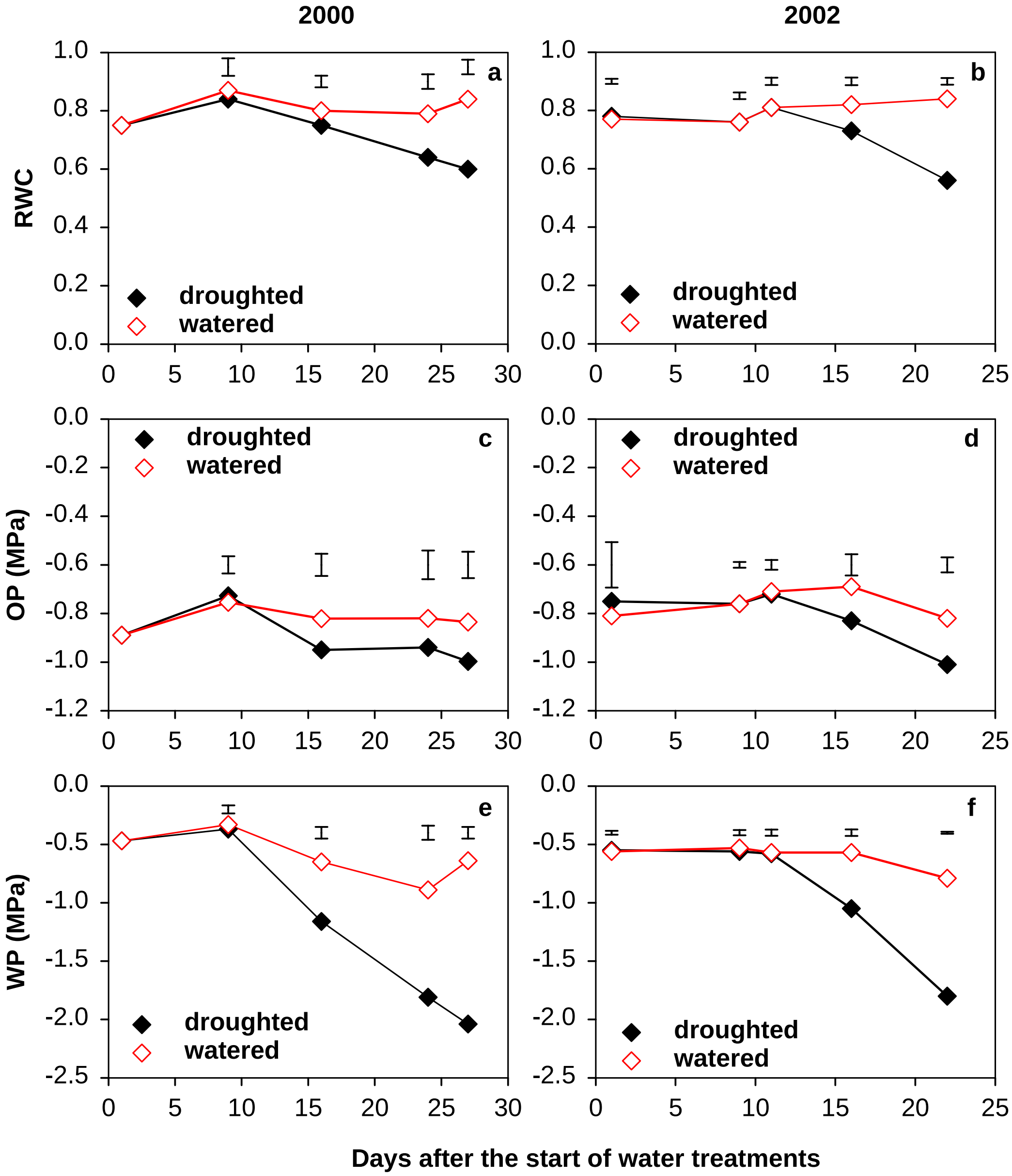


Fig. 6. **Relative water content (RWC) (a, b), osmotic potential at full turgor (OP) (c, d) and water potential (WP) (e, f) of African nightshade grown in the glasshouse under droughted and watered conditions in 2000 and 2002. Vertical bars show $LSD_{0.05}$.**

Water Relations

The water balance of plants is determined by the difference between transpiration and root uptake (Sinclair and Ludlow, 1985). Under well watered conditions, water is freely available from soil and stomatal conductance is maximum; thus environmental conditions around the shoot determine the rate of transpiration. At this stage, the relative water content (RWC) is maintained above 0.75 (Sinclair and Ludlow, 1986). In a drying soil, the soil hydraulic conductivity declines with the decline in volumetric water content and the rate of water uptake from the soil cannot match the potential transpiration rate. Consequently, stomatal conductance declines in an attempt to balance transpiration rate and the rate of uptake of soil water thus, maintaining RWC above 0.60. Under severe stress, there is stomatal closure and further decline in the plant water status leads to eventual death of the plant (Sinclair and Ludlow, 1986).

Declining plant water status under increasing soil water deficits has detrimental effects on various physiological processes and eventually plant productivity. Lawlor, 2002 has reported that decreasing RWC in a drying soil leads to a decline in stomatal conductance as well as CO_2 assimilation, with these two approaching zero at RWC of 40%. This has been attributed to impaired metabolism (Lawlor, 2002) for example through reduced activity of enzymes involved in assimilation such as Ribulose-1, 5-biphosphate carboxylase/oxygenase (Pary et al., 2002).

Osmotic adjustment (OA) resulting from accumulation of solutes within cells in response to declining water potential helps to maintain turgor of shoot and roots during drought (Jones, 1992; Angadi and Entz, 2002; Flower et al., 1990; Morgan, 1992; McCree and Richardson, 1987; Wright et al., 1997). This allows turgor dependant processes such as stomatal opening and expansive growth to continue at reduced rates under declining water potentials (Jones, 1992; Ludlow and Muchow, 1990). Osmotic adjustment would be of great importance to spiderplant and African nightshade provided that it enables leaf expansion to continue under drought. However, Wullschleger and Oosterhuis (1991) have reported that in bean and pepper, OA was not associated with the maintenance of leaf growth. Similarly, Flower et al. (1990) found that leaf area in sorghum lines with high and low OA capacity was reduced similarly under drought. Other beneficial effects of OA under drought include reduced rate of leaf senescence, enhanced root growth, which enhances water uptake and subsequently yield improvement (Ludlow and Muchow, 1990; Tollenaar and Wu, 1999).

Conversely, OA reduces the ability of the plants to avoid dehydration in the event of terminal drought through the delay in leaf senescence and stomatal closure (Ludlow and Muchow, 1990). In this case, there will be continued water use by the plants leading to progressive decline in leaf water potential, probably causing plant death (Sinclair and Muchow, 2001). The capacity for plants to adjust osmotically when subjected to water deficits is genetically determined, but the extent of OA is an inducible trait (Ludlow and Muchow, 1990). Thus, full expression of the extent of OA requires that drought be imposed slowly (Jones, 1992; Nguyen et al., 1997; Ludlow et al., 1985). Rapid depletion of soil water due to small soil volume or rapidly growing plants leads to lower OA than would be expected as has been observed in wheat and sorghum (Machado and Paulsen, 2001). Thus, the effects of water deficit on plant performance are expected to be minimized under field conditions where plants have access to large volumes of soil as compared to pots (Ludlow et al., 1985).

In spiderplant, water deficit reduced the relative water content (RWC) significantly and this occurred generally when the fraction of transpirable soil water fell below 0.2-0.6 (Fig. 7). The osmotic adjustment (OA) was in the range of 0.10-0.33 MPa. Similar results were obtained for African nightshade with relative water content and water potential and osmotic potential declining significantly as the water deficit intensified (Fig. 8). The resultant osmotic adjustment (OA) ranged 0.16-0.19 Mpa. The osmotic adjustment values for both spiderplant and African nightshade are relatively low compared to values for crops with high OA capacity. Such low osmotic adjustment suggests that the two species rely less on osmotic adjustment for their adaptation to drought. Moreover, this OA could not sustain turgor in leaves beyond water potential of about -2.00 MPa and RWC of 0.60. This is in the range of leaf water status at permanent wilting point for other crop species with similar low OA capacity (Moustafa et al., 1996; Kumar and Elston, 1992; Ludlow et al., 1983; Allen, et al., 1998; Premachandra et al., 1995; Awal and Ikeda, 2002; Blum, 1989; Jensen et al., 1996; Davies et al., 2002a; Wullschleger and Oosterhuis, 1991; Shackel and Hall, 1983; McCree and Richardson 1987). Plant species with a higher degree of OA are able to tolerate lower leaf water potentials as has been shown in vegetable amaranth (Liu, 2000), sorghum (Girma and Krieg, 1992) and wheat (Entz and Fowler, 1990; Gesch et al., 1992). Bolanos and Edmeades (1991) considered that an OA of 0.4 MPa and above was necessary to justify the inclusion of a cultivar in a crossing program for maize.

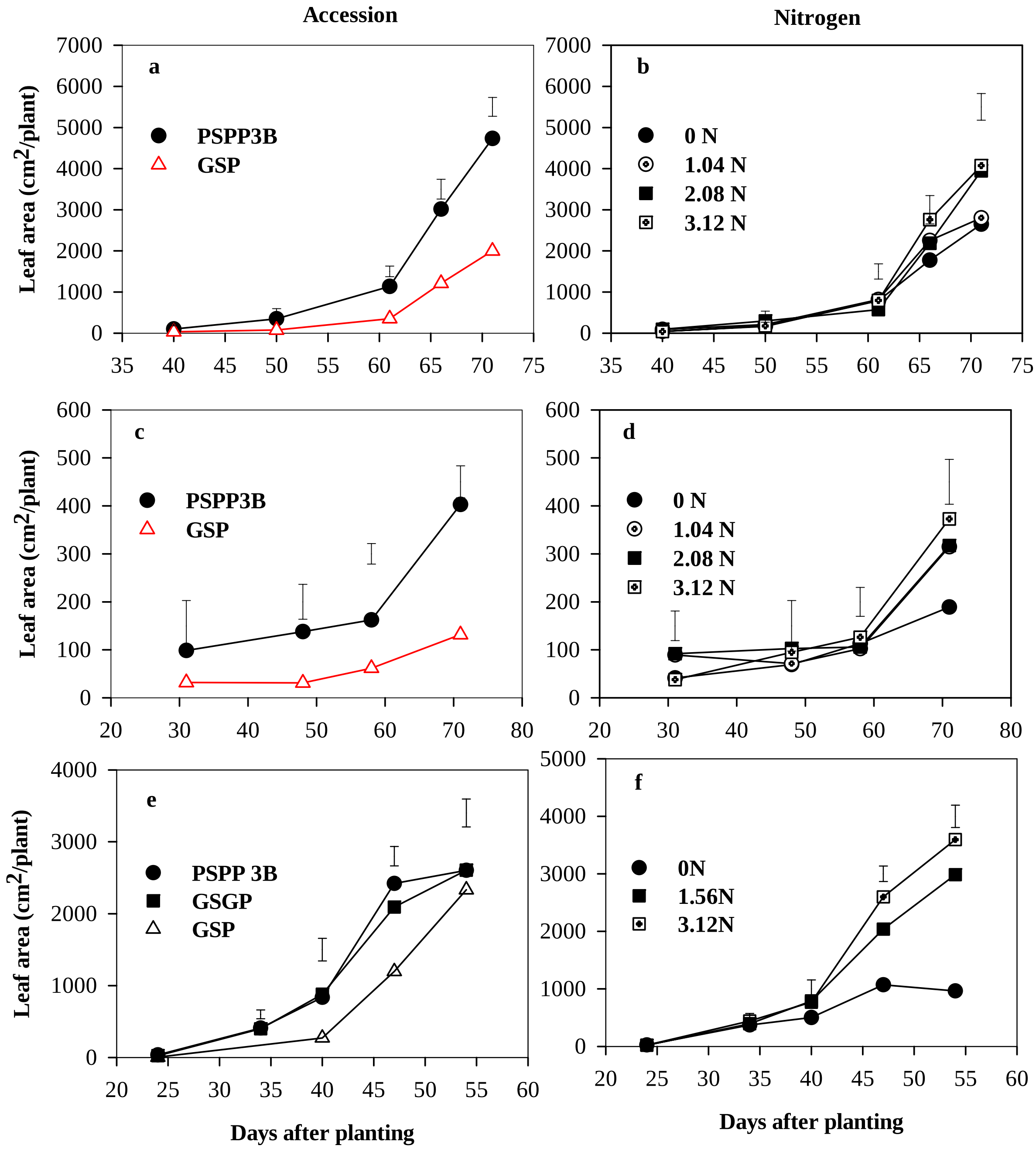


Fig. 7. **The influence of accession and nitrogen level on plant leaf area of spiderplant grown in the greenhouse in July-September (a, b) and October-December 2004 (c, d), and February-April 2005 (e, f) at JKUAT. Vertical bars represent the $LSD_{0.05}$.**

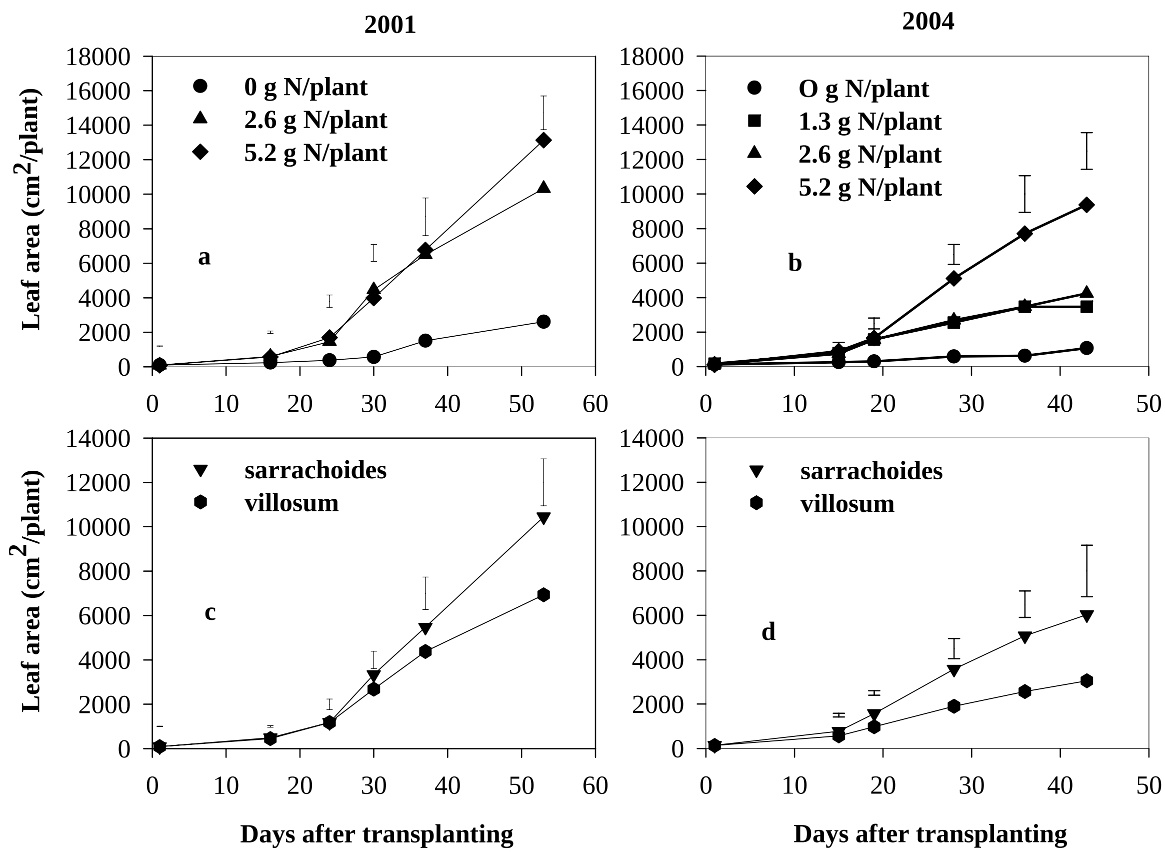


Fig. 8. **The leaf area as influenced by nitrogen rates (a, b) and species (c, d) for African nightshade grown at JKUAT farm in August-October 2001 and January-March 2004. Vertical bars show LSD0.05.**

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Effect of Nitrogen Application on Leaf Yield and Nutritive Quality of Black Nightshade (*Solanum nigrum* L.)

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Abstract

An experiment was carried out to investigate the effects of nitrogen application and plant age on the edible leaf yield and nutritive quality of black nightshade *(Solanum nigrum L.)* plants. The experiments were conducted at Egerton University Egerton-Kenya. Nitrogen levels were 0, 26, 52, 78 and 104 kg/ha N; applied in one, two or three splits. Seedlings were transplanted 8 weeks after sowing. Shoots were harvested fortnightly starting at 8 weeks up to 20 weeks after transplanting. Leaf yield increased with both increasing nitrogen application rates and plant age. Nitrogen at a rate of 104 kg/ha N gave the highest yield (15 t/ha), but it was not significantly different from 52 kg/ha N. (14.8 t/ha) and 78 kg/ha N (14.8 t/ha). Yields increased up to 14 weeks (2.4 t/ha) and 18 weeks (2.7 t/ha) after transplanting

in experiment 1 and experiment 2 respectively. Thereafter yields declined with successive harvests. Harvested leaves were dried, and analyzed for oxalate and phenolic contents. Plant age significantly affected the oxalate content of the leaves. In experiment 1, oxalate content decreased with increasing plant age between 8 weeks and 20 weeks after transplanting. In experiment 2, the oxalate content increased between 8 and 12 weeks after transplanting; but from 16 weeks, it declined with increasing plant age. Plant age had no significant effect on phenolic content in experiment 1; but its effect in season 2 was significant. Implications of these findings will be discussed.

Key words: Nitrogen, oxalates, phenolics, plant age, *Solanum nigrum*

Introduction

Solanum nigrum (Black nightshade) is a popular traditional vegetable in Kenya. Traditional leafy vegetables (TLVs) are defined as having been originally domesticated or cultivated in Africa for the last several centuries (Gockowski, et al., 2003). Leafy vegetables are a major component of the diets of rural and urban households in most parts of Africa. It is estimated (Maundu, 1993) that there are up to 800 species of traditional food plants. 46 species have been taxonomically identified as edible leafy vegetables (Mtotomwema, 1987). The most important traditional vegetables in Kenya include *Amaranthus spp, Solanum nigrum, Gynandropsis gynandra, Crotolaria brevidens and Vigna unguiculata*.

Green vegetables are the cheapest and most abundant potential source of protein because of their ability to synthesize amino acids (Aletor et al., 2002). Although Kenyans have traditionally made use of edible leaves of species growing wild or as weeds, these plants have been neglected by agriculturalists (Chweya, 1985). Traditional leafy vegetables have not benefited from research on selection and breeding for improved palatability.

Use of traditional vegetables in the tropics has declined because of the belief that the bitter species are poisonous (Fenwick et al., 1990). The presence of inherent toxic factors or anti-nutritional components in plants have been implicated, which although usually present in trace amounts may have profound effects on their nutritional quality (Aletor et al., 1995). A major constraint for the nutritional exploitation of these species is the presence of certain anti-nutritional and toxic substances such as nitrates, oxalates and saponins. Oxalates and phenolics are anti-nutrients, which are synthesized by many plants; and which if consumed in large concentrations, may impair the health of the consumer.

The presence of oxalates in foods reduces the bioavailability of essential minerals such as calcium (Savage et al., 2000). Some leafy plants and some root crops contain markedly high levels of soluble and insoluble oxalates; which when consumed can bind calcium and other minerals (Savage et al., 2003). The deleterious effects of oxalates have been reported by Pingle and Ramasastri (1978), Ferrando (1981), Okutani and Sugiyama (1994) and Savage et al. (2003). Oxalic content in plants is variable between species and sometimes even within specie.

Solanum nigrum (Messiaen, 1992) contains low contents of pure oxalic acid, or else the oxalic acid is in the combined form of oxalate. Phenolics are naturally present in most plant materials, a few of which are potent toxins (Singleton, 1981).

Problems of environmental degradation, shortage of arable land, moisture, diseases and pests and high production costs have reduced the reliability on exotic vegetables and narrowed the food base of most households. This has led to a new interest in traditional vegetables. Considering the beneficial attributes of leafy vegetables, Wallace et al., (1998), emphasizes the need to comprehensively establish their chemical, nutritional and toxicological properties before advocating for their increased utilization.

The aim of this study was to determine the yield potential of *Solanum nigrum* as well as investigate its anti-nutrient components (oxalates and phenolics) in order to ascertain its suitability for use in human diet.

Materials and Methods

Experimental design and materials

Two experiments were carried out at Egerton University, Njoro (Kenya). There were fifteen treatments arranged in a split plot design. Five nitrogen rates were applied (0, 26, 52, 78 and 104 kg ha^{-1}). Calcium ammonium nitrate (CAN, 26%N) fertilizer was used as the nitrogen source; and three application methods were used (one, two or three split applications). Nitrogen was first top-dressed three weeks after transplanting, with subsequent top dressings at three weeks intervals.

Measured parameters

Harvesting commenced 8 weeks after transplanting and continued at fortnightly intervals over a period of 14 weeks. Shoots of 5 to 10 cm in length were picked, weighed and the edible yield computed in tonnes per hectare.

Approximately 100 g of harvested leaves from each plot was analyzed every 4 weeks. Oxalates were determined from oven-dried leaf samples according to the method described by Marshall et al., (1967). The results were expressed as milligrams of oxalic acid per 100g. Total phenolics were determined on oven - dried leaf samples using the "Prussian Blue" method described by Price and Butler (1977). Phenolic content was expressed as mg tannic acid equivalent per 100 g sample.

Data Analysis

The collected data was subjected to Analysis of Variance (ANOVA) test as described by Steel and Torrie (1981), and means separated using the Least Significant Difference (LSD) at P=0.05.

Results

Effect of nitrogen on leaf yields

Leaf yields increased with increasing nitrogen application rates. In season 2 Nitrogen application at 52, 78 and 104 kg ha^{-1} gave significantly higher yields than at 26 kg ha^{-1} and the control (0 kg^{-1}); but yield differences between 52, 78 and 104 kg ha^{-1} were not significant. The highest yield (15 t ha^{-1}) was obtained at the highest nitrogen application rate of 104 kg ha^{-1} (Table 1).

Table 1: Effect of nitrogen levels on leaf yield of *Solanum nigrum* [z]

Nitrogen (kg/ha)	Season 1 yield (t/ha)	Season 2 yield (t/ha)
0	9.1[a]	12.0[b]
26	10.2[a]	12.2[b]
52	11.0[a]	14.8[a]
78	10.7[a]	14.8[a]
104	11.1[a]	15.0[a]
Coefficient of variation	16.11%	17.02%

[z]Means followed by the same letter within columns are NS different, P = 0.05.

Effect of nitrogen and application method on yields

In season 2 the interaction between nitrogen rate and application method was significant. The highest yield was obtained when nitrogen at a rate of 104 kg ha^{-1} was applied in 2 splits (Fig. 1). The significant effects were observed at application rates of 78 and 104 kg ha^{-1}.

Effect of plant age on leaf yield

Plant age significantly affected leaf yield. Yields increased with successive harvests. In season 1, the highest yield was recorded at the 4th harvest (14 wks after transplanting); and the lowest at the 7th harvest, i.e. 20 weeks after transplanting (Fig. 2). In season 2, the highest yield was observed at 18 weeks after transplanting.

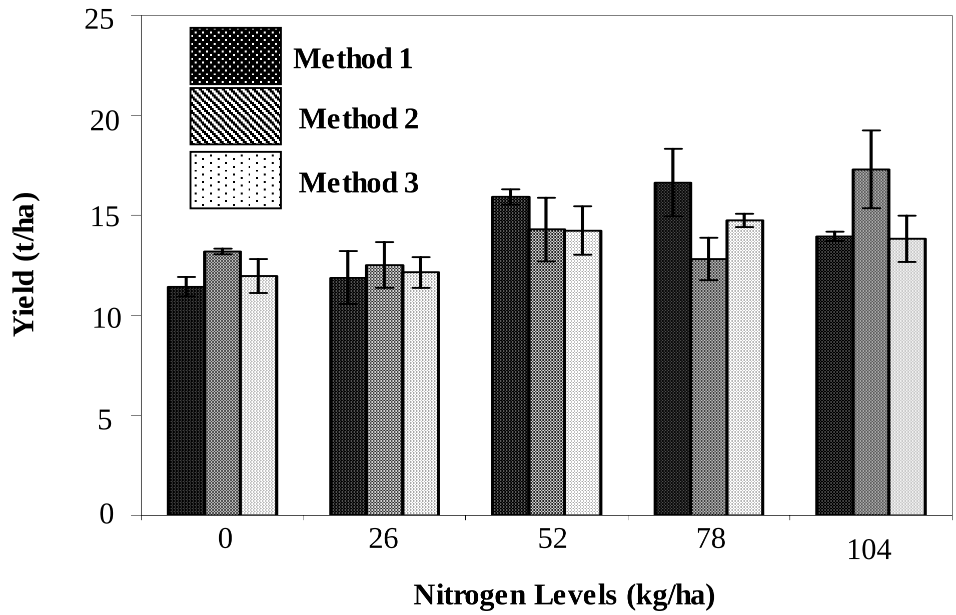

Figure 1: Effect of nitrogen level and application method on leaf yield (Season 2), Method 1: Single application; Method 2: Double split applications; Method 3: Triple split applications

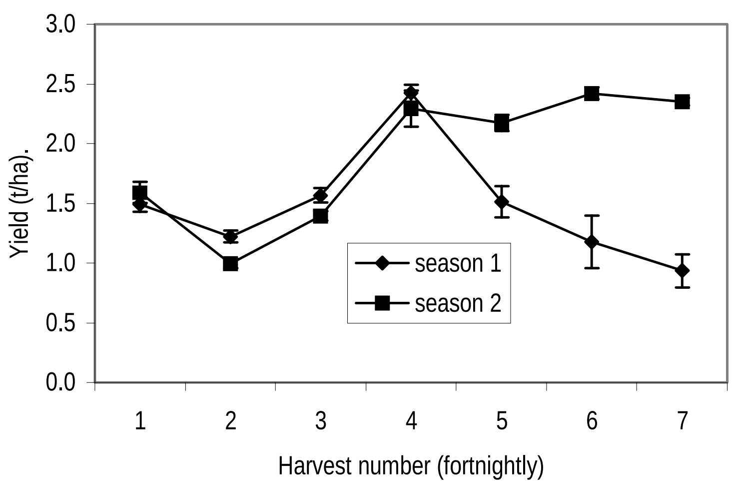

Figure 2: Effect of plant age on leaf yield of *Solanum nigrum*

Effect of nitrogen and plant age on oxalate content

Neither nitrogen rates nor application methods significantly affected the leaf oxalate content; plant age however, significantly affected the oxalate content of the leaves. In season 1, oxalate content decreased with increase in plant age (Table 2.). The highest oxalate content was recorded during the 1st harvest (8 weeks after transplanting). At the 7th harvest (20 weeks after transplanting), oxalate content was significantly lower compared to all other harvesting stages. The rise in oxalate content at 16 weeks after harvest was not significantly different from that at 8 and 12 weeks. In season 2, the lowest oxalate content was recorded at the first harvest (8 weeks after transplanting) and the highest during the second harvest (10 weeks after transplanting). As in season 1, oxalate concentration 20 weeks after transplanting, was significantly lower compared to other harvesting stages.

Table 2: Effect of plant age on the oxalate content of *Solanum nigrum* leaves

Plant age (weeks)	Season 1 mg/100g *	Season 2 mg/100g
8	611.0[a]	652.7[b]
12	511.9[a]	938.5[a]
16	591.9[a]	895.1[a]
20	480.7[b]	707.1[a]
Coefficient of variation	15.7%.	17.7%.

** Means followed by the same letter down each column are not significantly different at P = 0.05*

Effect of nitrogen and plant age on phenolic content

Plant age significantly affected phenolics content in season 2. In both experiments, the lowest phenolics content was recorded 16 weeks after transplanting (Table 3). The differences in phenolic content in season 1 were not significant. In season 2 the trend in phenolics concentration was irregular. After an initial increase at 12 weeks, there was a decrease in at 16 weeks, followed by another increase at 20 weeks after transplanting.

Discussion

Fresh yield of edible leaves increased with increasing rates of nitrogen application. In leafy vegetables, vegetative growth translates into leaf yield; which therefore explains the observations made during this study. Similar observations were made by Murage (1990), who found that yield of *Solanum nigrum* increased significantly with increasing rates of nitrogen application.

Table 3: Effect of plant age on the phenolics content of *Solanum nigrum* leaves [z]

Plant age (wks)	Season 1 (mg/100g)	Season 2 (mg/100g)
8	938.6[a]	1327[b]
12	909.7[a]	1455[ab]
16	797.6[a]	1153[c]
20	903.1[a]	1507[a]
Coefficient of variation	12.6%,	12.4%.

[z]Means followed by the same letter down each column are not significantly different at P = 0.05

In season 1, rainfall distribution was less favorable compared to season 2. According to Webster and Wilson (1980), inadequate soil water may restrict crop uptake of nitrogen. Under conditions of water deficit plant growth is slow and yields are low (Edmond et al., 1975). This possibly explains the lack of significance in yield increase due to fertilizer rates during season

1. Similarly, in a study on kale, Chahira (1982) did not find significant differences in leaf yield due to different levels of CAN fertilizer. According to Davies et al. (1975), in situations of adequate moisture availability the soil supplies considerable amounts of nitrogen, which is readily absorbed by the roots. This could have contributed to the yield differences observed during the two seasons.

A recommendation by Mathai (1978) is that in leafy vegetables, nitrogen should be applied in splits in order to help reduce leaching loses. Chahira (1982) and Cooke (1982) reported that extra yields are obtained by splitting fertilizer applications. In this study, no significant differences in yield due to the number of nitrogen applications were found. Studies by Archer (1985) showed that frequent nitrogen applications are most effective where no appreciable soil moisture deficit occur. This possibly explains the reason behind the likely higher yield (though not significant) results in single application in season 1 when moisture availability was less favorable, and double application in season 2 when moisture availability was more favourable.

The time interval between top dressings was three weeks. If interval between split applications of nitrogen is small (Chahira, 1982), lack of response to split applications may occur. Three weeks between top dressings used in this study is the recommendation for kales. This interval might have been unsuitable for *Solanum nigrum*. In season 2, the interaction between nitrogen rates and application method significantly affected yield. Significance was observed at nitrogen rates of 78 and 104 kg ha^{-1}, but not at rates below 78 kg ha^{-1}. It is possible that nitrogen rates less than 78 kg ha^{-1} is so low such that it is all used up before leaching takes place.

In both seasons, yield increased with increasing plant age. Similar observations in *Solanum nigrum* were made by Onyango (1992), who found that fresh shoot weight increased with each subsequent harvest until the 7th harvest after which yields declined. Aworh et al. (1980), also reported that shoot fresh weight in spinach increased with increasing plant age, particularly when nitrogen fertilizer was applied. Mnzava and Masam (1985) found that in *Amaranthus cruentus* (L), edible leaf yield declined in the 2nd harvest, then increased during subsequent harvests and finally declined as the plants approached flowering. Similar observations were made during this study. The results of this study indicate that provided moisture is not limiting, yields higher than 18t ha^{-1} per season can be attained.

Neither nitrogen application nor the application method significantly influenced oxalate concentration in the leaves of *Solanum nigrum*. But reports stating that increasing nitrogen rates results in a decrease in the oxalate content in leafy vegetables have been made by

Carlson (1983), Murage (1990) and Mwafusi (1992). It should however be noted that in those studies, all the nitrogen was applied in one application and harvesting was done once.

It was observed that oxalate content decreased with increasing plant age. Similar observations have been reported by Oke (1966), Okutani and Sugiyama (1992), and Adipala and Mugerwa (1993). According to Forbes and Watson (1992), a plant is most toxic with anti-nutrients when very young or when regenerating after cutting. On this basis, it is possible that oxalate content of the harvested edible leaves may fluctuate depending on the amount of new growth after harvest. Oxalate accumulation is affected by nitrogen source, inorganic ion availability and environmental conditions (light intensity and soil moisture); ontogenetic stage (growth rate), genotype and plant parts are important factors (Beis et al., 2002).

Observations that nitrogen application did not significantly influence the leaf phenolic content conforms to those reported by Murage (1990) and Murage et al., (1996). The favorable soil moisture in season 2 could have resulted in to higher synthesis of phenolics. In *Bergenia crassifolia* the levels of polyphenols have been found to be highest in years with moderate or prolific rainfall (Sakhaorva and Novikova, 1981). Phenolics are not (Masuki, 1996) end products that accumulate unchanged, but are thought to be part of a dynamic equilibrium in which even when produced in quantity, there is continual synthesis, turnover and degradation. Since phenolics are not an end product, and because there is continuous synthesis, turnover, and degradation, their content in the plant is likely to fluctuate over time; which possibly explains why in this study there was no clear trend on phenolic content of edible leaves with increasing plant age.

Conclusions and Recommendations

The results obtained during this study indicate that increasing nitrogen fertilizer rates will most likely increase the edible leaf yield of *Solanum nigrum.* Nitrogen application rates of between 26 and 104 kg N h^{-1} poses no danger of oxalate and / or phenolic concentration rising to harmful levels in the edible shoots of *Solanum nigrum*.

The size of traditional leafy vegetables markets in sub-Saharan market is substantial. According to Gockowski et al., (2003), the total market value in 1996 for these vegetables was US$ 56 million. In most parts of Africa there exists an abundance of traditional leafy vegetable species that grow all year round. They have the advantage of growing quickly and can be harvested within a short period of time. There is need to promote the marketing and utilization of these vegetables in Kenya.

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Feedback

Question: ***Two sources of nitrogen (ammonium and nitrate) were used. Which source is more important in relation to phenolics or oxalates?***

Answer: This study did not take into consideration the different sources of nitrogen, and how they would influence phenolics and oxalates. However, I wouldd be cautious in the use of nitrate due to nitrate accumulation in the leaves. Nitrogen as such is not involved in the synthesis of oxalates and phenolics.

Comment: ***Most researchers have come to a consensus on names used for naming African leafy vegetables. I would request the author to use African nightshade, but not black nightshade. Also specify Solanum spp. i.e. S. villosum but not Solanum nigrum because it is a poisonous plant in the temperate countries.***

Answer: When the study wwas carried out there was still a debate regarding the names to be used. However, I do agree that more recent literature refers to the common name as African nightshade. I do agree and appreciate the suggestion.

Question: ***Soils vary I their rate of nutrient release based on different soil properties. In your experiment did you do multi-locational testing to determine the effect of different places on nutrient release to the crop?***

Answer: The study did not involve differences in soil properties in different areas. The study was not multi-locational but was carried out at Egerton University over two seasons. Though moisture availability was not one of the components of the study, it was observed that seasonal variations in rainfall between the seasons contributed to variations in observations during the two seasons.

Effect of Proximity to Slender Leaf (*Crotalaria brevidens)* on the Growth and Yield of Intercropped Finger Millet (*Eleucine coracana*)

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Abstract

Experiments were conducted for two seasons at the field and demonstration plots of Maseno University to determine the outcome of varying the proximity between finger millet (*Eleusine coracana*) and slender leaf (*Crotalaria brevidens*) in three intercropping systems. The finger millet variety Serere was sown in four planting arrangements laid out in a randomized complete block design replicated 8 times. The planting patterns studies were finger millet as a sole crop, finger millet and slender leaf intercropped in alternate rows, finger millet and slender leaf alternated on the same row and finger millet and slender leaf planted on the same hill. Plants were sampled weekly for 12 weeks during the growing season to determine root depth, shoot height, weed diversity, weed biomass and head blast severity. At the physiological growth stage 92 (PGS_{92}) grain yield was also measured. Root depth, shoot height, weed diversity, weed biomass, head blast severity and yield in finger millet were significantly ($P \leq 0.05$) affected by intercropping although the magnitude and direction of these effects depended on the proximity of planting in the intercrops. Based on these results, it is concluded that there are beneficial as well as harmful consequences of increasing the proximity between finger millet and slender leaf in intercropping systems. Intercropping by planting in same hills as slenderleaf and solecropping recommended if the aim of finger millet cultivation is to obtain optimal grain and straw or fodder yields respectively. It is further recommended that additional studies be carried out to determine the stability of the observed effects over diverse agro-ecological zones, varying organic and inorganic fertilizer types and regimes, and diverse finger millet genotypes. We also suggest further investigations to test the authenticity of the many assertion we have used to interpret our results.

Key words: *Crotalaria brevidens*, *Eleucine coracana*, finger millet, growth, slenderleaf, yield, weeds

Introduction

The traditional cultivation technique of intercropping plays an important role in subsistence food production by smallholder farmers in Africa, especially in situations of limited water resources (Tsubo *et al*, 2005a, 2005b). Because canopy structures and rooting systems of the C4 and C3 plants are generally different, intercrops comprising such plant taxa probably have differing spatial and temporal use of environmental resources such that they may make more efficient use of solar radiation, soil water and nutrients than monocrops (Tsubo *et al*, 2005a). Where legumes are incorporated in intercrop system, additional benefits such as improvement of soil N content through symbiotic fixation as well as management of various biological crop growth constraints such as pests, weeds and diseases become possible. Simulation models have shown that intercrops of cereals and legumes equivalent to sole crops of either crop can confer greater energy and monetary values than pure stands of these crops in semi-arid regions (Tsubo et al 2005b). In the sub-humid zones of western Kenya, farmers usually utilize indigenous leafy vegetables (ILVs) such slender leaf (*Crotalaria brevidens*) are often grown in crop mixtures with cereals like maize (*Zea mays*), sorghum (*Sorghum vulgare*) and the indigenous species *Eleucine coracana* under rain fed conditions. Finger millet and slenderleaf are both well adapted to the ecological conditions in most sub-humid regions of western Kenya. Our thorough survey of existing literature on intercropping unearthed only the study by Akuja *et al* (2003), which reported that intercropping of finger millet and slenderleaf depressed yield of the latter crop. Similar findings have been reported for intercrops between other cereals and legumes but some studies have also shown that manipulating the proximity between the two component crops in the intercrop can increase yield of the cereal (Chemining'wa and Nyabundi, 1994; Chui and Nadar, 1984; Remison, 1978). Our study was conducted to investigate the effect of varying proximity between finger millet and slenderleaf on growth, weed infestation, head blast (*Pyricularia grisea*) severity and grain yield of finger millet.

Materials and Methods

The study was conducted at the Maseno University Field and Demonstration Plots located near the Equator (Latitude 0^{0} 5' S, Longitude 34^{0} 7' E), which is at an altitude of 1478m and where the soil is well-drained deep friable rhymbic nitosol. The first and second experiments were conducted from September 2004-February, 2005 (short rains season) and from February-July, 2005 (long rains season), respectively. In each season fallow land was prepared using standard cultivation practices (*viz.* clearing, ploughing and harrowing) to leave the moderate tilth for finger millet and slender leaf seeding. Plots were 2 x 3m in size and separated by 1m strip of unseeded land to minimize inter-plot interference. The finger millet variety *Serere* was planted in four arrangements (finger millet as a sole crop, finger millet and slender leaf intercropped in alternate rows, finger millet and slender leaf alternated within the same row and finger millet and slender leaf planted on the same hill). Slender leaf as a sole crop was also planted to allow estimation of land equivalent ratios. Plots were laid out in a randomized complete block design replicated 8 times. Where finger millet and slender leaf were intercropped in alternate rows, the spacing was kept at 25 cm between rows whereas in all the other treatments inter-row spacing was maintained at 50 cm. Within rows, a thumb-full of seed (approximately 10 seeds) was planted per hill (1cm deep) spaced 10 cm apart in all treatments except those in which finger millet and slender leaf were alternated within the same row where hills were spaced 5 cm apart. In the alleys (1m wide), the head blast (*Pyricularia grisea*) susceptible finger millet variety (IE 2628) was planted to act as disease spreader. Germinated plants were selectively thinned 7 days after emergence to leave 1 plant per hill (equivalent to a plant population of 200,000 plants/Ha) for each crop. The spreader rows were artificially inoculated with heterogeneous populations of *P. grisea* by transplanting visibly diseased IE 2628 plants to the alleys when plants in the spreader rows were at jointing (PGS_{31} according to the extended BBCH scale; Bleidholder, et al, 1997). The spreader rows, including the clumps were removed at PGS_{54} when it was assumed that all finger millet plants had been adequately exposed to *P. grisea* inoculum. Weeding was done by hand pulling twice in the season 5-wk and 9-wk after sowing.

Data collection was started one week after emergence corresponding to PGS_{13} and continued until full plant maturity (PGS_{92}). Parameters measured included; maximum root length (MED), maximum shoot height (MESH), weed diversity (WD) expressed as number of weed species per m^2 counted just prior to each weeding, weed biomass (WB) expressed as oven-dry weight of weed tissue per m^2 obtained after each weeding exercise, percent finger blast severity (%BS), and grain yield (g/m^2) at PGS_{92}. All data except those that did not require destructive sampling were collected using stratified sequential sampling where on each sampling occasion, a single plant from each of the two central rows (i.e. excluding the outer guard rows) was uprooted starting with plants at the ends of the row and moving inwards. Such sampling was preferable to random sampling (used where destruction was unnecessary) to avoid the creation of gaps that could have produced plant density effects and affected even grain yield and its components in subsequent samples. Plants sampled through destruction were uprooted by gentle digging of surrounding soil with minimal damage of roots to allow the measurement of root depth. Upon grain ripening (PGS_{92}), 1m length of each of the remaining portion of the two central rows of finger millet plants (about 20 plants) occupying 1 m^2 area were harvested to determine grain yield. All data parameters were subjected to analysis of variance and the means separated using Duncan's multiple range test at the 5% level of significance when the F-test was significant. Weed diversity data and percent head blast severity data were respectively transformed using log and arcsine equations before statistical analysis as recommended for count and percent data (Gomez and Gomez, 1983).

Results

Intercropping of finger millet and slenderleaf significantly ($P \leq 0.05$) increased root depth, weed diversity, weed biomass, but decreased head blast severity in finger millet (Figs 1-5). However, the magnitude of the increments or reductions in these parameters seemed to depend on the proximity between the two crops. The boost in rooting depth rose to a maximum and then declined (Fig. 1) whereas that of weed biomass rose continuously (Fig. 4) as the closeness between the two crops was increased. Conversely, the decrease in shoot height (Fig. 2) and weed diversity (Fig. 3) seemed to lessen whereas that of head blast severity (Fig. 5) remained more or less constant as proximity between the two crops was increased. The response of grain yield to changes in intimacy of intercropping, however, seemed to be more complex. The yield was numerically (though not statistically) higher when finger the two crops were planted in the same hills, but significantly lower when they were planted in alternate hills or alternate rows (Fig. 6).

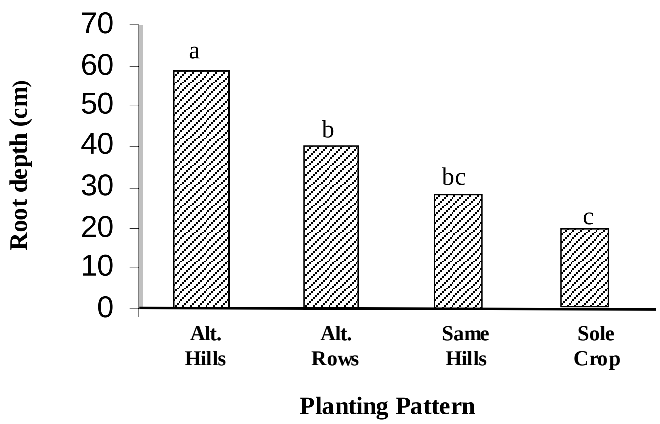

Figure 1: **Root length[a] (cm) of finger millet 11 weeks after planting as affected by planting pattern in an intercrop with slender leaf. [a] Root length was measured from stem base to tip of the longest root at PGS_{92}. Values followed by the same letter are not significantly different at 5% level of significance (DMRT).**

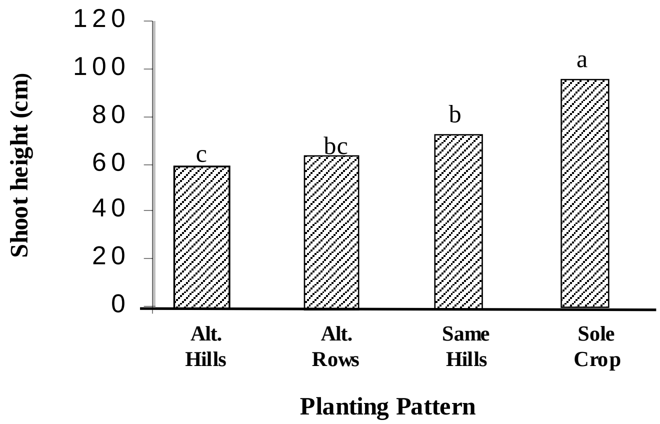

Figure 2: **Shoot height (cm)[a] of finger millet 11 weeks after planting as affected by planting pattern in an intercrop with slender leaf. [a] Shoot height was measured from stem base to tip of the tallest tiller at PGS_{92}. Values followed by the same letter are not significantly different at 5% level of significance (DMRT)**

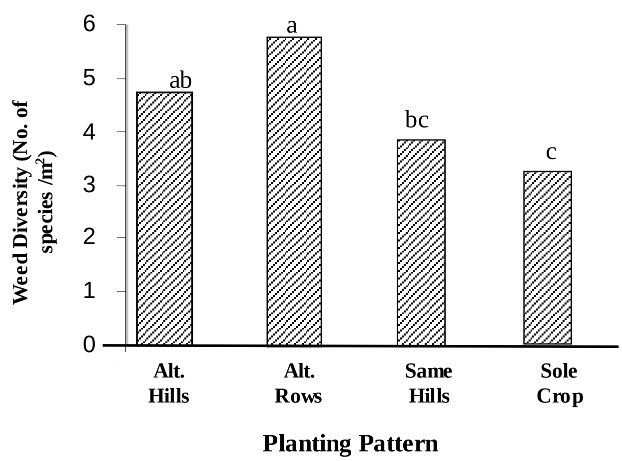

Figure 3. Weed diversity[a] in finger millet plots as affected by planting pattern in an intercrop with slender leaf [a]. Weed diversity was measured by counting the number of distinct weed species counted per m^2 of plot area 9 weeks after planting. Values followed by the same letter are not significantly different at 5% level of significance (DMRT).

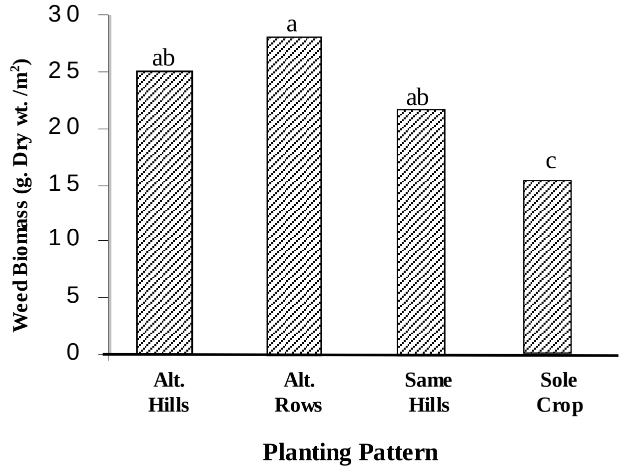

Figure 4: **Weed biomass[a] in finger millet as affected by planting pattern in an intercrop with slender leaf. [a] Weed biomass was measured after oven-drying weed tissue harvested from every m^2 of plot area 9 weeks after planting. Values followed by the same letter are not significantly different at 5% level of significance (DMRT).**

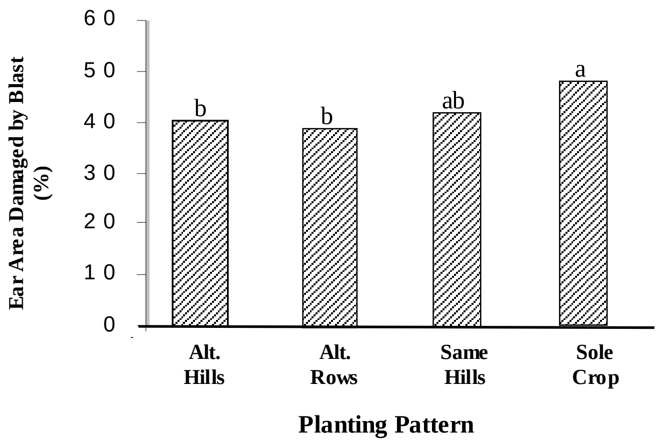

Figure 5: **Percent severity of head (finger) blast[a] caused by *Pyricularia grisea* in finger millet as affected by planting pattern in an intercrop with slender leaf. [a]Head blast severity was measured at PGS_{91}. Values followed by the same letter are not significantly different at 5% level of significance (DMRT).**

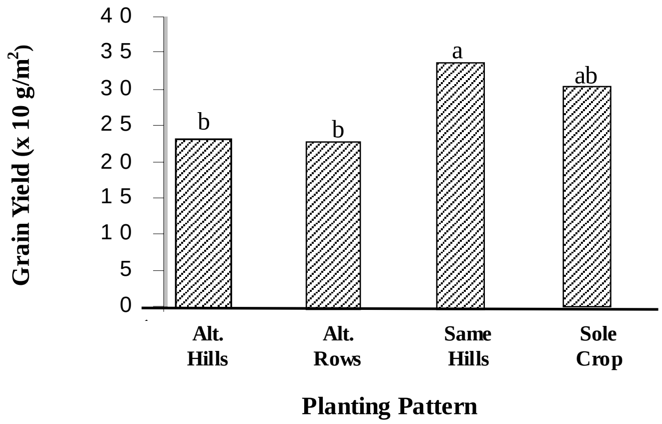

Figure 6: **Grain yield of finger millet at PGS92 as affected by planting pattern in an intercrop with slender leaf. Yield was measures at PGS_{92}. Values followed by the same letter are not significantly different at 5% level of significance (DMRT)**

Discussion

The apparent rise in root depth for finger millet intercropped with slender leaf could be explained by their attempt of the former crop to out-compete the rival crop for space, soil nutrients and moisture that would necessitate the development of profound root systems. It could also have been due to an attempt by finger millet to escape suspected slender leaf allelogens that we hypothesize to be a possible cause of the suppression of finger millet growth and yield by slenderleaf. Obviously, such out-competition of the rival crop or escape of the putative allelogens would only be possible if at the onset of growth the finger millet roots are far enough from the slenderleaf roots so as not to be affected by the allelogens. This would explain why the increase in root depth was smaller (Fig. 1) when the two crops were planted in the same hill (where the effective distance between the radicles of the two species at germination would be very close to zero) in comparison to where a greater distance was maintained between the two crops when they were grown in alternate hills and alternate rows. However, if the distance between the roots of the two species is very large, the finger millet roots would be less capable of absorbing the N that is leached into the rhizosphere by slenderleaf after fixation. This would restrict production of new root tissue because N is an essential component of life molecules that support accelerated root growth. This may explain why the increase in root depth due to intercropping was less where the two species were planted in alternate rows, where the distance between roots of the two species would be at least 25cm, in contrast to where they were planted in alternate hills where roots of the two crops would only be 5cm apart.

The decrease in shoot height of finger millet following intercropping (Figures 2 and 6) is a phenomenon that has been reported earlier (Akuja *et al*, 2004) and was probably the consequence of competition, the putative allelogens or both. The reduction in the magnitude of this decrease as the proximity between the two crops was increased (Fig. 2) is possibly because increasing cropping proximity lessened the negative impact of either competition, the supposed allelogens or both to a point where these effects were surpassed by increased access of finger millet roots to the growth promoting N-rich exudates released into the rhizosphere by *C. brevidens* after symbiotic *Rhizobium* sp. mediated fixation. The observation could also be explained purely on the basis of allelopathic compounds washed out from decaying leaves. After maximum plant height is attained in slenderleaf, the oldest plant leaves are mostly found at the margins of the canopy. Such leaves tend to land some distance away from base the central stem when they drop due to senescence. As planting proximity between the two crops is increased, the roots of finger millet plants tend to be closer to the base of the central stem of slender leaf. This places them further from the zone where the senesced slenderleaf leaves, and hence the putative allelochemicals, are deposited upon leaf-fall. Thus, finger millet roots closest to the stem base of slender leaf would be exposed to the least concentrations of such substances, and this may also explain the constrained decrease in shoot height as the cropping proximity is increased. The observed decrease in shoot height as the cropping proximity is increased may be explained by the need for finger millet to expand its food manufacturing potential above the ground to access sunlight so as to favorably compete with slender leaf, which having emerged earlier, had grown faster thus creating some shading effect for the slower sprouting finger millet. The urgency of such compensatory growth would be less crucial in treatments having finger millet and slender leaf intercropped in alternate rows and this may explain why these treatments had the slowest rate of stem length increment for finger millet in intercropped plots.

The increase in weed diversity and weed biomass in intercropped finger millet was possibly due to the suppression of finger millet growth and, hence suppression of its reputed strong ability to out-compete weeds when it was grown as a sole crop (Tenywa *et al*, 1999). We postulate that such suppression was possibly the outcome of the competition and/or allelopathic effects of component slender leaf crop. Obviously, any such suppression of finger millet growth would always in antagonism with the growth-promoting effects of fixed nitrogen leached into the rhizosphere by the slender leaf. As intercropping proximity is increased, there is greater availability of nitrogen leached into the rhizospere by slender leaf root nodules. This would promote better growth and hence putative allelopathic/competition effects of finger millet making it able to smother weeds as the as the proximity of intercropping was increased (Figures 3 and 4).

The reduction in head blast severity following intercropping (Fig. 5) could be due to the slowing-down of the dispersal of *P. grisea* spores occasioned by the interposition of non-host slender leaf branches between susceptible finger millet heads. Alternatively, it could be due to more complex phenomena such as the activation of systemic acquired resistance (SAR) in finger millet by *C. brevidens* pollen or organic compounds such as the putative allelogens or other bio-molecules that the species secretes. The apparent absence of differences in the magnitude of reduction in head blast severity as proximity of intercropping was varied is possibly because the proximity distances used in this study were too small to produce differences in the speculated obstruction of *P. grisea* inoculum dispersal or activation of SAR in finger millet.

The observed changes in grain yield as proximity of intercropping was varied (Fig. 6) could be due to the same reasons advanced for shoot height response and/or it could be due to the effects intercropping intimacy had on weed diversity, weed biomass and head blast severity (Figures 3, 4, and 5) all of which have a direct consequence on grain yield.

Conclusions and Recommendations

Since finger millet (*Eleucine coracana)* and slender leaf (*Crotalaria brevidens)* are both tolerant and resistant to sub-humid habitats, they are very important for food and nutrition security and the sustainable exploitation of drylands by the resource-poor communities in tropical areas. Under such farming conditions, the greatest benefits can be realized from intercropping of the two species by growing them in the same hill. Because finger millet emerges later than slender leaf, the former crop should be planted about three to four days earlier for uniform emergence of both crops so as to minimize the severity of its smothering effects on finger millet. Under such cropping systems, there would be reduced soil erosion through cover cropping and the sustainable replenishment of soil N through symbiotic fixation. As the beneficial consequences of increasing the proximity between the two crops may vary depending on the variety of finger millet being used in the intercrop, more research is needed to determine the appropriate planting pattern or cropping distance for specific finger millet varieties. More studies of similar planting patterns under varying soil fertilizer types and application regimes over several geographical locations are also needed to better understand ecological dynamics that are important in these cropping systems. Such research should also incorporate plant N and allelogen determination to confirm or disprove some of the premises we have used to explain the physiological basis of the differences in the plant response parameters investigated this study.

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Feedback

Question: ***Traditional farmers intercropped using broadcasting method that could be looked at and perhaps have an effect on weeds that were observed to be prevalent at some spacing in your intercropping layout.***

Answer: Although it is true that broadcasting was a preferred method of seeding/planting, scientific studies have proven that it is more wasteful of seed, prone to establishment of below optimum or above optimum plant population levels, and more labour demanding during weeding. We did not include it as a treatment in our study because it would have been difficult to control the planting proximity between the finger millet and slenderleaf in the intercrop. When one broadcasts seed, one has no control on how close to each other or how far the seeds will land.

Question: ***What is your response to the practice that farmers are abandoning intercropping of maize and beans because beans are causing reduced yield of maize and especially the size of the cob of this crop that they now consider to be a horticultural crop in Central Kenya?***

Answer: Our study has shown that intercropping can either lower or increase yields depending on the proximity that is maintained between the two companion crops. In the case of reduction in cob size of maize when intercropped with beans, it is possible that farmers are using a planting pattern that reduces rather than increases yield. It should also be remembered that the Land Equivalent Ratio often measures the true value of intercropping. Using this ratio, it sometimes becomes obvious that the total value or yield is measured in terms of the yields of both crops in the intercrop. This is the yield compared with the sole crop yield when one wishes to measure the benefits off intercropping.

Question: ***For what reason did you interpret your results as allelopathic?***

Answer: Our interpretation is purely speculative and relied on previous studies done at the University of Nairobi that also speculated that the cause of the inhibition was allelogens. We have been careful to use the term in our interpretations to emphasize the fact that we are not certain that the effect was allelopathic. We have also indicated that it might have been due to simple competition. In fact we categorically state that it could have been due to either or to both phenomena. We concede however that there is need to design more controlled studies to decidedly determine exactly what is responsible for the inhibition.

Question: ***Under our prevailing conditions it wouldd be more ideal for the vegetables to increase leaf area and reduce nitrogen retention. Do you oversee a situation where we can achieve this situation because the interest is increasing yields?***

Answer: Through selection and searching for genetic diversity, or creating genetic diversity through mutation, it is possible to have lines or varieties that maintain leaf area and reduce leaf nitrogen. The possibility is nevertheless low, since it appears that these species reduce leaf area drastically under nitrogen stress.

Farmer-Participatory Prioritization and Development of Agronomic Practices for African Leafy Vegetables

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Abstract

African leafy vegetables (ALVs) are a rich source of Vitamin A, which helps boost the human immune system, vitamin C, Folic acid, riboflavin and minerals such as iron and calcium. However, few Kenyans are aware of their importance. This project was primarily aimed at creating awareness of the value of ALVs in the rural communities. Ten groups each with an average of 28 men and women farmers in Thika and Machakos districts of Central Kenya were sensitized in 2003/04 on the importance of ALVs especially as regards their nutritional, medicinal and commercial value. The farmers were asked to prioritize, with reasons, the ALVs and research themes they would prefer to be pursued. The farmers selected amaranthus (*Amaranthus spp.*), spider plant (*Cleome gynandra)*, solanums (*Solanum spp.*), cowpeas (*Vigna unguiculata)*, pumpkins (*Cucurbita spp.*) and stinging nettle (*Urtica spp.*) due to nutritional and medicinal value, local adaptation, market availability, and prior knowledge of the vegetable. The prioritized research themes included development of optimal agronomic practices, seed production techniques, demonstration of varieties, preparation (cooking) methods, preservation methods and marketing. Farmer-participatory field trials were conducted in Yatta and Thika with two of the farmer-groups on African nightshade (*Solanum vellosum)* and spider plant (*Cleome gynandra*) in one season in 2004. The effects of three inter row spacings (30cm, 45cm and 60cm.) and two levels of diammonium phosphate (DAP) fertilizer (0 and 200kg/ha) on growth and vegetative yield of the two crops were tested. Spacing did not influence plant height or yield in the two crops. However, most farmers selected the 45cm spacing based on vegetative and seed yield, crop vigour, leaf colour, branching, and ground cover. At first harvest, the DAP fertilizer increased plant height of African nightshade by 158% and dry matter yield by 217 % in Yatta. For the spider plant the values were 23% and 64%, respectively. The two crops were relatively free from pest and disease attack, which further enhanced their suitability. Farmers requested for seed, further training on a wider range of the ALVs, and connection with outlet markets.

Key words: African leafy vegetables, agronomic practices, farmers

Introduction

African Leafy Vegetables (ALVs) include both indigenous and traditional vegetables. Indigenous plants are those that have evolved within and spread throughout an area unassisted by humans. Examples are cowpea (*Vigna unguiculata*), spider plant (*Cleome gynandra*) and crotalaria (*Crotalaria ochroleuca*), which are all indigenous in Kenya. Traditional vegetables are not necessarily indigenous but may have been introduced and incorporated into cultural practices of different ethnic groups. Examples include cassava and pumpkin whose origin is Tropical America and *Solanum nigrum*, whose specific origins is still debatable (Woomer, 2002).

African Leafy Vegetables project was part of a regional International Plant Genetic Resources Institute (IPGRI) programme whose goal was to improve the livelihoods, nutrition and incomes of vulnerable groups, namely women and children, in Sub-Saharan Africa (SSA) region. The purpose was to enhance the role of ALVs in the nutrition of vulnerable groups in Sub-Saharan Africa through improved production, preparation, promotion of consumption, processing, landrace improvement and management of their genetic diversity. At KARI-Thika the research intervention was towards development of improved horticultural practices for the ALVs.

About 10 million Kenyans, mainly under 15 years of age, have stunted growth due to poor nutrition (KENRIK, undated). There has been a sharp increase of nutrition related diseases and conditions such as diabetes, obesity, osteoporosis and heart diseases due to poor eating habits. Vitamin A, which is insufficient in the diet of most Kenyans and helps boost the immune system, is found in dark-green leafy vegetables. African Leafy Vegetables (ALVs) have been found to be superior to the exotic ones in human nutrition and medicinal value (Table 2). They also provide green leaves over a longer period of time. ALVs are also a rich source of Beta-carotene, vitamin C, Folic acid, riboflavin and minerals iron and calcium (Table 1). These vegetables constitute a valuable natural resource that needs to be preserved, genetically improved and their consumption encouraged. However, many people in Kenya are still unaware of the importance of ALVs and are yet to include them in their diets.

The major objective was to determine the status of awareness of the value of ALVs and the existing horticultural practices (Gitonga et al., 2002). The aim was to create awareness of the value of the ALVs in the rural communities.

Table 1: Mean composition per 100 g edible portion compared with cabbage

	Amaranth	**Spider plant**	**African nightshade**	**Cabbage**	**Kale**	***Crotalaria brevidens***	***Corchorus olitorius***	**Cowpea leaves***
Water (g)	84	86.6	87.2	91.4		74.5	80.4	
Iron (mg)	8.9	6.0	1.0	0.7	32	38	7.2	39
Protein (g)	4.6	4.8	4.3	1.7		4.5	4.5	4.6
Calories	42	34	38	26				
Carbohydrates (g)	8.2	5.2	5.7	6.0			12.4	
Fibre (gram)	1.8	1.4	1.3	1.2			2.0	
Vitamin C (mg)	64	13	20	54	93	122	80	87
Calcium	410	288	442	47	187	270	360	152
Phosphorus	103	111	75	40			122	
B-carotene (μg)	5716	10452	3660	100	7300	5800	6410	5700
Vitamin B_1 (mg)	0.05		-	0.04			0.15	
Vitamin B_2 (mg)	0.42	-	0.59	0.1			0.53	

Source: P. M. Maundu et al. 1999. Traditional food plants of Kenya, KENRIK.

Table 2: Medicinal properties of some indigenous vegetables

Vegetable	Local Name	Ailment treated
Cleome gynadra	Dek / Tsisaka	Constipation, worms, deafness, birth facilitation
Solanum sp.	Osuga / Lisutsa	Stomache, asthma, fever, dropsy, skin disorders, bladder and kidney inflammations
Crotalaria sp.	Mito	Stomache, skin diseases
Corchorus olitorius	Mlenda	Constipation
Colocasia esculenta	Nduma	Fast heart beat
Impomea batatas	Ngwaci	Bites, anaemia, diarrhoea
Stinging nettle	Thabai/Hatha	High blood pressure, anaemia

Materials and methods

Farmer-participatory methodology was chosen to ensure development of the technologies that the farmers needed, and to enhance technology dissemination. In December 2003 and January 2004 community working groups were selected in five Divisions in Thika, namely Gatanga, Kamwangi, Gatundu, Thika and Ruiru, and Yatta Division in Machakos in collaboration with the area Agricultural extension officers. The area traversed several agro-ecological zones from Upper Midlands (UM1) to Lower Midlands (LM5). A total of ten community-working groups were visited. Discussions were held with each group during which farmers were introduced to the ALVs project, its objectives and activities, and the importance of ALVs. Farmers were sensitized on the importance of the ALVs especially as regards their nutritional, medicinal and commercial value. Farmers were asked to name all the indigenous vegetables they knew and commonly utilized. They ranked them in the order of taste and preference and identified and ranked the research activities they would prefer carried out.

Results and Discussion

Recruitment of community working groups

Two groups were visited per division, except in Ruiru and Yatta where only one group was visited (Table 3). A total of ten farmer-groups whose membership ranged from 15 to 90 were met. All the groups, except three consisted of both men and women. When the farmer-groups were met the ALV project and its objectives were explained. Every group was stable, cohesive, active and expressed interest in working with the ALVs.

Table 3: Places and community working groups visited in Thika and Machakos

AEZ	Division	Location	Sub-location	Group name	Number
UM1	Gatanga	Gatanga	Chomo	Umbugicho self-help	32 (men & women)
UM1	Kamwangi	Gituamba	Kiriko/Igamba	Umoja Home Economics	12 women
UM2	Kamwangi	Chania	Nyamang'ra	Nyamang'ra self-help	21 (12)*
UM2	Gatundu	Kiamuoria		Kia kago self- help group	14 (5)
UM2	Gatundu	Gathage		Amani Wamwangi women group	(90)
UM2	Gatanga		Gaitegi centre	Gaitegi women group	(15)
UM4	Ruiru	Ruiru	Kiuu/ Kwihota	Kwihota Hort.	35 (5)
UM4	Thika	Munyu	Magana	Magana area community development	15 (9)
LM4	Thika	Gatuanyaga	Ngoliba	Kianda water harvesting	30
LM5	Yatta	Ndalani	Mamba	Canal Hort Self Help	15

[z] *Values in bracket refers to the number of women in the group*

Traditional leafy vegetables mentioned by farmers

During the discussion, farmers were asked to name all the leafy vegetables (indigenous, traditional and exotic) they knew and utilized. Farmers mentioned all the leafy vegetables they new and those commonly utilized. In virtually all areas visited, cabbage, kales and spinach were the most commonly used leafy vegetables. Cowpeas were also commonly used in Yatta Division especially during rainy seasons. Table 4 shows the traditional leafy vegetables mentioned by farmers. The leafy vegetables mentioned in the upper and lower zones included: cowpeas, amaranthus, solanums, spider plant, togotia, kahurura, pumpkins, stinging nettle, mahiu, and muhika-na-ihu. Farmers were also aware of two major types of amaranthus: the wide-leaved and the small-leaved varieties, and the latter variety was said to be tastier. It was noted that in some areas of the upper zones (notably Kiamuoria in Gatundu and Chomo in Gatanga) some farmers did not know of the spider plant.

A wider variety of indigenous vegetables were mentioned in the lower zones (especially in Gatuanyaga in Thika Division) than in the upper areas. In addition to the above vegetables, the range in the lower zones included murenda (*Corchorus sp.*) murenda – wa- kurugama, ubera, mitoo (*Crotalaria sp*), mithunga, maiganjo, wondering Jew and *Galinsoga sp*. Crop plants whose leaves were used as vegetables included beans (*Phaseolus vulgaris*), arrow root (*Colocasia esculenta*), Irish potato (*Solanum tuberosum*), lablab beans (*Lablab purpureous*), cassava (*Manihot eculenta*), sweet potato (*Impomea batatas*) and cherry tomato (*Lycoperscicum esculentum*). Banana (*Musa sp.*) pseudostem inner core and male bud were also utilized as a vegetable in the lower zones.

Table 4: Traditional leafy vegetables mentioned by farmers

Common name	Botanical name	Local name	AEZ where mentioned
Amaranths	*A. dubius, A. lividus*	Terere	All zones
Spider plant	*Cleome gynadra, Gynadropsis gynadra*	Thageti	Lower zones
African nightshades	*Solanum scabrum/ S. scabrum/ S. americanum*	Managu	All zones
Pumpkin leaves	*Curcubita spp.*	Marenge	All zones
	Cucumis ficifolia	Kahurura	All zones
Cowpea leaves	*Vigna unguiculata*	Thoroko	All zones
Arrowroot leaves	*Colocasia esculenta*	Nduma	All zones
Stinging nettle	*Urtica massaica*	Thabai/ hatha	All zones
	Asystasia mysorensis	Muhika-na-ihu	All zones
	Erucastrum arabicum	Togotia	All zones
	Sonchus sp.	Mahiu	Lower zones
	Corchorus olitorius	Murenda	Lower zones
		Murenda- wa-kurugama	Lower zones
	Crotalaria sp.	Mitoo	Lower zones
	Sonchus sp.	Mithunga	Lower zones
	Chenopodium sp.	Maiganjo	Lower zones
	Cucumis dipsaceus	Gakungui	Lower zones
	Galinsoga sp.	Mungei	Lower zones
Wondering Jew	*Commelina sp.*	Mukengeria	Lower zones
		Ubera	Lower zones
Bean leaves	*Phaseolus vulgaris*	Maboco	All zones
Lablab bean leaves	*Dolichos lablab*	Macahi	All zones
Cassava leaves	*Manihot esculenta*	Mianga	All zones
Sweet potato leaves	*Impomea batatas*	Ngwaci	All zones
Irish potato leaves	*Solanum tuberosum*	Waru	All zones
Cherry tomato leaves	*Lycoperscicum esculentum*	Manyanya	Lower zones
Banana pseudostem inner core	*Musa sp.*		Lower zones
Banana male bud	*Musa sp.*	Kiongoro	Lower zones

Sensitization of farmers on the importance of African leafy vegetables

Farmers were sensitized on the importance of indigenous vegetables, focusing on nutritional, medicinal and commercial values. Farmers were surprised to learn that Amaranthus, Solanums and spider plant had 36 to over 100 times more β-carotene than the commonly consumed cabbage (Table 1).

On medicinal value, farmers used some plants especially stinging nettle and solanums to counter high blood pressure and stomach ailments respectively.

On commercial value almost all the upper-zone farmers were not aware of the existence of markets for the ALVs. However, in lower zones (especially Ruiru, Gatuanyaga and Yatta), farmers were aware of the commercial value of spider plant, amaranthus, solanums and cucurbits (Pumpkin and *Kahurura* leaves).

Participatory selection of priority ALVs and research themes

Farmers were asked to prioritize with reasons the African leafy vegetables they would prefer to research on. They also mentioned the priority research themes (Table 5). The farmers selected amaranthus, spider plant, solanums, cowpeas, pumpkins and stinging nettle. The major reasons cited for selection of these vegetables were: nutritional and medicinal value, local adaptation, market availability, and prior knowledge of the vegetable. The research themes prioritized by farmers included development of optimal agronomic practices, seed production techniques, crop introduction (in particular spider plant), demonstration of varieties, crop protection, preparation (cooking) and preservation methods and marketing.

Farmer-Participatory Field Trials

Background

African nightshade (*Solanum spp.)* and spider plant (*Cleome gynandra)* were amongst the six ALVs prioritized by farmers (Table 5). All the farmers visited demanded development of horticultural practices for the vegetables.

Depending on the available funds, two farmers– groups, which were found to be among the most stable, cohesive, active and with great interest to work with the African leafy vegetables were selected for field trials. These were Magana Focal Area Development Community Group in Thika, and Canal Horticulture Self-help Group in Yatta (Machakos District). The Thika group had 15 members, nine of whom were women. The Yatta group also had 15 members (men and women). The unselected farmer-groups are potential sites for expansion of the on-farm ALV trials.

Objectives

- To grow and utilize with farmer participation selected African Leafy vegetables (African nightshade and spider plant)
- To determine effects of three different spacings on vegetative growth and yield of African nightshade (*S. scabrum)* and spider plant (*C. gynandra*).
- To determine the effects of DAP fertilizer on vegetative growth and yield of African nightshade (*Solanum scabrum)* and spider plant (*C. gynandra*).

Table 5: ALVs, selection criteria and research themes as ranked by farmers

Priority ALV	Farmers' selection criteria	Research area
Amaranth	Well known, Grows easily	Demonstration of varieties
	Consumed locally	Agronomy
	Ready market available	Food preparation
	High nutritional value	Seed production
	Easy to cook	Preservation
	Good stew for *Ugali*	Marketing
	Drought tolerant	
	Seed available	
	Medicinal value	
	Wide range of varieties	
	Low requirement for inputs	
	Healthy production	
Spider plant	Ready market available	Crop introduction
	To learn more about the crop	Demonstration of varieties
	High nutritional value	Seed production
	Medicinal value	Agronomy, Cooking methods
		Preservation, Marketing
African nightshade	Consumed locally	Demonstration of varieties
	High nutritional value	Agronomy
	Ready market available	Food preparation
	Acceptable taste	Seed production
	Medicinal value	Preservation
	Easy to cook	Marketing
	Well known, Grows easily	
Cowpeas	High nutritional value	Agronomy
	Seeds also used as food	Varieties
	Commonly used as a veg	Marketing
	Long picking period	
	Few field problems	
Pumpkin	Commonly used as a vegetable	Demonstration of varieties
	Fruit also consumed	Utilization
Stinging nettle	Medicinal value	Agronomy
	Increases blood	Food preparation
	Good food colour	Preservation methods

Materials and Methods

African nightshade (*Solanum scabrum)* and spider plant (*Cleome gynandra)* were planted in Magana and Kithimani sites at three different inter-row spacings of 30cm, 45cm and 60cm. DAP fertilizer was applied at two rates which were 0kg and 200kg DAP per hectare. The three by two treatment combinations were replicated three times in a randomized complete block design. Gross and net plot sizes were 2.4 m x 3m and 1.2m x 2m respectively. At each site the trials were planted together with farmers, a local agricultural extension officer and research team. Planting dates were 20th April 2004 for the Magana site, and 23rd April for the Yatta site.

In Magana site the two crops were planted on the same farmer's field. Poultry manure was applied in the planting furrows at the rate of 15 MT/ha. DAP fertilizer was applied where applicable in the furrows then thoroughly mixed with the soil to avoid seed scorch. Seed was mixed with sand in the ration of 1:15. The seed/sand mixture was spread evenly along the planting furrow and lightly covered with the soil. Water was applied using a bucket. The farmers participated fully during the planting process and continued to manage the plots (watering, weeding, thinning, guarding).

In Yatta site the two crops were planted in separate farmers' fields but both fields had access to irrigation water from The Yatta Furrow. Planting operations were similar to those at Magana site except that cattle manure and not poultry manure was used.

During monitoring and data collection visits by the research / extension personnel, crop management practiced including watering, thinning, top dressing, pinching were demonstrated to the farmers. In Yatta the African nightshade was top dressed with CAN fertilizer at the rate of 100 kg/ha at four and eight weeks after germination. At Magana top dressing was not done due to scarcity of water. However the African nightshade remained dark-green.

Sampling was done at four, eight, ten and twelve weeks after planting. Twenty plants were selected at random and cut at cut at ground level from each plot and immediately put in large paper bags and taken to NHRC laboratory. In the laboratory fresh weight and shoot lengths were recorded. The samples were then oven-dried at 60^{o} C. for 72 hours and their dry weights were recorded.

In Magana site access to irrigation water proved difficult so the crop wilted and dried early due to water stress although farmers made attempts to fetch water even on bicycles. Hence only two sampling were done for the African nightshade and one for the spider plant.

In Yatta African nightshade was watered adequately and four harvests were possible. However, the spider plant hardly received any irrigation especially after three weeks since germination. Consequently the crop flowered and matured very early due to water stress. Only two harvests were made on the crop. Data was analyzed using SAS statistical package.

Results

The different inter-row spacings at all stages of harvest did not significantly influence plant height or plant weight in either the African Nightshade or the spider plant at the two sites (Tables 6, 7, 8 and 9; Figures 1 and 2).

Table 6: Effects of spacing on height (cm) of African nightshade

Spacing (cm)	Yatta harvests				Magana harvests	
	1st	2nd	3rd	4th	1st	2nd
30	13.3	15.7	37.0	44.4	13.9	9.7
45	13.4	17.0	34.0	40.0	15.5	9.4
60	13.1	16.4	38.4	42.4	15.9	9.4
Mean	13.2	16.7	36.5	42.2	15.1	9.5
Lsd	NS	NS	NS	NS	NS	NS
CV %	31.3	17.9	12.3	19.1	19.3	15.9

Table 7: Effects of spacing on aboveground fresh weight of African nightshade

Spacing (cm)	Yatta harvests				Magana harvests	
	1st	2nd	3rd	4th	1st	2nd
30	94.0	81.0	226.2	372.5	134.0	50.3
45	75.8	127.7	199.8	324.8	184.8	48.2
60	94.2	96.3	287.2	371.0	175.3	52.7
Mean	88.0	101.7	237.7	356.1	164.7	50.4
Lsd	NS	38.2	NS	NS	NS	NS
CV %	49	29	34.9	39.0	43.0	29.4

Table 8: Effects of spacing on aboveground dry weight of African nightshade in Yatta and Magana sites

Spacing (cm)	Yatta harvests				Magana harvests	
	1st	2nd	3rd	4th	1st	2nd
30	11..5	17.7	36.0	37.8	21.5	9.5
45	9.9	18.8	32.8	57.3	24.3	11.0
60	11.8	18.5	41.9	58.2	36.0	8.3
Mean	11.1	18.3	36.9	51.1	27.3	9.6
Lsd	NS	NS	NS	NS	NS	NS
CV %	48.9	29.9	21.2	42.8	53.6	39.2

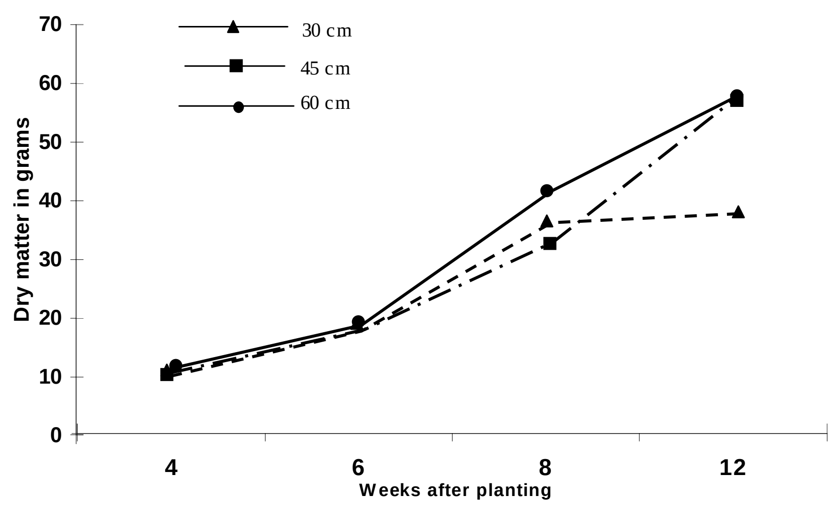

Figure 1: Effect of spacing on aboveground dry matter of African nightshade in Yatta

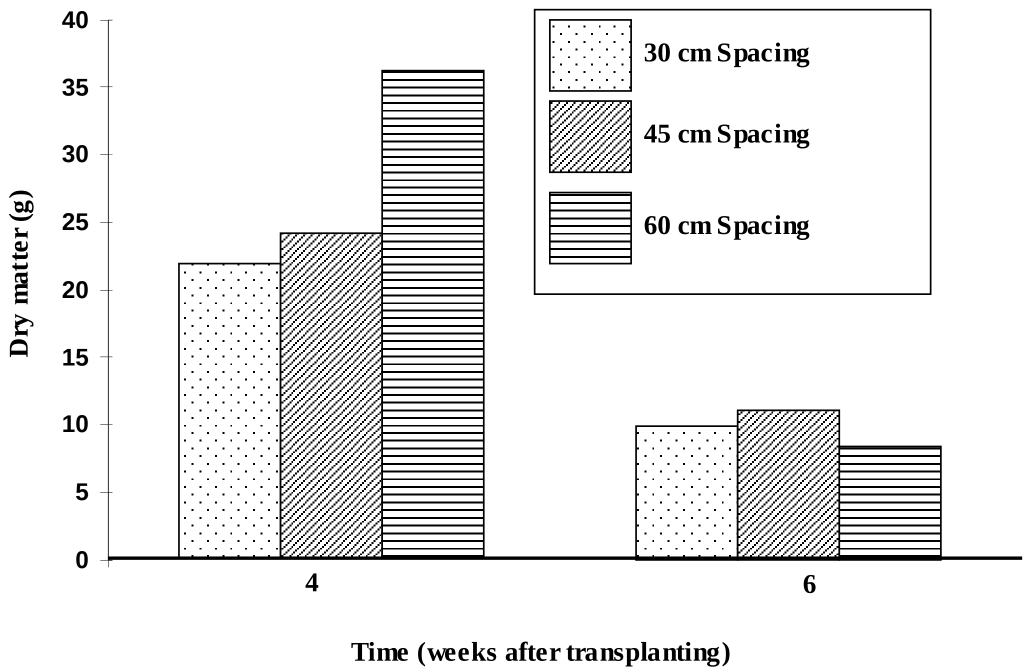

Figure 2: Effect of spacing on aboveground dry matter of African nightshade in Magana

DAP fertilizer increased plant height and dry matter yields in both crops at both sites (Figures 3 and 4; Tables 5, 6, 7 and 8). At first harvest the fertilizer increased plant height of African nightshade by 158% and dry matter yield by 217 % in Yatta. For the spider plant the figures were 23% and 64% respectively. The fertilizer effects appeared to decrease as the plants matured but this could have been due to farmers picking the leaves (especially the African nightshade) from the most vigorous plots for consumption.

Table 9: Effects of spacing on Spider plant in Yatta and Magana sites

Spacing (cm)	Plant height (cm)			Fresh weight (g)[1]			Dry weight (g)[1]		
	Yatta		Magana	Yatta		Magana	Yatta		Magana
	1st	2nd	1st	1st	2nd	1st	1st	2nd	1st
30	36.8	22.2	15.5	182.5	63.3	51.0	28.5	13.2	13.3
45	34.6	24.3	15.1	149.5	85.2	54.5	23.5	17.7	10.3
60	36.4	22.7	15.8	205.2	68.7	45.0	30.8	15.5	8.8
Mean	35.9	23.1	15.5	179.1	72.4	48.2	28.1	15.4	10.5
Lsd	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	34.1	46.5	54.7	59.6	96.0	34.2	59.7	77.0	39.6

[1]20 plants sampled for weight measurements

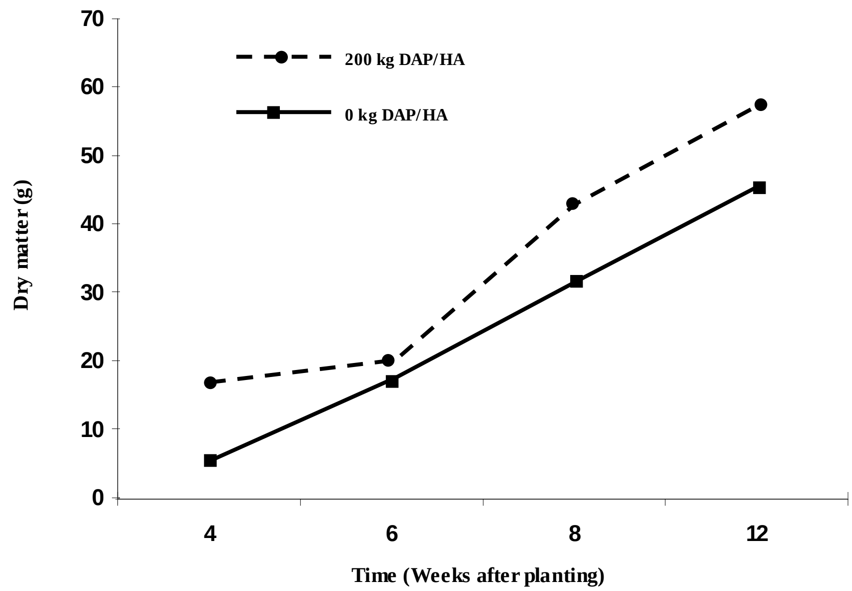

Figure 3: Effect of DAP on above-ground dry matter of African nightshade in Yatta

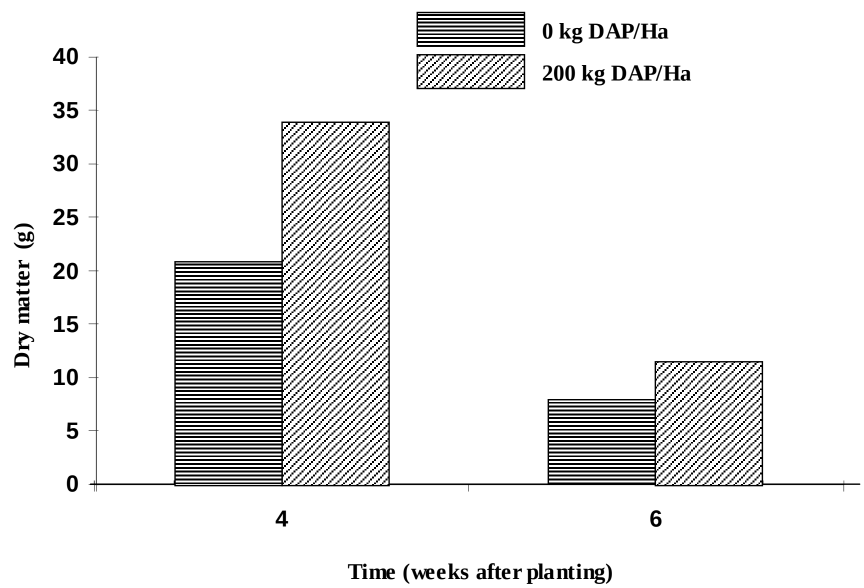

Figure 4: Effect of DAP on above-ground dry matter of African nightshade in Magana

Table 10: Effects of DAP on height of African nightshade in Yatta and Magana

DAP kg/ha	Yatta				Magana	
	1st	2nd	3rd	4th	1st	2nd
0	7.4	14.9	30.1	39.7	13.5	9.0
200	19.1	18.4	42.8	44.8	16.6	10.0
Mean	13.2	16.7	36.5	42.2	15.1	9.5
Lsd	4.3	3.1	4.7	8.5	3.1	N.S.
CV %	31.3	17.9	12.3	19.1	19.3	15.9
% increase due to DAP	158.1	23.5	42.2	12.8	23.0	11.0

Table 11: Effects of DAP on above-ground fresh weight of African nightshade in Yatta and Magana sites

DAP kg/ha	Yatta				Magana	
	1st	2nd	3rd	4th	1st	2nd
0	39.6	77.6	195.6	328.7	110.2	45.3
200	136.4	125.8	279.9	383.6	219.2	55.4
Mean	88.0	101.7	237.7	356.1	164.7	50.4
Lsd	45.9	31.2	NS	NS	74.4	NS
CV %	49.2	29.2	34.9	39.0	43.0	29.4
% increase due to DAP	244.4	62.1	43.1	16.7	98.9	22.3

Table 12: Effects of DAP on above-ground dry weight of African nightshade in Yatta and Magana sites

DAP kg/ha	Yatta				Magana	
	1st	2nd	3rd	4th	1st	2nd
0	5.3	17.0	31.3	45.0	20.7	7.9
200	16.8	19.7	42.5	57.2	33.9	11.3
Mean	11.1	18.3	36.9	51.1	27.3	9.6
Lsd	5.7	NS	8.2	NS	NS	NS
CV %	48.9	29.9	21.2	42.8	53.6	39.2
% increase due to DAP	217	15.9	35.8	27.1	63.8	43.0

Table 8: Effects of DAP on spider plant in Yatta and Magana sites

DAP kg/ha	Plant height (cm)			Fresh weight (g)			Dry weight (g)		
	Yatta		Magana	Yatta		Magana	Yatta		Magana
	1st	2nd	1st	1st	2nd	1st	1st	2nd	1st
0	31.0	26.1	10.9	139.0	98.0	36.4	22.1	19.9	8.1
200	40.8	20.0	20.0	219.1	46.8	64.1	33.4	11.0	13.6
Mean	35.9	23.1	15.5	179.1	72.4	48.2	28.1	15.4	10.5
Lsd	NS	NS	8.8	NS	NS	18.2	NS	NS	4.6
CV%	34.1	46.5	54.7	59.6	96.0	34.2	59.7	77.0	39.6
% increase due to DAP	31.6	-	83.5	57.6	-	76.1	51.1	-	67.9

[1]20 plants sampled for weight measurements

Farmer-participatory evaluation of African nightshade in Yatta

The field evaluation was conducted on 3rd August 2004 at twelve weeks after planting the African Nightshade. A total of seven farmers (three men and four women) did the evaluation. The farmers were instructed by the research personnel to each observe all the 18 plots critically and then select with reasons the best performing plot. The farmers were then to select the planting method they would adopt for their own fields. Below is a summary of the farmers' comments.

Farmers' comments

30 cm inter-row spacing

The plots had high vegetative yield. There was higher vegetative growth hence higher frequency of picking the leaves. There was complete ground cover hence better moisture retention, which translated to lower frequency of watering (thus freeing labour). The very close spacing resulted in damage of plants during weeding. The plants had fewer branches and smaller fruits, which translated into lower seed yield per plant. The leaves were pale-green in colour (not the desired dark-green).

45 cm spacing

The plants were strong and had. Dark-green healthy-looking leaves. Branching was more than in the closest spacing hence higher vegetative yield per plant. The wider spacing allowed easier weeding and picking (even by children) without trampling on the plants and damage to the roots. The spacing was wide enough not to habour pests. Fruits appeared larger hence higher seed yield

60 cm spacing

Poor ground cover hence loss of moisture and weeding time.

Participatory evaluation results

Four farmers (3 men and one woman) preferred the 45 cm spacing while two women chose the closest spacing. The seventh farmer (a woman) chose the widest spacing).

Farmers also noted the differences between the fertilized and the non-fertilized plots. The dark-green foliage and crop vigour on the fertilized plants were outstanding, while the unfertilized plants looked weaker and had pale green leaves. Statistical analysis results confirmed the farmers' observations.

Pests and diseases

Spider plants

Spider plants are generally hardier and more resistant to pests and diseases than other vegetables. However, a number of pests and diseases were observed and the necessary recommendations given.

Aphids were observed on the stems and especially on the young shoots and this caused stunted growth of the crop due to sucking of sap from the young shoots. However, it was also noted that most of the aphids were attacked by the natural enemy of *Aphidius* species that caused them to be mummified and eventually die. With the biological control naturally in place, no insecticides were sprayed, as they would inhibit the action of the natural enemies. Other insect pests observed were leaf miners, flea beetles, and nematodes, but their damage was minor.

A number of plants wilted and died prematurely, leaving a lesser crop population. Plant samples were therefore observed in the field, whereas others were taken to the laboratory for analysis and found to be having bacterial wilt pathogen. Excessive irrigation was discouraged since excessive moisture under hot conditions encouraged development of the disease.

African nightshade

The crop was very healthy and seldom affected pests or diseases. Only a small population of chewing beetles and leaf miners were observed but it was not necessary to spray any insecticide. The surrounding area was quite weedy and the farmers were advised to keep the surroundings clean and weed free since these weeds harboured these pests that would alternatively attack the crop. After weeding out the surroundings, the crop was free of pests.

Discussion

The criteria used by farmers to select the spacing method were vegetative and seed yield, crop vigour, leaf colour, branching, and ground cover. Farmers also took into consideration optimal utilization of resources (land, labour and water), and the ease of working in the different plots especially with respect to crop damage. Most farmers preferred the 45 cm spacing. Farmers also noted yield enhancement by DAP fertilizer application at planting. Farmers also appreciated the fact that the crop was free from pests and diseases throughout the growth period hence eliminating the need to use the potentially harmful and expensive pesticide sprays.

The primary objective of this work was, with farmer participation to grow and utilize two African Leafy Vegetables earlier prioritized by the farmers. During the farmer-participatory evaluation process the farmers eagerly picked African Nightshade leaves, which they said was delicious when eaten with 'ugali'. Farmers also picked the leaves of volunteer Amaranthus plants. Farmers in the group also said they used the leaves of black jack, 'kikoe' (*Commelina* sp) and 'muhika-na-ihu' (*Asystasia mysorensis*). The keenness with which the farmers picked the African nightshade leaves demonstrated their interest on, and acceptance of the vegetables.

Farmers also appreciated the leaflets titled 'opportunities for higher nutritional benefits' which were distributed to them. The leaflets showed mean composition per 100-gram edible portion of amaranth, spiderplant and African nightshade compared with cabbage.

Farmers requested for seed to plant on their own farms and for further training on a wider range of the African Leafy Vegetables. They also expressed the need to be connected with outlet markets.

Acknowledgement

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Feedback

Question: ***Comment on the commercialization level of the AIVs based on the survey you conducted***

Answer: Amaranthus, African night shade, cowpeas, spider plant and a few others, but on a lower level, are grown commercially around major towns such as Nairobi, Thika and Kiambu. The vegetables are sold in local, urban and roadside markets and even in large supermarkets. The demand is said to outstrip the supply and hence there are opportunities for farmers to commercialize the production of the indigenous vegetables.

Questions: ***Some of the ALVs that are presently growing in the wild (or weeds) are from experience important alternate hosts for important plant pests such as aphids in amaranthus and scales on stinging nettle. Did thee farmers identify these as important concerns? What was your experience in the farmer participatory trials?***

Answers: On the spider plant, aphids, leaf miners, flea beetles and also nematodes were observed in Yatta and Gatuanyaga (LM4 and LM5, respectively). Leaf miners and chewing beetles were observed on African nightshade. The level of infestation on the two crops was however low hence not warranting control measures. Spider mites were observed on African nightshade on a farmer's field in Kiambu where the crop was grown in successive seasons without effective crop rotation. Scales on stinging nettle have been observed. I suppose serious attention on the pest will be given once the crop it is domesticated.

Improved Community Landuse for Sustainable Production and Utilization of African Indigenous Vegetables in The Lake Victoria Region

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Abstract

Over 60% of the rural communities in the Lake Victoria Basin live below the poverty line which is manifested in malnutrition and poor health. High household food insecurity and prevalence of HIV and AIDS has made the situation worse yet the region is endowed with Agricultural biodiversity like African Indigenous Vegetables (AIVs). These are vegetables whose primary and/or secondary centre of origin is known to be Africa and do possess several value and potentials. Some of the identified species includes leaf amaranths, African nightshades, cowpeas, spiderplant and African kale. The Research gaps being addressed in this study include: Status of awareness of the potentials of AIVs is unknown, there is lack of quality seed and technical packages for sustainable production of AIVs. Poor landuse and marketing systems have been reported. The study sites included Bondo in Kenya, Mbarara in Uganda and Magu in Tanzania. These represent areas in the region where AIVs can be grown but has high poverty levels. The Objectives of the study were to; establish an information system on African Indigenous Vegetables for all endusers; enhance knowledge levels on production, utilization and marketing of AIVs; promote technologies that increase farmland productivity and yield of AIVs. A comparative study was carried out between October 2004 and September 2005 in three study sites in the Lake Victoria basin,. The study used a combination of quantitative and qualitative methods. Household, and market and small scale processing industry were done using appropriate structured questionnaires and key informants. Germplasm collection and evaluation was also done alongside the household surveys. Laboratory germplasm evaluation was also done at the three sites Eighteen institutions in the three countries were identified as dealing with AIVs and these included Universities, national and international research institutions and non-governmental organizaions. In Bondo site results from 200 respondents indicated that over 90% of them were aware of AIVs and their use as food mainly and as medicine. Five priority germplasm for each of the sites were identified and collected and these included cowpeas, slenderleaf, spiderplant, African kale, nightshades, pumpkin leaves, vegetable amaranths and jute mallow.. Thirty four small scale processors were identified in the three sites Bondo(5), Mbarara (14) and Magu (15). And the female respondents constituted 71%. A total of 201 traders were interviewed with the highest number of 100 in Mbarara and lowest in Magu (15) The major constraints of AIVs marketing highlighted by the traders included, perishability, attitudes, poor marketing system and competition with exotics. Dissemination using ora-media was done in bondo site where promotion of AIVs was done by performance at Nyang'oma open air market by Jarife Africa. In conclusion institutions dealing with AIVs in the three East African countries include Universities, research institutions and non-governmental organizations. In Bondo 90% of the respondents were aware of the importance of AIVs as food and medicine. 34 Processors and 201 traders were interviewed and other unconventional dissemination methods were used to promote AIVs.

Introduction

Background

Over 60% of the rural communities in the Lake Victoria Basin live below the poverty line, which is manifested in malnutrition and poor health. High household food insecurity and prevalence of HIV and AIDS has made the situation worse yet the region is endowed with Agricultural biodiversity like African Indigenous Vegetables (AIVs). African Indigenous Vegetable (AIV) is defined as that originating from Africa or whose natural home is known to be in Africa (Maundu 1997; Schippers, 2000, FAO 1988) Studies carried out in various parts of Africa indicate that African indigenous vegetables (AIVs) play a significant role in food security of the underprivileged in both urban and rural settings (Schippers 2000, Onyango 2002). Research indicates that these vegetables have a high nutritive value. They provide 100% of the daily allowance for vitamins and minerals and 40% for proteins when 100g are consumed (Adams & Richardson,1977; Chweya 1985) and possess medicinal properties for the management of HIV/AIDs and stomach related ailments (Olembo *et al*.,1995, www.avrdc.org). African indigenous vegetables are often grown as intercrops and are less demanding in management since their short growing periods readily lends them favorably to nutrition intervention programmes.

Some of the identified vegetables in the Lake Victoria region include leaf amaranths, spiderplant, African nightshades, cowpeas, slenderleaf, jute mallow, African kale and African eggplant. The use of these vegetables is part of cultural heritage, playing an important role in customs and traditions and in maintaining equity within the family structure since the appearance on the family table depends largely on the activities of women (Mnzava, 1997).

Indigenous vegetables do have a considerable potential as income earners. The major constraints facing the production of African indigenous vegetables include low awareness of their potential, lack of quality seeds, technical production, utilization packages and poor marketing system among others. They have been neglected for long by researchers, policy makers and funding agencies. As a result of this neglect, many of these vegetables are facing extinction and the communities in the region continue to languish in poverty.

Research Problem and Justification of the Study

Land use in the traditional African setting within the Lake Victoria Basin Region has been greatly affected by population growth and resultant land fragmentation. This has been compounded by introduction of exotic agricultural practices, which tend to impact negatively on the ecosystem. This has led to neglect of production and utilization of indigenous crops, which have a better potential for sustainable land-use and nutritional qualities.

Increasing poverty in this region has caused greater degradation of land as families struggle to maintain subsistence livelihood. The poor tend to be clustered amongst the handicapped, FHH, AIDS orphans (NPEP, 1999). The advent of HIV/AIDS has worsened this situation.

This study focuses on sustainable production of AIVs in three selected districts in the Lake Victoria Region: Bondo in Kenya, Mbarara in Uganda and Magu in Tanzania. The aim is to undertake a comparative study that helps to promote environmental friendly farming methods that will enhance the properties of the soil and the yield of AIVs. Because of over cultivation and use of artificial fertilizers, the soil suffers in terms of structure and chemical properties. It is anticipated that this intervention will enhance farmland productivity and livelihoods of households will be improved, thus leading to poverty reduction.

AIVs are those vegetables whose natural home is known to be in Africa or those vegetables whose centre of origin is believed to be in Africa (Maundu, 1997; AVRDC, 1990). The centre of origin of a crop is said to be a place where the widest degree of genetic diversity of that crop is found (Oluoch, 2002). Traditional African vegetables are those indigenous or introduced species which due to long use have become part of the culture of an African community (Maundu, 1999). Research has identified some of the important African indigenous vegetables as: cowpea, leaf amaranths, african nightshades, spiderplant, Ethiopian kale, slenderleaf, jute mallow and pumpkin leaves (Onyango 2002b).

This project observes a variety of indicators that are indispensable to sustainability. These include: social inclusion, improvement of households income and utilization of locally available resources. This project proposes to target among others: women, people with disabilities and the poorest of the poor. Through using women's groups and FHHs, the project envisages to give them visibility and social presence. People with disabilities and PLWHA have often been overlooked in project, unless such projects are specific. This project proposes to make them visible and enable them to participate in public life.

It is hard to comprehend the devastations HIV/AIDS is having on the social and economic development of East Africa. Over 50% of the infected persons in the three East African countries are women (Willis 2002). Data from National Control Council (2004) indicate that 2.5 million Kenyans are infected with 200,000 new infections per year of which 50% are below 25 years of age. Interventions include establishing Voluntary Counseling and Testing centres (VCTs) coupled with the use of Anti-Retro Viral (ARVs) drugs. Funding for Community Based Organisations (CBOs) have mainly been used by membership to provide nutritional needs for home based care. However, these CBOs pay little consideration to nutritional aspects of nursing care (Futures Group 2002). Yet, scientists have realized that a vegetable-rich diet can bolster the immune system and help it fight against HIV/AIDS (http:/www.avrdc.org). The extent to which the PLWHAs and their affected families in the L. Victoria region are aware of this information will be investigated and addressed by the study.

Nearly 3 billion people or half of the world population live on less than $2 a day and of these, 1.2 billion live on less than $1. The situation is particularly pathetic in Sub Saharan Africa where nearly half of the population live on less than $1 a day (Balimwikungu, 2003). Poverty is defined by the poor themselves as a situation where one cannot afford goods and services such as food, clothing, housing, health care and education. (Poverty Eradication Commission of Kenya 1999, AICAD Review 2002). Consumption data reveal that 44% of the population are unable to meet their basic needs (absolute poverty line), while 25% cannot even meet their daily food requirements (food poverty line) (1997). However, poverty decreased by 21% between 1992 and 1997 (UPPAP, 2000).

Hence, one of the major areas of concern is food poverty through the sustainable production and utilization of African Indigenous vegetables. The study makes the assumption that promotion of AIVs will empower communities in general and marginalized groups to produce their own food. It assumes that AIVs have both subsistence and commercial value for the poor. Another assumption is that women play an important role in both production and marketing of AIVs.

The traditional approach on AIVs has, however, been to sell or consume the leaves rather than process and package the leaves and seeds for a wider market (Schippers, 2000; Onyango, 2002). Such processing and packaging would also prolong the shelf life of the product.

To economically empower a given people ensures that they are able to control their own production and make decisions regarding their labour and lives. Community empowerment through involvement in this innovation is usually lacking. Such an approach would enhance the value of AIVs, increasing income and consequently promoting sustainability.

This study argues that when people use the tools they already know and identify with, the process of empowerment is easily achieved. This catalyzes our targeting of Ora-Media in harnessing and dissemination of information on AIVs. Ora-Media is an indigenous mode of performative communication. The media surpasses the conventional Oral Literature genres such as narratives, songs and the short forms to include: skits, verse drama and comedy among others. It is socially functional and its paramount role is to improve on the people's knowledge, attitude and behavior through advocating social messages. It is, therefore, a tool for lobbying for change in the social milieu. It has been identified as a strong communicative tool in that it is ethno-based (Mwai, 2000).

Research Gaps

- Status of awareness of AIVs potentials unknown
- Lack of quality seeds for AIVs
- Lack of technical packages for sustainable production and utilization for AIVs
- Poor landuse systems in the production of crops
- Poor marketing systems for AIVs

Research Hypotheses

The following hypotheses were tested:

- Inadequate knowledge, attitudes and practices bottleneck AIVs production & utilization
- Improved farmland productivity contributes to high yield of AIVs
- Small scale industries have capacity to add value to AIVs research gaps

Goal and Objectives

Goal (Impact)

Reduced Poverty Through Improved Food Security, Nutrition, Status And Income Generation Among Vulnerable Groups Of Communities In Lake Victoria Region

Broad Objective (Aim)

To Undertake A Comparative Study That Helps To Promote Environmental Friendly Farming Methods That Will Enhance The Properties Of The Soil And Yields Of AIVs

Specific Objectives

- Establish Institutions working on AIVs in three East African countries
- Determine the priority African Indigenous Vegetables in Kenya, Uganda and Tanzania
- Collect germplasm of priority AIVs, evaluate and bulk.
- Determine the AIVs processed and marketed in the three East African countries

Methodology

Introduction

This comparative study was done to run between October 2004 and October 2005. The study sites were in Mbarara district, Uganda; Bondo district, Kenya; and Magu district, Tanzania which are representative of the AIV growing areas with attendant high levels of poverty but varied agro-ecological zones. B ondo is a semi-arid region, Mbarara is a tropical/equatorial wet humid and Magu is sub-tropical. The study targeted farmers of AIVs especially women and the youth, persons living with HIV/AIDS, people with disabilities and the poor. Traders and small-scale industrialists dealing with AIVs are also among the respondents. The study uses a combination of data collection tools. Purposive sampling of industries was undertaken within and in zones neighboring the farming areas. Selection of households was also undertaken within the study area using stratified random sampling. Ranking of local AIVs was done to determine the sampling of the top five species for the next stage of evaluation and bulking. Secondary data sources provided an invaluable source for developing a basis for undertaking the primary data collection and also help in triangulation of such information.

Data Collection Tools

Institution Assessment

This involved finding out the institutions that were working on AIVs within the three countries. A self-administered questionnaire was used to help in building a data bank for the three countries involved. This survey allowed for snowballing from the institutions known to the researchers.

Household Interview Questionnaire

Interviewer – the person who was searching for information and recording it in the collection sheet or form. He or she also collected germplasm material from the plant, in which enquiry was made, and additional notes taken if any, and written at the end of the form

Key informant interview

Interviewee or Respondent **-** the person who was interviewed or asked questions or requested to give information about the plant and germplasm collected from it and the environment it was growing, for recording in the collection sheet. He or she also provided some amount of germplasm of the plant he or she had and this was placed in a labeled collection bag.

Germplasm collection sheet/questionnaire

This was a form or a questionnaire with empty spaces requiring to be filled in with information which was presented by the respondents and also made from field observations and measurements, about the plant from which germplasm is collected and the environment it was growing. When the form was filled in with information, it was also called "germplasm data sheet". The collected germplasm was put in collection bags made of porous cotton clothing material or paper, but clothing material was preferable. It varied in size of 10 x 6 inch or more or less. Note that each questionnaire or collection sheet corresponded to one collection bag. So there were 100 bags corresponding to 100 questionnaires, for the five priority AIVs.

Laboratory Evaluation and Multiplication and Characterization of Germplasm

Weight, germination %, moisture content of seed, purity of the seed was checked and from the results 5 priority vegetables and 4 accessions per species were selected. Seed multiplication was done in plots of size of varied from 1mx1m or 2mx2m or 2x1m at a spacing of 30cmx30cm. The design of the experiment was randomised complete block design with five treatments and four replications. Planting was done using organic manure. Field germination was stablished and Weekly measurements on 2 selected and tagged plants on plant height, leaf number, leaf shape, stem diameter, stem colour, time to 50%flowering. Destructive measurements taken once just before flowering on leaf area, plant dry and fresh weight, leaf fresh weight

Small scale processors and market survey

Small-scale processors and traders dealing with AIVs were selected through purposive sampling methods and snowballing

Results and Discussion

Inventory of Institutions Dealing with African Indigenous Vegetables

Twelve institutions in Kenya responded, four from Tanzania and two from Uganda to the self-administered questionnaire provided to them making a total of eighteen. A total of 222 researchers were found to be involved in research on AIVs. The institutions dealing with AIVs in the three countries include Universities, national and international research institutions and non-governmental institutions. The available documents in those institutions include: technical reports, annual reports, books, conference and workshop proceedings, theses, published refereed journals and leaflets. The source of funding was limited and included IPGRI, SIDA, Rockefeller, KEW, IFS and VicRes, DFID, ASARECA, USAID, AVRDC, Nestle foundation, JJ foundation, AICAD and a few government or institutional funded projects. The main vegetables that are being handled in these institutions include vegetable amaranths, vegetable nightshades, cowpeas, spiderplant, jute mallow, slenderleaf, vine spinach, African eggplant, African kale, okra, black jack, moringa and cucurbits. The trainings that are being carried out in these institutions include short courses, certificate, diploma courses, B.Sc. and M.Sc. projects, workshops and field days The major constraints in the production and utilization of AIVs include: neglect by stakeholders, poor marketing channels, lack of quality seed, lack of technical packages and lack of awareness of the value and potentials of AIVs, inadequate facilities and produce perishability.

Departments and individuals are involved in the research of AIVs, but the challenges would be how does the knowledge benefit communities. Existing collaborations (Kabete campus and Maseno University and between Maseno University and IPGRI and AVRDC) are at an individual level rather than institutional level. The challenge is to see how collaborations can be done at institutional level and also across disciplines

Household Survey

In Bondo site 27% respondents were males and 73% were females and 90% of respondents aware of AIVs regardless of gender, and 90% of respondents practice intercropping type of system. The preferred AIVs were cowpea, spiderplant, slenderleaf, African kale and African nightshades. All the AIVs listed above were commonly used for food. Ninety two percent (92%) of the respondents use AIVs for food, 5% for commercial purposes and only 3% use AIVs for medicinal value

Germplasm collected, evaluated and bulked

For Bondo, a total of 95 accessions were collected representing nine different vegetable types. The selected top five vegetable types were Vegetable Cowpea, Slenderleaf, Spiderplant, African kale and African nightshades. The selected accessions for each vegetable were based on the weight, germination % and moisture content. Cowpeas, slenderleaf and African kale accessions had the best germination of 80% and above, while spiderplant and vegetable nightshades had a germination percentage of less than 50%. Spiderplant and nightshades have been reported to have inherent dormancy problems especially if the seeds were not properly harvested and processed. The moisture content did not vary significantly within and between species where it ranged from 11-12.5%

Selection of Germplasm from Bondo Site in Kenya

1. Vegetable Cowpea	40
2. Slenderleaf	22
3. Spiderplant	14
4. African kale	11
5. African nightshades	03
6. Jute mallow	02
7. Vegetable amaranths	01
8. Pumpkin	01
9. Unknown	01
TOTAL	95

Table 1: Selected Accessions from Bondo site-Kenya

AIVs	Coll No	Quest. No	Weight (g)	Germination% Lab	Germination% Field	Moisture Content%
Cowpeas rep 1	10	164	22.7	100	90	11.9
Cowpeas rep 2	3	35	29.8	80	85	11.2
Cowpeas rep 3	2	137	27.4	100	85	12.4
Cowpeas rep 4	16	79	140.9	100	95	13.3
Slenderleaf rep1	8	46	30.6	100	100	11.3
Slenderleaf rep2	1	1	22.3	100	75	11.2
Slenderleaf rep3	136	170	15.6	100	99	11.1
Slenderleaf rep4	-	152	14.1	100	90	11.3
Spiderplant rep 1	6	44	40.6	0	100	11.3
Spiderplant rep 2	7	45	14.1	30	100	11.2
Spiderplant rep 3	3	7	8.5	30	90	11.2
Spiderplant rep 4	8	46	6.8	20	90	11.4
African kale rep 1	41	176	9.7	90	100	11.4
African kale rep 2	-	156	8.5	80	100	11.4
African kale rep 3	3	140	8.3	90	100	11.3
African kale rep 4	30	133	4.9	80	85	11.3
Nightshades rep 1	134	170	4.4	50	85	12.3
Nightshades rep 2	35	170	2.7	10	80	11.0
Nightshades rep 3	24	126	0.4	0	95	11.3
Nightshades rep4	Maseno University scabrum			70	95	11.0

The germination percentages of spiderplant and nightshades were significantly higher in the field compared to laboratory germination

Mbarara and Magu

Data analysis for Mbarara and Magu is on-going but the selected priority vegetables are shown in the tables below

Selection of Germplasm (Mbarara)

1.	Vegetable Amaranths	43
2.	African Eggplant	15
3.	Beans	10
4.	Pumpkin leaves	09
5.	Spiderplant	06
6.	Cowpea	05
7.	African nightshade	05
8.	Unknown	01
TOTAL		94

Note: 94% had <5g most of which were rotten or wet fungal infected. The remaining 8 either were rotten, wet seeds and those that were dry had 0%germination

Table 2: Selected Accessions from Mbarara site-Uganda

AIVs	Coll No	Quest. No	Weight (g)	Germination%	Comment
Amaranths rep 1	38	23	3.0	0	Wet seeds
Amaranths rep 2	30	17	3.1	0	Wet seeds
Amaranths rep 3	16	7	3.9	60	Rotting
Amaranths rep 4	28	15	3.6	0	Rotting
Pumpkin rep 1	47	34	2.0	40	Too few
Pumpkin rep 2	3	8	1.3	0	Too few
Pumpkin rep 3	19	9	6.9	0	Non viable
Pumpkin rep 4	41	23	0.9	60	Too few
Spiderplant rep 1	2	1	1.3	0	Not viable
Spiderplant rep 2	6	3	0.1	0	Not viable
Spiderplant rep 3	36	23	0.3	0	Not viable
Spiderplant rep4	1	3	0.9	0	Rotten seeds
Cowpeas rep 1	2	7	1.9	100	Too few
Cowpeas rep 2	1	4	1.3	0	Not viable
Cowpeas rep 3	2	3	0.6	100	Too few
Cowpeas rep 4	4	8	1.7	100	Too few
Nightshades rep 1	1	6	0.5	0	Wet seeds
Nightshades rep 2	2	2	0.1	0	Not viable & few
Nightshades rep 3	1	5	0.1	0	Not viable & few
Nightshades rep 4	6	8	0.1	20%	Few seeds

Selection Of Germplasm (Magu-Tanzania)

1.	Cucumber	17
2.	Cowpea	12
3.	Wild amaranths	09
4.	Pumpkin (Cucurbits)	07
5.	Spider plant	07
6.	Jute mallow	05
7.	Melon	01
8.	Green gram	01
TOTAL		59

Assessed role and impact of smallscale industries in production, utilization and processing

Thirty four (34) processors were identified in Bondo (5) and Mbarara (14) and Magu (15)

The female respondents constituted 71%. Of the total number interviewed. One small-scale processor was identified at Bondo site. She was processing cowpea leaves during the rainy season to be used for home consumption during the dry season. In Uganda the vegetables were harvested dried in the sun, pounded and packed in polythene bags and sealed. These were then utilized during periods of scarcity but not for commercial purposes.

Evaluation of the impact of marketing on production and utilization of AIVs

- A total of 200respondents were interviewed, from Mbarara, (100) from Bondo (86) and from Magu(15), of these 64 % were female and 36% male
- Some of the AIVs found in markets across the three counties were cowpeas, vegetable amaranths, vegetable nightshades and spiderplant
- The major constraints highlighted included, perishability, attitudes, no organized marketing system, competition with exotics

Table 3: Selected Accessions from Magu site-Tanzania

AIVs	Coll no	Quest. no	Weight (g)	Germination%	Purity %
Cowpea rep 1	49	152	16.92	0	100
Cowpea rep 2	9	15	7.60	100	100
Cowpea rep 3	8	13	6.92	100	100
Cowpea rep 4	16	58	4.54	100	100
Wild amaranths rep1	53	157	18.71	0	100
Wild amaranths rep2	6	5	3.00	50	100
Wild amaranths rep3	7	7	1.59	50	100
Wild amaranths rep4	13	51	1.19	0	100
Pumpkin rep 1	50	152	16.02	50	100
Pumpkin rep 2	42	125	7.37	0	100
Pumpkin rep 3	18	61	6.49	0	100
Pumpkin rep 4	24	93	2.86	0	100
Spiderplant rep 1	1	1	13.32	20	100
Spiderplant rep 2	21	77	5.64	0	100
Spiderplant rep 3	10	16	1.84	50	100
Spiderplant rep 4	14	52	0.51	0	100
Jute mallow rep 1	51	154	7.54	100	100
Jute mallow rep 2	38	117	4.39	50<	100
Jute mallow rep 3	11	29	3.03	50<	100
Jute mallow rep 4	50	106	1.19	50	100

Conclusions and Recommendations

- Several institutions were found to be dealing with AIVs in research, training and outreach that include national and international research institutions and public universities and non governmental organizations
- In Bondo over 90% are aware of the importance of AIVs as food but very few regard them as commercial crops
- Priority vegetables in Bondo, Mbarara and Magu have been identified and selected and include vegetable cowpea, slenderleaf, spiderplant, African nightshades, vegetable amaranths, pumpkin leaves and jute mallow

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Feedback

Question: ***What pests attack the crops in all three East Africa countries and how do they organically control them?***

Answer: The major pests are aphids, flea beetles, leafhoppers, caterpillars and cutworms. Most farmers usually apply ashes, extracts from Tithonia, *Tagetes minuta*, or hot peppers.

Question: ***What could have caused the laboratory seed germination test for spider plant seed to be very low (20%) and yet when the same seed was germinated in the field, the germination percentage was very high (95%)?***

Answer: The possible explanation is photoinhibition in the laboratory but is subject to further experimentation.

Questions: ***Please comment on the distribution of AIVs in Kenya and how adequate the training is with regard to AIVs.***

Answers: Most of the AIVs are concentrated in Western and Eastern Regions in terms of quantity and diversity. Training with regard to AIVs so far is inadequate in the investigated institutions.

Quality Aspects for Export Crops: Questions on Kenya's Horticulture Industry. Can Kenya Cope?

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Abstract

The horticultural sector is very important to the Kenyan economy and contributed 20% of all exports in 2003. Horticulture exports amounted to KShs 28.8 billion comprising of KSh 16.5 billion from cut-flowers, 10.6 billion from vegetables and 1.8 billion from fruits. Over 90% of all horticultural exports go to the European Union. Kenya is now the leading Exporter of cut-lowers to the European Union since 2001, accounting for 25 % of all cut-flower imports into the EU, followed by Israel and Colombia at 16%. For Kenya to maintain its leading position it must maintain its competitive edge. Some of the challenges that the horticultural sector faces include European Union regulations and market requirements, which could hinder entry of Kenyan horticultural products into EU markets. Various EU regulations such as on traceability of produce, maximum residue levels, EUREPGAP certification, etc have led to interception of Kenyan produce. Causes of interceptions include non-compliance with regulations, presence of harmful organisms (quarantine pests), inappropriate documentation and pesticide residues on produce. Major quarantine pests intercepted include bollworms (*Helicoverpa* spp) 32%, leaf miners (27%), whiteflies, fruitflies, thrips, spider mites and weeds (*Veronica spicata*). EUREPGAP certification requirements will also pose a great challenge especially for smallholder growers due to the cost of certification. Kenya Flower Council standard has now been benchmarked to the EUREPGAP (since June 2005). Out-growers need to be trained on export requirements, good agricultural practices and especially on safe-use of chemicals. The post-harvest quality of the produce needs to be ensured to deliver the produce to their

destination in suitable condition. The dilapidated state of some important access roads has made rapid delivery of produce to export points difficult e.g. Naivasha (Moi South Lake Road). Many smallholder farmers do not possess suitable cold rooms and therefore cannot guarantee proper post-harvest handling of produce. HCDA's satellite cold storage depots and insulated trucks are underutilized or idle. Ways of revitalizing of these facilities to assist smallholder farmers should be appropriated. Development of technologies to improve quality of produce, e.g. bunch cover for bananas, is important for improving export quality for premium prices. Many floricultural growers have installed state-of-the-art greenhouses to ensure quality cut-flowers. However, smallholders are constrained by limited capital. Kenya also faces stiff competition from other exporting countries such as Israel, China and neighboring African countries. Production of high quality produce as well as competitive prices will be decisive for Kenya to prevail in the market.

Key words: Export crops, horticultural industry, Kenya, quality

Importance of the Horticultural Sector

The Horticulture Sector in Kenya is very important and contributed 19.9% of all exports in 2003. Horticulture exports amounted to KShs 28.8 billions comprising of KSh 16.5 billions from cut-flowers, 10.6 billions from vegetables and 1.8 billions from fruits. The main export commodities of cut flowers, vegetables and fruits from Kenya are listed in Table 1.

Over 94 % of all flower exports go to the EU. Kenya is now the leading Exporter of cut-flowers to the EU since 2001 accounting for 25% of all cut-flowers imports to the EU followed by Israel and Colombia at 16%. It has now been reported to have reached 31%. The Kenya Flower Council (KFC) has signed agreement with NBV/UGA a German Flower Auction that will open the market for the direct sale of Kenyan Cutflowers in Germany.

Challenges faced by the Horticultural Sector in Kenya

European Union regulations and market requirements

The implementation of the European Union regulations and market requirements in Kenya has posed a great challenge to many horticultural producers and especially the Small-scale producers. The traceability of produce, maximum residue levels and EUREPGAP certification. Implementation of such EU regulations have led to interception of Kenyan produce. Causes of interceptions include non-compliance with regulations, presence of harmful organisms (quarantine pests), inappropriate documentation and pesticide residues on produce. Major quarantine pests include bollworms (*Helicoverpa* spp) 32%, leaf miners (27%), whiteflies, fruitflies, thrips, spider mites and weeds (*Veronica spicata*). In 2003 Kenya's export of *Pelargonium* banned due to *Ralstonia solanacearum*.

EUREPGAP Certification

Requirements pose a great challenge especially for smallholder growers due to the cost of certification. Out-growers need to be trained on export requirements, good agricultural practices and especially on safe-use of chemicals. Kenya Flower Council standard has now been benchmarked to the EUREPGAP (since June, 2005). There is increased use Integrated Pest Management (IPM) in Kenya. Dudutech Company has pioneered the use of natural enemies for pest control. They already have 4 natural enemies registered of certain pests ie. Phytoseiulus (predatory mite), Diglyphus, Encarsia and Aphidius (parasitic wasp).

Table 1: Kenyan fresh exports (flowers, vegetables and fruits) for the year 2003

Flowers	Export Amount (kg)	Vegetables	Export Amount (kg)	Fruits	Export Amount (kg)
Roses	45,668,563	F-beans combined	25,173, 593	Avocado	19020028
Mixed Flowers	6,253,690	Beans Fine	8,680,485	Mango	2,226,550
Carn. Standard	1,168,559	Bean Runner	5,145,226	Passion fruit	1,505,630
Eryngium	982,442	Mixed Vegetables	4,947,746	Pineapple	486,862
Hyphericum	917,899	Beans Prepacked	2,906,330	Macadamia nuts	171,047
Lisinathus	878,145	Beans X-fines	2,408,788	Strawberry	55,219
Alstroemria	767,550	Peas Snow	1,974,710	Oranges	32,983
Statice	563,545	Okra	1,840,894	Banana	18,950
Cut Foliage	555,060	Miraa	1,660,236	Apple	17,318
Zantedeschia/calla	531,944	Peas	1,618,065	Melon	13,343
Veronica	380,474	Bean Top tail	1,396,807	Grape fruit	7,127
Gypsophilla	327,008	Other Asian	1,024,957	Pawpaw	4,696
Ornithogalum	290,064	Peas Snap	805,698	Mixed fruits	3,954
Arabicum	208,549	Karella	795,283	Custard apple	3,158
Lilies	181,569	Ravaya	676,565	Raspberry/Blisses	3,121
Carn. Cuttings	178,861	Onions	517,653	Guava	3,004
Papyrus	154,613	Leeks	398,702	Sour sop	1,664
Carn. Spray	130,013	Capsicum/other	337,328	Rest	814
Chrysian cuttings	127,257	Aubergines/Brinjals	323,166		
Molucela	105,559	Chillies short	214,951		
Rest	611,524	Brocolli	204,232		
		Canned/Frozen	180,943		
		Valore	155,468		
		Dudhi	107,771		
		Baby corn	107,312		
		Rest	521,458		
Sub total	**60,982,885.36**	**Sub total**	**48674,162.36**	**Sub total**	**23,575,470.03**

Source HCDA Annual Statistics 2003

Other markets

The main export market for Kenya produce has been the EU. Export to other markets such as Japan has been limited by constraints such as high freight rates (US$3.4 –4.5/kg) and long distance leading to poor quality as well as plant quarantine.

Infrastructure

The dilapidated state of some important access roads has made rapid delivery of produce to export points difficult. Many smallholder farmers do not possess suitable cold rooms and therefore cannot guarantee proper post-harvest handling of produce. The Horticultural Crops Development Authority's (HCDA) satellite cold storage depots and insulated trucks are underutilized or idle. Ways of revitalizing of these facilities to assist smallholder farmers should be sought.

Competition from other exporting countries

Kenya is facing stiff competition from other exporting countries such as Israel, China and neighboring African countries. Kenya is still the leading grower of horticultural produce in Africa (Table 2). Uganda is on the rise with ideal climate and light intensity, water, fertile soils and labour. The Flower sector growing at 20% pa. Ethiopia has excellent climate, low labour costs and a number of growers from Kenya are relocating to Ethiopia. China's production is growing rapidly. Flower exports from China amounted to US$M82 in 2002 and has been growing rapidly (Table 3). The international horticultural industry is facing the prospect of China dominating the world market.

Table 2: Flower and Plant Production in Africa

Country	**Production area (Ha)**
Ivory coast	690
Kenya	2180
Morocco	320
South Africa	1050
Tanzania	106
Uganda	126
Zambia	125
Zimbabwe	1100
Total	5697

Table 3: China's flower production

Year	Cultivated area ('000Ha)	Sale B Y	Total Export USD M
1994	14	0.6	-
1998	90	10.4	80
1999	122	-	-
2000	150	25.46	80
2001	246	21.6	32.8
2002	334	29.4	100
2003	430	35.3	

Figure 1: China floriculture: (a) Poinsettia production, Nanjing, and tissue culture multiplication of orchids

The other challenges the horticulture industry faces are difficult labour conditions and human rights abuse allegations. This has tainted the image of the industry and has threatened the Kenyan market in the EU. Also the vagaries of weather have posed a challenge especially with the El Ninõ phenomenon in 1997/98, which caused serious loses. The high capital requirement and high cost of finance have severely limited investment in the sector. This is especially in capital-intensive crops such as roses. Many small growers have limited their investments to crops that require low capital outlay such as tuberose that do not need greenhouse structures. Other challenges include: Poor quality planting materials, limited floriculture research, inadequate water supply, high Freight cost and environmental pollution and health concerns.

Recommendations

Kenya needs to develop new technologies to cope with the challenges. Technologies for the improvement of the quality of produce e.g. Bunch cover for bananas, State-of-the-art greenhouses to ensure quality cut-flowers e.g. Oserian, Sher Agencies and the use of Soiless cultures e.g. Coir, Pumice need to be promoted. Kenya also requires to explore other markets e.g. Scandinavia, North America. With the publication of the America Growth Opportunities Act (AGOA), Kenya should take advantage to explore the American market. Due to the high cost of production, the Government should explore funding possibilities to enable growers to access cheaper credit. The Horticultural industry also requires institutional support especially for the smallholder growers.

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Feedback

Question: ***Comment on the shrinkage in the export market due to EUREPGAP.***

Answer: The Kenya Flower Council, FPEAK and various other organisations have made tremendous efforts to ensure that their standards are benchmarked to EUREPGAP standards and that farmers are trained on good agricultural practices and EUREPGAP requirements. This has therefore ensured that Kenyan produce can still access the EU market.

Question: ***There seems to be lots of focus on flowers, which is where we are heading. However, the market is largely in the EU, where conditions for marketing are also tough. What opportunities exist for expanding markets for other horticultural produce such as fruits and vegetables?***

Answer: Kenya could focus to countries such as in the Middle East where there is great potential, especially for fruits. Improved postharvest practices would be important for export to distant destinations.

Question: ***What do you have to comment about development of a flower consumption culture locally to enhance local usage and address competition from other producers in future for international markets?***

Answer: Kenya local consumption is negligible in terms of serving as a market for flowers. Large-scale producers market almost their entire production externally as the local prices are not competitive. Smallholder farmers dominated the local market with a market share of 60%. Therefore, it would only be feasible for smallholder farmers to target the local market.

Postharvest Handling Technologies Practiced by Informal Flower Vendors in Thika and Nairobi

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Abstract

This study used multistage, random sampling and a semi-structured questionnaire to interview 22 flower vendors in Thika and Nairobi, which are major flower outlets in Kenya. The objective of the study was to document the various postharvest handling practices employed by flower vendors and the accompanying constraints to identify areas of intervention that would reduce postharvest losses for increased income. The results of the study indicated that 17 of the vendors interviewed, were male while 5 were female. The most popular flowers sold were roses followed by carnations, Alstromellia and leatherleaf ferns in descending order of importance, while the least popular flowers included scabiosa, daisy, and derphinium. Most vendors sourced their flowers from the city market with a few buying them directly from the farms. Ninety-one percent of vendors operated in temporal structures with 9% operating in florist shops. Eighty three percent of vendors were aware of procedures such as sorting (83%) and water replenishment (100%). Vendors mainly sorted flowers to remove the broken and the diseased ones, besides putting them in water to preserve and prolong shelf life. Grading was based on the length, colour, and number of buds and stage of opening. Preservatives used included jik, flower food and aspirin but some vendors were not aware of preservatives. All respondents packaged their flowers, with 87% using cellophane papers. Lack of market, poor handling and poor facilities, diseases, wilting, drying and immaturity caused losses ranging from 2% to 65%. Consequently, the study recommends training of vendors on post harvest handling and value adding procedures, improvement of handling and selling sheds, and formation of vendor groups.

Key words: Flowers, market, postharvest technology, preservatives, vendors

Introduction

Flower production in Kenya has increased over the years. New flower varieties have been introduced and the production practices have also been perfected (Gikaara and Nduati, 2003). However, high post harvest losses are experienced in cut flowers although no study has been carried out in Kenya to document this. These losses translate into loss of large amounts of revenue and hence low profits to both farmers and vendors. Post harvest handling of cut flower influences longevity which ahs been shown to be a critical aspect of post harvest quality (Wernett et al., 1996). A baseline study was conducted in major markets of Nairobi City and Thika Town.

Objectives

The general objective of this study was to document the practices of flower vendors; the constraints and the way forward in order to identify areas of intervention to reduce post harvest losses and hence increase their income.

The specific objectives were six, and involved determining gender issues in flower vending, popularity rating of flowers, source of flower materials, the condition of flower vending structures, post harvest procedures being applied to the cut flowers by the vendors, and causes of post harvest losses.

Methodology

Surveys were carried out in both Nairobi and Thika urban and peri-urban areas. Multistage, random sampling procedures were used for selecting vendors for the survey. A semi-structured questionnaire was administered to the vendors who were chosen in the major flower outlets in those areas. Major flower selling points were visited within the urban and peri-urban areas. In Nairobi, 6 areas were visited *viz*: Westlands, City market, Hurlingham, Sarit Centre-shopping mall, Yaya centre and Village market. In Thika, two major flower vendors located within the central business district were interviewed

Results and Discussion

Twenty-two flower vendors were interviewed in both Nairobi and Thika, 17 of who were males and 5 females. This shows that males dominate flower business at the vending level. The survey revealed that some flowers are more popular than others with roses being most popular followed by carnations, Alstromeria and leatherleaf ferns while least popular flowers included scabiosa, daisy, and derphinium. Most vendors source their flowers from the city market while only a few buy direct from the farmers. The premises that the flowers are sold in are very poor with 91 % of them being temporary structures and only 9% being sold in florist shops. However, there is a high level of awareness of such procedures as sorting (83%) and water replenishment (100%). The main reasons given for sorting included broken stems and diseases. This shows that there is need to protect the flowers more from diseases during production and to transport and handle the flowers more carefully to avoid high losses. Proper packaging during transportation would also reduce the losses due to breakage. Reasons given for placing the flowers in water included preservation, prolonging the shelf life, preserving mechanism status, preventing wilting, for ease of water uptake and retention of freshness among other reasons. In fact, after transporting the flowers in higher than optimal temperatures, as is usually the case in Kenya, flowers can lose 5 to 10 % of the water that makes up most of their weight (Nell et al., 2005) hence the need for hydrating flowers. Grading which adds value to the flowers was practiced by only 39 % of the vendors. This shows that most vendors are losing the benefit of adding value by grading and hence make low profits. Some of the parameters used by the vendors for grading include length, colour, number of buds, and stage of opening, among others. Major treatments given to the flowers include cutting the edges and changing the water in the buckets daily. A fresh, clean cut prevents stem damage, while allowing for effective water uptake. It is recommended that 2.5 to 5 cm should be removed, as this section is most likely to contain microorganisms or bubbles of air that block water transporting cells (Nell et al., 2005).

Preservatives used included jik, flower food and aspirin while some vendors were not aware of preservatives. Use of biocides and flower food is essential in improving the vase life of cut flowers (Nell et al., 2005). All respondents package their flowers with 87% using cellophane papers commonly known as sleeves. This helps add value and hence fetch better prices. The post harvest losses incurred at the vendor level ranged from 2 to 65% mainly caused by lack of market which leads to excessive opening of flowers, yellowing of leaves and browning of some flowers. Another major cause of high post harvest losses was the poor handling and selling facilities, which do not protect the flowers from the sun, rain, or exhaust fumes from vehicles that contain ethylene, which is detrimental to vase life. Other causes mentioned included diseases, wilting, drying and immaturity among others.

Conclusions and Recommendations

The vendors need to be trained on proper post harvest handling and value adding procedures in order to reduce the high post harvest losses and hence earn more revenue from their businesses. The training would include such topics as temperature requirements of different type of flowers, the need for clean buckets, tools and coolers, hydration of flowers, proper use of flower food, guarding against ethylene and choice of high quality and long lasting varieties. However, it is also important for the vendors to have properly built handling and selling sheds to reduce weather and exhaust fumes effect on the quality of the flowers. This may be handled by the vendors forming groups in order to lobby for reform or to attract funding from both local and international donors while the postharvest scientists can provide technical expertise on proper siting and structure for best results.

Acknowledgements

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Feedback

Questions: ***Many of the local vendors could be getting second grade flowers that could not be exported either due to insect pests and diseases, or too mature heads. Could this be a major cause of the high post-harvest losses at vending? How significant did the vendors think this was or do you think it was an important concern?***

Answers: Yes, this could have been a big contributor to the high postharvest losses. However, most of the second grades were used for wreaths and wedding floral arrangements, which do not necessarily need flowers that last long. Those vendors who sold for household or office use preferred to buy better quality flowers.

Question: ***Why do we have few female in the vendor level while we have female dominating in the horticultural sector?***

Answer: At the farm level the women are good at precision duties such as sorting, grading and packaging and that is why they dominate. However, at the flower vending level, there is need for muscle power due to the nature of work e.g., lifting heavy buckets, running after moving vehicles to sell flowers and hence the male dominance at this level.

Questions: ***Which gender issues did you investigate and what methods did you employ in this investigation so as to achieve your stated specific objectives to establish gender issues in flower vending?***

Answer: We only investigated the male: female gender composition to assist us during training workshops, as we would know roughly the proportion of women versus men to invite to attend the workshops. However, gender issues, such as age would have also been helpful to investigate.

Farmyard Manure and Plant Density Affect Soil Characteristics and Productivity of Strawberry Cultivar Cambridge Favourite

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Abstract

Strawberry plant densities vary depending on cultivar, vigour, environmental conditions, farm equipment, system of production, and growers' preferences. Strawberry is a shallow-rooted, surface feeder plant and hence sensitive to moisture and temperature conditions in the upper layer of the soil. Specific cultural practices for optimal productivity of strawberry in the tropics are scanty. The main objective of this research was to determine the effect of plant spacing and cow farmyard manure on soil characteristics and productivity of strawberry, using Cambridge Favourite as a case cultivar. The experiment was conducted in a field on Tatton farm of Egerton University. The experiment was laid in a split block design, replicated three times and repeated over two growing seasons. Farmyard manure (0, 10, 30 and 60 t/ha) formed the main plot factor, while spacing (30 cm x 30 cm, 30 cm x 45 cm and 45 cm x 45 cm) was assigned to strip plots. Data was collected on soil temperature, soil pH, soil cation exchange capacity, soil total nitrogen, available macronutrients and micronutrients, and total nutrient and chlorophyll content in leaf tissues. Growth variables measured were number of leaves, number of runners, longest runner length, canopy spread, runner biomass, leaf biomass and root biomass. In addition, number of berries, weight of berries and total soluble solids of berries were assessed. The data collected were subjected to variance, as well as regression analysis, using MSTAT-C computer statistical programme. Yields from close spacing regime were significantly higher than those in wide spacing regime. Manure significantly increased soil cation exchange capacity and tended to increase soil pH, soil total nitrogen, available phosphorus, potassium, calcium and magnesium, but reduced soil available iron. However, manure was negatively correlated with leaf nitrogen content, as well as growth and yield of strawberry. Soil temperature correlated positively with vegetative growth, but had a significant negative correlation with strawberry yields. In general, yields were limited by low nitrogen as well as zinc and manganese deficiency.

Key words: Farmyard manure, *Fragaria*, plant density, productivity, strawberry, soil

Introduction

Strawberry (*Fragaria x ananassa* Duch.) is a herbaceous perennial plant belonging to the Roseceae family. It has short and thick stems called crowns that bear buds, which develop into long slender stems called runners, or into flowers (Edmond et al., 1994). The root system of strawberry plants is shallow, moderately extensive and a surface-feeder. Consequently good production is promoted by soil that is tilled well to remove clods and pests. In addition, adequate soil aeration essentially promotes healthy root growth, plant vigour and berry yields (Welch, 1989).

Wild strawberries (*Fragaria* species) at their best are unmistakably associated with moist, dark-coloured, friable soil that smells of well-rotted leaf mould (Wright, 1973). Strawberries are woodland, parkland and mountain plants. This means that they grow most readily in soils that are rich in humus and acidic in reaction or pH. In general, no amount of industrial fertilisers will help a strawberry grower unless the soil is of good physical characteristics and rich in humus (Hyams, 1962). This fact, therefore, implies that humus contributes to soil characteristics that favour strawberry growth. In addition to supplying nutrients to the soil, humus also improves soil health by increasing soil organic matter and prevalence of beneficial microorganisms (Miles et al., 2002). Strawberry yields are more frequently reduced due to lack of water, poor soil drainage and poor soil physical properties than due to lack of fertiliser (Hoover et al., 2003).

Growth and yield of strawberry is markedly influenced by moisture and temperature in the upper layer of the soil. Factors such as growth, expressed as height or as dry matter production, as well as uptake of nutrients, are decreased by low soil temperature. Reports show that even a small change of 1^{o}C in the soil temperature can influence the growth and nutritional behaviour of the strawberry plant (Gupta and Acharya, 1993).

Soil temperature, which influences microbial activity, root growth and length of the growing season, is influenced by climate, latitude, soil colour and drainage. Light-coloured or poorly drained soil warms more slowly than soil with darker colour and better drainage (Anonymous, 1995). Organic matter can play a central role in maintaining or increasing soil productivity by improving soil temperature, moisture and structure, and by reducing the danger of erosion (VexKol, 1986).

An adequate supply of organic matter in the soil is important and bears remarkable effects on soil properties such as colour, physical status, cation exchange capacity and nutrition. Organic matter encourages granulation, plasticity, cohesion and water holding capacity. Cation exchange capacity of organic matter is 2 to 39 times as great as mineral colloids, on mass basis, and accounts for 20% to 90% of the adsorbing power of minerals. It also supplies easily replaceable cations as well as nitrogen, phosphorus, sulphur and micronutrients, held in organic form (Brady and Weil, 1999; Anonymous, 1998).

Manure from livestock is an important source of nitrogen for crop production in the smallholder sector and can help farmers reduce inputs of commercial fertilisers and increase enterprise profitability. Manure contains a broad range of mineral nutrients although at a lower concentration than inorganic fertilisers. This is because a large portion of feeds initially ingested by animals contains generally 80% phosphorous, 90% potassium and 75% nitrogen upon excretion (Miles et al., 2002). Mineral nutrient availability, however, is determined by manure handling systems, as well as climate and soil characteristics. Mineral nutrients also vary depending on the type of livestock and animal feed rations, which in turn vary with season (Miles et al., 2002).

Strawberry planting and training systems varies greatly. In the hill system, mother plants are set close together and runners are pruned off or prevented from rooting to form new plants. On the other hand, a matted row system is where most of the runner plants from each mother plant are permitted to root in the row at random to a predetermined width. In the spaced matted row system, a predetermined small number of early daughter plants from each mother plant are anchored at a suitable distance (equidistant) around the mother plant. However, a solid set/bed system is where all runners are permitted to expand and root and no attempt is made to maintain discrete rows (Logsdon, 1974; Galleta and Himelrick, 1990).

It follows that in strawberry production, plant density and plant spacing varies, resulting in variation in yields and fruit quality. Plant spacing varies depending on the cultivar planted, planting system, soil type and growers' preference (Welch, 1989). The broad range in spacing distance is also due to great variation in runner production and irrigation systems used (Denisen, 1979). Strawberry plant spacing is also adjusted to compensate for plant vigour. Furthermore, size of farm equipment and tyre spacing must be taken into account when planning the spacing of strawberry row centres (Himelrick et al., 1996). Plant vigour may be influenced by ecological conditions among other factors. The choice of strawberry cultivar is perhaps more crucial than in most crops, because each clone has a very definite area or climatic zone to which it is adapted (Galleta and Himelrick, 1990).

Statement of the Problem

Although manure is essential for good strawberry growth and yield, there is insufficient information on the optimal amounts to use for optimal yield and fruit quality, particularly in the tropics. The strawberry yield and fruit quality has continued to be low in Kenya possibly because farmers don't incorporate the adequate amount of manure to sustain plant growth. Below optimal plant density affects yields and quality of fruits harvested and hence profitability of the enterprise. Currently, most of the spacing recommendations used have been borrowed from developed countries, where they suit ecological conditions and farm equipment used, a situation that is not relevant in Kenya.

Research Justification

Plant density influences light interception and hence growth and yield of strawberry plants. Establishment of optimal strawberry plant density in Kenya should enable farmers to maximise yields and utilise their land resources efficiently. On the other hand, adoption of manure in strawberry production should enable farmers to maximise their profits. Furthermore, the current trend in crop production worldwide is biased towards organic farming, which this research will endeavour to promote through use of farmyard manure to boost strawberry plant vigour so that it tolerates pest injury and avoids resorting to application of synthetic pesticides.

Objectives

The general objective of the current research was to study the effects of plant spacing and farmyard manure on soil characteristics and productivity of strawberry.

The specific objectives for the current research were:

- Determination of the FYM that maximises yields and quality of strawberries.
- Evaluation of the effect of FYM on soil temperature, moisture, pH, cation exchange capacity and plant nutrients, and how these characteristics relate to strawberry growth and yield.
- Determination of spacing that maximises yield and quality of strawberries.
- Assessment of the effect of plant spacing and farmyard manure on performance of strawberry.

Hypotheses

The following four hypotheses were tested in the current research:

- Farmyard manure maximises the quantity and quality of yields.
- Farmyard manure affects soil physical and chemical characteristics such as temperature, moisture, pH, CEC and mineral nutrients.
- Plant spacing maximises growth, yield and quality of strawberries through modification of soil resource availability.
- Plant spacing and farmyard manure affect strawberry performance through complementation of their individual effects.

Materials and Methods

The study was conducted at Egerton University's horticultural experimental field on Tatton farm located in the Rift Valley province of Kenya. The farm lies at latitude 0 ° 23' south, longitude 35°35′ east, and a mean altitude of 2200 m above sea level. The soils at the experimental site are well-drained, deep, dark-yellowish brown, friable, silty clay loam to clay. The texture of the topsoil ranges from clay loam to silty-clay loam and the colour varies from dark-brown to brown. The soil classification name is haplic phaeozem (Kinyanjui, 1979).

The rainfall at the experimental site is bimodal with long rains falling from March to August and short rains falling from October to December. The average annual rainfall is normally 1019 mm, whereas the average annual temperature is normally 16°C. The period from June to August experiences lower temperatures than the rest of the year.

The experiment was set up to test the effect of plant spacing and farmyard manure in a split-block design with three replications. Farmyard manure and plant spacing were randomly assigned to the plots. Farmyard manure formed the main plot factor and the manure was applied at four levels of 0, 10, 30 and 60 t/ha. Plant spacing was assigned to strip plots, giving inter-row and intra-row spacing of three levels: 30cm x 30cm, 30cm x 45cm and 45cm x 45cm.

The factorial experiment resulted in 12 treatments, with each strip plot measuring 1.5 m x 1.5 m. The three plant spacings gave plant populations of 16, 12, and 9 plants per 2.25 m^2, which corresponded to 71,111; 53,333; and 40,000 plants per hectare, respectively. The experiment was performed in two seasons, namely from August 2003 to May 2004, and from February 2004 to November 2004.

Land for planting was dug to a fine tilt, removing large clods and weeds. Slightly raised beds were made to facilitate free drainage, as strawberry is sensitive to waterlogging. Individual beds were then broadcasted with pre-determined rates of fully decomposed cow farmyard manure, which was mixed well with the top 15 cm of the soil. The fully decomposed cow farmyard manure was obtained from Tatton Demonstration Unit at Egerton University, Egerton-Kenya. The beds were then levelled to ensure uniform distribution of water. The planting beds were thoroughly watered a day before planting.

Strawberry cultivar Cambridge Favourite obtained from the National Horticultural Research Centre at Thika was planted. Cambridge Favourite is the main cultivar grown in Kenya (Epenhuijsen, 1976). It is an English variety that is highly resistant to leaf spot, fairly vigorous and produces very large, well-shaped and brilliantly coloured fruits of fair flavour (Wright, 1973). In addition, it fruits midseason, crops heavily and exhibits disease resistance (Anonymous, 1997). Cambridge Favourite runner plants of similar growth stage and crown diameter were used throughout, because crown affects growth and yield of the strawberry (Human, 1999). Dead and senescent roots, runners and leaves were removed from runner plants before planting. The plants were dipped in water to prevent desiccation as they awaited setting into the soils. Planting was done such that the crown-root zone was in line with the soil level, because setting the plants too deep delays runner growth and the growing point of the crown may rot, whereas in too shallow planting, the crown and tops of roots may dry out (Anonymous, 1998).

Drip irrigation tubes were installed along the beds after planting and used for irrigation throughout the growing season, with irrigation being done three times a week. Black plastic mulch (gauge 500) was laid over the beds after drip tubes were put in place. Holes were made through the plastic mulch to correspond to the planting holes and the plants were inserted into the soil at the holes marked in the mulch. The black plastic mulch prevented growth of weeds, among other benefits.

Insect pests and diseases on strawberry plants were monitored and judiciously controlled. Kelthane at a rate of 60 ml/20 litres of water was applied regularly to control mites, thrips and whiteflies. Powdery mildew on leaves was controlled using ridomil at manufacturer recommended rates.

One month after planting, the strawberry plants had established well and any senescent leaves were pruned to leave uniformly four leaves per plant to give an equal starting point for growth and development. Runners and flower stalks were also removed bi-weekly during the first three months after planting to avoid their competition and promote growth of optimal crowns for maximum productivity.

Parameters Assessed

Soil nutritional parameters

Before incorporation, samples of soil and farmyard manure were analysed to determine their characteristics with regard to inherent pH, cation exchange capacity (CEC), total nitrogen, available phosphorous, potassium, calcium, magnesium, iron, zinc, copper and manganese. A second soil analysis was done on soil taken 26 weeks after planting, after the plants had taken up nutrients. Procedures followed were those described by Hinga et al. *(*1980), and Okalebo et al. (2002).

Soil temperature

Two thermometers, one at 10 cm and the other at 15 cm depth were placed on each plot and readings taken daily at 8.00 am and 2.30 pm (when soil temperatures were minimum and maximum, respectively) beginning from 5 weeks after panting to 9 weeks after planting. The minimum and maximum temperatures were averaged to get daily temperature at each depth. The daily temperature was then averaged over the growing season to assess the effect of farmyard manure and plant spacing on seasonal soil temperature.

Leaf tissue analysis for mineral nutrient content

One middle-aged leaf from one plant per strip plot was taken at six months post planting and nutrients analysed following procedures described by Hinga (1980) and Okalebo et al. (2002).

Chlorophyll content determination in leaf tissue

The youngest representative, fully expanded leaf was taken from each plant in each plot at eleven months and seven months post-planting for season one and season two respectively.

The leaves were cut into small pieces using a scalpel. One and half grams of the chopped leaves were then crushed in a mortar using a pestle. The leaves were crushed in 60 ml excess 80% acetone so as to extract the chlorophyll and the mixture filtered. Absorbencies of the filtrates were read in a spectrophotometer (Model 632, China) at wavelengths of 646 nm and 663 nm. Chlorophyll content was calculated by fitting the formulae described by (Harbone, 1984) as: Total chlorophyll (mg/L) = 17.30A646 + 7.18A663.

Growth measurements

Top growth measurements included canopy spread, number of leaves, number of runners, length of longest runners, runner biomass and leaf biomass. These measurements began at three months post-plating and were taken fortnightly for three months. Canopy spread was measured by stretching a tape measure along the canopy on the widest region along the diameter to the canopy drip line. All the leaves on all plants in every strip plot were counted nondestructively. The resulting total number of leaves was divided by the number of plants in each plot to get the average leaf count per plant. One fully expanded leaf was taken from each plant in every strip plot. The leaves collected from each strip plot were put in separate paper bags and dried in an oven at 65^{0}C for 48 hours before their weight was measured on a weighing balance. The total weight of the leaves was then divided by the respective number of plants in each plot to get the average leaf biomass per plant. All runners on all plants in each strip plot were pruned off and counted. The total number of runners was divided by the number of plants that generated them to obtain the average number of runners per plant. Runners were assessed destructively because they do not contribute to reproductive performance of strawberries. New runners continued to emerge over time. At each time of assessment, the longest runner in each strip plot was measured using a tape measure and the measurement recorded. All runners harvested in each plot were placed in a paper bag and dried in an oven at 65^{o}C for 72 hours before their weight was measured on a weighing balance. The total weight of the runners was then divided by the respective number of plants in each plot to get the average runner biomass per plant. The middle plant in each plot was uprooted at six months after planting and cut at the crown-root zone. The roots were then cleaned with water to remove soil particles and dried in an oven at 65^{o}C for 72 hours before their weight was measured on a weighing balance.

Yield and quality measurements

These measurements included number of berries, fresh weight of berries and total soluble solids of the berries. Harvesting of the berries was done fortnightly to avoid berry deterioration before assessment. Red-ripe berries on all plants in every strip plot were harvested. The total number of berries in each strip plot was divided by the number of plants in the respective strip plots to obtain the average number of berries per plant. The red-ripe berries harvested from all plants in every strip plot were weighed on a weighing balance to obtain total weight, which was divided by the number of plants in the respective strip plots to get the average berry weight per plant. Three fruits from the harvested berries in each plot were randomly selected and analyzed for total soluble solids using a hand-held refractometer.

Data Analysis

The data collected were subjected to analysis of variance, regression and correlation appropriate to establish effects, relationships and associations, respectively, among farmyard manure, plant spacing and strawberry growth or yield, as well as soil characteristics. All counts data such as number of leaves and runners were transformed before being subjected to analysis of variance to determine if the effects of farmyard manure and plant spacing were significant or not at $P \leq 0.05$ level. The of leaves as well as number of berries were transformed using logarithms to base 10 while number of runners were transformed by taking their square root. The transformed counts were back-transformed to actual counts for reporting. Where the F-test was significant ($P \leq 0.05$), mean separation was done using the Multiple Range Test (Duncan's) (Little and Hills, 1978). The data were analysed using the MSTAT-C computer software.

Results

Manure significantly increased soil cation exchange capacity, but not pH, available phosphorus, potassium, calcium and magnesium, but reduced soil available iron (Table 1).

Table 1. Initial and subsequent soil characteristics

		Manure (t/ha)			
Parameter	**Initial value**	**0**	**10**	**30**	**60**
pH	6.1	6.0	6.0	6.2	6.3
CEC Meq/ 100 g	26.4	28.4	28.3	30.0	30.6
N %	0.56	0.40	0.41	0.40	0.44
P (ppm)	67.19	70.6	68.7	73.1	81.1
K (ppm)	713.67	610.6	638.4	631.7	664.8
Ca (ppm)	94.27	76.4	69.9	78.4	84.1
Mg (ppm)	266.84	254.5	257.2	273.8	292.2
Fe (ppm)	75.00	63.7	63.9	61.4	60.8
Zinc (ppm)	3.34	3.50	3.44	3.50	3.51
Cu (ppm)	0.37	1.46	1.59	1.72	1.48
Mn (ppm)	559.16	498.5	493.8	492.9	507.9

Comparison of soil sample and leaf tissue nutrient content

Leaf tissue yielded more nutrients than soils samples, indicating that the best sample for monitoring availability to the plant is leaf tissue (Table 2). Nitrogen and zinc were in deficiency range probably due to immobilization. Potassium and manganese were in sufficiency range (Table 2).

Yield and quality response

Results of this study reveal that there was no significant effect of manure on yield of strawberry Increasing rates of manure either had the same or slightly lower number of berries per hectare (Table 3). Berry weight per hectare was also slightly less in manure treated plots than the control (Table 4).

Table 2: Comparison of soil and leaf nutrient values

Element	Manure (t/ha)							
	0		10		30		60	
	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf
N (%)	0.4	0.86	0.41	0.78	0.4	0.8	0.44	0.78
P (ppm)	70.6	3347.4	68.7	3697.3	73.1	3672.6	81.1	3521.5
K (ppm)	610.6	15342.5	638.4	13521	631.7	15127.7	664.8	14992.2
Ca (ppm)	76.4	11965.8	69.9	11473.7	78.4	11370.1	84.1	11351.7
Mg (ppm)	254.5	1978.6	257.2	1584.8	273.8	1912.3	292.2	1881.1
Fe (ppm)	63.7	208.3	63.9	211.1	61.4	299.6	60.8	205.6
Zn (ppm)	3.5	6.26	3.44	6.02	3.5	6.36	3.51	6.26
Cu (ppm)	1.46	25.71	1.59	18.64	1.72	21.29	1.48	19.5
Mn (ppm)	498.5	81.1	493.8	76.9	492.9	85.5	507.2	79.5

The 10t/ha manure rate decreased numbers of berries per hectare by 7.53%, while the 30t/ha and 60t/ha reduced weight of berries per hectare by 10% and 5% respectively. Total soluble solid of berries were also significantly reduced by manure (Table 5).

Close spacing had significantly higher number and tonnes of fruits than wide spacing (Tables 3 and 4). The wider spacing of 45 x 45cm had significantly lower fruit numbers and fruit weight than the close spacings of 30x45cm and 30x30cm. The number and weight of fruits increased by 44% and 48% when plant spacing increased from 45 cm x 45 cm to 30 cm x30 cm, respectively. Spacing had no significant effect on berry quality (Table 5).

Table 3: Effect of farmyard manure and spacing on number of fruits/hectare [z]

	Manure (t/ha)				
Spacing (cm)	0	10	30	60	Mean
30x30	1468926	1468926	1358313	1468926	1441273a
30x45	1258925	1078947	1258925	1258925	1213931a
45x45	857038	794328	736207	857038	811153b
Mean	1194963	1114067	1117815	1194963	
Spacing LSD $_{0.05}$	1.5				
CV (%)	1.4				

[z] *Mean followed by the same letter or no letter are not significantly different according to DMRT at P≤0.05*

Table 4: Effect of farmyard manure and plant spacing on weight of fruits (tonnes per ha) [z]

	Manure (t/ha)				
Spacing (cm)	0	10	30	60	Mean
30x30	2.7	2.4	2.3	2.4	2.5a
30x45	2.1	1.9	2.0	1.9	2.0a
45x45	1.3	1.2	1.1	1.4	1.3b
Mean	2.0	1.8	1.8	1.9	
Spacing LSD $_{0.05}$	0.54				
CV (%)	22.4				

[z] *Mean followed by the same letter or no letter are not significantly different according to DMRT at P≤0.05.*

Table 5: Effect of farmyard manure and plant spacing on total soluble solids (% sugar) [z]

	Manure (t/ha)				
Spacing (cm)	0	10	30	60	Mean
30x30	7.0bcd	6.6d	6.7cd	7.1bc	6.8
30x45	6.9cd	6.5d	6.6cd	6.7cd	6.7
45x45	7.6a	6.5d	6.5d	7.4ab	7.0
Mean	7.2a	6.6c	6.6bc	7.1ab	
Interaction LSD $_{0.05}$	0.43				
Manure LSD $_{0.05}$	0.46				
CV (%)	3.5				

[z] *Mean followed by the same letter or no letter are not significantly different according to DMRT at P<0.05.*

Soil characteristics versus manure and spacing

Most soil variables were positively related to manure and spacing, but the degree of significance varied. Soil micronutrients were weakly related to manure (M) and spacing (S), explaining only 20.2%, 6%, 4.3% and 6.5% of the variations in iron, zinc, copper and manganese, respectively.

- Soil pH = 5.9 + 0.09M + 0.01S R2 = 30%
- CEC (me/100 g) = 26.8 + 0.8M + 0.3S R2 = 71%
- SN (%) = 0.4 + 0.012M + 0.003S R2 = 30%
- SP (ppm) = 62 + 3.6M + 1.0S R2 = 46%
- SK (ppm) = 646 + 15.6M - 24.3S R2 = 39%
- SCa (ppm) = 65 + 3.7M + 1.5S R2 = 37%
- SMg (ppm) = 236 + 13.0M + 0.6S. R2 = 67%

Soil temperature both at 10 cm and 15 cm depth had a good linear, but negative relationship with manure, unlike with plant spacing.

- T10 (C) = 19.97 - 0.053M + 0.575S. R2 = 82%
- T15 (C) = 19.68 - 0.063M + 0.388S. R2 = 67%

Leaf nutrient content versus manure and spacing

Leaf tissue nutrient content poorly related with manure and spacing

- TN (%) = 0.8 - 0.02M + 0.05S R2 = 42%
- TP (ppm) = 3641 + 54.16M - 0.02S R2 = 27%
- TK (ppm) = 13768 + 55.6M + 419.5S R2 = 8%
- TCa (ppm) = 10584 - 194.6M + 721.5S R2 = 32%
- TMg (ppm) = 1855 + 3.5M – 12.4S R2 = 0.2%
- TFe (ppm) = 194 + 8.0M + 8.7S R2 = 6%
- TZn (ppm) = 6 + 0.03M - 0.03S R2 = 0.3%
- TCu (ppm) = 24– 1.6M + 0.7S R2 = 30%
- TMn (ppm) = 74 + 0.2M + 3.2S R2 = 8%

Relationship of manure and leaf chlorophyll depended on the season.

- CHL1 (mg/L) = 25.33 – 0.760M – 0.088S R2 =75%
- CHL2 (mg/L) = 23.97 + 0.007M – 0.200S R2 =35%

Growth versus manure and spacing

Manure and spacing related positively with canopy spread, number of leaves, and root biomass, though poorly. Manure related negatively with leaf biomass, number of runners, length of runners, and runner biomass, though poorly. Spacing related positively with leaf biomass, number of runners, runner biomass, and canopy spread, though poorly.

Yield and quality versus manure and spacing

Manure and spacing accounted for a high percentage (94% and 96%) of the variation in number and fresh weight of berries, respectively, though negatively. Manure and spacing related poorly (4%) with total soluble solids. Attributed to nutrient imbalance in manure.

Growth and yields versus soil characteristics

Soil characteristics, except temperature related poorly with growth and yield. Soil temperature related positively with vegetative growth, and had a significant negative correlation with yields.

- NB = 9,908,458 - 472210 ST10 R2 = 87%
- WTB = 19.37 - 0.83 ST10 R2 = 77%
- NB = 11,663,425 - 574790 ST15 R2 = 74%
- WTB = 21.80 - 0.98 ST15 R2 = 61%

Discussion

Initial farmyard manure and soil characteristics

Soil pH, total nitrogen and available macronutrients were higher in manure than in soil. This was unlike available micronutrients where the content of nutrients in manure was much less than in soil. This observation resulted probably because soil is heterogeneous (Brady and Weil, 1999).

Effect of farmyard manure and spacing on soil pH

Although not significant, increasing rates of manure increased the soil pH. Regression analysis also showed that manure is positively related to soil pH though not significantly. The results therefore indicate that repeated application of manure is likely to raise the soil pH significantly. The observation made in this study agrees to that of Albregts and Howard (1981) who observed no significant change in soil pH with poultry manure. They explained that the differences in soil pH due to poultry manure might have been masked by the 'salt effect'. However, other researchers have reported significant increases in soil pH with manure application. For example, Patiram and Singh (1993), Whalen et al. (2000), and Shen and Shen (2001) got a higher soil pH in manure-amended soils than in un-amended soils. The increase in soil pH due to manure has been attributed to buffering from bicarbonates as well as organic acids with carboxyl and phenolic hydroxyl groups (Whalen et al, 2000) and decrease in Al^{3+} and release of basic cations of Ca^{2+}, Mg^{2+} and K^{+} (Patiram and Singh, 1993 and Shen and Shen 2001). Analysis of variance in the present study showed that manure raised the available Ca^{2+}, Mg^{2+} and K^{+}. Likewise, manure was positively correlated with calcium, magnesium and potassium. Soil pH, however, has been shown to decline in some manure-amended soils. The effect of manure on soil pH depends on manure source and soil characteristics (Whalen et al., 2000). Spacing did not alter the soil pH and had little correlation with pH. Likewise, there was no interaction of manure and spacing in influencing soil pH.

Effect of farmyard manure and spacing on soil cation exchange capacity

Higher rates of manure (30t/ha and 60t/ha) significantly increased the cation exchange capacity. Similarly, the correlation of manure with cation exchange capacity is positive and highly significant, indicating that an increase in manure level leads to increase in soil cation exchange capacity. This means that manure applied soils are likely to be more fertile and may contain more exchangeable cations. In this study, manure had a positive and significant correlation with magnesium and calcium while that of micronutrients (Fe, Zn, Cu and Mn) were not significant. The increase in cation exchange capacity due to manure is attributed to its colloidal nature (Patiram and Singh, 1993).

Effect of farmyard manure and spacing on soil macronutrients

There were no significant effects of manure on soil nutrients although increased doses of manure tended to increase soil total nitrogen and available P, K, Ca and Mg and tended to reduce Fe. The variation of zinc and copper with increasing manure rates was very little. On the other hand, regression analysis showed manure to be positively related to soil nitrogen and calcium whereas the positive correlation of soil phosphorus and magnesium with manure was significant. Potassium, however, had a weak positive correlation with manure. These positive correlations suggest that repeated application of manure to soil may result in significant increase in fertility in regard to the said nutrients.

Studies done by Albregts and Howard (1981), Patiram and Singh (1993), Whalen et al. (2000) and Shen and Shen (2001) resulted in significant increase of P, K, Ca and Mg in manure amended than un-amended soils. However, in all these cases, manure was applied in combination with mineral nutrients. Shen and Shen (2001) attributed the increase in mineral nutrients to the addition of mineral elements in pig manure.

Nutrients mineralization from applied manure depends on soil temperature, soil moisture, soil properties, manure characteristics and microbial activities. Since these factors cannot be accurately predicted, nutrient mineralization can only be approximated. Generally, nitrogen mineralization differs for different manure types and is low for composted manure and high for swine or poultry manure. Phosphorus from all animal manure is high (>70%), while potassium is 100%, calcium and magnesium is greater than 55% and zinc, iron, manganese, copper, sulphur and boron is less than 40% (Eghball et al., 2002).

The non-significance of available nutrients to applied manure in the present study may also be related to the fact that soil pH was not altered significantly by manure application. Soil pH is known to modify transfer of elements from the soil-phase-bound form to soil solution (Kieken, 1983; Xian and Shokohifard, 1989). The soil pH affects nutrient solubility and the sorption or precipitation of nutrients with aluminium and iron; increasing the pH of acid soils improves plant availability of macronutrients while reducing the solubility of elements such as aluminium and manganese (Whalen et al., 2000).

However, availability of nutrients varies with time. Immediately after manure application, Whalen et al. (2000) got a greater mineral nitrogen concentration in manure amended than un-amended soil but the effect was not significant after an eight-week incubation period. The decline in mineral nitrogen of manure amended soils after an eight-week incubation period was likely due to immobilization and /or de-nitrification. In this present study, soil samples were collected and analysed for nutrients at six months after planting.

Analysis of variance showed that spacing does not affect soil macronutrients significantly. Spacing had a weak, insignificant positive relationship with soil total nitrogen and available phosphorus, calcium and magnesium. This means that in a wider spacing regime, there is slightly more soil nitrogen, phosphorus, calcium and magnesium. Conversely, in a close spacing regime (more plant density), there is slightly less nitrogen, phosphorus, calcium and magnesium in the soil, probably due to competition and plant uptake. This is in contrast to soil available potassium, which had a negative correlation with spacing.

Effect of farmyard manure and spacing on soil micronutrients

Manure was positively correlated with soil available zinc, copper and manganese and negatively correlated to soil iron. Spacing on the other hand was positively correlated with all the micronutrients considered. In all the cases, however, the correlations were low and insignificant. Initial soil and manure analyses showed that the micronutrient content of manure was far less than the corresponding nutrient level in the soil and this explains the negligible contribution of manure to available micronutrients (Table 1). The negative correlation of manure with soil available iron is explained by the fact that phosphorus is antagonistic to soil iron (Tisdale et al 1993, Katyal and Randhawa 1983,). In this study, manure had a strong positive correlation with soil phosphorus.

Effect of farmyard manure and spacing on soil temperature

There was no significant effect of manure on soil temperature although increasing rates of manure tended to have a slight reduction in temperature. Manure is known to increase organic matter in the soil, which in turn darken and absorb more heat energy and hence increase in soil temperature (Brady and Weil, 1999). However, the increase in soil organic matter following transition to organic management occurs slowly, generally taking several years to detect (Clark et al, 1998). Manure also is known to have good water retention (Brady and Weil, 1999). The negative correlation of manure with soil temperature therefore implies that manure may have retained more moisture, leading to a decline in soil temperature. Soils that are light coloured or poor drained warm more slowly than soils with a darker colour and better drainage (Anonymous, 1995). Despite this, the black polythene mulch used in this experiment may have modified moisture storage and resultant soil temperature more than manure, explaining the non-significance of soil temperature to applied manure.

A wider spacing regime of 45cm x 45cm had a significantly higher soil temperature at 10cm depth than the closer spacing regimes of 30cm x 45cm and 30cm x 30cm. In addition, regression analysis showed that spacing is highly and positively related to soil temperature both at 10 cm and 15 cm soil depth. This implies that the wider the spacing, the higher the soil temperature and vice versa. This observation is probably due to the shading effects of leaves in the closer spacing regimes.

Effect of farmyard manure and spacing on leaf tissue nutrient content

Farmyard manure did not significantly affect the leaf nutrient content. Increasing farmyard manure levels lead to increase in levels of soil total nitrogen. Increasing levels of manure lead to a decrease in leaf nitrogen content; the leaf nitrogen content was high in treatments that had lower doses of manure. It is probable that immobilization and/ or denitrification may have taken place, leading to low available nitrogen in manure treated plots.

Although not significant, manure had a positive relationship with leaf phosphorus, potassium, magnesium, zinc, copper and manganese. These nutrients also increased in the soil with increase in manure levels though insignificantly.

Soil nutrients may be synergistic or antagonistic, enhancing or depressing uptake of other nutrients respectively. The negative correlation of manure with leaf calcium content may be due to depressed uptake by magnesium and potassium, which are antagonistic to calcium (Brady and Weil, 1999; Tisdale et al., 1993)

Soil available nutrients were not significantly affected by manure rates and therefore non-significance of manure effect on leaf nutrient content is not unexpected. Generally the nutrient content of leaves is low in some elements. The leaf nutrient content of nitrogen ranges from 0.78% to 0.86% while that of potassium ranges from 1.3% to 1.5%. Locasio et al. (1977) reports a leaf potassium content of 1.5% to be the critical range for strawberry while the leaf nitrogen content of 3.1% to 3.5% is above the critical range. Zinc leaf nutrient content, which range from 6.02 to 6.36 ppm, is also in the deficient range. Normal plant leaf zinc content ranges from 25 to 150 ppm while values below 15 ppm indicate sure deficiency (Tisdale et al, 1993; Katyal and Randhawa, 1983). The levels of leaf manganese content in this study ranged from 76.9 to 85.5 ppm, which are within the normal range of 20 to 500 ppm in most plants. However, apart from manganese concentration, the level of iron in the plant regulates the incidence of manganese deficiency or toxicity; very high or low plant iron in comparison to manganese induces manganese deficiency or toxicity (Katyal and Randhawa, 1983). Thus, under such circumstances an interpretation based on manganese concentration may create complications. For optimum plant growth, the ratio of iron to manganese should be between 1.5 and 2.5; values above 2.5 lead to manganese deficiency while those below 1.5 causes its toxicity (Katyal and Randhawa, 1983). In this study, the ratio of iron to manganese in the leaf tissue ranges from 2.6 to 3.5, which suggest deficiency. It is therefore suspected that the plants under this study may have suffered from nutrient deficiency considering that only manure was applied without supplementing any inorganic fertilizers.

Effect of farmyard manure and spacing on leaf chlorophyll content

Leaf chlorophyll content was measured at 11 and 7 months post planting for season one and two respectively. Whereas manure caused little variation in chlorophyll content in season two, increasing rates of manure tended to reduce chlorophyll content in season one and had significant negative correlation with it. A decrease in chlorophyll content may be caused by several factors including low soil fertility as well as soil salinity. Livestock manure has been proven to contain a lot of soluble salts (Hao, 2003), which are detrimental to growth of transplanted strawberries (Locasio et al., 1977).

Studies done by Albregts and Howard (1981), Cenzig et al (2001) and Kaya et al. (2002) showed that dry weight, fruit yield and chlorophyll content of strawberry decreased with increase in salinity/soluble salts. However, the range of soil pH recorded and the general characteristics of the soil used in the present study (Haplic phaeozem) rules out the possibility of salinity in the soil. The observed effect of manure on chlorophyll content can therefore be explained by the fact that increasing levels of manure had a negative correlation with leaf nitrogen content. The role of nitrogen in chlorophyll synthesis is obvious, since it is a structural component of both chlorophyll-A and chlorophyll-B (Brady and Weill, 1999; Tisdale et al, 1993). The variation of chlorophyll due to spacing was negligible and generally chlorophyll had very little correlation with chlorophyll content.

Effect of Farmyard Manure and Spacing on Strawberry Growth

Effect on number of leaves

Analysis of variance showed that manure significantly increased number of leaves at 17, 19 and 21 weeks after planting. In addition, the regression of manure with leaf number showed manure to have a positive and significant relationship in almost all the weeks assessed. This observed growth response is attributed to the increase in available soil nutrients with increasing manure levels.

Spacing also had a positive a positive correlation with leaf number although not significant. This implies that increasing the spacing regime tends to increase leaf number and is probably due to reduced interplant competition for plant nutrients.

Effect on leaf biomass

Manure had no significant effect on leaf biomass. However, in all the time of assessment, manure had a negative correlation with leaf biomass. This is in contrast to the relationship of manure with number of leaves. It can be deduced, therefore, that the high number of leaves stimulated by manure did not develop fully and may have competed for nutrients leading to a decline in leaf biomass. This is especially possible, considering that leaf nitrogen content decreased with increase in manure level. This implies that the increased soil total nitrogen with manure level was not in an available form. Among the major functions of nitrogen is promotion of vegetative growth (Tisdale et al 1993). Furthermore, strawberry leaf growth is reportedly promoted by nitrogen fertility (Chowa et al., 2002; Breen and Martin, 1981).

Higher spacing regimes of 45cm x 45cm and 30cm x 45cm had significantly higher leaf biomass than close spacing regime of 30cm x30cm. This effect is perhaps due to reduced interplant competition for available resources. The interaction of manure and spacing shows that low doses (10t/ha) of manure and highest spacing regime (45cm x 45cm) result in greatest leaf biomass. Handley and Pollard (1986) reported that reduced plant density decrease interplant competition and thus stimulate vegetative growth and development of individual plants especially in regard to growth and development of leaves and runners.

Effect on number of runners

Throughout the assessment period, farmyard manure did not have significant effect on number of runners. As in the case for leaf biomass, manure had negative correlation with number of runners. In spite of the fact that manure tended to increase the level of available P, K, Ca and Mg, the negative correlation of manure indicates that nitrogen is essential to promote vegetative growth of strawberry. Tworkorski et al. (2001), obtained increased number of runners with increase in nitrogen levels. In addition, the nutrient use efficiency in manure treated plots may have been low. Pritam and Gupta (1994) observed that phosphorus application had a significant effect on phosphorus use efficiency and by and large, phosphorus utilization patterns were of higher magnitude at lowest dose of applied phosphorus. They explained the observation by the fact that plants being grown in a given soil exhibit a greater competition for nutrient absorption at lower doses. In the present study, manure correlated negatively with leaf calcium and zinc despite the positive correlation with the said nutrients in the soil.

As in the case of number of leaves, spacing correlates positively and significantly with number of runners. The wider spacing regime resulted in higher number of runners perhaps due to reduced interplant competition for soil resources. In addition, the higher spacing regime may have received more light intensity which reportedly favour runner production (Ferree, 1988; Galletta and Himelrick, 1990)

Effect on runner biomass

There was a significant effect of manure on runner biomass at 19 weeks after planting, with runner biomass of manure treated plots being lower than the control. In addition, the negative correlation of manure with runner biomass is significant at 19 and 21 weeks after planting. This observation is not unexpected since manure also correlated negatively with number of runners. On the other hand, close spacing regime of resulted in significantly lower runner biomass than those in wider spacing regime. This corresponds to the observation made on effect of spacing on number of runners.

Effect on length of runners

Lower doses of manure (10t/ha) resulted in significantly longer runners at 21 weeks after planting. Again, the relationship of manure versus runner length is negative during all the time of assessment. This growth is again attributed to the available nitrogen in the control.

Unlike in number of runners and number of leaves, closer spacing regimes resulted in significantly longer runner length than in wider spacing regime. This observation is attributed to lower fertility in close spacing regime, since spacing had positive correlation with most soil nutrients. Runners are reported to grow longer in nutrient poor sites (Tworkorski et al., 2001).

Effect on canopy spread

Analysis of variance showed that increasing rates of manure increased canopy spread though not significantly. Manure, therefore had a positive effect on canopy spread. This promotion of canopy spread by manure is attributed to the fact manure also increased number of leaves in this study.

The effect of spacing on canopy spread was also not significant throughout the assessment period although it had a positive effect on canopy spread. The wider spacing regime promoted canopy spread as evidenced by the positive correlation at week 23 post-planting. Reduced interplant competition for soil resources in the wider spacing regime accounts for this observation.

Effect of Farmyard Manure and Spacing on Strawberry Yield and Quality

Studies done by Kaya et al. (2001) resulted in 47% and 34% fruit yield reduction for 'Oso Grande' and 'Camarosa' strawberry varieties respectively and the reduction was attributed to soil salinity. Locacio et al (1977) reported that soluble salts that exceed 2.3 to 2.5mmhos/cm of conductivity in saturated extracts (about 2650 to 2900ppm at 10% soil moisture) reduce strawberry yields by 50%. Presence of soluble salts in soil in the present study is unlikely since the pH values recorded showed that the soil was slightly acidic while soil salinity is mostly common in alkaline soils (Brady and Weill, 1999). Further more, electrical conductivity values measured indicated that there was no salinity in the soil (data not shown). Yield limitation by manure in this experiment is therefore attributed to low available nitrogen in manure, probably caused by immobilization and/or denitrification. Despite the increase in soil total nitrogen with manure, the negative correlation of manure with leaf nitrogen content indicate that the soil nitrogen in manure treated plots was not in an available from. Albregts et al. (1991) implicated nitrogen and potassium deficiency to especially account for small fruit and low fruit weight of strawberry. In addition, it is probable that nutrient imbalance in manure treated plots could limit yields, given that manure had much less micronutrient content compared to the initial soil.

Results in number of berries as influenced by spacing are similar to those of Freeman (1981), Human (1999) and Legard et al. (2000) who observed increased marketable yields with increasing plant density. Similarly, Sarooshi and Cresswell (1994) recorded a 42.7% increase in fruit weight when plant density was increased from 53,500 to 93,500 plants/ha. Although production per plant was higher in the wider spacing, Freeman (1981) attributes the high yields in close spacing to higher plant densities per unit area. Despite that high light intensity which may have been absorbed by plants grown in wider spacing regime is a factor that may reduce fruit yield since it tends to reduce flowering in strawberry (Ferree, 1988).

Relationship of Soil Temperature with Strawberry Growth and Yield

The relationship implied that increase in soil temperature tends to promote vegetative growth while retarding fruit yield. Galleta and Himelrick (1990) reviewing the effect of soil temperature on growth and yield of strawberry revealed that runner developed only in soil temperature range of 18.3^{o}c to 32.2^{o}c with the optimum being 23.9^{o}c. The authors concluded that root growth is best at cool (12.8^{o}c), crown growth at moderate (18.3^{o}c), leaf growth at moderately warm (23.8^{o}c) and fruit development at quite cool (7.2^{o}c) soil temperature.

Conclusions

- FYM increases pH, CEC, soil N, P, K, Ca and Mg, reduces Fe.
- FYM has little effect on Zn and Cu.
- Close spacing increases uptake of soil nutrients.
- FYM negatively relates to temperature due to moisture retention.
- Close spacing shades and reduces soil temperature.
- Short-term FYM may not improve vegetative growth due to ltd N.
- Wide spacing promotes vegetative growth via reduced competition.

– FYM relates negatively to yield due to N, Zn and Mn deficiency.
– Wide spacing results in low yields through low plant density.

Recommendations

– Adopt 30 t/ha manure and 30 cm x 30 cm plant spacing.Integrated nutrient management to counteract nutrient imbalance, nitrogen immobilization and adverse pH.
– Apply manure repeatedly to determine whether benefits will be higher than those realised in the current study.
– Develop large-sized, day-neutral strawberry varieties for tropical climates.

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Feedback

Question: ***Considering the slow release of nutrients from FYM in the soil may be you could test the residual effects of the previously applied FYM on soil characteristics and productivity of the strawberry?***

Answer: Yes, similar studies have been conducted in other crops.

Question: ***With 30 t/ha manure you add considerable amount of nitrogen, possibly much more than is exported from the system through harvest. Are you afraid of nitrogen losses to the environment?***

Answer: There is need to determine the amount of nitrogen harvested in the fruits/berries to help adjust amount of synthetic nitrogen fertiliser to integrate with FYM. Yes, there is a risk of N loss if excessive amount is applied, but this risk can be tackled through split application in small doses of the synthetic nitrogen fertiliser.

Response of French Beans (*Phaseolus vulgaris*) to Intra-row Plant Density in Maseno Division, Kenya

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Abstract

French bean is one of the members of Fabaceae family. It originated from Mexico and currently it is distributed all over the world. It is a rich source of proteins, minerals and vitamins. In Kenya it is grown mainly for fresh export market. Due to increased demand for French beans, there is a need for increased production to meet the demand. One of the husbandry practices that can be manipulated to increase production is plant density. Appropriate density also improves the quality of beans because of reduced pest and disease incidences, weed infestation, as well as competition among plants for nutrients. This cuts down the use of the inorganic fertilizers, insecticides, fungicides and herbicides. Based on these facts, research was carried out between June 2005 to July 2005 at Maseno University Horticultural farm with the objective of investigating the effect of plant density (intra-row spacing) on growth and yield of French beans. Seeds of the French bean variety Totai were first subjected to germination test in the laboratory. The seeds were then sown in the experimental plots using randomised block design with four treatments, namely T1= 30 cmx15 cm (control), T2= 30 cm x 10 cm, T3 = 30 cm x 20 cm, T4= 30 cm x 30cm. Various cultural practices were carried out throughout the experimental period. Observations on plant height, leaf number and branch number were made from the 2nd to the 6th week after sowing. Leaf area, plant dry weight and number of flowering plants were measured 6 weeks after sowing. Plant density significantly affected plant growth with optimal density being 30 cm x 20 cm, which is therefore recommended for Maseno area. Further research needs to be done to determine intra-row effects and yield response.

Key words: French beans, *Phaseolus vulgaris*, plant density, spacing

Introduction

French bean is a member of fabaceae family. It is believed to have originated from Mexico (Tindall, 1983). Early domestication of the species occurred in Peru and other Central American countries. It was introduced to Europe in 16th century and to tropical Africa shortly afterwards. It is currently widely distributed throughout the world. In Kenya the crop is grown mainly for fresh export market. However, processing of the beans, including canning and freezing is steadily increasing. French beans from Kenya are especially popular in France and United Kingdom (HCDA Export Crop Manual, 2002).

French bean can tolerate a wide range of soil types ranging from light sandy loam to clay. They however grow best on friable, medium loam soils that are well drained and have a lot of organic matter (HCDA Export Crop Manual, 2002). The optimum pH is 6.5 to 7.5, but the beans can tolerate a low pH of 4.5 to 5.5. The crop requires moderate rainfall of 900 to 1200 mm per annum. Heavy rainfall adversely affects fertilization. The optimum temperature ranges between 14 to 27^{0}C. French bean grows well at an altitude of between 1500 to 2100 m above sea level (HCDA Export Crop Manual, 2002).

Young pods and mature seeds are used as cooked vegetables. Young leaves are also eaten particularly in Africa. Fresh pods are rich in vitamins and minerals. The bean seeds also contain appreciable amount of minerals and vitamins (Kroll, 1997).

The main export season for fresh produce is from October to May. Planting should be well scheduled so that the bulk of the crop is ready during the periods from October to mid December and from mid January to the end of May. In warm areas, the beans take about 45 to 50 days from planting to time of first picking.

There are several biotic and abiotic factors that affect growth and yields of French bean such as climatic factors, edaphic factors, pests and diseases and plant density among others. Inappropriate plant density in particular, has accounted for poor yields of most of the small-scale farmers (Ngugi *et al*, 1982). This is because if plants are widely spaced, not all land area is covered by leaves and much of the light available for photosynthesis is wasted. Resources of water and mineral nutrients in the soil are similarly underutilized. On the other hand, if plants are overcrowded, there is competition for water and minerals salts in the soil, as well as light because their leaves begin to shade one another (Forbes and Watson, 1992).

Statement of the Problem

Due to the increasing demand for French beans in the world there is need for increased production in order to meet the demand. Increasing supply necessitates increase in land area under production and/or increasing production per unit land area. Given the increasing human population, the option of increasing land area under production is not very viable. This leaves the option of increasing the production per unit area as a viable alternative. To increase production per unit area requires improved husbandry practices and provision of the factors of growth. One of the husbandry practices, which can be manipulated to increase production, is the appropriate spacing.

Research Justification

French bean is one of the important horticultural crops contributing to the expanding export market in the country. Farmers in Maseno division can earn income by engaging in production of the crop. The crop also produces high yields per unit area (9 –12 tons/ha) and this can benefit most farmers in Maseno division since they have small pieces of land. The crop also matures early (45 days); it is simple to grow, it is not eaten by monkeys, and there is an efficient transport network (good road and airport) to carry the produce to the market. Therefore increasing production of French beans per unit area through the use of optimum plant density will contribute to poverty alleviation strategies in Maseno Division.

Objective

To study effects of plant density (intra- row spacing) on growth and yields of French beans.

Methodology

Description of the study area

The research was conducted in Maseno University Horticultural Farm between the months of May to August 2005. The farm is located in Maseno division, Kenya. The site is located between latitude 5^0S and 5^0N and longitude 34^0 30′ E at an altitude of 1463m above sea level. The area receives mean annual rainfall of 1510– 1678mm. Annual temperatures range is between 21 and 24 ^{0}C with the hottest season occurring between January and April (Jaetzold et al., 1982). The soils are well-drained, deep reddish brown to black brown slightly friable clay acidic humic topsoils. The soil structure is regosols with ferric, cambisols, lithic phase and weak rock outcrops (FAO/UNESCO, 1990).

Germination tests

The seeds were subjected to germination test in the laboratory on 12th June 2005. Thirty seeds were placed on individual petri dishes that were lined with filter paper and replicated three times. Water was added to the Petri dishes on a daily basis just to keep the filter paper moist. Daily measurements on the number of germinated seeds were recorded for a period

10days.Percentage germination was then calculated at the end of the experiment. Tokai variety was used since Monel was not available.

Land preparation, planting and cultural practices

The experimental field was cultivated to a fine tilth. Twelve (12) plots were prepared each measuring 1.5m x 1.5m. Well-decomposed cattle manure was incorporated into the soil at a rate of 10 ton/ ha before planting. The seeds were then sown. The spacing was as per the treatments discussed below in this report. DAP was applied as a basic dressing at a rate of 200kg/ha. Two seeds per hill were planted at a depth of 2 to 3 times the diameter of the seeds. After planting, watering was done followed by mulching.

Various cultural practices were conducted throughout the experimental period. Thinning was done after two weeks leaving one plant per hill. Irrigation was done during the dry period. 100kg/ha CAN as a top dress was applied in two splits, first application done at two-leaf-stage and the second one at the beginning of flowering. Other cultural practices were carried out i.e. weeding and pest and disease control.

Experimental design

Randomized block design with four treatments each replicated three times was used. The four treatments were as shown below

Treatment number	Spacing	Number of plants per plot
1	30 x 15 cm (control)	50
2	30 x 10 cm	75
3	30 x 20 cm	37
4	30 x 30 cm	25

The experimental field measured 8.5m x 7 m. Each experimental plot measured 1.5m x 1.5 m. The boundaries and walkways were 0.5m wide. The field layout was as shown below;

Parameters measured

The following non-destructive measurements were measured on a weekly basis starting from the second week up to the sixth week after sowing i.e. plant height, leaf number and branch number. Leaf area, number of flowering plants and plant dry weight were measured in the sixth week. Three plants per plot were sampled.

Data Analysis

Analysis of variance (ANOVA) was carried out at 5% and 1% level of significance to determine whether the treatment effects were significant. Where there was significant effect between the treatments, least significant difference (LSD at 5% level of significance) was used to separate the means.

Results and Discussion

Plant height

Plant height of French beans increased with time from the second to the sixth week in all the four treatments. Plant density had no significant (P<0.01) effect until the 5th week after sowing. There was increased plant height with increased intra-row spacing up to 20cm though it was not significant.

Number of branches

Number of French bean branches increased with time from the 2nd to the 6th week in all the four treatments. There was no significant effect due to intra-row spacing until the 3rd week after sowing. There was significant increase in branch number with increased intra-row spacing up to 20cm beyond which the branches decreased significantly with increase in intra-row spacing. However, there was no significant difference between treatment 1 and treatment 3 as shown in Figure 1 below.

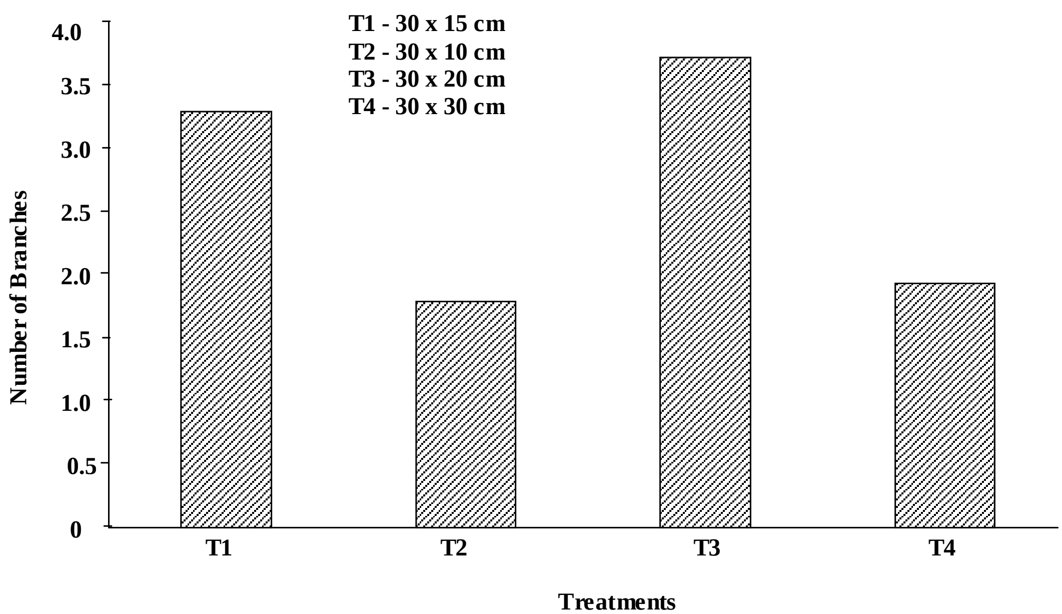

Figure 1: he effect of intra-row spacing on number of branches of French beans, 5 weeks after sowing. Sig-0.01, LSD-0.5

The increase in number of branches with increased intra-row spacing is consistent with studies done on legumes (*Vicia faba*) that indicate legumes respond partly to density by reduction in branch number (Harper, 1990).

Photosynthesis and gaseous exchange of leaves are affected by many stresses including drought, salinity, high temperature, inadequate nutrition etc. Stomatal conductance and the rate of assimilation of CO_2 per unit area often decrease when stress occurs. Stress lead to increased levels of hormone abscisic acid (ABA) in leaf epidermis and it is shown to close stomata when applied in leaves (Jones et al 1993). Therefore the above observation can be attributed to reduced competition among plants planted at a bigger intra-row spacing i.e., there is reduced competition among the plants for water, nutrients and sunlight. On the other hand, there is great competition for the above resources for the plants, which have smaller intra-row spacing.

Number of leaves

Leaves increased with time in all the 4 treatments from the 2nd to the 6th week after sowing. Significant effect on number of leaves due to intra-row spacing was not recorded until the 4th week after sowing. Leaves increased significantly with increased intra-row spacing up to 20cm beyond which the leaves decreased significantly. However, there was no significant difference in leaves with increased intra-row spacing between T_2 as T_1 (Figure 2).

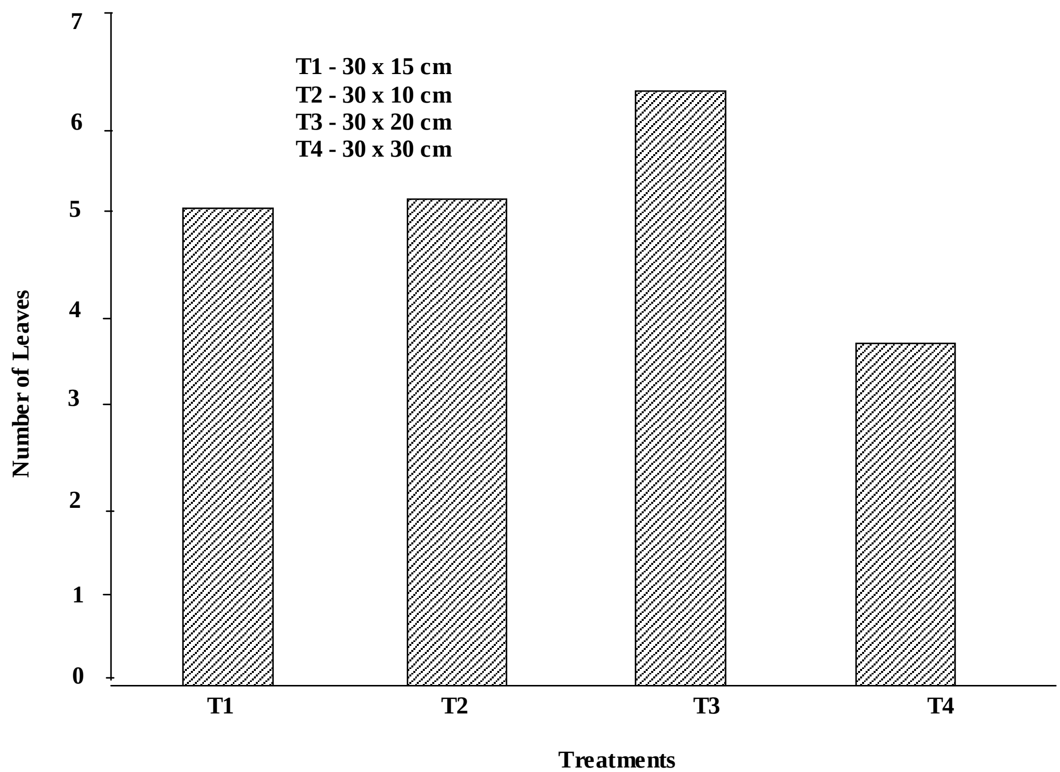

Figure 2: Effect of intra-row spacing on number of leaves of French beans, 5 weeks after sowing. Sig-0.01, LSD-1

A linear relationship between growth rate and turgor can be demonstrated in many plant parts. In many reports leaf growth curve rates apparently declines with declining turgor (Jones et al 1993). The above observation is attributed to competition among plants for water. Closely spaced plants experienced moisture stress due to competition for water and it resulted to decline in turgor and hence a reduction in leaf number. Plants also competed for light and nutrients. Decrease in intra-row spacing led to interference among plants for light, leading to decreased photosynthesis and in extension a reduction in photosynthates and subsequent decrease in leaf number. Lower leaves also received less light and as a result, they died and dropped off the plant. Shaded leaves abscise because their nutrients are translocated to the actively growing plant parts.

Plant dry weight

Intra-row spacing had a significant effect on plant dry weight 6 weeks after sowing. Dry weight significantly increased with increase in intra-row spacing up to 20cm beyond which the plant dry weight decreased. Plant dry weight significantly ($P<0.01$) increased from 7.6g in treatment 2 (10 intra-row spacing) to 15.4g in treatment 3 (20cm intra-row spacing). However, there was no significant difference in plant dry weight between treatment 1 (15cm intra-row spacing) and treatment 4 (30cm intra-row spacing).

The increase in mean dry weight of French beans is consistent with studies done on maize that indicate that plants respond to density stress by a reduction in biomass of the plant. The mass per plant is affected according to the intensity and duration of the interference and biomass accumulation varies as a reciprocal of density (Loomis and Corner, 1996). $W = AP + B$, Where W = yield per plant, P = density, A and B – constants. The above observation can be attributed to competition among plants for light, moisture and nutrients in the soil. Crowded plants compete for light. This leads to reduced photosynthesis and ultimate reduction in dry matter of the plants.

Leaf area

Leaf area was significantly affected by intra-row spacing as evident from the results obtained on the 6th week after sowing. Leaf area significantly increased with an increase in intra-row spacing up to 20cm beyond which it reduced significantly (Figure 3).

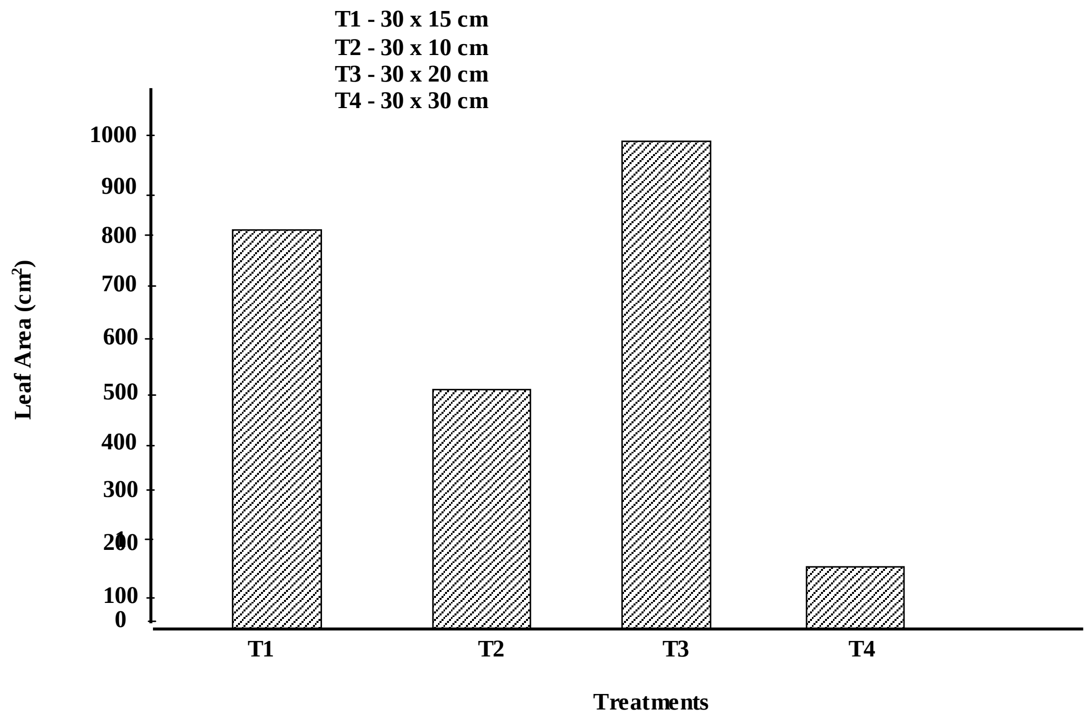

Figure 3: Effect of intra-row spacing on leaf area of French bean 6 weeks after sowing. Sig-0.01, LSD-315.3

For example leaf area significantly (P<0.01) increased from 467.9cm^2 in T_2 (10cm intra-row spacing) to 930cm^2 in T_3 (20cm intra-row spacing). The increase in leaf area/plant with increased intra-row spacing is consistent with studies done on maize that indicate plants respond to density stress by a reduction in leaf are per plant (Harper, 1990)

Number of flowering plants (%)

Intra-row spacing had a significant (p<0.01) effect on the number of flowering plants 6 weeks after sowing. Number of plants significantly decreased with increased intra-row spacing up to 20cm beyond which the number of flowering plants increased. For example the % number of flowering plants significantly decreased from 90.5% in T_2 (10cm intra-row spacing) to 73% in T_3 (20cm intra-row spacing). However there was no significant difference between T_1 (15cm intra-row spacing) and T_2 (10cm intra-row spacing).

The increase in number of flowering plants at closer intra-row spacing can be attributed to stress experienced among the plants due to competition for light, water and mineral salts. Stress in plants led to production of ethylene, which is known to promote floral initiation.

Conclusions

Intra-row spacing had an effect on growth of French beans. Increased intra-row spacing led to an increase in branch number, leaf number, plant dry weight and leaf area. However it also led to a decrease in plant height and number of flowering plants.

Recommendations

The recommended intra-row spacing of French beans in Maseno Division is 20cm because it leads to a high growth rate (branch number, leaf number and area and plant dry weight).

Further research could be conducted to investigate the effect of intra-row spacing on yields of French beans. The experiment could also be repeated in another plot of land in order to account for the unusual observation in treatment 4. Further research can also be conducted on the effect of inter-row spacing on growth and yields of French beans.

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Feedback

Question: ***In your justification you stated that French beans increase soil nitrogen. However, considering that French beans do not form nodules and are considered poor nitrogen fixers, what did you mean by that?***

Answer: The low percentage of French bean nitrogen fixation end up increasing soil nitrogen, however little it is. Besides nodule formation is a function of soil factors. So depending on soil conditions, nodule formation will vary and hence nitrogen fixation.

Effect of 'Purafil' Ethylene Absorber on Postharvest Quality of 'Fuerte' Avocados

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Abstract

Global avocado production has risen by 27% over the last 10 years to reach 2.4 million tonnes in 2001. In Kenya, avocado (*Persea Americana* Mill.) is an important export fruit with a total of 19.02 tonnes being exported in 2003 and claiming 80% share of the total fruit exports in the same year. Postharvest losses are a major concern with regard to increasing avocado export to earn more foreign exchange for Kenya. Avocado is a climacteric fruit, emitting large amounts of ethylene gas during ripening and this ethylene increases the rate of deterioration of avocados. 'Purafil' is a commercially available ethylene absorber, which removes this deleterious gas from storage atmospheres of many horticultural produce. However, there is lack of accurate data with regard to what concentrations to use to prolong postharvest life of avocado. In the current study, fruits were exposed to four levels of 'purafil' (0g, 10g, 20g and 40g) and observed daily for 24 days, during which various postharvest indices were recorded. The optimum 'Purafil' level was 20g. After day 20, there was significant deterioration of all the fruits due to accumulation of moisture within the enclosed fruit packages. It is recommended that further research be carried out, especially to find out the effect of these 'Purafil' levels on nutritional qualities of avocado fruits.

Introduction

Developing nations with over 80% of the world's population and a projected 90% by 2050 must strive to produce more from the same cultivated land in order to improve food security. Post harvest activities in these countries represents more than 55% of the economic value of agriculture and horticulture, and the Figure is up to 80%in developed nations (Opara, 2002) Good postharvest management, and development of rural agro-industries of various types is widely recognized as good foundations for socio-economic improvement in rural areas because of their crucial role in improving food security, nutrition, poverty alleviation through employment and income generation. With increasing external pressures such as demographic shifts to urban areas, globalization of the food supply chain, and growing emphasis on product quality, safety and traceability, small scale resource poor farmers need access to appropriate post harvest innovations to reduce losses, maintain quality, and enhance market access. There is thus a need for renewed attention to the area of post harvest handling of horticultural produce. Universities offering horticulture courses as well as other industry stakeholders need to carry out relevant cost effective trials on how to prolong shelf life of horticultural produce whose physiology is highly varied.

Avocado production is a low cost easy type of horticultural farming, which can be done both on a small scale and on a large-scale for local and export consumption. It is important to know the best post harvest handling method to prolong its shelf life making it possible to get to consumers in a good condition hence fetching good profits for growers. Potassium permanganate is a well-known ethylene absorber which removes ethylene from storage environments of many horticultural products especially fruits and ornamental crops (Saltveit, 1980). It has been proposed as a cheap way of prolonging the post harvest life of horticultural produce especially by small-scale horticultural growers who do not have access to cold storage refrigerated facilities (Shanmugasundaram and Manavalan, 2002). It is also an alternative where low temperatures cause chilling injury to horticultural produce of tropical origin such as bananas, avocadoes and some tropical flower crops. Alternative ethylene absorbers such as ozone and 1-methylcyclopropene (1-MCP) are known to be difficult to dispense since they are of gaseous nature. Opiyo and Ying (2005) found that ethylene production was greatly lowered in cherry tomato fruits that were treated with 1-MCP. Higher 1-MCP concentrations delayed the ethylene induced climacteric peaks in mature green fruits. 1-MCP is an ethylene antagonist that has generated a lot of interest. It is believed (Blankenship & Dole, 2003) that 1-MCP occupies ethylene receptors such that ethylene cannot bind and elicit action. Sisler & Serek (2000) reported that 1-MCP controlled ethylene responses at the receptor level, which, together with the very low level at which it acts, makes it suitable to treat edible fruits such as avocadoes. However, 1-MCP is not readily available hence the decision to carry out this study using the readily available Purafil.

Increasing ethylene levels in storage environments have been found to highly correspond to color changes in fruits placed under these environments (Jayanty et al, 2002). It can then be concluded that keeping ethylene levels low will lengthen post harvest life of fruits.

Controlled atmosphere storage of fruits has also been noted to prolong shelf life of fruits and other horticultural produce. However, plant responses to very low O_2 and high CO_2 concentrations include induction of fermentation pathways, accumulation of succinate and/or alanine, and decreases in intracellular pH and ATP levels. One pathway of fermentative metabolism results in accumulation of acetaldehyde and ethanol. The major function of fermentative metabolism is to use NADH and pyruvate when electron transport and oxidative phosphorylation are inhibited so that glycolysis can proceed. This will allow for the production of some ATP through substrate phosphorylation, which permits the plant tissues to survive temporarily (Dangyang et al, 1995). This fermentation results in undesirable flavor changes in avocadoes (Kanellis et al, 1991) rendering modified atmosphere storage an unsuitable method of prolonging fruit shelf life. This research aimed at finding out the effect of different levels of potassium permanganate on the shelf life of 'Hass' avocado fruits under natural laboratory conditions.

Materials and Methods

'Hass' avocado fruits used in this experiment were harvested from a growers' field in Kapsabet area of Nandi North District of Rift Valley Province of Kenya. These were transported to Moi University Horticulture Department Laboratories some 50 km from the growing site. Sixteen mature ripe fruits were used for each treatment, divided into units of four fruits each and arranged in a complete block design on a table in the laboratory. Four treatments were tested. Avocado fruits were enclosed in transparent 12" x 12" polythene bags containing 0g, 10, 20g and 40g of commercially available potassium permanganate (Purafil). The bags were sealed to be airtight and placed in the laboratory under ambient environmental conditions of 23 degrees C day temperature and lowest night temperatures of 12 degrees C. Fruit color or green life was recorded for a period of 24 days. All the fruits were scored for firmness on day 20 and 24. A score was made on day 24 for condition of fruit scar tissue to assess its condition. On day 24, the number of unsaleable fruits was assessed for all treatments. An extra set of 16 avocado fruits was left in open ambient laboratory condition without being enclosed in polythene bags. This set served to give an assessment of the effect of enclosing fruits in airtight polythene environmental conditions.

Results and Discussion

Duration taken by fruits to fully develop brown colour

The results obtained in this experiment indicate that there was a gradual delay in fruit ripening as the amount of purafil increased. The fruits left in the open laboratory environment were found to show full brown color (an indicator of ripening) very fast. After 6 days, all the fruits in this category had full color development where as those enclosed with 10g purafil started showing full color development (ripening) after day 9 (Table 1).

Table 1: Duration of avocado fruits to develop full brown color

Day No.	Percentage of fully colored brown (ripe) fruits				
	Unenclosed fruits	Fruits enclosed in polythene bags with purafil			
		0g	10g	20g	40g
0	0	0	0	0	0
3	25	10	0	0	0
6	100	40	0	0	0
9	100	65	25	0	0
12	100	100	65	25	0
18	100	100	100	40	0
21	100	100	100	100	30*
24	100	100	100	100	100*

The 20 g treatment level had the most significant delay effect on ripening of avocado fruit. Although the 40g treatment had a significant level, most of the fruit under this treatment stayed green but developed signs of rotting.

Fruit color change during ripening is mainly because of the transition of chloroplasts into chromoplasts. According to Abdi et al. (1998), colour change can either be ethylene dependent or independent. We observed that in fruits treated with potassium permanganate, both color initiation and color development were delayed. The initiation and accumulation of both lycopene/carotenoids responsible for avocado fruit changes during ripening was delayed by purafil in a dose-response manner suggesting that not only does the initiation of lycopene/carotenoids biosynthesis require ethylene perception, but the accumulation of these pigments also requires continuous ethylene perception.

Fruit Firmness Score on Day 20 And Day 24.

All the five treatments were subjected to a firmness evaluation on day 20 and on day 24. A fruit firmness index of 1 to 5 was established as follows: 1 = Very firm; 2 = Firm; 3 = Soft; 4 = Very soft; 5= Extremely soft

All the fruits left in the open laboratory environmental conditions were found to be extremely soft due to the long period of time they had stayed fully ripe. The same was the case with the

0g purafil treatment fruits. There was however some significant differences observed between the fruits placed under 10g, 20g, and 40g purafil levels (Table 2). A period of 20 days and 24 days was selected because this was deemed an average period avocado fruits might be on board of a ship destined for either European Union export destination or the Middle East. Also, this period is deemed appropriate for distant avocado sale points within Kenya such as between point of production in western Kenya to sale outlet points at the coast of Kenya.

Table 2: Fruit Firmness Scores on Day 20 and Day 24

Treatment	Day 20	Day 24
Open Lab. Environment	5^a	5^a
0g Purafil	5^a	5^a
10g Purafil	4^a	5^a
20g Purafil	1^b	2^b
40g Purafil	2^b	5^a

1: Very firm 2: Firm 3: Soft 5: Extremely Soft 4: Very Soft

The superscripts in the table above indicate the levels of significance as per each of the observations. At day 20, the 20g and 40g purafil treatment fruits were significantly different from the rest of the treatments. The evaluation done on the final day of this study (day 24) indicated that only 20g purafil treatment level fruits were firm enough.

It was later realized that this period of assessment after 20 and 24 days might have been too long. However, it was done on these days to avoid enhancing post harvest deterioration or rotting resulting from pressed avocado fruits

Avocado Fruits in Saleable Condition on Day 24

A final evaluation was done on day 24 which assessed how many fruits per category were in saleable condition on this day. The overall fruit appearance was assessed and shriveled fruits or those with blemishes, exudates, and other undesirable visual characteristics rated as non-saleable quality. Table 3 indicates the percentages of fruits of saleable quality as assessed on this final day 24 per each treatment.

Table 3: Percentage of fruits in good saleable condition on day 24

Treatment	Percent of fruits in good saleable condition
Open Laboratory Environment Fruits	0
0g Purafil	1
10g Purafil	0
20g Purafil	45
40g Purafil	5

Conclusions and Recommendations

The effect of potassium permanganate on the ripening and post-harvest quality of 'Hass' avocado fruits was influenced by concentration. The 20g concentration was found to be the optimum level. Fruit color is a major quality trait for consumer acceptance, yet the application of Purafil seems to impair or slow down colour development. There is need to carry out more studies to be able to balance colour development and long shelf-life of 'Hass' fruits.

Based on these results, there is also need to conduct more experiments with regard to how to enclose the potassium permanganate in such a way that it does not get into direct contact with the fruit being preserved to prevent scorching that makes the fruits acquire an undesirable, consumer acceptable colour. Furthermore, there is need to determine the effect of potassium permanganate on other edible fruit qualities such as flavour, total soluble solids (TSS), odour etc. Further studies to find out the interactions between temperature and Purafil concentrations should also be conducted since temperature is a major environmental factor affecting fruit deterioration rate.

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Feedback

Questions: ***How long does it take to sea-freight avocados from Kenya to Europe? Would the findings assist at all in avocado export to Europe?***

Answer: It takes 10 to 14 days to sea-freight horticultural produce from Mombasa-Kenya to the Middle East. I do not know how long it takes to sea-freight produce to the European Union countries.

Question: ***Did you consider a combination of cold storage and the 'Purafil"?***

Answer: No. We did not consider use of cold storage to prolong avocado shelf life because very few avocado farmers have access to cold stores and also because tropical and subtropical fruits get damaged by cold store low and/or chilling temperatures.

Question: ***How was maturity of the avocado fruits for experimentation determined?***

Answer: Mature fruits were selected based on formation of a brown umbilical maturity ring at the junction of the fruit and the stalk.

The Role of Botanic Gardens in Horticultural Crops Germplasm Production and Conservation In Western Kenya

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Abstract

Botanic gardens are as old as the humanity and have played crucial role in the development of crop and ornamental plants over the years. They can be taken to be synonymous with ethno-aesthetics in human civilization. Modern botanic gardens have to advance scientific development of nature and the environmental awareness for the sustained life on this planet now and for the future generations. Universities have been treated as ivory tower by the communities around the institutions. This is because the interaction between the communities and scholars has not been possible due to intellectual

nature of scholarly life. However, this has to change since most communities are now looking at the public institutions around them for the interpretation of the ever changing environmental and biodiversity phenomena. Horticultural germplasm production is a key factor and undertaking in the development and sustenance of the horticultural industry. Good quality seeds or planting materials must be pure to minimize the inherent heterogeneity in production lines. Botanic gardens have played major role in human civilization, aesthetic, research and education. Ancient's gardens were well known for their floral setups. Germplasm conservation is receiving urgent attention form the scientific communities as part of the agenda 21 set in the last century. This is basically due to the fact that sustainability of nature and humans' environment heavily depends on how currently available biodiversity is conserved for future generation and continued life on earth. Scientific research has revealed that only less than 50% of nature's organisms have been positively described. However, about 20% of the known species are either extinct or faced with extinction unless a deliberate effort is made to conserve them. The conservation of biotechnology and by extension the environment needs the involvement of communities that depend on these natural resources for their daily survival. They are the ones better placed to conserve and protect their environment at a minimal cost to tax payers. This can nonetheless be achieved effectively by involving the community's right from the initial planning phase of any project. It calls for a study of what the community understands about the environment and how they have conserved the same over the years. In most cases the analysis reveals that the destruction of forests or environments or lost of germplasm if any is done by those not depending on the particular environment for their daily needs. The advancement of current technology manifested in the biotechnology and the production of genetically modified organism is a testimony that we need to conserve our biodiversity more urgently than before. The biotechnology principles depend on the genetic diversity of organisms from where gene hunters get their raw materials. Biotechnology is credited for having solved several medical and nutritional problems that would have otherwise taken more time to realize. However, there are a lot of grey areas in biotechnology development, especially those concerning food production. This is mainly because the side effects and any modifications due to natural mutations (that may be harmful to human life) have not yet been understood.

Key words: Botanic garden, conservation, germplasm, horticultural crops

Introduction

Botanical Garden refers to a garden in which plants are grown and displayed primarily for scientific and educational purposes. A botanical garden consists chiefly of a collection of living plants, grown out-of-doors or under glass in greenhouses and conservatories. It usually includes, in addition, a collection of dried plants, or herbarium, and such facilities as lecture rooms, laboratories, libraries, museums, and experimental or research plantings.

The plants may be arranged according to one or more subdivisions of botanical science. The arrangements may be systematic (by plant classification), ecological (by relation to environment), or geographic (by region of origin). The larger botanical gardens often include special groupings, such as rock gardens, water gardens, wildflower gardens, and collections of horticultural groups produced by plant breeding, such as roses, tulips, or rhododendrons. A plantation restricted to exhibits of woody plants is called an arboretum.

One of the earliest botanical gardens for the study of plants was established in ancient Athens about 340 BC by Aristotle and run by his pupil Theophrastus. The oldest public botanical gardens in the world are those established at Pisa, Italy, in 1543; at Padua, Italy, in 1545; at Paris in 1635; and at Berlin in 1679. In the 16th and 17th centuries, herbalists cultivated medicinal herbs in private gardens. In 1673, the Society of Apothecaries planted the Chelsea Physic Garden in London to provide materials for research and medicine. The first experimental botanical garden in the United States was established by the American botanist John Bartram near Philadelphia in 1728.

Almost every major city has a botanical garden. The Royal Botanic Gardens, better known as Kew Gardens, near London, founded in 1759, is the largest in the world. Experiments and research done there have led to the transplanting of commercially productive crops, such as rubber, from their native habitats to other parts of the world.

More than 300 botanical gardens are in the U.S. Among the most important are the Missouri Botanic Gardens in St. Louis (1859); the New York Botanical Garden in Bronx Park (1895) and the Brooklyn Botanic Garden, both in New York City. The Arnold Arboretum, established in 1872, is located at Harvard University.

Horticultural in Botanic Gardens

Fruit crops

The temperate, subtropical, and tropical regions of the world all grow important fruit crops. Apples, pears, peaches, plums, nectarines, and cherries are the major temperate fruits. Oranges, lemons, limes, tangerines, olives, and figs are subtropical crops. The leading tropical fruits include bananas, avocados, mangoes, dates, pineapples, and papayas. Small fruits and berries are also widely grown, particularly in temperate regions. Most important are grapes, strawberries, blackberries, raspberries, blueberries, and cranberries.

Nearly all commercial fruit trees are propagated *vegetatively*—that is, without the use of seed (*see* Plant Propagation). Growers take cuttings or buds from the varieties that have desirable fruit qualities and graft these onto seedling rootstocks of the strains selected for adaptation to local soil and climatic conditions and for resistance to root-destroying diseases and insects. In recent years many fruit growers have shifted to the use of "dwarfing" rootstocks to reduce tree size. This procedure makes fruit harvesting easier and less costly, and it permits increased plant density and high yields per unit area of land.

Cultural practices differ for each fruit species, depending on the type of soil, climate, and fertilizer it needs. Close control of insects and diseases is essential in commercial plantings to produce high-quality fruit and profitable yields. Commercial growers began to rely heavily on chemical sprays in the 1960s, but after two decades of accelerating pest resistance and environmental damage, modern growers have shifted toward biological controls and careful monitoring of pest populations, spraying chemicals only at those times when the controls would be most effective (*see* Pest Control).

Most fruit crops are harvested by hand, but commercial fruit growers in the United States and Europe are mechanizing where practical in order to reduce labor and other costs. By the 1980s, mechanical harvesters picked many grape and cherry crops in the United States, and machines were adapted for use on apple and berry crops.

Vegetable farming

A wide variety of herbaceous plants are cultivated for their edible leaves, stems, roots, fruits, and seeds. Vegetables provide important minerals and vitamins in human nutrition and add variety and interest to our meals. Vegetables are grown in environments ranging from city window boxes and home gardens to large commercial farms. More than 40 types are widely cultivated, including leafy salad crops (such as lettuce, spinach, endive, celery, Chinese cabbage), root crops (beets, carrots, potatoes, sweet potatoes, radishes, turnips, rutabagas), cole crops (cabbage, broccoli, cauliflower), and a variety of other types grown for their fruit or seed (peas, beans, sweet corn, squashes, melons, tomatoes).

Many vegetable species, through a careful selection of varieties, can be grown in widely diverse environments. Growers must still be careful, however, to choose varieties adapted to their particular soils and climates. Most of the common vegetable species used for crop farming were developed in temperate regions, but some have been adapted to the Tropics. Tropical vegetables include a variety of root crops (particularly yams and cassava); diverse melons, squashes, and beans; and many kinds of plants grown for their edible roots, leaves and stems.

Vegetable farming, particularly in North America and Europe, changed dramatically in the decades following the end of World War II in 1945. Most fresh vegetables were formerly grown close to population centers by garden or truck farmers and were available only during or shortly after harvest. Canning was the major method of processing. The shift to marketing through chain-store supermarkets, and the development of large food processing companies, concentrated purchasing power among comparatively few buyers who require steady, year-round supplies of uniform-quality vegetables. At the same time, large-scale vegetable production became possible in areas far from major population centers because of rapidly expanding irrigation systems, improved insect sprays and weed control, and the development of sophisticated machinery for planting, spraying, harvesting, and grading.

Since 1980, more than 60 percent of the fresh-vegetable supply in the United States has come from long-season areas, particularly from the states of California, Florida, Texas, and Arizona and from Mexico. Southern Europe and North Africa were expanding as vegetable sources for northern Europe. Local producers are still a substantial source of vegetables in season, but the large southern sources provided the year-round variety of fresh and frozen vegetables that have become commonplace in large market centers. In the early 1980s, rising energy costs for long-distance shipping helped to increase the competitive advantage of small producers close to the markets. Roadside stands, farmers' markets, and "pick your own" farm sales expanded in the 1970s and offer new opportunities for local growers. Farmers' markets remained the major outlet for vegetable growers throughout much of the world, particularly in Asia, Africa, and South America.

Vegetable farming, compared with other types, requires substantial skills and luck to be successful. Growers must be adept at producing high-quality, attractive vegetables that the public will want to buy. They must be knowledgeable about soil preparation, planting and growing crops, weed and pest control, and water management. They must harvest and handle their products carefully to maintain quality, and they must develop and follow well-planned sales strategies. Mistakes, oversights, poor weather, or bad luck can render a vegetable crop unsightly and unsalable or reduce yields below profitable levels.

New and underutilized crops

Most crops today have been bred and cultivated over thousands of years, but new varieties, techniques, and products continue to be developed. At the same time, plant scientists search for new crops among the less familiar plants. A new food crop is triticale, developed as a hybrid of wheat and rye; it can produce high yields of protein-rich flour. T'ef, a cereal from Ethiopia, could be developed for wider use, as could grain amaranth and others.

Guayule, a plant of semiarid lands, has been exploited as a source of a form of rubber; interest in this crop has been renewed in recent years. Buffalo gourd is under consideration as a source of starch, oil, and protein (*see* Gourd). Gumweed, another semiarid plant, is being studied as an animal feed and a resin source, and crambe is under development as a substitute for rapeseed. Paper products are now being made from the pulp of keraf, an annual from eastern Africa. *See* Jojoba.

Energy-producing crops are receiving increased attention as supplies of fossil fuels dwindle. The conversion of plant material to usable energy depends either on direct burning of the material or on fermentation of plant sugars into alcohol. Wood, corncobs, straw, and other fibrous and woody products can be converted directly to energy by burning but are difficult to gather, handle, and transport over long distances. Therefore, current attention is being devoted to crops such as sugarcane and sugar beets that produce large quantities of sugars easily fermented into alcohol. Close behind in potential are starch producers such as corn and potatoes. Available low-cost chemistry can convert these starches into sugars for making alcohol. Other possibilities exist wherever plant materials and crop wastes are produced, but technologies for breaking down cellulose and other plant fibers into sugars for fermentation are complicated and costly at present and need further development before they can be commercially feasible.

Horticulture and Botanic Gardens

Horticulture (Latin *hortus,* "garden"; *cultura,* "cultivation"), science and art of growing fruits, vegetables, flowers, shrubs and trees. Horticulture originally meant the practice of gardening and, by extension, now means the cultivation of plants once grown in gardens. In contrast, the term *agriculture*, by derivation, referred to more open forms of culture such as the production of grains and grasses, known as agronomic crops, which are cultivated on a large scale. The original distinctions have been so blurred that many crops formerly considered either agronomic or horticultural are now categorized sometimes in one field, sometimes in the other, depending on the intended use of the crop. Thus a plant grown for home consumption may be called horticultural; the same plant cultivated for forage is regarded as an agronomic crop.

Horticulture includes the growing of fruit (especially tree fruits), known as pomology; production of vegetable crops, called olericulture; production of flowers, termed floriculture; and ornamental horticulture, known also as landscape gardening, which includes the maintenance and design of home grounds, public gardens and parks, private estates, botanical gardens, and recreational areas such as golf courses, football fields, and baseball diamonds.

Commercial aspects of horticulture

In addition to these four divisions, horticulture is divided into three specialized commercial areas: the nursery industry, the plant-growing industry, and the seed-production industry. The nursery industry produces fruit trees for the fruit grower, and ornamental plants, particularly woody plants, for the ornamental horticulturist. The plant-growing industry supplies annual, biennial, and perennial plants to the vegetable and flower grower as well as to the ornamental horticulturist. The seed-growing industry produces the seed required for flower and vegetable growing. Bulb production, a major industry in the Netherlands, is commonly associated with both the plant-growing and seed-growing industries.

Horticulture became a major industry during the 17th century, in a period when the growth of large cities made it impractical for individuals to produce necessary garden crops on their own property. Only a few horticultural crops had been grown previously on large acreages, the most important being the grape, olive, date, and fig. The most advanced countries in the field of modern horticulture are the following: in Europe, the Netherlands, Germany, France, Belgium, and Great Britain; in the Americas, the United States; in Africa, South Africa; and in Australasia, Australia, Tasmania, and New Zealand. In recent years Japan, China, and the countries of the former Soviet Union have extended their horticultural crop production. Even crops that have been grown since ancient times, such as coffee, tea, bananas, and vanilla, are presently cultivated by modern horticultural techniques.

Scientific aspects of horticulture

The science of horticulture, its primary concerns being maximum yield and superior quality, utilizes other sciences such as genetics, physiology, mathematics, chemistry, physics, and botany. Horticulturists trained in genetics are responsible for most of the improvements in fruits and vegetables and for the production of new varieties. They also develop new strains of plants that resist diseases and insects. Physiologists have succeeded in improving the quality of fruits and vegetables, in extending their storage life, in bettering the techniques of propagation, and in controlling weeds, nutritional deficiencies, and the amount of growth. Mathematicians appraise horticulture, with computers providing research evaluations as well as permanent data records. Chemists, particularly biochemists, have advanced the understanding of plant-growth processes, permitting horticulturists to develop plants that can utilize their environments more effectively. Biochemists, by studying such problems as winter hardiness and drought resistance, have aided in developing plants able to withstand unfavorable environmental conditions. Physicists have provided solutions to certain problems involving the crotch angles in trees; the shapes of shrubs, hedges, and screens; planting techniques; and ways in which plants can be modified to withstand heavy loads of snow and ice.

Horticultural organizations

Various organizations provide the public with information on methods of propagation and culture as well as on control of plant diseases and pests. They are typically composed of amateurs and commercial growers and dealers concerned with the breeding of a specific flower. The American Rose Society, for example, tests the many rose varieties produced by commercial and amateur horticulturists; their work has led to a tremendous expansion of the geographical area favorable to the growing of roses in the U.S.

Scientific information and research are collected and disseminated by organizations such as the Royal Horticultural Society of Great Britain, the American Society for Horticultural Science, and the American Horticultural Society. Several technical organizations have been formed to supply scientific information to horticulturists all over the world. In the U.S., federal and state agencies furnish such information; nearly every state experimental station includes a department devoted to horticulture.

Conclusions

- Botanic gardens are as old as humanity and have played a crucial role in the development of ornamental plants over the years
- Germplasm conservation is receiving attention in order to ensure that important plant species are not lost
- The conservation of biodiversity needs the involvement of communities
- The biotechnology principles depend on the genetic diversity of organisms where raw materials are obtained.

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Feedback

Question: ***How should conservation of plant species adapted to areas within ecological conditions different from those around Maseno be handled?***

Answer: Plants from ecological conditions different from those around Maseno could be conserved in appropriate areas by establishing subsections of the Maseno University Botanic Garden in those areas, or use in situ conservation.

Question: ***Have you already as a Botanic Garden applied for affiliation to the Botanic Garden International at Kew?***

Answer: Yes, application has been done and membership began in 2004.

Question: ***Are you working together with seedbanks for long-term storage?***

Answer: Yes, there are different partners in the project and we are working together with international seed banks.

Question: What is the pest/disease situation in botanical gardens?

Answer: We have not yet experienced any since the garden is quite young.

Performance of African kale (*Brassica carinata*) to intercropping with other Indigenous Vegetables

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Abstract

The use of African indigenous vegetables (AIVs) among the many communities has gained widespread popularity. These vegetables have a wide range of usage that include provision of food, medicine, income and employment. Despite this, their potential in food security and poverty alleviation has not been exploited. Production is constrained by lack of good seed quality, poor farming systems and practices. Traditionally these crops have been found in the wild or grown as intercrops with other indigenous vegetables or with staples especially cereals and rarely occupy a significant portion of land. However there's hardly any study reported on intercropping African kale with other AIVs to ensure full exploitation of the vegetables. Intercropping as a farming system increases agricultural biodiversity controls weeds, pests, and diseases and increases productivity. The lack of information however, has equally made it rather difficult to determine the most suitable intercrop. The main objective of this study was to evaluate the suitability of intercropping African kale with slenderleaf, cowpea, African nightshades, and spiderplant. The study was conducted at Maseno University horticultural research farms during the long rains of 2005 (March- August 2005). Seeds were sown directly into the fields after ascertaining viability. The experiment was laid out in a randomized complete block design (RCBD) with five treatments replicated three times. The treatments were T1= African Kale, T2= African kale/slenderleaf, T3= African kale/Cowpea, T4= African kale/Spiderplant, and T5=African kale/African nightshades. Growth and biochemical measurements were taken regularly and this included plant height, leaf number; stem diameter, branch number, canopy spread, leaf area, leaf yield/edible portion, horizontal and vertical root lengths, and chlorophyll determination. Intercropping African kale with the other four indigenous vegetables had no significant effect on plant height, leaf number, branch number, stem diameter, land equivalent ratio (LER) and vertical root length. However intercropping had a significant effect on chlorophyll content, leaf area, leaf yield, canopy spread and horizontal root length. African kale intercropped with cowpea, and African kale intercropped with African nightshade showed a better performance compared to the other intercrops. This could be due to less weed infestation, better moisture conservation and stiff competition.

Key words: African kale, African indigenous vegetables, and intercropping

Introduction

African indigenous vegetables (AIVs) are those vegetables whose natural home is Africa and therefore Africa is referred to as their primary or secondary centre of origin. Some of the identified African indigenous vegetables include cowpea (*Vigna unguiculata*), slenderleaf (*Crotalaria ochroleuca*), African nightshade (*solanum scabrum, S. villosum, S. eldoretianum, S. americanum*), spiderplant (*Cleome gynandra*) and African kale (*Brassica carinata*) (Schippers, 2000; Maundu et al., 1999; Guarino, 1997; Mnzava, 1997**).** These vegetables are important as they provide nutrition, medicine, cultural equity, employment opportunities and agronomic advantages. Limited research reports have indicated that indigenous vegetables have a high nutritive value (Onyango 2002). They are also a source of medicine, either through their action after consumption or through the use of their other plant parts (Chweya and Eyzaguirre, 1999; Mnzava, 1997). These vegetables have also been at the forefront in the provision of food security, particularly during famines or natural disasters and as a source of income and employment generation to the majority of communities.

Inspite of the great potential attributed to these vegetables the emerging production constraints have not been favourable to sustain them. Apart from limited research, the production has been hampered by various constraints which have included limited land, tedious preparation, processing and poor marketing, lack of production and utilization packages, financial inability, poor seed quality, and inadequate dissemination of existing technology to the farmers in a user friendly manner. The current competition for land by the various land use activities leading to fragmentation of the available small pieces of land has not helped either. It has only enhanced the decline in food production and to an extent the AIVs are no longer gathered from the wild. The scenario is set to worsen further with the increasing population growth and therefore calls for an urgent reexamination of the present farming systems. Intercropping, as a farming system could be a viable alternative because diversity in time and space will ensure sustainability. To take advantage of the differences in demand for nutrients, water and sunlight among the individual crops, Intercrops can be planted with crops having different maturity dates.

Intercropping involves growing two or more crops in the same field at the same time. Some of the benefits associated with intercropping include; control of soil erosion, control of pests and diseases, maximum use of available soil moisture, light and plant nutrients, suppression of weeds, increased production per unit area of land and minimized risk of crop failure (Baumann *et al.*, 2000; Saree, 1996; Liebman *et al.,* 1993; Richards, 1983**)**. However, high total cost of production per acre, and greater management of time, and skills can hamper intercropping (Bley, 2003; Liebman *et al*., 1993). In order to assess the benefits of intercropping the land equivalent ratio (LER) is calculated. Land equivalent ratio (LER) compares the yields from an intercrop with the yields from a pure stand (LER=intercrop1/pure crop1+intercrop2 /pure crop2) at the same level of management. When the LER is one, there is no advantage to intercropping over sole cropping while a LER < 1, means that more land is needed to produce a given yield by each component as an intercrop. A LER greater than one shows that intecropping is advantageous and thus suitable (Willey, 1979).

Objective of the study

To evaluate the suitability of intercropping African kale with slenderleaf, cowpea, African nightshades, and spiderplant

Materials and methods

Study site

The study was carried out at Maseno University horticultural research farms during the long rains (March-August) of 2005. Maseno University is located on the equator, 30 km Northwest of Kisumu city in Nyanza province at 34^{o} 37′ East and 0^{o} North at an altitude of about 1560 metres above sea level (Otieno *et al*., 1993).

Long-term average rainfall data measured in Maseno town is 1630 mm per annum. Soils are ferralsols, acrisols and lixisols, with a fairly acidic pH in water of 4.5 to 6.5 (Otieno *et al*., 1993; GOK, 2002). The soils are also deep, very deficient of P and N and have a moderate P fixation (FAO, 1990). Mean annual day temperature is 20^{o}C with the average maximum daily temperature not exceeding 31^{o}C and the average minimum night temperature not dropping below 15^{o}C (Otieno *et al*., 1993; GOK, 2002).

Planting material and cultural practices

Seeds of African kales, Slenderleaf, spiderplant, cowpea, and African nightshades were used for propagation. The seeds were collected from the Maseno University Botanic garden, and rural outreach program (ROP).. The seeds were subjected to germination tests to ascertain viability and vigour in the laboratory. Seeds with the highest germination percentage and vigour were then selected for field experiments. Thirty seeds of each vegetable were placed in moist filter papers inside petri dishes; the petri dishes were covered using their lids to minimize microbial contamination and water loss. The tests were replicated three times to ascertain a suitable viability of 80% and above. The filter papers were kept moist until the seeds germinate. Observations were made on the number of seeds that had germinated and the germination % calculated which helped in determining the seed rate that was used during sowing. The vigour of the seeds was determined by calculating the mean germination time (MGT) as follows:

$$MGT = \frac{\Sigma(fx)}{\Sigma(f)}$$

Where: f is the number of newly germinated seeds at a given time (day)

x is the number of days or hours counted from the day of sowing.

The experimental plots were cultivated to a fine tilth by deep ploughing and harrowing. Farmyard manure was then incorporated into the plot a week before planting and seeds of vegetables were directly planted according to the treatments. For all the vegetables in both the intercropped and sole cropped plots, seeds were drilled in rows spaced at 30cm a part and covered with fine soil till seedling emergence. Four weeks after seedling emergence plants were thinned to leave 20 cm within rows. Cultural practices such as pest and disease control, weeding, watering and harvesting were carried out throughout the experimental term to ensure optimal plant growth.

Experimental set-up and treatments

The experiment was laid out in a randomised complete block design (RCBD) with 5 treatments replicated three times. In each block there were five plots each of size 3 m x 2 m corresponding to an area of 6.0 m^2 separated from each other by a space of 0.5 metres and plots were also separated by a space of 0.5 metres. This arrangement gave a total of 15 plots arranged in three blocks in a total area of 12 m by 10 m.

Treatments

Treatment 1 African kale

Treatment 2 African kale/ Slenderleaf

Treatment 3 African kale /cowpea

Treatment 4 African kale/ spiderplant

Treatment 5 African kale/ African nightshades

Sampling and data collection

Two plants of African kale and two plants of the intercrops were chosen at random per plot and tagged. The tagged plants were used for the measurement of the parameters studied throughout the experimental period. Data collection commenced four weeks after planting (at thinning time).

Growth measurements

Both non-destructive and destructive growth measurements were taken on both the intercrop and African kale. Non-destructive measurements were taken weekly on plant height, leaf number, branch number, canopy spread and stem diameter per plot for a period of 14 weeks. This was taken on the two plants per plot that were tagged so that all non-destructive growth measurements were done on the same plants.

Plant height: This was measured using a metre rule, by measuring the length of the fresh vegetative shoot from the stem base to the growing shoot apex.

Leaf number: This was determined by counting the emerged, fully expanded leaves including senesced leaves. The leaves counted included the ones on the main stem and also on the main branches.

Branch number: This included all side or axillary branches emerging from the main stem.

Stem diameter: This was measured using a pair of verniar calipers from the soil surface.

Canopy spread: This was measured using a meter rule by measuring the length of the widest leaves that formed the canopy.

Plants were harvested for destructive measurement, which included leaf area, plant and leaf fresh weights and plant dry weights. This was done at thinning and subsequent measurements were taken after every two weeks till all the vegetables had flowered and fruited on two guarded plants to avoid border effect. Seed yields were estimated using two plants at the end of the crops life cycle (4-6months) and also from the whole plot.

Leaf area measurements: This included tracing freshly harvested leaves over a graph paper and its area calculated by counting the squares that were occupied by the leaves, and this determined the total leaf area per plant.

Leaf Fresh weights: Plants were uprooted and leaves harvested before weighing**.** The leaf fresh weights were then used to calculate land equivalent ratio (LER) as follows:

LER=intercrop1/pure crop1+intercrop2 /pure crop2.

Seed yield: The dry seeds of slenderleaf, cowpea, spiderplant and African kale were harvested when the fruits were ripe and not dry, these were then dried under sun for 2-5 days and then threshed. The seeds were further dried under direct sun for 3-5 days till the moisture content of 7% or below had been attained. This was ascertained by using a moisture content meter. Seeds were placed on a moisture content meter and by crushing them the meter then indicated the moisture content of the seeds. The weights of the seeds were then taken and seed yield per plot estimated.

For nightshades wet seed processing was done, it involved picking fully ripe berries squeezing them in a bucket of water and then fermenting them for 2-4 days. The seeds were then washed and rinsed thoroughly till the seeds were free of the flesh. The seeds were dried under shade for 4 days after which they were sun dried for another 3-5 days or until the moisture content was less or equal to 7%. The seeds were then weighed and seed yield per plot estimated this was also used to calculate the LER. Counting 1000 seeds and weighing them using an analytical balance determined the 1000 seed weight of each of the species.

Biochemical measurements

This involved measuring the chlorophyll content using the method of Arnon (1949) and Coombs *et al*., 1987 as described by Netondo (1999). The uppermost fully expanded compound leaf was randomly sampled from all treatments and placed in polyethylene bags and taken to the laboratory for extraction. In the laboratory 0.5 grams of the fresh leaf tissue was measured and cut into very small pieces and put into a specimen bottle. 10 ml of 80% acetone was added and then the set-up was kept in the dark for 7 days for chlorophyll to be extracted by the acetone. 1 ml of the filtered extract was then diluted with 20 ml of 80% acetone, and the absorbance (D) of the chlorophyll solution was measured using a spectrophotometer at 645 and 663 nm. The absorbance was then used to determine chlorophyll a (chl a), b (chl b) and also the total chlorophyll (tchl) of the leaf tissue. The respective chlorophyll content in milligrams (mg) of chlorophyll per gram (g) of leaf tissue was then calculated as follows using the formula of Arnon (1949).

Mg chl a/g leaf tissue= 12.7 (D663) –2.69 (D 645) x V/1000 x W

Mg chlb/g leaf tissue= 22.9 (D645) -4.68 (D663) x V/1000 x W

Mg tchl/g leaf tissue= 20.2 (D 645) + 8.02 (D663) x V/1000 x w

Where: D = the absorbance measured at wavelength 645 & 663 nm,

V = the volume (ml) of the acetone extract;

W = the fresh weight (g) of leaf tissue from which the extract was made.

Root interaction studies

Root systems of the AIVs were excavated by digging around each plant within a radius of 20cm at various depths of 15cm, 20 cm and 30cm. Soil was removed using a trowel and a panga. Soil around the roots was washed and only roots with a diameter of 1mm were considered. The total root length horizontally and vertically downwardly oriented was measured using a meter rule.

Data Analysis

The data collected on African kale was subjected to the Analysis of variance (ANOVA) to indicate whether the intercrop treatments had a significant effect using F –test at 5% and 1% levels on all variables. After significant effects of treatment had been determined, multiple comparisons were calculated to separate the means of the variables, using the least significant differences (L.S.D $_{5\%}$). Land equivalent ratio (L.E.R) was also calculated to find the suitability of intercropping African kale with other indigenous vegetables.

Results

Seeds of African indigenous vegetables for the study were sourced from ROP (Rural Outreach Program) and Maseno university botanical garden. They showed a high percentage germination of over 80% and a mean germination time of approximately 2 days. This result agreed with the field observations that showed a germination percentage of about 98% 8days after sowing.

Effect of intercropping on plant height, leaf number, branch number and stem diameter

Intercropping African kale with other indigenous vegetables had no significant differences ($p>0.05$) in height, leaf number, branch number and stem diameter throughout the experiment as shown in table 1. However there was growth overtime during the experimental period.

Table 1: Effect of intercropping African kale with other indigenous vegetables 14 weeks after planting

Treatment	Plant height (cm)	Leaf number	Branch number	Stem diameter (mm)
African kale	138.2	54	31	13.5
African kale /slenderleaf	121.8	51	26	13
African kale /cowpea	140.3	80	35	15.7
African kale/ spiderplant	93.83	57	29	14.6
African kale /African nightshades	116.17	66	29	15.2
Significance	ns	ns	ns	ns
$LSD_{5\%}$	-	-	-	-

From the above table African kale intercropped with cowpea had the highest height, while African kale intercropped with spiderplant had the lowest height. African kale intercropped with cowpea had a slightly high number of branches and leaves compared to the other crops.

Effect of intercropping on canopy spread

Intercropping African kale with other indigenous vegetable has a significant ($p<0.05$) effect on canopy spread four weeks after sowing but become insignificant ($p>0.05$) between five weeks and twelve weeks after sowing. At week 13 and 14 the canopy spread was significantly ($p<0.05$) different as shown in table 2.

Table 2: Canopy spread as affected by intercropping African kale with other indigenous vegetables

Treatments	Week4	Week 12	Week13	Week14
African kale (T1)	9.75	43.08	48.2	39.4
African kale /slenderleaf (T2)	11.67	45	55.33	47.33
African kale/cowpea (T3)	8.17	47.5	40.33	51.75
African kale/spiderplant(T4)	4.75	57.83	61.8	56.4
African kale/A. nightshades(T5)	9.25	57.5	50.67	42.67
Significance	*	Ns	*	*
$Lsd_{(0.05)}$	5.62	_	14.16	11.91

Canopy spread differed from week to week among the intercrops. For example in week 12, 13 and 14 the widest canopy spread was in the treatment where African kale was intercropped with spiderplant, while in week 4 it was the treatment where African kale was intercropped with slenderleaf. The position of the leaves (leaf angle) basically determines the canopy spread and this position is what determines the efficiency of a leaf in trapping sunlight for photosynthesis.

Effect of intercropping African kale on Leaf area

Leaf area was not significantly (p>0.05) affected by intercropping during weeks 4, 6 and 10 but it become significant in week 12 as shown in figure 1.

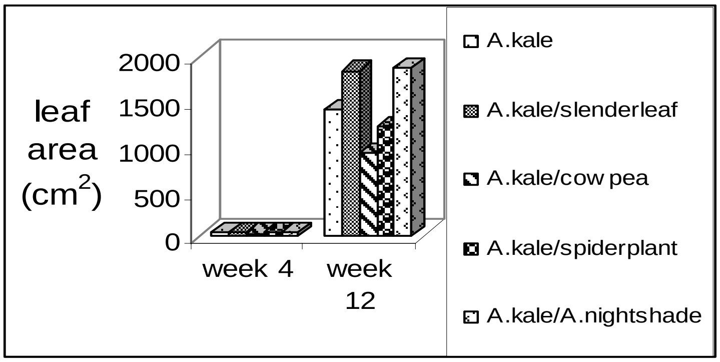

Figure 1: Leaf area of African kale when intercropped with other indigenous vegetables at week 4 and week 12

From figure 1above the African kale intercropped with African nightshade (T5) and African kale intercropped with slenderleaf (T2) had the highest leaf area. Leaf number, canopy spread and leaf area (size) determines the leaf yield, from the results above (table 1) leaf number was not significantly (p>0.05) affected by intercropping. However, African kale intercropped with cowpea (T3) and African kale intercropped with African nightshade (T5) gave the highest number of leaves of 80 and 66. African kale intercropped with cowpea had the smallest leaf area of about 921.5 cm^2.

Effect of intercropping African kale on leaf fresh weight

There was no significant (p>0.05) effect in leaf fresh weight of African kale in all treatments between week 4 and week 11. However in week 12 it was significant (p<0.05) as shown in figure 2. African kale intercropped with slenderleaf and African kale Intercropped with African nightshade had the highest weight. African kale intercropped with cowpea had the lowest weight.

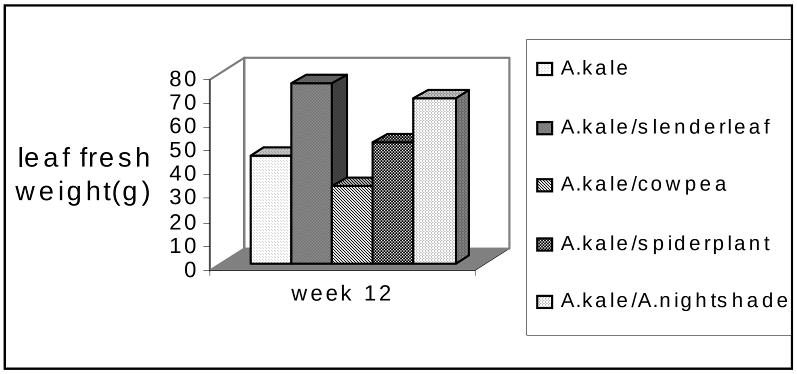

Figure 2: **Leaf fresh weight of African kale when intercropped with other indigenous vegetables 12 weeks after sowing.**

Effect of intercropping African kale on root growth

There was no significant ($p>0.05$) difference in vertical root depth in all the treatments during the experimental period. However African kale intercropped with spiderplant had a deep root followed by African kale intercropped with African nightshade, slenderleaf, cowpea and finally sole African kale. Horizontal root length was significantly different ($p<0.05$) ten weeks after planting. African kale intercropped with spiderplant had the widest root followed by African kale intercropped with African nightshade; sole African kale, African kale intercropped with slenderleaf and African kale intercropped with cowpea had the smallest root length (Figure 3).

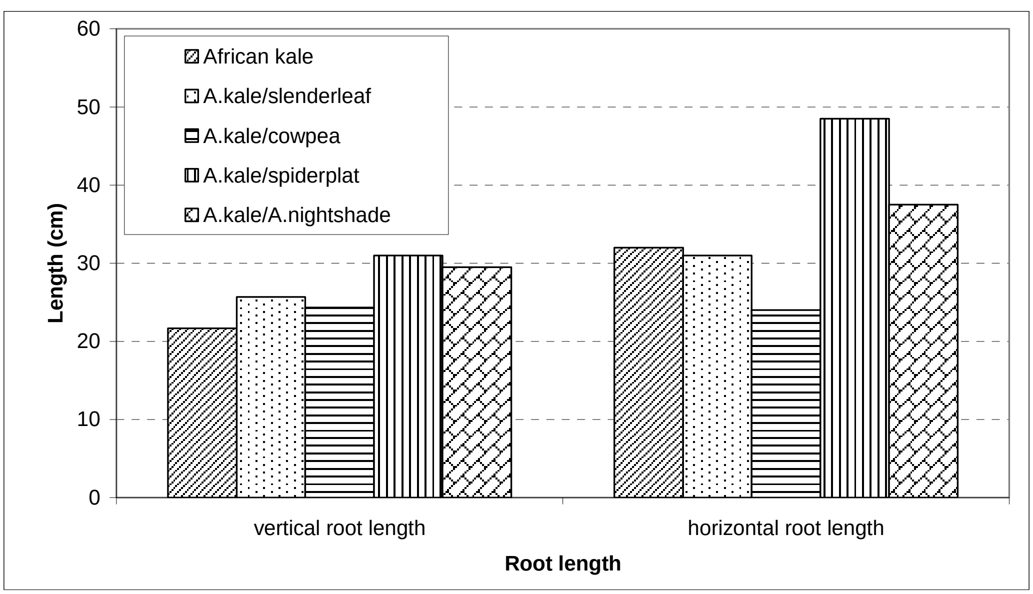

Figure 3: **effect of intercropping African kale with other indigenous vegetables on root growth**

Effect of intercropping on seed yield, 1000 seed weight and land equivalent ratio (LER) of African kale

Seed yield was not significantly (p>0.05) affected by intercropping as shown in table 3. However, the seed yield was affected by stem rot disease and aphids that attacked African kale immediately after it had started to flower. The disease and pest effect was so more pronounced in shorter Kales than in the longer ones. 1000 seed weight of African kale was not significantly (p>0.05) affected by intercropping as shown in table 3 however it varied between 3.65 and 3.15 grams. Sole African kale, African kale intercropped with cowpea and African kale intercropped with African nightshade had slightly high weights of 3.65 and 3.47 grams. African kale intercropped with slenderleaf had a low weight of 3.15 grams. Except for African kale intercropped with spiderplant all treatments (African. kale/slenderleaf, African kale/cowpea and African kale/African nightshade) had LER values greater than one Table 3. This indicates that there were some advantages in intercropping.

Table 3: Effect of intercropping African kale with other indigenous vegetables on seed yield, 1000 seed weight and LER (seed yield)

Treatment	Seed yield/plot (gm/m^2)	1000 seed weight (gram)	Seed yield/plant (gm/plant)	LER (seed yield)
African kale	35.93	3.65	3.02	-
African kale/slenderleaf	6.75	3.15	2.23	1.14
African kale/cowpea	17.3	3.47	1.32	2.51
African kale/spiderplant	8.6	3.35	3.13	0.64
African kale/African nightshade	22.27	3.47	3.25	1.93
Significance level	Ns	Ns	ns	-

Effect of intercropping on biochemical parameters

The concentration of chlorophyll a, chlorophyll b and total chlorophyll decreased over time. Concentration of chlorophyll a ranged from 0.001-0.06 mg chl a/g leaf tissue, while chlorophyll b ranged from 0.005-0.03 mg chl b/g leaf tissue. Concentration of total chlorophyll ranged from 0.007-0.09 mg tchl/g leaf tissue. During the early weeks after planting the concentration was high but not significant (p>0.05) however at week ten the concentration was lower but significant (p<0.05). The field observations made showed very green succulent leaves in the early weeks of the experiment than later.

Discussion

Most edible horticultural crops and bedding plants are grown from seed. In selecting seed to grow, quality becomes an important aspect. The aim is to produce synchronized germination, uniform crop characteristics (e.g. height) and healthy, robust growth. Germination percentages of the five indigenous vegetables varied widely and this variation of performance is called vigour. A germination percent of greater than 70% and a mean germination time of approximately 3 days could imply that the seeds are both of high viability and vigour. In general from this experimental result growth, and biochemical parameters have shown that intercropping indigenous vegetables has some effects on the parameters and this agrees with the reports of intercropping of African nightshade with tea (Maritim, 2005), and intercropping soybean with maize (Wekesa 2001).

Effects of intercropping on plant Growth.

Plant height increments help a plant to compete with other plants in a community. The non-significance in plant height of the indigenous vegetables could be due to sufficient or ideal plant growth conditions, such that no competition for nutrient, light, water, and space was experienced. Leaf growth is a part of the total dry matter accumulation and leaf itself is the part of the dry weight of a plant. The parameters used to measure leaf growth included leaf number, leaf fresh weight and leaf area. Leaf number showed non-significance during the experimental period, this could be attributed to minimal competition for light, water, nutrients and space. Another reason could be the genetics of the species, maybe due to ideal environmental conditions the leaf primordia were produced at a constant rate. As the plant increased in size, larger meristematic regions (division area) per plant existed and more leaves were present to act as photosynthetic energy source.

Photosynthesis and dry matter production of a plant are proportional to the amount of leaf area on the plant and as long as some leaves are not heavily shaded by others. Leaf area in week 12 was significantly ($p<0.05$) affected by intercropping; the size of leaves could be attributed to genetics and the environment. The rate of increase of leaf area determines the rate of increase in photosynthetic capacity of the plant, by week twelve all the African Kales had reached maximum leaf production and hence the maximum photosynthetic capacity. However the environment could have modified the genetic potential of African kale. Slow growth rate of African kale relative to large plants could be attributed to the relatively small number of cells that could divide, the small leaf area available for light interception and photosynthesis and perhaps to the relatively large percentage of photosynthates going to the roots. Normally African kale takes just over two months to produce seed from seed (Schippers, 2002) but in this case it took three months, indicating slow growth.

Intercropping African kale with other indigenous vegetables on branching did not show any significance differences. Branching is usually affected by genetic and environmental factors. Buds (axillary buds) for branching are always there; however the environment could inhibit production of plant growth regulators (hormones) responsible for branching (especially the auxins). It is also important to know that the genotypic potential for number of leaves is same as that of number of branches. However spacing could prevent buds from producing branches due to less light penetration (Meyer et al., 1986). The taller Kales were observed to have less branches this observation is in line with Salisbury and Rose (1986) who observed that plants that increased their height by having longer internodes did not form axillary branches. This adaptation enabled the plants to conserve energy and mobilize it towards stem elongation. Intercropping African kale with other indigenous vegetables did not have any significance with regard to stem diameter. Increase in stem thickness is initiated by lateral meristems (usually the secondary growth) and it's initiated by the cambium.

Canopy spread showed significance differences ($p<0.05$) when African kale was intercropped. The canopy spread determines the position of leaves (leaf angle) and this position is what determines the efficiency of a leaf to trap light for photosynthesis. The horizontal leaves in African kale had large surface area with fewer leaves, while upright leaves had more leaves and thus intercepted much light. Intercropping had no significant effect on vertical root growth, but had an effect ($p<0.05$) on the horizontal root length. This could be attributed to enough space downwards and hence less competition for nutrients and space. In the horizontal root length African kale intercropped with spiderplant had the widest roots, this could be due to lack of competition for space, water, and nutrients. African kale had all the time to grow because spiderplant only took eight week to mature and produce seed.

Seed yield was not significant ($p<0.05$) during the experimental period; this could be attributed to several factors. One of the major factors could be the stem rot disease and the masses of green aphids observed immediately after African kale had started to flower. Due to the attack by pest and diseases, most leaves senesced prematurely, before retranslocating the photosynthates to the reproductive organs such as flowers and fruits. Decline in growth rate near maturity was also another factor. This could be attributed to several factors such as change from vegetative to reproductive phase. As plants become older, a large portion of the plant structure becomes inactive. In leafy vegetables like spiderplant, cowpea, slenderleaf, African kale and African nightshades the length of the vegetative phase is very important (Chweya, 1997). The longer the vegetative phase the higher the expected leaf yield (Chweya and Mnzava, 1997). However leaves become heavily shaded or non-photosynthetic due to senescence. Leaves fall from plant and represent loss of dry weight. Large portions of the plant may be comprised of stem or other tissue relatively low in metabolic activity and therefore not contributing to growth. In addition competition from neighbouring plants for water, light and nutrients may have caused a reduction in growth rates when African kale in crop stand become large (big).

The land equivalent ratio (LER) for seed and leaf yield was not significant ($p<0.05$) even though it was greater than one for all treatments except for African kale intercropped with spiderplant (seed LER=0.64). Even though yield was not significant the LER greater than one showed that intercropping had other benefits. The non-significance response of intercropping African kale to percentage water content by weight indicated that the plants had enough water and thus little competition for water and no moisture stress.

Effect of intercropping on Biochemical parameters

The photosynthetic capacity of a plant is determined by several factors including photosynthetic pigment composition (including chlorophyll content), co_2 fixation capacity, light intensity, and the activity of various enzymes (Netondo, 1999). Furthermore the efficiency of light captured to drive photosynthesis is directly correlated to the chlorophyll concentration in leaf tissue (Netondo, 1999). It therefore follows that the decline in chlorophyll a, chlorophyll b and total chlorophyll after twelve (12) weeks when it was significant ($p<0.05$) contributed to the reduction in photosynthesis and ultimately in plant growth. Some of the important Biochemical changes are change in synthesis of protein, nuclei acid, phospholipids multiplication of organelles and utilization of energy in the form of ATP. The reduction of chlorophyll content in week 12 could also be attributed to the reduction of the above biochemical changes. This is because nitrogen is the main component in the formation of all these biochemical processes however, due to change from vegetative to reproduction and due to depletion of macronutrients the nitrogen content must have decreased. The fact that the earlier leaves were very green while the later formed leaves were pale green also indicates low chlorophyll and nitrogen content.

These preliminary results are not conclusive and therefore the study is been repeated in the field during the short rains (October 2005-February 2006) to ascertain these findings.

Conclusion and Recommendations

- Intercropping African kale had no significant effect on plant height, leaf number, branch number, stem diameter, vertical root length, seed yield, and land equivalent ratio (LER). However it had significant effect on canopy spread, leaf area, plant, leaf, and dry weights and horizontal root length
- Intercropping African kale had a significant effect on chlorophyll content even though the chlorophyll content decreased over time.
- African kale intercropped with cowpea, spiderplant and African nightshades performed better than sole African kale and African kale intercropped with slenderleaf. Therefore a suitable intercrop for African kale is cowpea, spiderplant and African nightshade.

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Feedback

Question: ***What interactions did you expect from the individual intercrop combinations, which you chose?***

Answer: Farmers in western Kenya plant a lot of AIVs. These vegetables are planted randomly in the field and if a suitable intercrop is not found most farmers will plant crops that suppress or hinder growth of other plants.

Question: ***If it is true as you report that the LER values were not significant why did you still conclude that intercropping was advantageous? In other words if your interpretation is that intercropping was beneficial because LER values were >1.0, did you do any statistical test to check if they were significantly greater than 1?***

Answer: LER is calculated by the formula: pure crop x/intercrop x plus pure crop y/intercrop y. If the ratio is >1.0 even before subjecting to statistical test it is advantageous through weed suppression, maximum utilization of light, nutrients, water and space. Thus after subjecting to statistical test and find that it is not significant, don't condemn intercropping but utilize the other advantages.

Preliminary Assessment on Seed Polymorphism and Germination of Kakamega and Arusha Accessions of *Vignia subterranean*

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Abstract

Bambara groundnut, *Vignia subterranea* (L.) Verdc. also *Voandzeia subterranea* (L.) Thousars., is a common pulse crop cultivated in most parts of Western and Coast Provinces of Kenya. Despite its high food and economic value, augmented by high demand and good market prices, it largely remains underutilized. The priority of bambara groundnuts to farmers in western Kenya remains extremely low, owing to expensive and unavailable authentic seed. There is an acute dearth of data on bambara groundnut seed quality tests. Given the emphasis placed on ensuring household food security, particularly in the rural parts of Kenya, the long-term goal of this study was to draw attention on the potential of bambara groundnut, with a focus on improving and popularizing its productivity and utility, respectively. This paper reports on the preliminary evaluation of seed characters and germination vigour of bambara groundnut accessions collected in Kakamega and Arusha districts of Kenya and Tanzania, respectively. A collection of nine accessions, comprising the red, dark and cream-seeded varieties, was subjected to laboratory and field evaluation to assess their comparative seed characters and germination vigour. The accessions were evaluated for seed polymorphism by determination of seed length, thickness, width and weight. Germination vigour was determined through germinating seeds in Petri dishes, in sterile soils on trays, and in the field. Germination was performed at 20°C, 25°C and 35°C to simulate the natural temperature conditions experienced in the bambara growing regions of Kenya. The seeds sown in field plots were assessed for variation in percent germination. Variation was noted in the parameters evaluated. Among the seed polymorphism attributes assessed, seed weight recorded the highest variation, followed by width and length. Average seed length variation among accessions was low. The average of seed characters observed were as follows: 36.3-57.9g per 100 seed-lot for seed weight; 7.64-8.6 mm for seed width; 9.71-10.61 mm for seed height, and 7.69-8.63 mm for seed thickness. The characterization and evaluation of these bambara groundnut

accessions revealed great seed morphological diversity, which can be used for crop improvement. Experimental data across the three seed varieties indicated that the dark-seeded accessions have more vigour than the red or cream-coloured ones.

Key words: Bambara, groundnut, seed, polymorphism, vigour

Introduction

Bambara groundnut (*Vignia subterranean* L. (Verdc)) also *Voandzeia subterranea* (L.) Thouars, has many common names in Kenya such as njugu-mawe (Swahili), bande (Luo), tsimbande (Luhya), nzugu mawe (Giriama) and tendegwa (Kamba). It is a popular crop in the whole of sub-Saharan Africa. In Kenya it is widely cultivated in Western and Coast Provinces.

Bambara groundnut is a herbaceous, intermediate, annual plant, with creeping stems at ground level. According to Goli (1995), differences in the length of internodes result in bunched, intermediate (semi-bunched) and spreading types. The general appearance of the plant is bunched leaves arising fro m branched stems which form a crown on the soil surface. The plant has a well-developed root from which nodules for nitrogen fixation develop in association with rhizobia. Leaves are pinnately trifoliate, glabrous with erect petiole thickened at the base. Flowers are borne on hairy peduncles arising from stem nodes. The pods usually develop underground. Mature pods are dehiscent and often wrinkled. Various test colors and patterns are recognized.

Bambara nut is grown for human consumption. The seed contains sufficient protein, carbohydrate and fat (Linnermann, 1987), making the crop ideal for alleviating food insecurity. Seeds contain 60-63% carbohydrate, 14-24% protein and 6–12% oil. The protein is higher in the essential amino acid methionine than other grain legumes. Gross energy value of is greater than most common pulses including cowpea, lentil and pigeon pea (FAO 1982).

Bambara groundnuts are prepared and consumed for various purposes in an array of ways. They can be eaten fresh or grilled while still immature. The seeds harden on maturity and therefore require boiling to make a sweet and pleasant taste. In Kenya, each community has its own way of preparing bambara groundnuts. The Giriama at the coast utilize it when vegetables are in short supply. The seeds (fresh or dry) are pound to remove the seed coat, winnowed, boiled and stewed for serving with 'ugali' or rice. The Luhya have many preparation modes including; cooking fresh in pods, roasting, stewing pounded seed, and boiling alongside maize and beans. In many West African countries, the fresh pods are boiled with salt and pepper and eaten as snacks. In Cote d'Ivoire, the seed is pounded to make floor used to prepare stiff porridge (Holm and Marloth, 1940). Roasted seeds can also be boiled, crushed and eaten as a relish. In Nigeria according to Obizoba (1983), a paste made out of dried seeds can be used to prepare steamed products such as 'akara', 'okpa' and 'moin-moin'. In Ghana the product is available the whole year round as canned in gravy (Bagemann 1986).

Brough et al. (1993) reported on the comparative milk flavor and composition prepared from bambara groundnut, cowpea and soybean. In this trial, bambara groundnut milk was ranked first due to acceptability and light colour.

Bambara groundnut has use as animal feed. The groundnut is successfully fed to pigs and poultry. The seeds have been used to feed chicken (Oluyemi et al. 1976). The haulms are a valuable cattle feed. Bambara groundnut leaves are suitable for animal grazing due to the rich content of nitrogen and phosphorous (Rassel, 1960).

In Kenya, bambara groundnut cultivation is very low compared to other African countries. Most of the cultivation is generally found in agro climatic temperatures I-3, I-4, II-3, II-4, III-1, III-3 and VI-1, VI-1 and VII-1 at the coast (MOENR, 1994). Total land acreage under bambara groundnut cultivation in 1994 was only 229 hectares (Ngugi, 1994). In most regions, the major constraint to cultivation is expensive and unavailable planting seed. Otherwise the crop has a good potential especially in Western province.

The long-term objective of this study is to select cultivars adaptable to different environments and improve productivity through sustainable cultivation practices. This paper reports on the preliminary findings of the comparative evaluation of selected bambara groundnut accessions collected in Kakamega and Arusha districts in Kenya and Tanzania, respectively.

Materials and Methods

Seed collection

Bambara groundnut seeds were collected from five localities. Seven accessions were collected in various regions of Western Kenya while 2 were from Arusha. The accessions were given code numbers 1-9 for reference purposes. The collected seeds had different physical attributes. Table 1 gives a summary of the ecogeographical information of the accessions.

Table 1: Ecogeographical data for cultivated populations of Bambara groundnut studied

Code	Population	Sampling site	Country	Morphological features
1	K-1b	Mumias	Kenya	Black testa, white eye
2	K-3b	Eregi	Kenya	Black testa, white eye
3	K-3a	Eregi	Kenya	Red testa, white eye
4	K-2b	Bukura	Kenya	Black testa, white eye
5	Aru-2	Arusha	Tanzania	Cream testa, white eye,
6	Aru-1	Arusha	Tanzania	Cream testa, black eye,
7	K-2a	Bukura	Kenya	Red testa, white eye
8	K-4a	Khayega	Kenya	Red testa, white eye
9	K-4b	Khayega	Kenya	Black testa, white eye

Seed polymorphism

Seeds were dried in the oven at 35° C for 24 hrs to create uniformity in moisture content. To determine the seed length, width and thickness, 25 randomly selected seeds in four replicates were chosen to make an experimental unit in a completely randomize design. Make four replications. A pair of vernier calipers was used to measure length, width and thickness of 100 seeds per accession to the nearest 0.02mm. To determine weight, 100 randomly selected clean seeds per accession in four replicates were weighed using a digital balance to the nearest 0.0001g.

Root and shoot growth

Four replicates containing 25 seeds per accession were selected, soaked twice for 5 minutes in sterile 10% sodium hypochlorite solution, rinsed in sterile water for 30 minutes and blot dried. Petri dishes were lined with sterile cotton wool. Batches of 25 seeds were placed in the Petri dishes, sterile distilled water sprinkled to just wet the cotton wool. Petri dishes were covered and incubated at ambient temperature for germination. After 4 and 7 days following incubation, seedlings were randomly selected root and shoot growth. A pair of venier calipers was used to determine the growth of shoots and roots of selected 10 seedlings per Petri dish.

Tray germination trials

River sand was sieved through a 0.08 cm diameter sieve and then washed and sterilized before packing onto trays. 25 seeds per accession in four replicates were selected and planted on a level layer of moist sand in plastic trays. The seeds were covered with 2.5 cm of uncompressed sand. The sand was kept moistened to about field capacity for the duration of the test. 2 trays each were placed in incubators (conditioned with air circulation) at different constant temperatures of 20C; 30C; 35C to reflect the normal environmental conditions of bambara groundnut cultivation regions. After 10 days, the germination percentage, radical and shoot lengths were determined.

Germination under field conditions

Plots measuring 4 x 3 m were used to sow seedlings. Seeds of all accessions were sown at a spacing of 6″ in row and 12″ between rows. Plots were replicated 3 times in a completely randomized design. Data was collected on percent germination 2 weeks after planting. Primary evaluations on the growth characters were done. The parameters recorded included; growth habit (bunch or spreading), color of stem, petiole length and leaflet sizes, plant base spread, number of braches/plant, canopy spread, leaflet length and width. The findings on the collected growth characteristics will be published elsewhere.

Results and Discussion

There were variations in all the physical morphological attributes of the assessed seed accessions. The seed width sizes ranged between 7.64-8.6 mm with an average of 8.2mm. Accession Kak-2a and kak-2b sampled from the same area recorded the highest and lowest width sizes respectively (Fig. 1). The cream seeded varieties from Arusha had the highest average width sizes in comparison to red and dark seeded varieties (Table 2). Observed variation in the average seed length was low with a range of 9.71-10.61mm and a mean of 10.2mm. Accessions kak-2a and kak-2b again recorded the highest and lowest seed lengths respectively (Fig. 2). The difference in the length variation between varieties was also insignificant although the red seeded varieties tended to be longer followed by lack varieties (Table 2). Significant variation was observed in seed weights between bambara groundnut accessions. The cream seeded varieties were heavier than the other accessions (Table 2). The average weights across accessions ranged between 36.3-57.9 g per 100 seed-lot. The cream-colored accession aru-2 and black colored kak-3b recorded the highest and lowest seed weights (Fig. 3). The average thickness of seeds ranged from 7.69-8.63mm with a mean of 8.3mm. The heavier seeds tended to be thicker. In fact, the cream-colored accession aru-2 had the thickest seeds (Fig. 4).

Germination vigor was closely related to germination temperature. As such variations were observed in the % germination rates of similar accessions subjected to different growth temperatures. Generally, germination rate was highest at 20°C (82.8%) followed by 35°C (77.7%) and lastly 30°C (65%). Germination rate for the red bambara groundnut varieties whose mean germination rate was 75.2% had an optimal germination temperature of 20°C followed by 35°C and 30°C (Table 2). The dark colored varieties recorded the highest mean germination rate (82.5%), which was above the average germination (Table 2). In this variety higher temperatures seemed to enhance germination. In fact, germination rate was highest at 35°C (90%). The germination rate of the dark varieties was very good (82.3%) with well above average % germination of all the soil trials (77.1%). Generally the germination of the cream colored accessions was comparatively low with a cumulative % germination average of 69.6% that was well below the calculated cumulative average for all accessions and temperatures. High germination rates have been reported in dark colored varieties of Zimbabwe (Zengeni and Mupamba, 1995). The germination for accession aru-1 was very low at lower temperatures due to seed-borne fungal infections (data not shown). The aru-1 trials were all infected. In fact, tangible growth was only achieved when seeds were subjected to sterility using very high concentrations of sodium hypochlorite solution.

The evaluated bambara groundnut accessions displayed variations in the germination rates at different temperatures. At 30°C accession kak-1b had the greatest germination rate at 87.5%

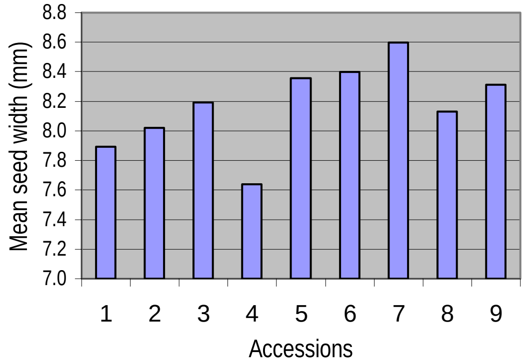
followed by kak-4b (85%) while the least was recorded for aru-2 (45%) (Fig.5). At 20°C accessions kak-2a and aru-1 recorded the highest germination rates while aru-2 had the least again (Fig.5). At 35°C kak-1b, kak-3b and kak-4b had the highest rates of seed germination and kak-3a the least (Fig.5). The dark colored accessions seemed to have higher rates of germination in contrast to the red and cream accessions.

The characterization and evaluation of the bambara groundnut accessions revealed great seed morphological diversity which can be used for crop improvement. The dark colored accessions (kak-1b, kak-2b, and kak-4b) that displayed great germination vigor at high temperatures (35°C) could be selected for agronomical suitability trials for agro-ecological areas like Kilifi district at the coast province that experience with high temperatures. Varieties for most parts of western province could do well with the red colored varieties like accessions kak-3a and kak-2a. The enhanced germination capacity of the black seeded varieties could have resulted from operational selection, among other factors.

Bambara groundnut is a promising commodity that needs more publicity, both as a crop and as a food. Even in Kenya, few people in the rural regions recognize its existence. Bambara groundnut is a low cost, dependable crop that grows in harsh environments where many other crops fail. In an effort to popularize consumption and cultivation, its high nutritive value should be made known to the public especially the rural poor. To ensure wider adoption of bambara groundnut, innovative recipes and preparation modes need to be improved. Research on the crop need be enhanced to process and add value to bambara groundnut products.

Table 2: Mean seed characters and germination percentage of the black, red and cream seeded varieties of bambara groundnuts

Parameter	Black	Red	Cream	Mean
Seed width	8.0	8.3	8.4	8.2
Seed length	10.1	10.3	10.0	10.2
Seed weight	41.5	44.5	50.8	44.5
Seed thickness	8.1	8.4	8.5	8.3
% Germination at 20°C	80.6	82.8	71.3	79.3
% Germination at 30°C	76.3	65	62.5	69.4
% Germination at 35°C	90	77.7	71.3	73.6
Mean % germination	82.3	75.2	69.6	77.1



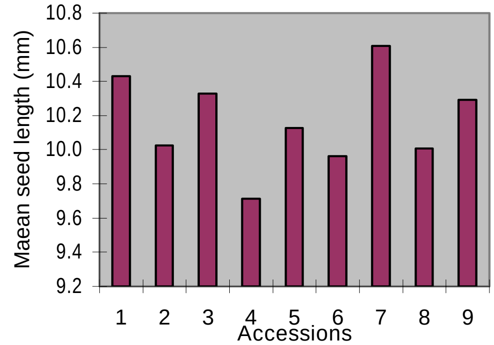
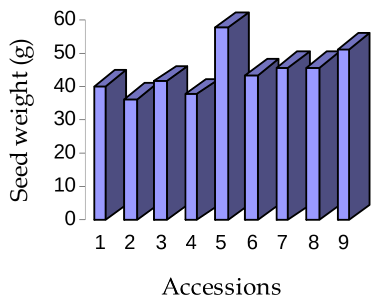


Figure 1. **Mean seed width of bambara accessions and Figure 2: Mean seed length of bambara groundnut accessions**



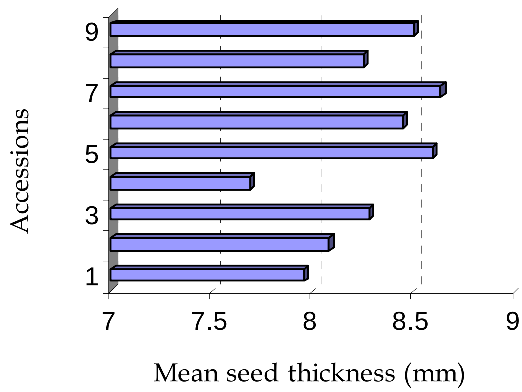


Figure 3: **Mean seed weight of bambara accessions and Fig. 4. Mean seed thickness of accessions**

Conclusions

Seed color is a useful attribute for delineating germination vigor among bambara groundnut accessions. Black seed varieties have generally higher vigor than cream and red colored varieties. Red varieties may be more suitable for cultivation in relatively cooler regions, while dark coloured varieties prefer warmer environments

Recommendations

Bambara groundnut characterization should be expanded to include all the accessions held by farmers in the country. In addition, the application of molecular characters as markers will augment the use seed polymorphic attributes in bambara groundnut improvement.

Collections and exchange of bambara groundnut germplasm should be carried out to fill gaps in the existing collections in the country.

There should be concerted efforts to promote the crop in Kenya, especially among the rural folk. This may be accomplished by use of the locally available genetic resources of bambara groundnut for research, breeding and crop improvement.

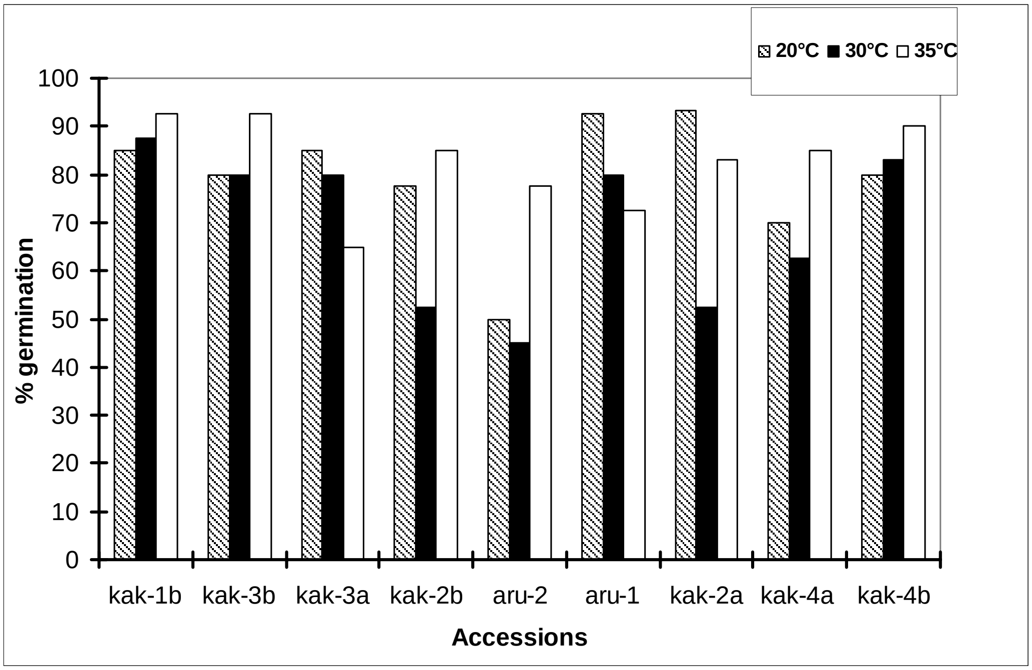


Figure 5: Germination % of bambara accessions at 20°, 30°, and 35°C

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POSTERS

Potential for Organic Macadamia Nut Production in Eastern Kenya: A Case Study of Meru Central District

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Abstract

Small-scale farmers, who intercrop macadamia trees with coffee trees, mainly grow macadamia nut. This study used two-stage purposive random sampling technique and a structured questionnaire to interview 56 macadamia farmers in Meru Central District. Over 25% of the respondents ranked coffee and macadamia as the main sources of farm income, with macadamia contributing on average between 11,000KES to 30,000KES per year. Crop husbandry is minimal; most of the farmers did not use fertiliser on their trees. Approximately 99% of the farmers used manure at initial establishment of the crop, 30% of the farmers applied manure annually during the long rains, and the most frequent rate was 15 kg per tree. The main insect pest problems experienced by the farmers were rodents, macadamia stinkbug and nut borer. The farmers controlled rodents by physical chasing and some trained cats to eat bats. Smoking was used to control macadamia stinkbug and nut borer. The main diseases were root rot and tree dieback and in both cases farmers did not use any control measure. The poor market prices of nuts over the last three decades led to a scenario where farmers paid little attention to their trees. With the current improved prices it is expected that the general management of the trees will improve, thus providing an opportunity to improve and/or explore organic farming practises with these farmers.

Key words: Macadamia, nut, organic production

Introduction

Macadamia nut is an important high value export market cash crop that has experienced tremendous price changes over the last year. Macadamia nuts are eaten raw, roasted, or as edible salad oil. The nuts are increasing becoming important in domestic and external markets and as an ingredient in various confectionery products in the hotel and airline industry. The tree can also be used for ornamental and timber production purposes.

Macadamia nut is an important high value export market cash crop in Kenya. Macadamia nut is mainly produced in Central and Eastern provinces in Kenya; the average production is between 25-28 kg per tree per year which is low when compared to the potential yield of 85 kg per tree per year if the orchards are well maintained (Table 1).

Table 1: Macadamia Production in Meru Central District

Year	Estimated Ha	Estimated number of bearing trees	Estimated production in Kg
1999	360	80,000	320,000
2000	360	83,000	330,000
2001	362	85,000	330,000
2002	365	90,000	350,000
2003	365	90,000	350,000
2004	365	100,000	400,000

Source: Various annual reports, MoA Meru Central. NB: Figures on number of trees are not based on the annual reports but estimates

The national average yield is 28% with only 16% exportable nut and 12% local markets nut. Meru Central district covers an area of 3012 km^2. Over 90% of the total area in the district has arable land 2800 km^2. The main food crops grown are maize, beans and bananas, which cover approximately 1200Ha. Coffee is the main cash crop covering approximately 18,600Ha while tea covers an area of 5,000Ha (MoA Meru Central District). Macadamia production in the district is at approximately 360Ha; the number of producing trees and the estimated production in the kilos has been increasing gradually over the last five years.

The aim of this paper is to report on the potential for organic production of macadamia nuts based on baseline information describing the production situation of the macadamia in Kenya, the use of recommended technologies, yield levels and the various aspects that affect farm production.

Materials and Methods

Survey and desk review methods were used to collect data used in this study. Secondary data was collected from various sources mainly the district and provincial agriculture annual reports. Primary data collection involved the use of two-stage purposive random sampling technique to arrive at the various sampling units. Divisional agricultural officers were used to select a random sample of at least 12 farmers per division. The farmers were interviewed through single visit interviews using a structured questionnaire. Qualitative and quantitative information was obtained from the various sampling units regarding various details of crop management and some household socio-economic characteristics.

Data Analysis

Data were subjected to descriptive statistics using the SPSS programme.

General characteristics of the respondents

A total of 56 farmers were interviewed during the survey 84% of them were male with an average age of 58.2 years. Approximately 76% of the households visited were male headed with wife present. Approximately 12% were female headed with male present, while 6% had divorced female heads of households. Majority of the respondents interviewed (90%) had the main occupation as farming. About 47% were full time farmers, 26% were also involved in church work and business. About 27% were involved in various activities including casual labour and other informal employment (Figure 1). A total of 68% of the respondent had formal education with 15% having tertiary education (Figure 2). Taking into account the average age of the respondents and the education level it would be assumed that most of the respondents were involved in formal employment at some point in time.

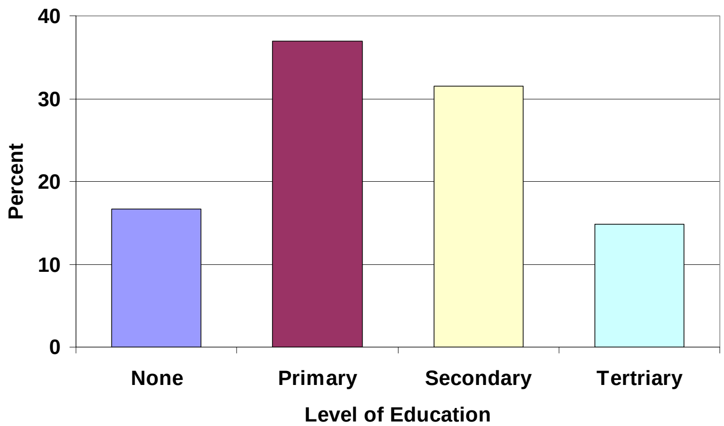

Figure 1: Respondents' level of education in percent based on survey data

Table 2: Location of the farms within the district (km)

	Sample size	Mean	Standard deviation
Distance to all weather road	56	3.37	2.241
Distance to the nearest market	56	4.28	1.974
Distance to the nearest extension office	56	4.87	3.596

Source: Computed from survey data

In reference to Table 2 it is possible to deduce that most of the farms visited are within reach of the necessary communication avenues relevant to macadamia production that is the road, the market and the extension service. How effective this communication link is, a different research question.

Wealth Indicators

About 55% of the respondents had semi-permanent residential houses (timber and stone), while 36% had permanent houses (stone) and 9% had temporary housing type (timber).

Table 3: Other wealth indicators in percent

Response	Sample size	Knapsack sprayer	Milk cow	Ox-cart	Oxen	Vehicle	Water tank	Water pump
Yes	56	84.8	87.0	13.0	19.6	15.2	43.5	4.3
No	56	15.2	13.0	87.0	80.4	80.4	56.5	95.7

Source: Computed from survey data

Most of the respondents had one or more of the following knapsack sprayer, milk cow, oxen and water tank. Most of them did not own vehicles and water pumps. There is however not a need for water pumps in some division because the benefit from the gravitational pull that allows water to flow from Mount Kenya.

Table 4: Land size and usage within the farm households (acres)

Characteristics	Sample size	Mean	Standard deviation
Total land size	56	7.77	7.237
Total land size under food crops	56	1.69	1.467
Total land size under cash crops	56	4.56	5.931

Source: Computed from survey data

Eighty of the respondent had possession of a title deed for the land they owned and only 13% did not. Table 4 shows that, the average farm size in the district is 7.77 acres. Most of the land in farm households in the district is allocated to cash crop production. The main cash crop grown in this area is coffee and in the higher regions of the district tea. Food crops occupy approximately a 20% portion of the total farm size, which is usually around the homestead. 32% of the respondents ranked maize as the main source of food from the farm followed by beans, bananas, yams, potatoes, in that order as shown in Figure 3.

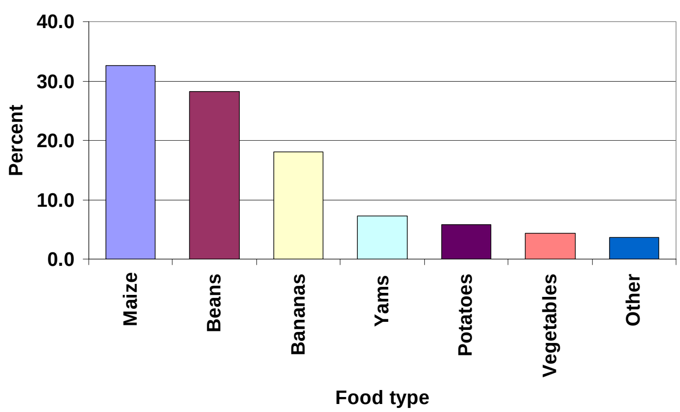

Figure 3: Family food availability according to rank in percent, based on survey data

The main source of farm income is coffee and macadamia, which over 20% of the respondents ranked as first and second Figure 4. Followed by diary and bananas, 'others' was used to cover vegetables, sale of Napier grass and sale of other produce form the farm like sweet potatoes etc. Less than 10% of the respondents ranked tea as the sixth because Meru Central district is a coffee growing area; tea growing has started in the recent past and is only grown in the higher altitude areas of the district.

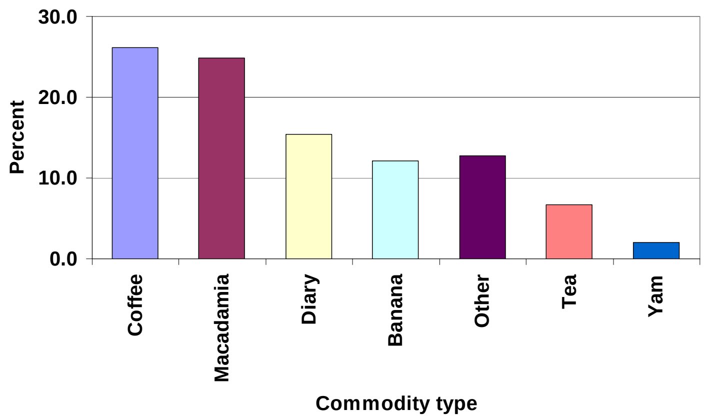

Figure 4: Source of farm income in percent, based on survey data

The average estimated annual income for each farm household is shown in Table 5. Macadamia on average yields between 11,000KES to 30,000KES per year according to 42.2% of the respondents. Only 4.4% earned over 90,000KES per year from the crop. Other cash crops yield between 5,000KES to 10,000KES according to 22.5% of the respondents, 20% indicated that they earned over 90,000KES.

There was no response of the income earned from food crops because most of the respondents considered that small money or '*pesa ya mama*' and did not keep track; these sales are normally handled by women and their husbands did not inquire how much they earned.

Sales of livestock earned 31.3% the households less than 5,000KES, while 25% reported between 5,000KES to 10,000KES. Only 4 respondents were engaged in off farm salaried employment earning on average between 11,000KES to 30,000KES while 8 respondent were involved in off farm self-employment, earning over 90,000KES per year on average.

Crop Production Profile

Varieties of macadamia grown

Only 2% of the respondents knew the varieties on their farms, most were not aware and majority classified the varieties as grafted and local variety supplied by the coffee co-operative society. Up to 80% of the farmers acquired their seedlings through the coffee co-operative societies in their areas.

Table 5: Estimated average annual incomes of farm households

Source	<5,000	5,000–10,000	11,000-30,000	31,000-50,000	51,000-70,000	71,000-90,000	Over 90,000
Macadamia	12 (27%)	9 -20%	19 (42%)	1 (2.2%)	1 (2.2%)	2 (4.4%)	2 (4.4%)
Other cash crops	7 -17.50%	9 -23.00%	6 -15%	7 -18.00%	2 -5%	1 -2.50%	8 -20%
Food crops	-	-	-	-	-	-	-
Sale of livestock products	10 -31.00%	8 -25%	5 -16.00%	2 -6.00%	2 -6.00%	1 -3.00%	4 -13.00%
Off farm salaried		1 -25%	2 -50%				1 -25%
Off farm self employment			3 -33.00%	1 -11.00%			5 -56.00%

Source: Computed from survey data

Number of trees

In Meru Central the average number of trees per farm household is 48 trees plus or minus 51 trees. These households have been growing these trees is 30 years with a plus or minus 11 years Table 6.

Table 6: Number of trees and year's macadamia has been grown

	N	Mean	STD
Number of years macadamia has been grown	42	29.83	11.21
Number of macadamia trees	43	47.95	51.334

Source: Computed from survey data

Table 7: Plant spacing

Plant population	Recommended spacing	Meru Central*	Percent
Pure Stand	7.5x7.5m	6x6m	7
Intercrop	10x10m	2.7x2.7m	10
		6x3m	5
		6x4.5m	40
		9x4.5m	5
		Random	33

**The figures have been converted from feet. Respondents gave the estimates.*

Thirty three percent of the farmers had their macadamia trees randomly spaced in the coffee plantation. Approximately 50% of the farmers had a spacing that ranged between 6m x 3m and 6m x 4.5m. However in most cases all the subsequent plantings after the initial planting was not randomly spaced (Table 7).

Intercrops

Over 50% of the main intercrop in the orchards was coffee or an intercrop of coffee and bananas other crops included beans, maize and yams (Figure 5). There is therefore that interaction of crop management practises between the trees and the other crops in terms of fertiliser use and general field hygiene.

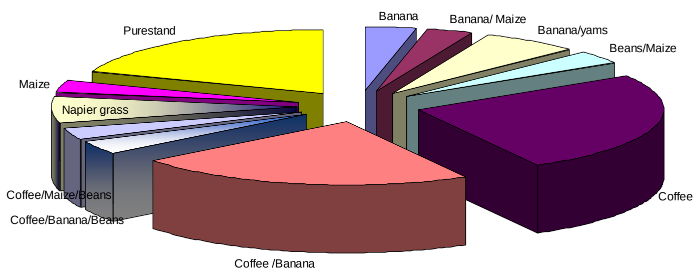

Figure 5: Intercrops in macadamia orchards

Fertiliser Application

Eighty percent of the farmer used fertiliser at the initial crop establishment only. Then selectively applied fertiliser when funds were available. The commonly used fertilisers were the compound fertilisers and occasionally DAP (Figure 6). The rate of application ranged from 100g/tree to 1kg/tree applied once per season usually when funds were available. The most common rate was 300 to 500g.The measures used were mainly a handful and/or a glass.

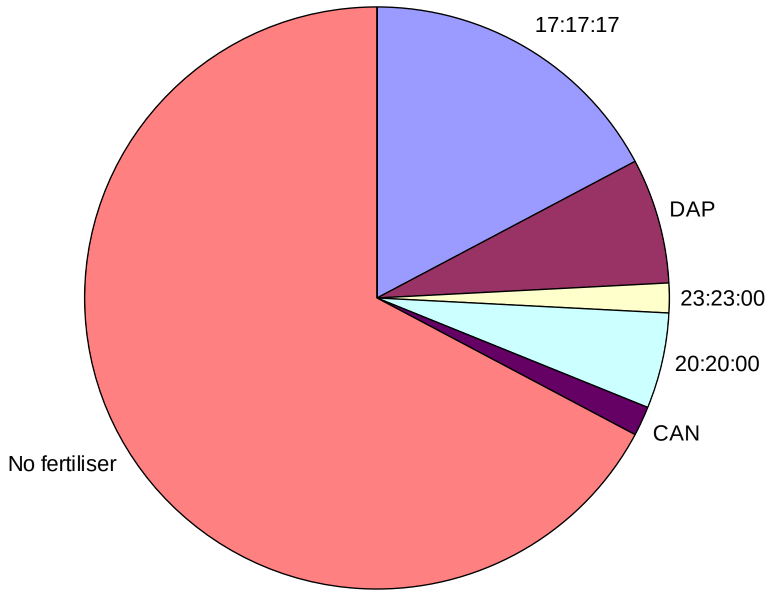

Figure 6: Fertiliser types used

Manure and manure type. Ninety nine percent of the farmers used manure at initial establishment of the crop. And apply manure even after establishment. Eighty five percent of the farmers use farm yard manure at various stages of decomposition it was not possible to establish the actually state of manure at time of application and the components of this manure apart from cow dung.

Rate of application. The rate range was 15 to 45 kg per tree. However, most frequent rate was 15 kg (50%).

Frequency of application. Fifty percent of the farmers apply once a year during the long rains. There rest applied only when the manure was available. The measures used were mainly the '*Debe*' (metallic tin) and/or wheelbarrow

Pruning

80% of the farmers were not familiar with the practice however they practiced some form of pruning e.g. removing low branches, reducing the number of branches to allow light especially when sourcing for firewood.

Irrigation

All the farmers relied on the rain and only provided water for the seedling during the initial establishment.

Crop Protection

Major pests

The major pests affecting macadamia are rodents 75% (Fig. 7), the macadamia stinkbug and the nut borer were recorded by less than 10% of the farmers. 3.5% of the farmers controlled rodents by physical chasing them away and trained cats to eat bats. 21% used smoking and 1.2% used pesticides as the control measure for macadamia stinkbug and nut borer.

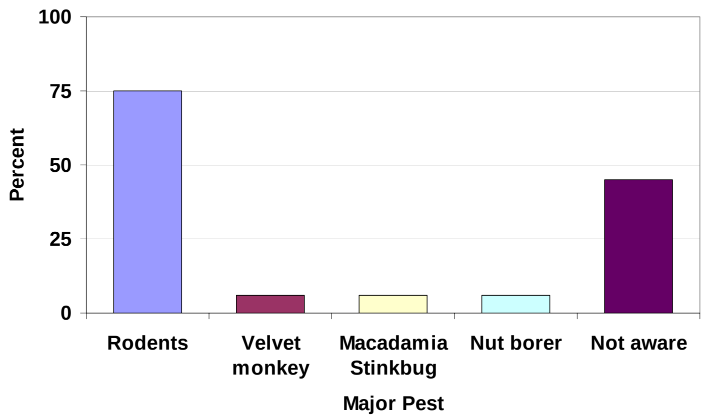

Figure 7: Major pests

Major diseases

60% of the farmers reported die back of branches and 7% reported root rot. Die back of branches is an early indication of root rot. 33% did not have a clue. General tree decline as a result of root rot is gradual and farmers only realise when the tree is nearly dead. Farmers are therefore not using any control measure.

Awareness of pest and disease management

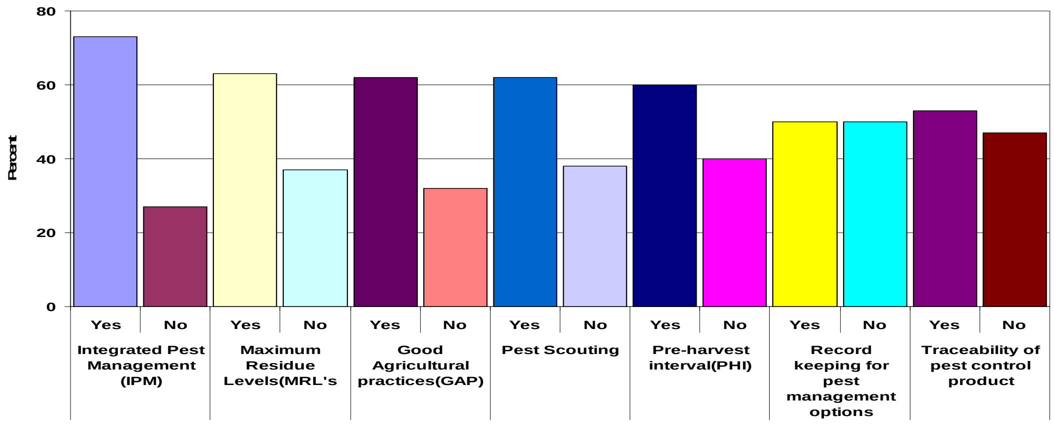

Figure 8: Awareness of pest and disease management

More than 50% of the farmers are aware of issues dealing with pest and disease management integrated pest management (IPM), Maximum residue levels (MRL's), good agricultural practises, pest scouting and pre-harvest interval (PHI). At least 50% of the farmers are aware about record keeping for pest management options and traceability issues of pest control products (Figure 8). However this knowledge based on other horticultural produce with very little reference, if any, to macadamia.

Conclusions

Macadamia is a main source of income for farmers in Meru central district second to coffee. The current practice of crop husbandry by the farmers' is quite minimal. Farmers cite the lack of good return from the nuts as the main reason for the neglect. However it cannot be refuted that the trees benefit from the field hygiene and fertiliser use carried out on the intercrops. Macadamia farmers are at least 50% aware of good agricultural practises. There is therefore potential for introducing organic farming for macadamia nuts thus creating a differentiated product that will attract premium prices.

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Evaluation of Postharvest Performance of 'Moby Dick' Cutflowers

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Abstract

Moby Dick belongs to the family Asclepiadaceae and the genus Asclepias. Many of the 108 species contained in this genus are used as cutflowers and garden ornamentals. The cutflowers are widely distributed in the fields and prairies of North America and also South Africa. Moby Dick is a new cut flower in Kenya domesticated from wild plants. There were no recorded exports of Moby Dick until the year 2001. However, exports probably did occur and were recorded in another flower category. The expansion of production has been aggressive due to high market prices and low costs of production. In 2003, the export of Moby Dick amounted to 47 metric tonnes, earning KES 7.8 million. Smallholder growers whose share is 100% produce Moby Dick. The current study was conducted to compare the performance of Moby Dick cutflowers in different preservative solutions and to establish the best preservative solution. Seven different solutions: 5% sucrose, 10% sucrose, 0.5% NaOCl, 0.5% NaOCl + 5% sucrose, 0.5% NaOCl + 10% sucrose, 0.1 M $AgNO_3$, and 0.2 M $AgNO_3$ were poured into glass containers, with two stems per vase, replicated twice. Nearly all balls had purple spots after three days and there was a change of colour of the balls from light-green to yellow after five days. The yellowing on the balls in distilled water, 5% sucrose, and 10% sucrose solution started one day later. These balls remained 25% yellow until the 12th day of the experiment. The other balls became 50% or more yellowish after nine days. Stems developed black spots after three days. The stems in the $AgNO_3$ became grayish-black from the lower side towards the balls and on the 8th day some balls were grey. The stems in solutions containing NaOCl were highly macerated at the base depending on the concentration. Silver nitrate and NaOCl produced poorest vaselife. These solutions may have been toxic to the cut flowers. Vaselife was 13 days for 5% sucrose, 12 days for 10% sucrose, and 6 days for solutions containing NaOCl or $AgNO_3$.

Key words: Cutflowers, 'Moby Dick', postharvest, vaselife

Planning Integrated Pest Management for Mites with Emphasis on Roses

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Abstract

Horticultural production both for the local and export markets is an important activity in Kenya that contributes significantly to growth of the economy, domestic food needs, generation of foreign exchange, and creation of employment. The cut flower sub-sector accounts for 60% of the total earnings from horticultural production. The industry has a horde of challenges, among them being increasing cases of pests and diseases. Rose flowers are among the most important, earning half the total income from cut-flower production. Growing of roses is mainly constrained by red spider mites (*Tetranychus* spp.). Pesticide application has been the main method of controlling all pests in flowers. Repeated application of pesticides, however, causes indirect problems such as high costs of production, reduction of beneficial natural enemies, pesticide resistance, pest resurgence, and pollution of the environment. Such problems have necessitated the need to seek alternative pest control methods. Integrated pest management (IPM) based on sound cultural and biological controls, with the targeted use of only the most pest-specific and environmentally benign chemical pesticides, has been the accepted way forward in this regard for most horticultural products. Researchers have for a period searched for the acceptable IPMs with some level of success reported. In Kenya, for example, studies which have been conducted on rose farms, include: a) Verification of the existence of both generalist as well as specific natural enemies of the phytophagous mites, *Tetranychus* species, with the aim of conserving them and complementing conventional acaricide use, b) Assessment of the importance of the surrounding natural vegetations as a basis for conservation of the biological agents, and c) Synchrony of application of pesticides and their affect on the natural enemies of mites. Encouraging results have been achieved from these studies. For example: a) Roses are now grown in many farms scattered in the Kenyan highlands at Limuru, Karen, Kiambu, Athi River, Thika, Nakuru, Naivasha, Nyahururu, Nyeri, Embu, Kericho, Nandi Hills, Eldoret and Kitale; b) Positive identification of mite species present on roses in Kenya, including *Tetranychus urticae, T. cinnabarinus*, *T. ludeni,* and *T. lombardinii*, which is a prerequisite for planning effective IPM controls; c) Identification and recording of a large number of natural enemies of mites in a number of rose flower farms and surrounding vegetation, including anthocoroids, ants (predominantly *Pheidole* spp. and *Camponotus* spp.), parasitoid Braconidae (*Dolichogenidea apanteles ultor* and *Meteorus laphygmarus*) and Trichogrammatidae (*Trichogrammatoidea armigera*), Ichneumonidae (*Charops ater* and *Netelia* sp.), and the predatory mite *Phytoseulus persimili*, which was found in the Naivasha flower growing epicentre of Kenya; d) The suitability of surrounding vegetation species composition and diversity as hosts and refuges for mites. Predaceous mite population dynamics from four commercial rose flower farms in Naivasha division was enhanced by several plants such as bougainvillea, *Tarchonanthus*, *Terminali, Schefrera*, African pencil cedar, *Aloe, Rhus* and Gum trees. Plantations with total ground cover of 50% or more than 18% cover of reproductive host plants of mites had adequate predaceous mite population to maintain mite density in rose plants below economically damaging levels; e) Higher mite incidences in plots sprayed with certain pesticides such as thiodicarb, dimethoate and methomyl were recorded, as compared to untreated control plots. Plots treated with bifenthrin and endosulfan were similar to control plots, while those treated with dipel, amitraz and pyrethrin had lower mites than control plots. Based on these results and personal communication with stakeholders, the purpose of the current study was to suggest areas for planning practical IPM for the control of mites, the key pests of roses. Usually the concept of IPM is an attractive one, although lip service is generally paid to it by pest managers, academicians, advisory and commercial agents, many of whom would also claim to be practicing it. When it comes to planning and usage of an IPM system, one must have a

clearer idea of what is involved. The way forward is to plan as policy attempts to introduce IPM into rose production, based on the studies whose results are highlighted in this paper. The major emphasis will be to integrate the results in the planned technology with the possibilities of reducing chemical usage that currently is the case. The impact of predatory phytoseiid mites that are currently produced by a private farm (DuduTec) has been discussed as well and a recommendation for large-scale adoption suggested. However, it will be generally very hard for rose growers to fully adopt holistic biological IPM, as they fear blemishes on the flowers. Nevertheless, it is hoped that the switchover from routine calendar application of pesticides to decision-making before a control measure is taken will slowly be adopted.

Key words: Flowers, integrated pest management, mites, roses

Introduction

The horticultural sub-sector contributes significantly as a foreign exchange earner with cut flower production accounting for 60% of the total earning. Profitable production of ornamental is constrained by pests the major one being the two-spotted mites, *Tetranychus* spp. (Anon 1996). Up to now pest control in flowers rely on pesticides with varied levels of success registered. There has been need searching alternative pest control methods. Toward this end a three-year project (2002-2004) whose results are summarised started with mite of roses as the entry point to introduce IPM in cut flower production. Field surveys as well as field trials in flower farms searched for the existence of biological agents of mites in rose flower farms.

Materials and Methods

Survey for the natural enemies of mites

Field surveys for the natural enemies of *Tetranychus* spp. was carried out on unsprayed potions of rose flower farms (Table 1) in 2002 and 2003 on rose varieties *First-red* (inside) and *Diadem* (outside greenhouse). Ground dwelling natural enemies e.g spiders, earwig and ants were gathered using pitfall traps (Greenslade, 1964; Baar, 1979). Parasites and pathogens was verified using infected and dead mite cadavers reared in laboratories at NARL, Nairobi.

Table 1. Selected farms onto which natural enemies of spider mites were surveyed

Code	Farm	Administrative district	Agroecological zone	Altitude (m a.s.l)	Rainfall (mm)
Al	Alora	Nandi Hills	LH_2	2011	1400
Fl	Finlay	Kericho	LH_1	1980	1515
MEl	Mt Elgon	Tran-Nzoia	LH_3	1770	1045
MwB	Mwega Blooms	Nyeri	UM_4	1890	900
Nd	Ndalo	Uasin Gishu	LH_3	1750	1100
Su	Sulmac	Nakuru/ Naivasha	UM_5	1900	600
Wa	Waridi	Machakos	UM_6	1690	550

Influence of vegetation on red spider mites and natural enemies

The study was conducted on two-year commercial rose flower farms at Sulmac, Sher, Noordam and Shalima in Naivasha division. Only non-rose plants surrounding the farm with a coefficient from 0.2 to 20 (Table 2) were sampled 2-3 m from the edge of the farms.

Effect of insecticide on natural enemies

This trial was conducted on established rose flowers in 2003/04 at Sulmac farm, Naivasha division sprayed by the chosen insecticides (Table 3) that were the core treatments. Mite and natural enemy counts were confined at centre middle rows per plot. Subsequent sampling continued weekly after the final insecticide application, until the experiment was terminated, when *Tetranychus spp.* showed increase over four successive checks in control plots.

Table 2. Occurrence of the most common surrounding wild vegetation and clear ground of roses during dry periods, 2002

Plant family	Common name	Scientific name	Plantations (mean % horizontal cover)			
			Sulmac		Sher	
			2003	2004	2003	2004
Araliaceae	Shefrera tree	*Schefflera volvensis* Harms	3.8	4.6	0.2	0.3
Amaranthaceae		*Rhus natalensis* Bernh	5.5	5.4	0	0
Combretaceae		*Terminalia spinosa* Engl.	4.5	8.9	0	0
Compositae		*Tarchonanthus camphoratus* L.	3.6	2.1	0	0
Cupressaceae	Cedar	*Juniperus procera* Hochst. (Endl.)	1.3	1.6	0	0
Cyperaceae	Papyrus	*Cyperus papyrus*	0	0	13.3	14.2
Cyperaceae	Dense sedge	*Cyperus* spp	0	3.6	12.6	13.3
Euphorbiaceae	Euphobia	*Euphorbia cande-labrum* Korschy	6.6	6.8	0	0
Flacourtiacea	Kei apple	*Dovyalis caffra* Warb.	0.6	1.6	1.6	1.8
Graminea	Napier grass	*Pennisetum purpureum* Schu.	0	1.1	0	0
Graminea	Grass	*Seratia verticillata* (L.) Beanv	0.2	0.6	0	0
Graminea	Star grass	*Cylodon plectostrachyum*	1.2	0.5	0	0
Liliaceae		*Aloe kedongensis* Reynolds	1.9	2.3	0	0
Mimosoideae	Fig. tree	*Ficus capensis* Thumb	2.1	2.1	0.2	0.5
Mimosoideae	Naivasha thorn	*Acasia xanthophloea* Benth	0	1.2	0.2	0.4
Myrtaceae	Gum tree	*Eucalyptus bicoststa* Maiden	0	1.8	0.6	0.7
Nymphaeaceae	Water lily	*Nymphaea caenelea*	0	0	10.7	11.1
Podocarpaceae	Podo tree	*Podocarpus gracilior* Pilger	0	0	0.3	0.4
Solanacea		*Solanum incanum*	0	4.1	0	0
		Themeda (G)	5.2	8.1	0.1	0.3

Table 2 (continued)

Plant family	Common name	Scientific name Plantations	Plantations (mean % horizontal cover)			
			Noordam		Shalimar	
			2003	2004	2003	2004
		Lucern (G)	0	1.1	0	0
		Pruchea ovalis (G)	1.2	0.8	0.2	0.3
		Salvinia (G)	0	0	0.3	0.2
		Bouginvelia	0.2	1.5	2.2	2.1
	Cactus fence	*Oputius spp*	3.0	4.4	12.6	11.6
Total % cover			40.5	64.2	55.1	57.2
No.plants sp			15		14	
Bare ground			59.5	35.8	44.9	42.8
Diversity %			60		56	
Total[a]			100	100	100	100
Araliaceae	Shefrera tree	*Schefflera volvensis* Harms	1.1	0.9	1.6	1.3
Amaranthaceae		*Rhus natalensis* Bernh	3.3	1.6	6.1	5.5
Combretaceae		*Terminalia spinosa* Engl.	0.9	1.3	1.4	0.5
Compositae		*Tarchonanthus camphoratus* L.	3.3	2.9	5.5	6.1
Cupressaceae	Cedar	*Juniperus procera* Hochst. (Endl.)	4.5	1.3	1.0	0.7
Cyperaceae	Papyrus	*Cyperus papyrus*	11.3	9.3	0	0.5
Cyperaceae	Dense sedge	*Cyperus* spp	2.1	1.6	0.2	0
Euphorbiaceae	Euphobia	*Euphorbia candel-abrum* Korschy	0	0	0	0.4
Flacourtiacea	Kei apple	*Dovyalis caffra* Warb.	1.9	0	5.1	2.0
Graminea	Napier grass	*Pennisetum purpureum* Schu.	0	2.1	0	0.2
Graminea	Grass	*Seratia verticillata* (L.) Beanv	0	0	0.6	0.5
Graminea	Star grass	*Cylodon plectostrachyum*	1.0	0.6	0.8	1.1
Liliaceae		*Aloe kedongensis* Reynolds	2.1	1.4	2.5	1.4
Mimosoideae	Fig. tree	*Ficus capensis* Thumb	0	0	0.1	0
Mimosoideae	Naivasha thorn	*Acasia xanthophloea* Benth	0.3	0.5	0.5	1.2
Myrtaceae	Gum tree	*Eucalyptus bicoststa* Maiden	4.9	3.4	0	0
Nymphaeaceae	Water lily	*Nymphaea caenelea*	3.9	2.4	0	0
Podocarpaceae	Podo tree	*Podocarpus gracilior* Pilger	0	0	0	0
Solanacea		*Solanum incanum*	0.1	0.8	0	0.5
		Themeda (G)	3.2	1.6	0.1	1.1
		Lucern (G)	0	0	0	0.2
		Pruchea ovalis (G)	2.0	1.9	1.1	2
		Salvinia (G)	0	0	0	0
		Bouginvelia	2.0	2.3	10.2	8.1
	Cactus fence	*Oputius spp*	11.1	12.4	4.3	2.1
Total % cover			59	48.1	41.1	35.3
No.plants sp			18		16	19
Bare ground			41	51.9	58.9	64.7
Diversity %			72		64	
Total[a]			100	100	100	100

[a]Total % cover of predominant plant species (at least 0.2% cover in at least one flower farm) and ground area

Table 3. Pesticides for the control of arthropod pests on roses

Common name/ Treatment codes	Trade names	Rate	Insecticide group	Purpose
control (check) (1)	--	--	--	compare to treatments
dimethoate (2)	Rogor, Reldan	500 g ai/ha	OP	aphids, caterpillars, mites, leafminer, whitefly, thrips
endosulfan (3)	Endosulfan, Ekatin	480 g ai/l	Organochlorine	caterpillars, aphids
bifenthrin (4)	Brigade, Talstar	45 g/ha	Pyrethroid	aphids, whitefly, thrips, mites
thoidicarb (5)	Larvin	900 g ai/kg	Carbamoyloxime	caterpillars, thrips, aphids
methomyl/ [flucythrihate] (6)	Lannate, Larvin, Cybolt	900 g ai/kg	Carbamoyloxime	caterpillars, thrips, aphids, leafminer
amitraz (7)	Mitac	30 g ai/ha	Amidine	mites, thrips, aphids, caterpillars
Bacillus thuringiensis (Bt) (8)	Dipel	2000 i.u. /mg	Bacterial	caterpillars, coleoptera (beetle)
pyrethrins (9)	Pyerin, Pyegar	1 ml/l	Pyrethrins	thrips, mites

Results and Discussion

Results on surveyed and incidence of natural enemies is summarised on Table 4 listing the natural enemies of mites identified from the farms. Only two groups of the natural enemies stood out as common at most sites namely ants and Anthocoridae. Staphylinidae were common in rose canopy in several surveyed sites where and it is assumed they could be playing a role as predators of mites among other arthropods.

Table 4. Natural enemies identified from field sites, 2000-2002

Species*	Site**	Comments***
PREDATORS Hemiptera: Anthocoridae *Blaptostethus* sp *Orius albidipennis* (Reuter) [1and2]*Orius insiosus* Say[1and2] *Orius laevigatus* Fieber[2] *Orius majusculus* Reuter[1and2] *Orius* sp[2]	Al, Nd, MwB Su, MwB Nd, MwB, MEl Al, MwB Fl, Su	common, egg common, egg
Lygaeidae *Geocoris amabilis* Stal[1and2] *Geocoris ochropterus*[1and2] *Geocoris palllens*[1and2] *Geocoris attricolor*[1and2]	Fl, Al Wa, Al Wa, Fl Fl	lab lab lab
Miridae *Deracoris pallens*[1and3]	Wa	lab
Nabidae *Nabis alternatus*[1] *Tropiconabis capsiformis* Germar[3]	Wa, Al MwB, Nd	lab
Thysanoptera: Thripidae *Aelothrips faciatus* (L) [1,2and3].	Su, MEd, Nd, Wa	common, adults
Neoroptera: Chrysopidae *Chrysoperla* spp[2and3] *Mallada* spp[3]	Al, Su Su	homop, lab
Coleoptera: Carabidae *Calleida fasciata* (Dejean) [1] *Stenidia* sp[1and3].	Su, Fl, MtE Su	adults, pitfall
Coccinellidae *Cheilomenes aurora* (Gerstaecker)[1] *Cheilomenes lunata* (Fabricius) [1] *Cheilomenes propinqua* (Mulsant)[1] *Cheilomenes sulpurea* (Olivier) [1] *Exochomus ventralis* (Gerstaecker) [3] *Stethorus* sp	Nd, Al, Su Su, MEl Fl Nd, Al, Wa Wa Su, Wa	adults, common adults, common
Staphylinidae *Paederus eximius* Reiche[1and2] *P. riftensis* Fauvel[2]	Su, MEl, Al Al, Su	adults, pitfall
Hymenoptera: Formicidae *Acantholepis* sp[3] *Camponotus flavomarginatus* Mayr[1] *Camponotus maculatus*[3] *Monomorium opacum*	Al, Nd Wa, Al Su MEl, MwB Fl Al Wa Su, MEl, Fl,	adults, pitfall adults, pitfall
Forel[1] *Myrmicaria opacivenis* Emery[3] *Myrmicaria* sp[3] *Oligpmyrmes* sp[3] *Pheidole* sp[3] *Tetramorium zonacaciae* (Weber) [1]	Wa Wa	larvae pitfall pitfall common, pitfall
Vespidae *Belonogaster* sp[3] *Polistes* sp[3]	Wa, Al Fl	lab lab
Acari Phytoseiidae *Amblyseius barkeri* Hughes[3] *Amblyseius cucumeris* Oudemans[3] *Crytomorpha desjardini* Guer[3] *P. persimilis*[2,3]	MEl, MwB MEl, MwB MwB Su	adults adults adults
PARASITOIDS Hymenoptera: Braconidae *Dolichogenidea apanteles ultor*[1 and3]*Meteorus laphygmarus* (Brues) [1and3]	Su MwB	L1-3 L3-4
Trichogrammatidae *Trichogramma* sp[1and3] *T. armigera* Nagaraja[1and3]	Wa, MwB Al. Wa	E E
Ichneumonidae *Charops ater* Szepligeti[1] *Netelia* sp[1and3]	Su, Al Al, Wa	L1-3 L5-6
PATHOGENS Nuclear polyhedrosis virus	Su, Al, MwB, Nd	L1-3

** Identified at: [1] - NARL, [2] - Nairobi Museum, [3] Confirmed at IIE - London*
*** Al- Alora, Fl - Finlay, MEl - Mt. Elgon, MwB - Mwega Bloom, Nd - Ndalo, Su - Sulmac, Wa - Waridi.*
**** homopt,. often associated with; egg, known predator of spider mite eggs; larva, known predator of immature spider mites; lab, observed feeding on spider mite in laboratory; pitfall, caught on the pitfall traps; E, parasitizes spider mite eggs in the lab; L1-6, parsitizes spider mite larvae instars indicated.*

Data on incidence of phytophagous mites and natural enemies as affected by surrounding vegetation cover and composition are shown in Tables 5 and 6. The four rose flower farms (Sulmac, Sher, Noordam and Shalimar) ranged in the degree of plant species diversity and percent cover showing a skewed distribution pattern, typical of most plant communities (Odum, 1971).

A total of 163 plant species, representing 122 genera and 25 families were observed surrounding the farms (Table 5). Indigenous trees/ shrubs e.g *Sheffrera* (Sulmac), *Pyperus* and cactus (Sher), *Rhus,* and *Tarchonathus (*Noordam) and bougainvillea and *Cripple* (Shalimar) with coefficient > 22.5% were more preferred by phytoseiid mites (Table 5) from all direction they occurred than bare ground (Table 6).

There was negative correlation between prey to predatory inside compared to outside greenhouses (Spearman r=0.14, N=12, p=0.12 and r=0.35, N=12, p=0.12 respectively). On selected dominant vegetations however the correlation became positive e.g. *Sheffrera* for Sulmac (r=0.59, N=11, p=0.06), Sher (r=0.62, N=11, p=0.11), *Tarchonanthus* for Noordam (r=0.77, N=11, p=0.03) and bougainvillea for Shalimar (r=0.53, N=11, p=0.09) for outside door cases (Table 6).

Table 5. Average occurrence and density of spider mites and predatory mites (*Phytoseiulus persimilis*) on rose flowers (inside and outside greenhouse) and in surrounding vegetations in the four plantations in 2000 and 2001

Common name of adjacent vegetations	Coeff.[a]	Spider mite present		Phytoseiid mites per 100 leaves		
		Present	Reprod-uctive	Present	Mean ± SE	Samples
Aloe	5	x	r	x	30.9 ±20.7	5
African pencil cedar	8	x	r	x	41.9 ±13.5	4
Bougainvillea	2	x	r	x	294.6 ±107	7
Cactus fence	2	x		x	6.4 ±2.4	7
Euphobia	5	x	r	x	4.6 ±1.9	5
Fig. trees	10	x			8.1 ±5.2	5
Gum trees	20	x		x	24.8 ±10.5	6
Kei apple	2	x		x	9.5 ±3.7	9
Naivasha thorn	2	x	r	x	1.8 ±0.4	5
Podo trees	5	x			11.5 ±5.6	4
Rhus	2	x	r	x	29.9 ±17.0	5
Schefrera trees	3	x	r	x	46.5 ±28.1	5
Solanacia	0.5	x			16.5 ±8.2	4
Rosa (Outdoor)		x	r	x	251.3 ±110	18
Rosa (Indoor)		x	r	x	4.6 ±1.5	18
Tarchonanthus	2	x	r	x	137.2 ±60.5	5
Teminali	2	x	r	x	117.0 ±66.2	5
Themeda	0.2	x				9
Typha	0.5	x				7

[a] *- Coefficient based on approximate size of plants (e.g. 0.2 represents one-fifth of the size of a normal rose plant.*

x - Indicate that only adult mite stages were found on the plant species;

r - Indicates that the species was a reproductive host for spider mites (that is spider mites eggs, immature spider mites, and adult spider mites were observed).

Table 6. Density of phytoseiid prey mite on rose plants and on adjacent trees in a 2¼ ha rose farm. Samples were taken on 9th Sep. 2001 from trees in northern (N), eastern (E), western (W) and southern (S) parts of the plantation

Rose plant sample	Phytoseiid mites number[a]		Prey density (number per leaf)
	Per leaf	Per plant[b]	
Sulmac (N)	0.61	732	1.55[c]
Sulmac (W)	1.81	2172	1.01
Sulmac (E)	1.37	1644	2.97
Sulmac (S)	1.42	1704	4.14
Sher (N)	0.51	612	0.91
Sher (W)	1.41	1692	2.09
Sher (E)	1.22	1464	1.12
Sher (S)	0.15	180	0.36
Noordam (N)	0.25	300	3.10
Noordam (W)	1.09	1300	4.06
Noordam (E)	0.91	1092	6.63
Noordam (S)	1.17	1404	5.12
Shalimar (N)	1.61	1932	2.01
Shalimar (W)	1.04	1248	1.33
Shalimar (E)	0.92	1092	1.60
Shalimar (S)	0.28	336	0.89

Rose plant sample	Greenhouse ratio of pred: prey	
	Inside	Outside
Sulmac (N)	1:8.31	1:2.54
Sulmac (W)	1:11.62	1:0.55
Sulmac (E)	1:9.42	1:2.87
Sulmac (S)	1:12.66	1:2.92
Sher (N)	1:18.32	1:1.78
Sher (W)	1:13.67	1:1.48
Sher (E)	1:15.21	1:0.92
Sher (S)	1:16.22	1:2.40
Noordam (N)	1:20.12	1:12.40
Noordam (W)	1: 19.15	1:3.72
Noordam (E)	1:23.23	1:7.29
Noordam (S)	1:18.91	1:4.38
Shalimar (N)	1:15.84	1:1.25
Shalimar (W)	1:16.89	1:1.28
Shalimar (E)	1:19.20	1:1.74
Shalimar (S)	1:20.61	1:3.18

[a] *Phytoseiid mite species.* [e] *Estimated total numbers of leaves per rose plant in the locality.* [c] Tetranychus *spp mean numbers including eggs.*

Effect of insecticide on predators

The insecticides had a high significant effect on abundance of *Tetranychus spp* in all the three experiments (experiment 1, F = 27.5, df = 7, *31*, P = 0.001; experiment 2, F = 47.1, df = 7, 31, P = 0.001; experiment 3, F = 26.6, df = 7, 31, P = 0.001) (Table 7). Roses treated with amitraz, dipel and pyrethrins had significantly lower final spider mite abundance than the control treatment. The early-occurrence of phytoseiid predators showed significant negative relationships with the late occurrence of *Tetranychus spp***.** i.e. (F = 112.3; df = 1, 28; P = 0.001), and *Orius spp* (F =7.84, df = 1, 28; P = 0.001) - coefficient (r^2) of 0.74. The slopes for all predators were positive (slope ±SE, phytoseids 201 ± 0.34; and *Orius spp,* 193 ± 0.015 indicating that populations of *Tetranychus spp***.** increase earlier in rose with fewer predators in early-season.

Table 7. Population lag-period of *Tetranychus spp* in each treatment and number per plant before and after applications began to increase

Treatments	**Population lag-period**	**Rate of increase**	***Tetranychus spp* in early season**	***Tetranychus spp* in late season**
Experiment 1 (June 2002-Jan. 2003)				
control (check) (1)	15	0.006±0.001	0.6	13.1[c]
dimethoate (2)	14	0.007±0.001	0.55	44.6[d]
endosulfan (3)	16	0.007±0.001	0.71	14.4[c]
bifenthrin (4)	14	0.005±0.002	0.91	48.6[d]
thiodicarb (5)	13	0.012±0.002	0.88	49.5[d]
methomyl (6)	10	0.009±0.001	0.28	46.1[d]
amitraz (7)	18	0.005±0.002	0.3	2.3[a]
B. thuringiensis (Bt) (8)	16	0.004±0.002	0.2	7.1[b]
pyrethrins (9)	12	0.006±0.002	0.18	3.5[c]
Experiment 2 (Feb. 2003-July 2003)				
control (check) (1)	17	0.006±0.001	0.3	51.6[c]
dimethoate (2)	22	0.005±0.002	1.1	104.6[e]
endosulfan (3)	14	0.004±0.002	0.4	47.7[c]
bifenthrin (4)	12	0.003±0.002	0.6	104.6[e]
thiodicarb (5)	13	0.002±0.002	1.3	111.1[e]
methomyl (6)	19.5	0.005±0.002	1.07	118.6[e]
amitraz (7)	20	0.004±0.002	0.33	4.6[a]
B. thuringiensis (Bt) (8)	22	0.004±0.002	0.21	8.1[ab]
pyrethrins (9)	13	0.003±0.002	0.27	16.7[b]
Experiment 3 (Aug. 2003-Feb. 2004)				
control (check) (1)	31	0.014±0.002	0.7	31[c]
dimethoate (2)	30	0.010±0.002	1.1	205[e]
endosulfan (3)	29	0.012±0.002	0.2	13[b]
bifenthrin (4)	33	0.007±0.001	0.88	193[e]
thiodicarb (5)	30	0.009±0.001	1.3	216[e]
methomyl (6)	34	0.009±0.001	1.04	139[d]
amitraz (7)	29.5	0.004±0.002	0.28	6.1[a]
B. thuringiensis (Bt) (8)	35	0.004±0.002	0.24	13.4[b]
pyrethrins (9)	32	0.004±0.002	0.16	4.8[a]

Values = mean ± SEM, n=8. For each experiment means in each column followed by the same letter are NS different at P = 0.05.

Conclusions and Recommendations

Implementation of biological control in horticultural crops is in demand and long overdue. Results from this study shows occurrence of the natural enemies varying between sites. Phytoseiid mites were common only in Naivasha division. Parasitoids like Braconidae, Trichogrammatidae and Ichneumonidae also have potential in horticulture production.Over plant >50% thickets cover by *Sheffrera* spp, *Rhus* spp, *Tarchomanthus* spp, *Acacia* spp encourage availability of phytoseiid mites more predictably outside greenhouses.

Host plants as *Tacrchonanthus*, cactus hedge and *Camphoratu* have higher potential to facilitate phtyoseiid colonisation even after toxic pesticide applications. Phytoseiids depends on flower pollens rather than prey mites that serve as food (Touvinen, 1994).

Flower farmers should be encouraged to spare broadleaf border plants and exotic hedge around farms, and do proper selection of insecticides in early-season crop to bust predator populations and future farm planning should encourage this.

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Plant Health and Playing Quality of Two Turf Grass Species as Affected by Root-Zone Material Composition

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Abstract

A balance has to be found between providing an all-time playable field and quality turf. In utility turf, selecting the right media composition is critical in determining intense of usability and turf growth performance. Two types of turf grasses were tested for growth performance and playing quality when grown under different types of root-zone material. The objectives of the experiment were to determine how root-zone factors of media composition influence watering frequency, the playing quality and growth of turf grass. The factorial experiment tested four media types, consisting of sand and soil mixture in the ratios of 2:1, 1:1, 1:2 and 0:1, and planted with *Pennisetum clandestinum* (Kikuyu grass) and *Cynodon dactylon* (common Bermuda grass). Measurements for watering frequency, rate of infiltration, yield, mowing frequency and resiliency were done 4 weeks after establishment and following a compaction treatment. Results showed that both watering frequency and rate of infiltration followed similar trends, being highest in media with high sand composition and lowest in media with soil only. Bermuda grass demanded more

frequent watering compared to Kikuyu grass to maintain media at field capacity. There were significant differences between the grasses in resiliency with Bermuda grass showing more resilience than Kikuyu grass. Yield for the sand-soil mixtures was 2:1 followed by 1:1, 1:2, and soil only, in decreasing order. Kikuyu grass yielded higher than Bermuda grass at all media ratios and withstood compaction effects longer than Bermuda grass, which developed stress symptoms after two compression tests. Therefore, Bermuda grass is considered most suitable for light sports such as golf and bowling greens, while Kikuyu grass grown in root-zone material consisting of sand-soil mixture in the ratio of 2:1 was considered best to providing good playing quality for relatively rough sports such as soccer. Further investigation on best particle size distribution will give more information for best composition in meeting playing quality needs.

Keywords: Root-zone, turf grass growth, playing quality, watering frequency

Introduction

Turf growth and functions is affected by several factors that are as a result of soil physical conditions and even with proper nutrition, growth and performance may still be poor. In high use sports fields compaction decreases the pore size of soil medium and eliminates all free draining macro pore space resulting in soils susceptible to saturation (Adams and Gibbs, 1994). The problem of fields getting waterlogged as a result of compacted soils is a nagging one for turf grass managers. Modification of the natural soils has therefore been necessary to improve the drainage and water retention characteristics. Changing the pore size class through the addition of sand has done it. McNitt and Landschoot (2003) tested and found that the type and rate of reinforcement materials in high-sand root zone had varying effects on surface hardness, bulk density, water content, and turf density of the root zone. Reinforcing material that lowered soil bulk density and surface hardness had low level of wear inflicted on the turf grass.

Watering frequency affects the visual quality and hence appearance of the field. According to Richiea et, al (2002), a deeper infrequent watering resulted to better visual quality for tall fescue (*Festuca arundinacea* Schreb.) grown on sandy loam soils. For prudent use of water it is necessary to determine the watering frequency needed to keep media moisture content within allowable levels. For sports fields the challenge is even higher because the balance of good media type and type of turf grass should ensure a good playing surface. Most sports fields in Kenya have root zones of natural soils modified with sand. It is not clear however how the different mixing proportions influence watering frequency and playing quality.

The objectives of these experiment were two-fold: determining how different media compositions for the root-zone influence water infiltration time, the playing quality and growth of turfgrass; and determining the effect of compaction on turfgrass growth performance and playing quality

Materials and Methods

The experiment was set out at the Jomo Kenyatta University of Agriculture and Technology (JKUAT) horticultural demonstration farm. Experimental plots were prepared by constructing a profile that was filled at the bottom with aggregate up to 8 cm depth, followed by fine aggregate layer of 3 cm and then the top root zone layer of about 5 cm depth which was made of sand/soil mixture in ratio of 0:1, 1:1, 1:2 or 2:1.

The experiment was laid out in a split-plot design. There were two turfgrass types (main plots) of *Cynodon dactylon* (Bermuda grass) and *Pennisetum clandestinum* (kikuyu grass) and 4 media types with various sand / soil mixture in ratios of 0:1, 1:1, 1:2 or 2:1 and. The experiment was replicated three times. Grass was planted by laying out sod material on the finely prepared and firmed beds.

Figure 1 shows the root zone profile constructions of the experimental plots. Measurements commenced after 4 weeks of grass establishment. Tillering was determined by counting tillers of specified quadrant area within a sub-plot. Time taken for moisture level to drop from field capacity to a pre-determined allowable moisture content (AMC) was monitored using a hydro-sensor.

Compaction was simulated by rolling a 55 Kg roller on the turf surface. Soon after, measurements were done for the time taken for water in a cylindrical tube to infiltrate into the media. Re-watering of the plots was done when moisture level of the media dropped to 7 % of a pre-determined field capacity. Grass resiliency was measured as the time taken for the shoots to regain upright growth after removal of the roller. Mowing was done when the shoots reached a height of 13 mm to height-of-cut of 10 mm. The rate of the shoots to re-gain 13 mm height was used as a measure of recuperative capacity. After every mowing, dry weight of clippings was determined.

Figure 1: Layout of the experimental plots

Results and discussion

The number of tillers recorded was highest in media with highest soil content. Days taken to reach the height-of-cut increased as the proportion of sand in media increased (Fig. 2). These observed trends could be attributed to the fact that soil has a high organic matter content and nutritional value than river sand. The water infiltration time for the different treatments is shown in Fig. 3.

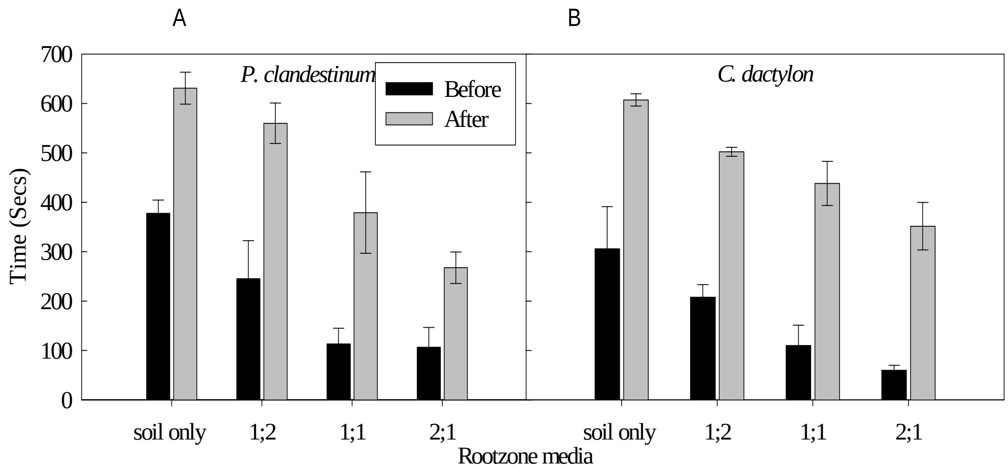

Figure 2: Number tillers formed within 4 weeks of establishment (A) and number of days taken to reach mowing height in the different media types (B).

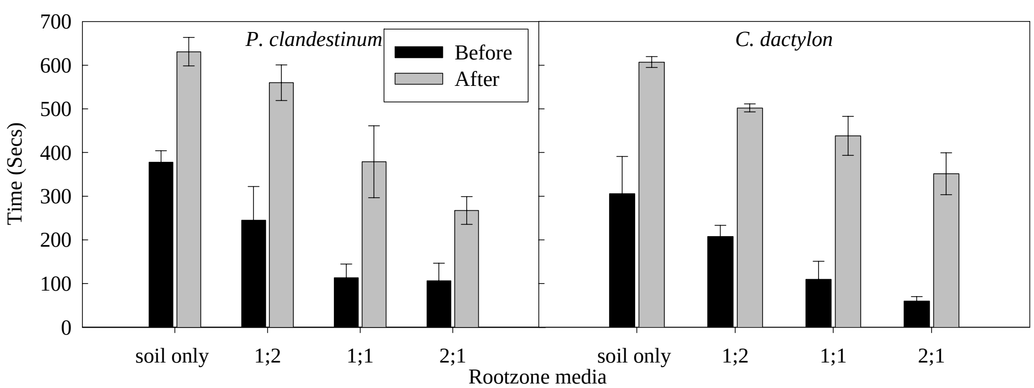

Figure 3: Water infiltration before and after compaction of the turf grass surface

Longer infiltration times were recorded in soil only root zone media and shorter times as sand is increased in root zone media. Infiltration times were always longer after compaction than before compaction treatment in all the media. Figure 4 shows the change in media moisture content with time from field capacity to the pre-determined allowable moisture content (AMC). There was rapid decline in moisture content for 2:1 media followed by 1:1, then 1:2 and slowest in soil only. Consequently, watering frequency was highest in the 2:1

sand/soil mixture. These trends were similar for both turf grasses. Statistical analysis showed significant differences between the different media and the turf grass species (Table 1).

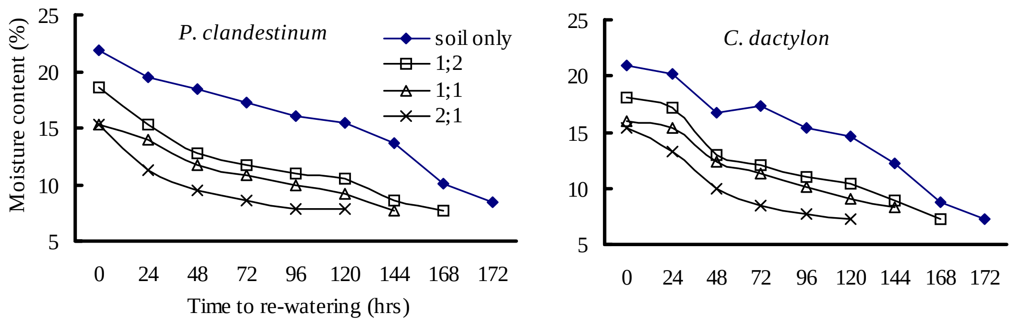

Figure 4: The time taken for media moisture content (m.c) to fall from initial. m.c. to the lowest set m.c. for two turf grass species, *Pennisetum clandestinum* and *Cynodon dactylon*

Table 1. Treatment means and mean separation. Means with same letter along columns indicate no significant difference [Z]

	Tme to re-water (secs)	Infiltration time (secs) before and after compaction		Resilience	Clippings (g) before and after compaction	
Species		Before	After		Before	After
Kikuyu grass	114.8a	210.6a	474.6a	489.6a	12.4a	11.7a
Bermudagrass	95.6b	170.7a	459.3a	209.6b	9.5b	0b
LSD0.05	8.9	ns	ns	28.6	1.5	1.8
Media						
Sand:soil (0:1)	129.6a	341.7a	619a	511.8a	12.4a	5.9a
Sand:soil (1:2)	110.4b	226.3b	531b	258.3c	10.3bc	4.1b
Sand:soil (1:1)	97.6c	111.5c	408.5c	374.2b	11.9ab	7.3a
Sand:soil (2:1)	83.2d	83c	309.3d	254.2c	9.2c	6.1a
LSD0.05	4	54.2	53.1	21.1	2.1	1.4
Species x media	ns	ns	*	***	***	**

[Z] *Values of treatment means with same letter following each other along columns indicate no significant difference (ns).*

Significant effects on infiltration time after compaction, resilience and clippings yield were observed on 'media type × turf grass type' interaction. The lowest resilience was recorded in Kikuyu grass and highest in Bermuda grass. Resilience affects ball rebound and ball roll characteristics. Magi et al., (2004) showed that ball rebound was higher in native soil as compared to sand profile and ball roll was longer in native soil. The observations agree with our results and indicate that compaction lowers resiliency the effect being more on un-amended soil than on sand based profile. Wear, inflicted through compaction lowered grass cover especially for Bermuda grass. This is shown by the significant differences in clippings weight between the two turf grasses (Table 1). This is important because it affects playing quality aspects of soccer of ball-surface and player-surface characteristics (Reyneri and Bruno, 2004). Thus although resilient, the low shoot density of Bermuda grass limits the amount of pressure it can take if subjected to intense repeated use.

Discussion

Compaction increased infiltration times in all media and the differences between media were significant ($P<0.05$) (Table 1). Infiltration time was highest in soil only and lowest in sandy media. As a result watering frequency increased as the sand proportion in media increased. Resiliency was significantly best in media amended with high sand, 2:1 type. Turf grass health was severely affected by wear due to compaction as shown by weight of clippings. Bermuda grass was most susceptible to compaction but had better resilience quality.

Conclusions

The results show that when evaluating turfgrass, media physical factors must be amended with respect to expected intensity of use of turfgrass surface. This is because the adverse effects of wear due to compaction affects not only the turfgrass but also the media. The usefulness of regular field de-compaction in turf grass management is emphasised. However still, a media of allowable physical properties and has nutritional value is still needed for healthy turf and quality playing surface.

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Natural Pest Control and Organic Farming in Tanzania

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Abstract

In recent years, awareness and interest in organic farming has been on the increase in Tanzania due to rising global-market demand, concern about side effects of chemicals, and environmental protection. The use of natural pesticides in many parts of Tanzania is not new to farmers. *Tephrosia vogelii*, *Neuratanenia mitis*, pyrethrum powder, tobacco extracts, tobacco dust, chillies, black pepper, pine leaf ash, fresh and dry cow dung are some of the natural pesticides commonly used. These pesticides are used to control insect pests and nematodes in banana, maize, beans, cotton and vegetable crops. Other non-chemical pest control measures such as biological and cultural practices are also applied though not adequately. However, most of the practices rely on farmer's experiences and indigenous knowledge. Most research conducted in Tanzania is not conclusive. As a result, there are few scientific recommendations on the types, methods and rates of application for the common natural pesticides. Commercially, however, only a few of these plants, and especially those containing azadirachtin and pyrethrins have been used to a large extent. The majority of plants that can be used for control of insect pest are only found in their natural habitats e.g. forests. There is, therefore, a need for germplasm collection, protection of natural sources of the plants, and increased commercial processing of different types of natural pesticides. To increase productivity of organically grown crops, there is also a need to improve research to provide scientific verification of farmers' experiences. Particular emphasis should be placed on dissemination of technical information that is already available in different research and training institutes to organic farmers. This paper reviews the research work done on natural pest control in Tanzania. Details of the common plant extracts used to control insect pests in Tanzania are also presented.

Key words: Neem, organic farming, pest control, pyrethrum, Tanzania

Introduction

Organic farming is defined as a way of farming that avoids the use of synthetic chemicals and genetically modified organisms (GMOs) and according to its proponents, follows the principles of sustainable agriculture (Wordiq Dictionary and encyclopedia, 2004). The major differences between organic and conventional farming lie in their approaches to soil fertility and pest management (Oelhaf, 1978). While conventional agriculture relies upon synthetic chemicals to control pest, organic farming largely uses biological methods. Organic farming puts emphasis on preventive non-chemical pest management while the conventional approach is chemical and eradicative (Diver et al., 1995).

One of major constraints in organic farming in Tanzania is pest and diseases, which reduces yield and quality of different crops. The situation has been attributed by unavailability of botanical extracts at commercial level, inadequate data on efficacy of botanical extracts, inadequate information on cultural and biological methods and inadequate scientific verification of farmer's experiences. In order to establish sustainable organic farming systems in Tanzania, there is a need to solve the existing constraints and identify unexploited potentials. Unfortunately, today there is inadequate coordination of organic farming research activities in Tanzania. Therefore, the objective of the present study was to elaborate the status of research on natural pest control in order to generate information that will be used to develop strategies and policies necessary for improvement of organic farming in Tanzania.

Methodology

The study involved literature search and reviewing of different government and institutional documents relevant to the objective. Information on the status of research was extracted from a detailed inventory of research programmes and recommendations conducted in all National Agricultural Research Institutions (NARs) in Tanzania early this year by a team from the Ministry of agriculture HQ (Kanyeka and Kamala, 2005).

Results

Organic farming in Tanzania

Though organic farming is currently practiced at a small scale in Tanzania, there is an increase in awareness and interest in the society. In 2001 the land area under organic cultivation in the country was 5155 ha (World Resource Institute, 2003). By the end of the year 2002, there were about 4000 registered organic farmers in the country (Crawley, 2002). Organic fruit, vegetables, nuts, oil and oil seeds, coffee, honey, herbs and spices are produced in Tanzania (Olesen, 2000).

Currently, a number of organic products including black tea, hibiscus tea, essential oils and spices are exported. Organic tea has been grown and exported from Tanzania since the 1980s (YuWen and YW, 2000) and currently is produced in Usambara and in the southern highlands (Clipper Teas, 2002), while organic spices are cultivated in Zanzibar (Hampl et al., 2000). Organic cotton is produced in Meatu under the supervision of a partnership project between GTZ, Unionmatex, Remei and Tanzania government. In Meatu, organic cotton farming was introduced in 1996 starting with two villages. Until 2002, the number of farmers participating in the project was 750 and the area under organic cotton cultivation was 3519 hectares (Hohmann, 2002).

The Ministry of Agriculture and Food Security (MAFS) in collaboration with NGOs, CBOs, traders, exporters and other development partners is promoting the development of organic agriculture in the country. MAFS has taken this challenge seriously by including it in the Agriculture Sector Development Strategy (ASDS) and the Agricultural Sector Development Programme (ASDP). Other organizations include Tanzania Organic Agriculture Movement (TOAM), a Non Governmental Organization (NGO) that unites different stakeholders and all institutions that are interested in organic farming, "Kilimo Hai Tanzania" (KIHATA), Tanzania Organic Foundation (TOFO), the Export Promotion of Organic Products from Africa (EPOPA), Global Service Corps (GSC), Family Alliance for Development and Cooperation (FADECO) of Karagwe, Peramiho Organic Farming Institute in Songea and the Students Partnership Worldwide (SPW), a registered NGO based in Iringa.

Marketing organizations such as Amka of Moshi and trading companies like Kowei of Tanga, Family Alliance for Development and Cooperation (FADECO) of Karagwe and Zanz-Germ Enterprises Ltd of Zanzibar, purchase and export organic produces. Through efforts and assistance from EPOPA, Tanzania has managed to establish its own organic certifying body TANCERT.

Research in natural pest control

Research on alternative or natural methods to control pest and appropriate management of soil fertility is inevitable for increased production and productivity of organic crops. In organic farming, control of pests and diseases is based largely on biological methods including cultural practices and use of botanical extracts. Research done in different institutions in Tanzania; have come up with various recommendations as presented in Table 1, 2 and 3.

Cultural methods

Cultural methods recommended for organic farming include crop rotation, mixed farming and diversification, host plant resistance and tolerance, flooding, deep ploughing, flaming, fallow, use of trap crops, field sanitation, intercropping and many others (Wang et al., 2000; Katan et al., 2000; Stoll, 2000; Jansson, 2001). However, most of these methods are not adequately practiced by farmers in Tanzania. Table 1 presents an inventory of research done on control pests using different cultural methods and recommendations given by various research institutions.

Use of botanical extracts

The effect of botanical extracts on pest control is through structural strengthening of the plant, (by supplying nutrients, trace elements, growth substances and vitamins) increasing its resistance to the penetration of fungal mycelia and sucking insects such as aphids, or through encouraging vigorous growth to overcome an attack rather than by any direct toxicity. Horsetail for example, contains the fungitoxic saponium equisetonin as well as silicic acid that confer structural benefits (Lampkin, 1992). However, others have fungi-toxic or insecticidal effects. In Tanzania, the commonly used plant extracts for controlling pests and diseases include neem *(Azadirachta indica A. juss*), pyrethrum (*Chrysanthemum cinerariaefolium)* and garlic (*Allium sativum*), Comfrey, *Bauhnia* spp., Tagetes spp, tobacco, wood ashes, Rhubarib, Quassia, chillies, *Faurea salisina* and many others. In southern highlands, the use of natural pesticides is common to many farmers. *Tephrosia vogelii*, *Neuratanenia mitis*, pyrethrum powder, tobacco extracts, tobacco dust, chillies, black pepper, pine leaves ash, fresh and dry cow dung are some of the natural pesticides commonly used (BACAS, 1996). These pesticides are used to control insects and nematodes in banana, maize and beans (Mindasi et al., 1994).

Table 1. Examples of recommended cultural methods for controlling insect pests

Crop	Pest	Control method	Institutions
Beans	Bean stem maggot (*Ophiomyia phaseoli*),	Early planting, crop rotation, seed treatment, resistant varieties,	Uyole, Lyamungu, Ilonga, Selian
	Bean foliage beetle (*Ootheca benningseni*)	Timely planting, post harvest tillage	
	Aphids (*Aphis fabae, Aphis craccirora*)	Timely planting	
	Bean bruchids (*Ancathoscelides obtectus*)	Early harvest, hygienic storage	
Coconut	Coreid bug (*P.s wayii*), Rhinoceros beetle (*Oryctes monoceros*)	Intercrop coconut + citrus & mango, remove pests, destroy infested wood	ARI-Mikocheni
Maize	-Stalk borers *(Busseola fusca)*. -Armyworm (*S. exempta*) & Large grain borer (*P. trancatus)*	-Timely sowing, field sanitation, rouging, intercropping with pulses -Burning of crop residue	Uyole, Ilonga, Dakawa, Selian and Ukiriguru
Cassava	Cassava green mites (*Mononychellus tanaja*)	Sanitation, crop rotation, resistance, clean plants, early planting, intercrop	Kibaha, Ukiriguru and Naliendele
	Meal bug (*P. manihot)*	Early planting	
Cabbage	Diamond back moth *(Plutella xylostella)*	Crop rotation, intercropping with onion or garlic, mulching	HORTI Tengeru
Sweet potatoes	Rough weevils, *Cylas puncticollis*	Early planting, harvesting, crop rotation, hilling up	Ukiriguru
	Stripped weevil (*Alcidodes dentipes)*	Destruction by hand picking	
Rice	Stem borer (*Maliarpha spp),* rice gall midge *(Oryseolia oryzvola)*	Crop rotation, remove crop residues, field sanitation, early planting	Katrin, Ukiriguru
Irish potatoes	Potato tuber moth (*Phthorimaea opercullella*)	Hilling, removal of volunteer & alternative hosts, field sanitation, & disposal of culls	Uyole
Tomato	Fruit worm	Destroy infected residues and fruits after harvesting	HORTI Tengeru
	Red spider mite (*Tetranychus spp*)	Moist microclimate, remove and destroy infested plant residues	
Onion	Thrips (*Thips tabaci)*	Sanitation, intercropping with carrots, mulching	

Neem tree (*Azadirachta indica*) that originated from Asia was introduced to Tanzania about 40 years ago by the Indians. Currently, the number of neem trees in Tanzania is estimated to be 4 million, which are widely spread in Tanga, Mtwara, Kilimanjaro, Dodoma, Morogoro, Shinyanga, Ruvuma and parts of Tabora (NBRA, 1999). The active ingredient in neem is Azadirachtin. Neem posses a wide range of pest and disease control properties including insecticidal, repellent anti-feedant, growth inhibiting, fungicidal and nematicidal. Studies have shown that neem is effective in controlling nematodes (*Meloidogyne incognita*) in tomato (Siddiqui and Alam, 1997; Nanjegowda et al., 1998; Naik et al., 1998; Reddy et al., 1998). As to fungal infections, neem is effective against *Fusarium oxysporum* (Stoll, 1986; Padmodaya and Reddy, 1999) and powdery mildew in tomato, cashew nut, grapes (NBRA, 1999), cucumber and apples (Stoll, 2000). Stoll (1986), listed a number of insect pest that are controlled by neem including American bollworm, aphids, diamond back moth, cabbageworm, Colorado beetle, cutworms, flea beetle, large cabbageworm, leaf miner, mites and white fly. Neem showed high potential for the control of *Helicoverpa amigera* in tomato (Mahadevan, 1998) and in cotton (Ng'homa, 1999).

Pyrethrum (*Chrysanthemum cinerariaefolium*) is believed to have originated from Dalmatian Mountains of Yugoslavia (Stoll, 1986). Tanzania used to be the world's second largest producer of pyrethrum (Karel *et. al*., 1983). The main active ingredient in pyrethrum is pyrethrin 1 and pyrethrin II (Extension Toxicology Network (EXTOXNET), 1994). The effective range of pyrethrum is pure contact poison, repellent, insecticidal and anti-feedant (Stoll, 1986; Lampkin, 1992). Pyrethrum is effective against beetles, aphids, mites, locusts, thrips, moths, leather jackets and carrot fly (Stoll, 1986; Lampkin, 1992). However due to its broad spectrum characteristics pyrethrum kill beneficial insects as well as pests and is suspected to have harmful side effects on fish or other organisms (Lampkin, 1992). In an experiment conducted in Iringa (Mindas et al., 1994), pyrethrum dust (1.5%) was effective in controlling maize stalk borers.

Neorautanenia species that belong to the family Papilionaceae are widespread in the parts of Central and South Africa where they are used for fish poisoning and insecticidal purposes (Puyvelde et al., 1987). In addition, the author found that 12a-hydroxyrotenone is the active ingredient responsible for the insecticidal properties in *Neorautanenia mitis.* The plant is commonly used in the Southern highlands of Tanzania; where it is locally known as "Lidupala". Little information is however available on its effective range in controlling crop pests since there is only limited research results. Nevertheless, according to Shetto *et al.* (1995) preliminary results obtained on its effectiveness on maize pest control, are promising. Other studies conducted at Uyole Agricultural Centre (UAC), also reveal effective results on control of bean bruchids and pods borers (Kanyeka and Kamala, 2005). Table 2 presents an inventory of research done on botanical extracts and recommendations given by different research institutions.

Table 2: Recommended botanical extracts for control of insect pests

Crop	Pest	Botanical extracts	Research Institute
Beans	Bean stem maggot (*Ophiomyia phaseoli*)	*Tephrosia vogelii* extract	Uyole, Lyamungu, Ilonga, Selian
	Aphids	*Tephrosia vogelii* extract, *Vernonia amygdalina* leaf extract, *Neuratanenia mitis* tuber extract	
	Pods borers	*Tephrosia vogelii* extract	
	Bean bruchids	*Neuratanenia mitis* tuber extract, Neem powder, pyrethrum powder	
Maize	Maize stalk borers	*Tephrosia vogelii*	Uyole
Tomato	Fruit worm	Neem extract, powder, oil	HORTI-Tengeru
Cabbage	Diamond back moth (*Plutella xylostella*)	Neem seed water extract	HORTI-Tengeru
Cotton	American bollworm (*H. amigera*)	Neem	Ukiriguru
Irish potato	Potato tuber moth (*Phthorimaea opercullella*)	Use repellent plants such as lantana to protect stored tubers	Uyole

On the overall, the use of botanical extracts is yet to become a common practice in plant protection in Tanzania. Despite of the long list of botanicals known or being used by farmers, there is inadequate scientific research so far done to verify farmers' experiences (Table 2). Due to unknown active ingredients of some plants species, it has been difficult to recommend proper rates of application. Sometimes preparation methods at farm level involve the use of crude methods due to lack of processing equipment. The use of some botanical extracts such as tobacco to control insect pests may result in transmitting diseases such as tomato mosaic virus to tomato crop. Plants that can be used for pest control are not found everywhere, while production of botanical extracts at commercial level has only been achieved with neem and pyrethrum. Therefore, there is a need for more research to improve the situation. In addition, the current trend of destruction of forests poses a threat or may influence the disappearance of plants that are useful for pest control. There is therefore a need for germplasm collection and protecting the natural sources of the plants.

Biological control of pests

Biological control is one of the methods used to control pests in Tanzania. Having realised the importance and the need for such control measure, the ministry of agriculture established the Kibaha National Biocontrol Centre located in the Coast Region. Biocontrol programmes currently carried out at the centre include management of Cassava Green Mite (CGM), management of Cassava Mealy bug (CM), management of Citrus wooly flies, management of Cereal stem borer and management of diamond back moth in cabbage. Table 3 presents an inventory of research done on biological methods and recommendations given by different research institutions. Research to evaluate the effectiveness of a natural occurring bio-agent, the Nucleus Polyhdrosis Virus (NPV) as a possible management option for armyworm control is going on in Arusha. The initial results have been positive in Arusha Region thus further trials are being carried out in other locations. Other biological research includes control of *P. wayi* in coconut and cashew conducted at ARI-Mikocheni and ARI-Naliendele respectively.

Table 3: Recommended biological methods for control of insect pests

Crop	Pest	Natural enemy for Control	Research Institute
Cassava	Cassava meal bug Cassava green mite	*Epidnocarsis lopez* *Typhlodromallus aripo*	Kibaha
Cabbage	Diamond back moth, Aphids	*Bacilus thuringensis, Diadegma semiclausum*	Kibaha, HORTI-Tengeru
Cashew	Coconut bugs (*P. wayi*), Cashew mosquito (*Helopeltis analard*)	*Oecophylla longinoda*	Naliendele
Various	Armyworm	NPV	Armyworm-Tengeru
Coconut	Coreid bug (*Pseudotheraptus wayi* Brown)	*Oecophylla longinoda*	ARI-Mikocheni, ARI-Naliendele

For effective results it is recommended that coconut trees should be intercropped with suitable host trees for *O. longinoda* such as citrus and mango while at the same time allowing limited growth of weeds to facilitate movement and refuge for *O. longinoda* (Seguni, Z. and Mwaiko, 1994).

Conclusions and Recommendations

Awareness and interest in organic farming are on the increase in Tanzania. Insect pest is one of major constraint in organic farming. The use of natural methods of control is a logical choice for sustainable organic farming. Though inadequate, valuable research findings exist in different research institutions. However, there is limited adoption of the recommended technologies by farmers due to barriers in dissemination and up-scaling mechanism.

In order to increase production and productivity of organically grown crops, there is a need to improve the limited scientific research in natural crop protection to provide scientific verification of farmer's experiences. Furthermore, there is a need for germplasm collection and conservation, protection of the natural sources of the plants and increasing the commercial processing of different types of natural pesticides. Particular emphasis should also be given to dissemination and up-scaling of technical information on organic farming that is already available in different research and training institutes in the country, to organic farmers. Capacity building at various levels for different stakeholders is important. In addition, collaboration between research institutes and establishment of international, regional and country networks for information sharing is highly recommended.

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Effect of UV-Absorbing Greenhouse Covering Materials on the Immigration and Dispersal of Western Flower Thrips (*Frankliniella occidentalis*

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Abstract

Management practices that alter the light environment within growing areas have been shown to be effective in deterring the immigration of many insect pests into fields and greenhouses. However, the effect on the dispersal of insects and the mechanisms behind these phenomena still remain ambiguous. Studies were conducted to investigate the effect of UV-absorbing greenhouse covering materials on immigration and dispersal of western flower thrips (WFT) and their potential application in modification of the greenhouse environment for the control of WFT. Greenhouse UV-absorbing materials were compared with conventional UV-transmitting covers in choice and no-choice experiments, conducted in small tunnels. In choice tests, WFT were released from a black box at the centre of two tunnels and recaptured on either sticky cards or plants. Western flower thrips were found

to prefer the UV-A rich environment where 80-99% were recaptured under UV-transmitting materials. In no-choice tests with blue sticky cards, WFT flew further in UV-transmitting than in UV-absorbing tunnels. However, when plants were used, there was no significant difference observed in the dispersal of WFT. The results show a clear reduction of immigration of WFT and probable reduction in dispersal by UV absorbing materials. Thus these materials can be used in reducing pest pressure in protected cultivation.

Key words: *Frankliniella occidentalis,* greenhouse covers, Ultra Violet-light

Effect of Substrate Compost Content on the Vertical Growth of *Trichoderma harzianum* Along the Depth of Substrate

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Abstract

The efficacy of artificially introduced Trichoderma spp. in biocontrol is partly influenced by the individual isolate's capacity to establish and colonize the soil environment, and thereby form a sufficiently high population density for effective disease control. A study was conducted to evaluate the role of substrate compost content on the proliferation and spatial spread (vertical growth) of Trichoderma harzianum (T12). Tomato seeds were inoculated with a spore suspension of T12 before planting in substrate mixes containing varying amounts of compost, made by diluting compost with sand. The set up was laid out in the greenhouse for 4 weeks, after which the growth of T12 along substrate depth was assessed by estimating the number of Trichoderma propagules (colony-forming units, CFU) at 0-5, 5-10 and 10-15 cm substrate depths. Experiments were made on both sterilized and non-sterilized substrates. Increase in the amount of compost in the substrate stimulated the growth of Trichoderma in the top 0-5 cm, but did not yield significantly higher growth of T12 down the soil depth, except in compost-only treatments. The number of CFU counted at the upper (0-5 cm), middle (5-10 cm) and lower (10-15 cm) depths ranged from 64% to 83%, 9% to 14% and 4% to 21%, respectively, of the total propagules. Growth of the antagonist from seed inoculum was lower in non-sterilized compared to sterilized substrate.

Key words: Compost, growth, depth, *Trichoderma harzianum*

OFFICIAL CLOSING SPEECH

Prof. L. S. Wamocho, Department of Horticulture, Jomo Kenyatta University of Agriculture and Technology, Kenya

LADIES AND GENTLEMEN,

It gives me great pleasure to officiate at the closing ceremony of this memorable workshop on the status of plant health in organic horticultural production systems in the tropics. I would like to congratulate and thank all of you for the stimulating papers and discussions that have taken place for the last two days. It is commendable that the papers that have been presented addressed a variety of important issues that are pertinent to horticultural development. I would also like to congratulate this 5th HAK Workshop for electing into office Board of Trustees. This is a milestone in the development of HAK as a vehicle that will support growth of the horticultural industry in Kenya and Africa, as a whole.

LADIES AND GENTLEMEN,

It would be prudent to comment on the crucial role our friends from Hannover, who have been the Sponsors of the Horticultural Workshops, have played, resulting in the birth of this annual event. In this regard I would like to allude to a historical event a little bit. In 1995, Prof. Hartmut Stuetzel and a colleague of his whom I cannot recall by name visited the Department of Horticulture at JKUAT. I was the sitting chairman of the department then. The mission of their visit, I can recall, was noble and one of its kind ladies and gentlemen. Thus, to seek establishment of a linkage with their institution with the aim of helping sustainable establishment of greenhouse production of quality vegetables in the suburban market of Nairobi. At the time, however, the Horticulture Department at JKUAT was thin as most academic staff were on further studies. When Prof. Stephen Agong came for short leave, I mentioned to him about Prof. Hartmut Stuetzel's visit. I also handed to him the business card of Stephen with the hope that he would make a follow up. I want to recognize Prof. Agong's role in having made the connection and the role he has played this far. To Prof. Hartmut Stuetzel and the team members he has always brought with him, Dr. Andreas Fricke and Prof. Bernard Hau, HAK, the Kenyan horticultural industry, and the region as a whole owe you immensely for helping bring us the professionals together for this noble calling. The best we can say is that we shall continue to promote HAK and attract more membership through sustained participation. We also urge you not to shake HAK off your purse, as we still need you at this point in time.

LADIES AND GENTLEMEN,

Horticultural farming in Kenya began during the early settlements of immigrant races under the British colonial rule. Missionaries brought with them some fruit trees and vegetable seeds for growing in their kitchen gardens and so did the early settlers. There was no commercial activity as all the products were consumed at family/group level.

Thus Asians, who came during the building of the Kenya–Uganda railway from 1893–1902, brought with them the Asian vegetables and fruits (Karela, Gourds, Mooli, drumsticks, mangoes etc) while the Europeans brought cabbages, carrots, beetroots, rhubarb, plums, apples, pears, peaches, and strawberries. The Dutch settlers brought citrus, avocados, South African grapes, potatoes, fennel, Kales, fenugreek, cape gooseberries, and essential oils such as geranium, cedar, tung and eucalyptus.

Although the industry has made great strides in the more than 40 years it has existed it continues to face a number of challenges that need to be overcome. To my fellow colleagues from Kenya and from the region, I want us to remind ourselves of the challenges that face us. As an example, in 1998 I had an opportunity to participate in the 75th Japanese Horticultural Congress Anniversary. Their approach to research strategy and communication skills was very simple and specifically directed at solving farmer and industrial problems. This is very admirable.

LADIES AND GENTLEMEN,

From what I have heard and what has taken place in this workshop, I would like to make some brief observations:

1) First, I would like to congratulate the organizers for targeting such an important thematic area for sustainability of horticultural production in the tropical regions.
2) Secondly, this year's theme, 'Plant Health in Organic Horticultural Production Systems in the Tropics' is of crucial importance not only to us the consumers of resultant products but also the environment that we all live in. It is an undisputable fact that any country that does not utilize its resources well, losing its ability to feed itself becomes a slave to those who feed it. The ability to feed an ever-growing population depends on constant research and development of appropriate technologies.

LADIES AND GENTLEMEN,

It has taken us many years of searching for this forum through which we can use to assemble ourselves, share ideas and knowledge and even better know who is who and who is doing what. Now that we have a forum let us use it in an assertive way for the benefit of the farmer, policy makers, horticultural industry growth, professional development and well being of our people in general. To succeed, we need to remind ourselves constantly of the SWOT (**St**rength, **W**eaknesses, **O**pportunities and **T**hreats) of HAK as an organization, aims, objectives and its operations.

In this regard some observations I want to make are as follows: after our Hannover friends who have continued to fund HAK, what options do we have thereafter? Do we have the resources to continue to grow from strength-to-strength? In Kenya, the horticultural industry is doing well as far as the economy is concerned bringing in cash to the tune of KES 46 billions annually despite the many technical and social challenges it faces. Can you ladies and gentlemen imagine just what 1% of this money could do if channeled to HAK for its operations? Or for that matter, a small levy, say from the Kenya Flower Council (KFC), Fresh Produce Exporters Association of Kenya (FPEAK), Horticultural Crops Development Authority (HCDA), etc, who are the beneficiaries of the existence of HAK! This is only food for thought.

Given that it is over 30 years after the country started training its own technical personnel (thanks to the 5th HAK Workshop host institution, Egerton University, as a college at that time it was the government's chosen institution mandated to do so and it recruited its first 10 specialists in 1971) the Government does not seem to recognize the existence of the professionals in the horticultural industry when it comes to crucial appointments. Horticulture is taught at five of the six institutions of higher learning. An educational division of HAK could help evaluate and provide direction as to the professionals' valuable contribution to the development of various commodities and better utilization of resources. For instance, ornamental horticulture in general and floriculture, in particular, are displacing potential food crop producing areas when we know that ornamental crops do not necessarily need fertile soils but rather media manipulation to allow growth of quality produce and products.

LADIES AND GENTLEMEN,

Many economic giants that we know today have had their economies evolve through strengthening of agricultural bases and structures that undertake specialist roles such as HAK members are doing. We in Africa should take a cue from successful developments elsewhere and we can no doubt make a difference if we work hard and work together with our partners such as we have witnessed with our Hannover friends. We in HAK remain greatly indebted to Germany for the support given in this initiative.

Finally, ladies and gentlemen, let me finish by thanking the chief local organiser, Prof. D. K. Isutsa and her team for working around the clock to ensure everything went on smoothly. The paper and poster presenters should also be acknowledged for a job well done.

With those few remarks, it is now my pleasure to declare this 5th HAK Workshop officially closed. Thank you.

End.

WORKSHOP PROGRAMME

A.1: Programme of the Fifth Workshop on Sustainable Horticultural Production in the Tropics

Theme: 'Plant health in organic horticultural production systems in the tropics'
23rd to 26th November 2005, Egerton University, Njoro, Kenya
Wednesday, 23rd November 2005

08.00-08.30	**Registration and poster placement**
08.30-10.30	Opening Ceremony **Chair**: Prof. Dorcas K. Isutsa **Rapporteur:** Ms. Victoria A. Anjichi **Welcoming remarks:** Prof. Mary O. A. Onyango, Chair-Horticultural Association of Kenya (HAK) Prof. Stephen G. Agong, DVC (APD), JKUAT Ms. Gabriele von Firck; Regional Director, DAAD Prof. Louis M. Mumera; Dean, Faculty of Agriculture, Egerton University Prof. Shaukat A. Abdulrazak; DVC (R & E), Egerton University **Official Opening** by: Prof. Euticus M. Wathuta, Acting Vice Chancellor, Egerton University **Keynote Address**: Prof. Hartmut Stuetzel, Leibniz Universiät Hannover, Germany
10.30-11.00	Tea/coffee break with posters
11.00-12.30	Session 1 'Disease management for plant health' **Chair**: Dr. Andreas Fricke **Rapporteur**: Ms. Nancy Muthoka **Keynote lecture 1: 'Biological control of bean diseases using microorganisms' (*Prof. B. Hau**)** 1.1: Resistance expression to stem canker pathogen in a local *Brassica* species by Koech, J.* 1.2: Current characteristics of cassava mosaic disease in post-epidemic areas increase the range of possible management options by Mallowa, S. *, Isutsa, D., Kamau, A., Obonyo, R. and Legg, J. 1.3: Nematodes: major pests of tuberose (*Polianthes tuberosa* L.) produced by small-scale flower growers in Kenya by Muriithi, A. N.*, Njoroge, J. B. M. and Wamocho, L. S. 1.4: Seed disease effect on plant health of three African leafy vegetables by Ndinya, C. *, Van der burg, J., Auma, E., Groot, S. and Ochuodho, J. Reactions to all presentations
12.30-13.30	Lunch break
13.30-15.00	**Session 2 'Insect pest management for plant health'** **Chair**: Prof. Stephen G. Agong **Rapporteur**: Dr. John B. M. Njoroge Keynote lecture 2: 'Insect pest management for plant health: population dynamics of thrips in pure and mixed cropping' (*Dr. T. Losenge*)* 2.1: Effects of capsicum extracts on aphid infestation on cowpea by Gichimu, B. M. * and Ndong'a, M. F.O. 2.2: Development of tomato hybrids (*Lycopersicon esculentum* X *Lycopersicon hirsutum*) resistant to tobacco spider mite (*Tetranychus* evansi) by Wosula, E. N. *, Agong, S. G. and Knapp, M. 2.3: Impact of onion thrips (*Thrips tabaci* Lind.) infestation on dry matter partitioning and onion bulb yield by Waiganjo, M. M*, Sithanantham, S., Mueke, J. M. and Gitonga, L. M.

	2.4: Use of horticultural mineral oil for pest management by Wesonga, J. M. *
	2.5. Plant protection for sustainable horticultural production in the tropics by Bernhard Löhr
	Reactions to all presentations
15.00-15.30	Tea/coffee break with posters
15.30-17.00	**Session 3 'Appropriate technology and cropping systems for plant health'**
	Chair: Prof. Mary O. A. Onyango
	Rapporteur: Dr. Peter Masinde
	Keynote lecture 3: 'Effects of coloured mulch on aphids and/or *Lepidoptera* in lettuce and broccoli' (*Dr. A. Fricke)**
	3.1: Chemical suitability of some organic materials available in Kenya as components of potting substrate by Andika, D. O. * and Ngamau, K.
	3.2: Evaluation of potential trap crops for reduction of soil seed bank of *O. ramose* L. and *O. cernua* L. in tomato in the Central Rift Valley of Ethiopia by Engda Taddesse, G. *
	3.3: Utilisation of organic resources in the management of banana nematodes by Njeru, E. S. *, Kimenju, J. W. and Mutitu, E. W.
	3.4: Effect of water stress on physiology of mango seedlings by Luvaha, E.*, Netondo, G. and Ouma, G.
	Reactions to all presentations
Thursday, November 24th 2005	
08.00-09.00	**Session 4 'Economic, environmental and socio-economic issues in plant health'**
	Chair: Dr. Kamau Ngamau
	Rapporteur: Dr. John M. Wesonga
	Keynote lecture 4: 'Marketing Kenyan horticultural crops: opportunities and constraints' (*Ms. N. Muthoka**)
	4.1: Survey of the current status of weed control and herbicide usage by the small-scale commercial vegetable farmers in Kenya by Mburu, D. N. *
	4.2: Statistical assessment of the performance of planting materials of banana varieties for an on-farm trial in Kenya by Wepukhulu, S. B. * and Nguthi, F. N.
	4.3: Photosynthesis in avocado during salinity stress by Musyimi, D. M. *, Netondo, G. W. and Ouma, G.
	Reactions to all presentations
09.00-10.30	**Session 5 'Indigenous crops'**
	Chair: Dr. Monica M. Waiganjo
	Rapporteur: Ms. Alice N. Muriithi
	Keynote lecture 5: 'Effects of water stress on the growth of spider plant * African nightshade' (*Dr. P. Masinde)**
	5.1: Effect of nitrogen application on leaf yield and nutritive quality of black nightshade by Opiyo, A. M. *
	5.2: Effect of proximity between intercropped finger millet (*Eleucine coracana*) and slenderleaf (*Crotalaria brevidens*) on growth, development and yield of finger millet by Nyanapah, J. *, Dida, M. and Simbowo, F. O.
	5.3: Farmer-participatory prioritization and development of agronomic practices for African Leafy Vegetables by Mbugua, G. *, Gitonga, L., Gatambia, E., Mureithi, J., Karoga, J. and Manyeki, L.
	5.4: Improved community land use for sustainable production and utilization of African indigenous vegetables in the Lake Victoria region by Onyango, M. O. A, *, Tushabomwe-K, C., Wangari, M., Onyango, G. M. and Macha, E. S.
	Reactions to all presentations
10.30-11.00	**Tea/coffee break with posters**
11.00-12.30	**Session 6 'Quality aspects of crops for export'**
	Chair: Prof. Joel Koech

	Rapporteur: Ms. Florence Masia
	Keynote lecture 6: Questions on Kenya's horticultural industry: can Kenya cope? (*Dr. K. Ngamau**)
	6.1: Postharvest handling technologies practiced by informal flower vendors in Thika and Nairobi by Muchui, M. N. *, Manyengo, J., Gikaara, D., Muthama, B. and King'ara, G.
	6.2: Farmyard manure and plant density affect soil characteristics and productivity of strawberry cultivar Cambridge Favourite by Ogendo, R. O. *, Isutsa, D. K. and Sigunga, D.O.
	6.3: Response of French beans (*Phaseolus vulgaris*) to intra-row plant density in Maseno Division, Kenya by Mureithi, D. M. * and Onyango, M. O. A.
	6. 4: Effect of 'Purafil' ethylene absorber on postharvest quality of 'Fuerte' avocados by Anjichi, V. A.*, Okong'o, O. M., Opile W. R. and Muasya, R. M.
	Reactions to all presentations
12.30-13.30	**Lunch break**
13.30-15.00	**Session 7 'Genetic resources of horticultural crops and plant biotechnology'**
	Chair: Prof. Bernhard Hau
	Rapporteur: Dr. Wariara Kariuki
	Keynote lecture 7: Role of botanic gardens in horticultural crops' germplasm production and conservation in western Kenya (*Prof. J. C. Onyango*)
	7.1: Evaluation of some exotic turf grass species in the upper midland 1 agro-ecological zone at Maseno, Kenya by Okeyo, D. O. * and Njoroge, J. B. M.
	7.2: Response of African kale (*Brassica carinata*) to intercropping with other Indigenous Vegetables by Oseko, J. K*, Onyango, M. O. A. and Onyango, J. C.
	7.3: Preliminary assessment on seed polymorphism and germination of Kakamega and Arusha accessions of *Vignia subterranean* by Palapala, V. A. *
	7.4: Spatial analysis of Kenya's traditional leafy vegetable species: distribution and implications for plant genetic resources conservation by Mutegi, E. *, Muthamia, Z., Nyamongo, D. and Githae, P.
	Reactions to all presentations
15.00-15.30	**Tea/Coffee break with Posters/Working groups**
15.30-17.00	**Annual General Meeting of the Horticultural Association of Kenya**
	Chair: Prof. Mary O. A. Onyango
	Secretary: Ms. Alice N. Muriithi
17.00-17.30	**Closing Ceremony for Sessions**
	Chair: Prof. Mary O. A. Onyango
	Rapporteur: Dr. Peter Masinde
	Organizers remarks:
	Prof. Stephen G. Agong
	Prof. Hartmut Stuetzel
	Vote of thanks:
	Ms. Jacquiline Oseko, Participants' Representative
	Official Closing: Prof. Leonard S. Wamocho

Friday, November 25th 2005

08.00-17.00 Excursion to "Njoro Canning Factory, Baraka Agricultural College-Molo & Mau Narok Farmer''

Saturday, November 26th 2005

08.00-13.00 Excursion to "KARI-Njoro and Hygrotech Seed Company-Naivasha"

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