RESPONSE OF CLONAL TEA TO DIFFERENT TEA GROWING LOCATIONS, NITROGENOUS FERTILISER RATES AND PLUCKING INTERVALS IN THE KENYA HIGHLANDS

BY:

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DECLARATIONS

I certify that this thesis has not been previously presented for a degree in Maseno University or in any other University. The work reported herein is my original work and all sources of information have been supported by relevant references.

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DEDICATION

To my entire family.

ABSTRACT

Tea *Camellia sinensis*, is widely grown in the highlands of Kenya for manufacture of mainly black tea. The most costly inputs in tea cultivation are nitrogenous fertiliser and plucking which are key determinants of yield and quality. Previous studies evaluated yield and quality responses in single locations and results used to draw general agronomic recommendations. Consequently, recommendations are uniform in different locations despite variations in conditions responsible for growth. Blanket input use, may be subjecting some locations to lower yield and quality. Trials were conducted in five different tea growing locations in Kenya to assess yields and quality response of clone BBK 35 cultivar to location of production, nitrogenous fertiliser rates (0, 75, 150, 225, 300 Kg N/ha/year) and plucking rounds (7, 14, 21 days). From each location the green leaves were plucked and yield recorded. On three occasions when plucking intervals coincided, leaf was CTC manufactured and quality determined. There were significant ($P \leq 0.05$) yield increase and quality decline with increasing nitrogenous fertiliser rates at all locations, with significant ($P \leq 0.05$) interaction between geographical area of production and nitrogenous fertiliser rates in yields, demonstrating that the pattern of yield response of clone BBK 35 to nitrogen varies with locality. All the plain black tea quality potentials except thearubigins varied significantly ($P \leq 0.05$) with location of production. It is therefore impossible to make black tea with similar black tea quality parameters in all the locations. There were significant ($P \leq 0.05$) yield responses in various locations with three locations indicating yield increase with plucking intervals and two indicating decline with increase in plucking rounds with significant ($P \leq 0.05$) interaction between location and plucking intervals in yields, demonstrating that the pattern of yield response of clone BBK 35 to plucking intervals did not occur uniformly. Theaflavins, thearubigins, total colour, brightness and taster A and B scores varied significantly ($P \leq 0.05$) with plucking intervals while theaflavins, brightness and taster B declined while thearubigins and total colour increased at all locations. Quality of black tea declined with long plucking intervals at all locations. To increase yield in tea production, it is necessary to optimise nitrogen fertiliser application rates and plucking intervals for different locations. Shortening plucking intervals also leads to maximisation of quality. The various tea growing locations in Kenya therefore require different agronomic inputs to maximise on yield and quality.

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LIST OF ABREVIATIONS

BBK 35	Cultivar/Clone BBK 35
BR%	Brightness %
CTC	Cut Tear and Curl
DM%	Dry matter percentage
C	Catechin
EC	Epicatechin
ECG	Epicatechin gallate
EGC	Epigallocatechin
EGCG	Epigallocatechin gallate
IBMK	Isobutyl methyl Ketone
ISO	International Organisation for Standardisation
Mt	Made tea
N	Nitrogen
NS	Non significant
S15/10	Cultivar/Clone AHP S15/10
TC	Total colour by Robert's method
TF	Theaflavins
TR	Thearubigins
TRFK	Tea Research Foundation of Kenya

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CHAPTER ONE

1.0: INTRODUCTION

1.1: Background information

Tea, *Camellia sinensis* L. O. Kuntze, is widely grown in the highlands of Kenya and is mainly used to process black tea. It is grown on the foothills of Aberdares and Kenya mountains in the East of the Rift Valley and on the foothills of Mau ranges, Nandi, Kisii and Kakamega Hills in the West of the Rift Valley (Anon, 2004). However, the different locations record variable yields and quality leading to non-uniform earnings of the tea growers in different parts of the country.

Most tea growing agronomic recommendations in Kenya were developed at the Tea Research Foundation of Kenya (TRFK) in Kericho and recommended for use in the whole country (Othieno, 1988; Anon, 2002). However variations in yields (Wachira *et al.,* 2002) and quality (Owuor *et al.,* 1987c, 1988, 2010) have been recorded even in the same cultivar grown in different parts of Kenya. Thus the uses of recommended agronomic practices have not given identical tea yields and quality, in different locations of Kenya. There is urgent need to assess the agronomic inputs to establish the optimum requirements for high production and quality of tea in different Kenyan locations.

1.2: Nutrition

Fertiliser application is the second most expensive agronomic input in tea production (Othieno, 1980; Ellis & Grice, 1981; Ruto *et al,* 1994) after harvesting. Nitrogenous fertiliser application influences the yield through variations in rate of shoot extension, individual shoot weight and density (Odhiambo, 1989; Owuor *et al.,* 1997). Appropriate use of nitrogenous fertilisers lead to increase in tea production (Wanyoko, 1983; Willson, 1975; Owuor & Wanyoko, 1996) but the high rates of fertiliser application reduce black tea quality (Owuor *et al.,* 1990d, 2000). Despite the lowering of quality, high rate of application of nitrogenous fertiliser to tea is mandatory since it enhances yields (Othieno, 1988; Bonheure & Willson, 1992).

At present, uniform rates of nitrogenous fertilisers are recommended across the country (Othieno, 1988; Anon, 2002). The recommended rate of fertiliser application in Kenya is 100 to 250 Kg N/ha/year as NPKS 25:5:5:5 or NPK 20:10:10 (Othieno, 1988; Anon, 2002) the actual rate being dependent on level of production. But it is unknown if the optimal rate of nitrogen for production of high yields and quality tea vary with the region. These fertiliser recommendations were established under Kericho conditions, and may not be suitable for other tea growing locations in Kenya.

An evaluation of the fertiliser application rates is necessary so as to establish region specific requirements that would lower the cost of production due to the high price of fertiliser, indeed it is necessary to establish nitrogen fertiliser rates that would be a compromise between yield and quality in different tea growing areas of Kenya so that farmers realise high net returns.

1.3: Harvesting (plucking) intervals

Plucking is an important step in tea production. During the operation, young leaves are removed (Willson, 1992) for processing into various tea beverages. In the processing of black tea, the recommended plucking standard is two leaves and a bud that gives desirable good quality teas (Othieno, 1988; Owuor *et al.,* 1987a; Willson, 1992).

Generally, long plucking intervals reduce tea yields and produce coarser leaf than short plucking intervals (Odhiambo, 1989; Owuor & Odhiambo, 1993). However, conflicting information has been reported where yields decrease with shorter plucking intervals in Malawi and India, respectively (Palmer-Jones, 1977; Tanton, 1979) while in Kenya, yields increased with short plucking intervals (Othieno, 1988; Owuor *et al.,* 1997, 2000; Owuor & Odhiambo 1993, 1994). This could be due to differences in regional conditions of growth.

Tea grows at different rates in different locations (Obaga *et al.,* 1988, 1989; Squire *et al.,* 1993; Ng'etich & Stephens, 2001a, 2001b; Ng'etich *et al.,* 2001c). This leads to achievement of the recommended two leaves and a bud (Othieno, 1988) after different time lengths in different locations, suggesting that suitable plucking intervals may vary with locality. It is necessary to establish region specific plucking intervals that give high yields and quality tea to enable farmers maximise incomes from the tea.

1.4: Locational effects

The effect of region on growth is one of the factors determining the potential productivity of tea cultivars (Ng'etich & Stephens, 2001a, 2001b; Ng'etich *et al.,* 2001c). Cultivars that were bred and selected in Kericho are now grown in the entire Kenya tea growing locations and in many parts of Africa. Most farmers believe a cultivar will maintain the yield and quality potential as assessed in the region it was developed and respond uniformly to the agronomic practices everywhere it is grown. It is not known if the cultivars maintain their yield and quality potentials in the new habitats which differ widely in regional conditions such as total rainfall and its distribution, temperature and edaphic factors including drought, cold, frost, high solar radiation and soil characteristics (Wachira *et al.*, 2002). There is need to evaluate suitability of the use of uniform fertiliser rates and plucking frequencies suitable for providing high yields and good quality tea in different tea growing areas.

1.5: Tea clones and cultivars

Clones are tea plants that are derived from one bush (a mother bush) through vegetative propagation. Cultivars are plants that have been purposely selected and maintained through cultivation, i.e. culti(vated)+var(iety). They differ from others of the same species in minor but heritable characteristics e.g. clone BBK 35. Cultivars are normally registered and protected under law (Kamau, 2008).

1.6: Black tea quality

World tea production has been rising faster than demand (Anon, 2007), whilst costs of production continues to rise (Herath & Weersink, 2007). As a result only producers of high quality tea can sell at reasonable prices (Anon, 2007). Tea quality is traditionally judged by tea tasters through sensory/organoleptic methods. The quality parameters perceived by sight and taste are collectively called plain black tea quality parameters. They are composed of mainly theaflavins and thearubigins (Hilton & Ellis, 1972; Roberts & Smith, 1963). The theaflavins influence black tea astringency, briskness and brightness while thearubigins affect black tea thickness and infusion colour.

Many studies have shown significant relationship between theaflavin levels and sensory evaluation and/or price of black tea (Cloughley, 1983; Deb & Ullah, 1968; Owuor *et al.*, 1986, 2006). Indeed, the theaflavin levels have been proposed for use as an indicator standard in the tea trade (Davis, 1983). It is necessary to develop agronomic practices in tea production that lead to high quality teas.

1.7: Statement of the problem

Making the correct choice of agronomic inputs remains a big drawback among farmers. It is not known if nitrogenous fertiliser rate and plucking interval leading to production of high yield and quality at one site will be suitable in other tea growing locations. As a result the current blanket agronomic recommendations in all locations may not be ideal and may lead to farmers' failure to achieve the desired yields and quality, hence low incomes. There is need to assess how adaptable and successful the current agronomic recommendations are and to develop region specific agronomic recommendations to increase productivity that give maximum profit and reduce losses due to poor agronomic practices.

1.8: Justification

Nitrogenous fertiliser application and harvesting are the most expensive field agronomic inputs in tea production (Anon, 2002; Othieno, 1988). Inappropriate fertiliser use leads to farming losses through low yields and poor quality. It is necessary to evaluate various nitrogenous fertiliser rates in different tea growing locations of Kenya aimed at developing optimal rates specific to each region for maximisation of yield and quality and reduction of tea farming losses.

Recommended plucking frequencies (Anon, 2002; Othieno, 1988) in Kenya tea growing locations are the same. However yields (Wachira *et al.,* 2002) and quality (Owuor *et al.,* 1987c, 1988) vary with geographical area of production suggesting variations in growth rates. It is necessary to establish the most appropriate fertiliser rates and plucking intervals that would compromise between yield and quality in different tea growing areas in Kenya.

1.9: Research questions

1. Will the fertiliser requirements for BBK 35 vary with locality?
2. Will plucking intervals for BBK 35 vary with locality?
3. Will yield and quality potentials vary due to fertiliser rates and plucking intervals?

1.10: Research objectives

1.10.1: Broad objective

1. To evaluate the black tea yield and quality response of clone BBK 35 tea grown in different parts of Kenya to varying nitrogenous fertiliser rates and plucking intervals.

1.10.2 Specific objectives

1) To establish if fertiliser requirements for clonal tea varies in various localities.
2) To determine if yield and quality response of one clone in different localities varies with plucking frequency.
3) To establish the effects of nitrogenous fertiliser rates and plucking frequency of clonal tea in different parts of Kenya.

1.11: Hypotheses

Stable performance of a crop cultivar over a wide range of locations is regarded as desirable. It is hypothesized that the black tea quality and yield response of clone BBK 35 cultivar planted in different locations of the country would not vary due to nitrogenous fertiliser rates and plucking intervals.

CHAPTER TWO

2.0: LITERATURE REVIEW

2.1: Importance of tea to Kenyan economy

Tea, *Camellia sinensis* L. O. Kuntze, is an important commodity crop in Kenya and the leading single foreign exchange earner. Kenya is the fourth leading producer of tea in the world after China, India and Sri Lanka accounting for about 20% of world tea production (Anon, 2007). The tea industry and its allied activities employ directly over 500,000 families, each on the average supporting 6 members (Ogola & Kibiku, 2004). It is estimated that tea and allied industries/activities support over 3 million Kenyans, most of them being smallholder families living in rural areas where economic activities are low. Multinationals also contribute to the success by creating job opportunities to the local population in the factories and in the estates. Tea therefore contributes to poverty reduction, promotes infrastructure development in the rural areas and earns the government foreign exchange and revenue.

The favourable conditions for tea cultivation include suitable temperature (15-25^{o}C), high relative humidity (80-90%), high annual rainfall (1200-2000 mm) and acidic soils pH (4.0-5.6) (Othieno, 1988; Anon, 2002) conditions that prevail in Kenya highlands. Such lands have high potential and should be subjected to maximum economic production for faster industrial development and poverty reduction. The lands under tea and total tea production in Kenya over the years is summarised in (Table 2.1).

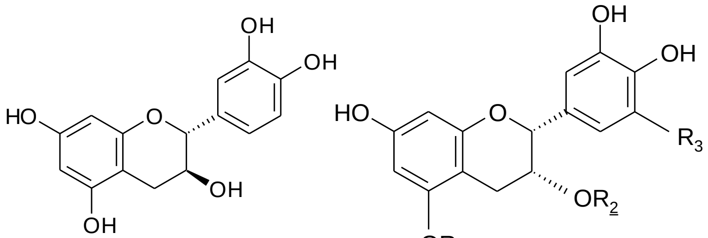
Table 2.1**:** Area under tea and tea production in Kenya

Year	Area under tea (Ha)	Tea production (metric tons)
1997	110,222	209,422
1998	114,458	294,165
1999	117,437	248,818
2000	117,350	236,286
2001	118,650	294,631
2002	124,201	287,102
2003	126,203	293,670
2004	131,581	324,609
2005	139,976	328,584
2006	131,419	310,607

Source: Anon, 2007.

2.2: Tea chemistry

Tea leaf contains high levels of polyphenols. These polyphenols are dominated by (+)-catechins (C) **[1]**, (-)-Epicatechin (EC) **[2],** (-)-Epicatechin-3-gallate (ECg) **[3]**, (-)-Epigalocatechin (ECG) **[4],** and (-)-Epigalocatechin-3-gallate (EGCG) **[5]** flavan-3-ols. **[6]** (Balentine *et al.,* 1998). The structures (Robertson, 1983a) of the catechins are summarised in Figure 2.1 below:-

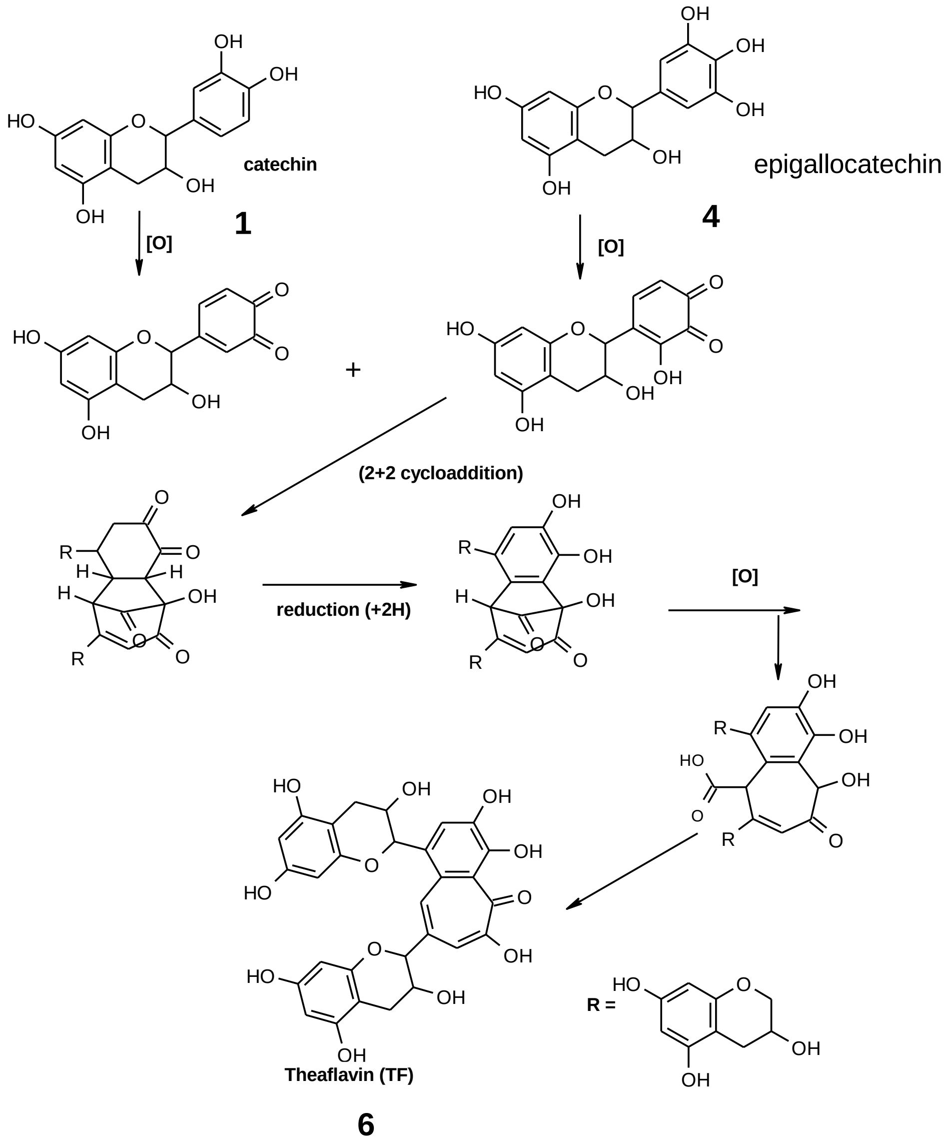


1

	R_1	R_2	R_3
2	H	H	H
3	H	gallate	H
4	H	H	OH
5	H	gallate	OH

Figure 2.1**:** The flavan-3-ols (catechins) in fresh tea leaves

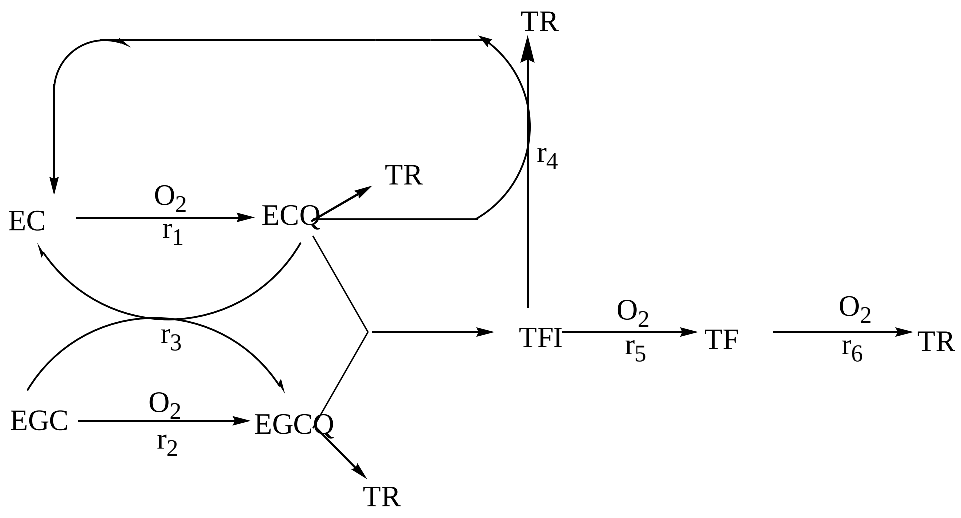
During the fermentation phase of tea processing various theaflavins **(5)** are produced by oxidative dimerisation of a simple dihydroxy catechin **[3]** and a trihydroxy catechin **[4].** The fermentation is catalysed by polyphenol oxidase O-diphenol: O_2 oxido reductase (Takino *et al.,* 1964) in presence of oxygen as outlined in (Figure 2.2).



Source: Takino *et al.*, 1964

Figure 2.2**:** Simple representation of formation of theaflavin molecule

Theaflavins **[6]** contribute to the astringency (briskness) and brightness, thearubigins contribute to the colour and thickness (mouth feel) and caffeine is responsible for the stimulatory effects of black tea (Biswas *et al.,* 1971, 1973; Biswas & Biswas, 1971). Thus, the correct levels and balance between theaflavins and thearubigins ensure high quality in tea production.



EC, epicatechin; EGC,epigallocatechin; ECQ, epicatechin quinones; EGCQ, epigallocatechin quinone; TFI, theaflavin

intermediate; TF, theaflavin; TR, thearubigin

Source: Robertson, 1983a.

Figure 2.3**:** Scheme showing formation of thearubigins

2.3: Nitrogenous fertiliser effects on quality and yield

Beneficial yield responses have been recorded in tea production due to nitrogenous fertiliser applications (Bonheure & Willson, 1992; Othieno, 1988; Owuor *et al.*, 2008a). Nitrogen is the most important nutrient for tea (Ranganathan & Natesan, 1987) and it is required in large quantities, accounting for approximately 4 to 5% of the dry weight of the harvested shoots. Nitrogenous fertiliser use varies from 45 Kg N/ha/year in Democratic Republic of Congo to 800 Kg N/ha/year in Japan (Owuor & Wanyoko, 1996). For most tea cultivars, 100 to 150 Kg N/ha/year range is the most economical (Owuor & Othieno, 1996; Ruto *et al.*, 1994; Kamau *et al.*, 2005). In the Kenya highlands where tea is planted, there are usually heavy rains leading to massive leaching of nutrients. Additionally, the harvested crop also carries with it high amounts of nutrients (Owuor, 1997). Fertilisation is therefore an important approach to nutrient replenishment. High nitrogen fertiliser rates has been reported to improve the fresh weight of shoots harvested in Malawi but the dry matter yields declined and the proportion of waste fibre in the final product increase (Tanton, 1979, 1982; Grice, 1982; Mitini-Nikhoma, 1989). In Kenya, yields have been increased by application of NPKS 25:5:5:5 fertilisers (Owuor & Odhiambo, 1994; Wanyoko, 1983; Owuor & Othieno, 1996; Owuor & Wanyoko, 1996). The recommended rate of nitrogen application on tea in Kenya varies from 100 to 250 Kg N Ha/Yr (Othieno, 1988). However, no fertiliser trial has compared yield responses to nitrogen fertiliser rates using a single cultivar grown in different locations of Kenya. Application of fertiliser to improve plant growth and crop yield has long been a common practice in tea cultivation, but high quantity of nitrogenous fertilisers has a deleterious effect on quality of made tea (Guseinov, 1973; Ranganathan & Natesan, 1987; Owuor, 1989, 1997; Owuor & Othieno, 1996; Owuor & Wanyoko, 1996; Owuor *et al.*, 1987, 1997, 2000). However, trials used to formulate fertiliser use recommendations were conducted at single locations and it is not known if the results would be repeated at different locations. Where comparisons have been done at different locations the varieties have been different (Owuor, 1997, Kamau *et al.,* 2005; Owuor & Othieno, 1996) making it difficult to isolate the effects of locality and cultivars. Indeed, no fertiliser trial has compared quality and yield responses to nitrogenous fertiliser using the same cultivar grown in different locations of Kenya.

2.4: Plucking intervals and yields

Late plucking interval leads to over growth making it necessary that extra leaf is broken back (Mwakha & Anyuka, 1984). This late harvesting can be overcome by plucking at optimal harvesting interval. The yield potential in tea production is highly dependent upon the plucking interval. Whenever plucking intervals are too long, puckers' harvest mostly young tender shoots of two leaves and a bud and then break-back, a practice done to remove extra mature leaf left above the plucking table. The "broken-back" leaves are thrown away and are losses to farmers (Mwakha & Anyuka, 1984). Alternatively, some farmers pluck everything on the plucking table leading to quality decline. Conflicting yield results have been obtained due to long plucking intervals. It has been observed in Malawi (Tanton, 1979, 1982; Grice, 1982; Mitini-Nikhoma, 1989) and South India (Sharma, 1987) that long plucking intervals improves yields. The yield increase with long plucking intervals in Malawi was due to faster production of a large number of shoots of harvested size; production of more shoots per unit area of bush surface and enhanced photosynthetic efficiency due to better light penetration in the lower crop canopy. For example 80% of tea in Malawi is produced within 5 months of the year that is December to April (Cloughley, 1983).

In Kenya yield increase has been reported with short plucking intervals (Odhiambo, 1989; Owuor &Odhiambo, 1993, 1994; Owuor *et al.,* 1997, 2000). Such variations in response could be due to regional factors or length of the experiments. Growth in Kenya is continuous throughout the year, although high yields are observed in April to June and October to December (Owuor *et al.*, 1990b). The studies in Kenya were however carried out over longer periods (Odhiambo, 1989) than those in Malawi (Mitini-Nikhoma, 1989). It has been argued in Kenya that the higher total number of shoots harvested in the shorter plucking intervals compensate for the higher mean shoot weights obtained with the longer plucking intervals (Odhiambo, 1989). It is necessary to correctly assess plucking interval for various tea-growing areas in Kenya for farmers to realise high economic production and the high potential lands to be optimally utilised.

2.5: Effects plucking intervals on quality

Plucking is a very labour intensive and costly exercise (Ellis & Grice, 1981). In India, it is estimated that harvesting constitutes up to 70% of the total costs of field operations (Sharma *et al.,* 1981; Sharma, 1987). Despite the high costs, the undertaking is indispensable but incorrect plucking operations lead to farming losses. Black tea quality varies with plucking standards (Owuor *et al.,* 1987b; Mahanta *et al.,* 1988). The recommended plucking standard practiced in Kenya, is the tender two leaves and a bud (Othieno, 1988; Anon, 2002). This produces black teas with acceptably high quality and good economic returns (Mahanta *et al.,* 1988; Owuor & Obanda, 1998; Owuor *et al.,* 1987a, 2000; Obanda & Owuor, 1994). It is necessary to harvest leaves when they have attained the recommended plucking standards.

Plucking intervals affect black tea quality (Baruah *et al.,* 1986; Owuor & Odhiambo, 1994). Black teas plucked from short plucking rounds have been shown to have superior quality compared to those from long plucking rounds (Mahanta *et al.,* 1988; Owuor & Odhiambo, 1993; Owuor *et al.,* 1990c, 1997, 2000). Previous studies have also shown that leaf standard, chemical composition and quality of black tea also vary due to plucking intervals (Owuor *et al.,* 1990c).

With long plucking intervals, there is a higher proportion of coarse leaf to fine leaf and low black tea quality. With frequent plucking, the shoots obtained are mostly young as the proportion of coarse leaf or leaves to be broken back leaf is reduced (Grice, 1982). Where there is no selection of leaf, long plucking intervals reduce black tea quality (Baruah *et al.,* 1986; Owuor *et al.,* 1990c, 1997; Owuor & Odhiambo, 1993, 1994). However, even when the plucking standard is maintained at two leaves and a bud, long plucking intervals reduced tea quality in a single site study using high yielding clone S15/10 (Owuor *et al.,* 2000). However, these studies were conducted at single site and it is not known if the responses would vary with locality. Plucking intervals need to be optimised in different localities in Kenya to improve black tea quality and reduce crop losses.

2.6: Effects of plucking techniques on yield and quality

Quality chemical and sensory evaluation parameters of black tea change with method of plucking. In South India (Ravichandran & Pathiban, 1998) hand-plucked teas were found to be very rich in their green-leaf biochemical quality precursors and had higher contents of made-tea quality constituents than shear-plucked teas. The quality deterioration with shear plucking is mainly due to mechanical injury and non-selective plucking with shear-harvesting. However, tea obtained by shear-harvesting from a continuously sheared field over a prolonged period is superior. At the same time quality parameters also change due to the use of mechanical harvesting due to varying plucking round lengths and height (Owuor *et al.,* 1991b).

The use of hand held shears reduced the yield and increased the plucking average with a net decrease in cost of production compared to hand plucking. Similarly in a study using two different cultivars, hand plucked teas had higher theaflavins (TF), caffeine, brightness, flavour index, and sensory evaluations than shear plucked teas irrespective of variety (Owuor & Odhiambo, 1993; Owuor *et al.,* 1991).

2.7: Locational effects on yield and quality

Even though tea production continues throughout the year in Kenya, seasonal variations in yields and chemical composition occur due to changes in regional conditions (Owuor *et al.,* 1991; Obaga *et al.,* 1988, 1989; Squire *et al.,* 1993; Mahanta *et al.,* 1988). Quality of tea has been found to change with region (Owuor *et al.,* 1988, 2008a). Black tea quality and taste change with variations in geographical (Yamanishi *et al.,* 1968; Horita & Owuor, 1987; McDowell *et al.,* 1991; Borse *et al.,* 2002; Peterson *et al.,* 2004) and climatic (Howard, 1978; Cloughley *et al.,* 1982; Owuor, 1992) conditions. In other studies, using five different clones, levels of black tea theaflavins, thearubigins and caffeine varied with geographical area of production (Owuor *et al.,* 1987b, 1988). The green leaf composition varied with locations in China (Lin *et al.,* 1996). Such changes did not occur in any predictable way and varied with cultivar and agronomic practices (Lin *et al.,* 1996; Owuor, 1989). Due to these variations, black tea phenolic composition has been suggested as a way of predicting geographical origin (Mc Dowell *et al.,* 1991). The quality variations were in part attributed to differences in regional factors (Lin *et al.,* 1996; Anandacoomaraswamy *et al.,* 2000). These factors cause changes in growth patterns leading to variations in the chemical components which affect quality (Owuor *et al.,* 2008a). Where such comparisons have been done in the past (Owuor *et al.,* 2008a; Howard, 1978; Lin *et al.,* 1996; Yamanishi *et al.,* 1968), it has been assumed that the difference in regional factors were large. However, regional conditions in tea growing areas along the equator can be minimal. Despite this, region of production influences the black tea quality chemical characteristics even within Kenya (Owuor *et al.,* 1987c, 1988) suggesting that there may be variations in tea potentials depending on geographical area of production. In a study comparing teas of unknown backgrounds (Owuor *et al.,* 1986; Horita & Owuor, 1987a) large variations were noted in the chemical composition of black tea. This was partly due to regional conditions of growth but contributions of cultivars could not be isolated.

In a recent study, it has been shown that same tea cultivars ferment much faster in Malawi compared to Kenya possibly due to differences in regional conditions leading to different shoot growth rates and biochemical composition in the shoots (Owuor *et al.,* 2008a).

2.8: Effects of location, nitrogenous fertiliser rates and plucking intervals on yield and quality

There have been few trials in other localities to assess if these recommended agronomic inputs in Kenya are appropriate or optimal in their new locations. Trials from which the fertiliser use recommendations were derived were conducted at single locations and it is not known if the results would be repeated at different locations. Where comparisons have been done at different locations the varieties have been different (Owuor, 1997, Owuor & Othieno, 1996) making it difficult to isolate the effects of locality and cultivars.

Although widely used in various locations, it is not known if the fertiliser rates and plucking intervals recommended at the Tea Research Foundation of Kenya in Kericho are also optimal everywhere in the country, It is therefore necessary to evaluate the yield and quality response of one single cultivar to region, nitrogenous fertiliser rates and plucking intervals so as to establish compromised requirements that would give high yields and quality

CHAPTER THREE

3.0: MATERIALS AND METHODS

3.1: Site selection and cultivar

The trials were set on selected mature clone BBK 35 plantations that had been uniformly managed and with known past cultivation history in different geographical areas, namely Karirana Estate in Limuru, Timbilil Estate in (Tea Research Foundation of Kenya TRFK) in upper Kericho, Changoi Tea Estate in lower Kericho, Sotik Highlands Estate in Sotik and Kipkebe Tea Estate also in Sotik. The altitude, latitude/longitude, year of planting, age of plantation and last date of pruning are summarised in Table 3.1.1 below:

Table 3.1.1 Site locality and history

Site Locality/history	Karirana	TRFK Timbilil	Changoi	Sotik Highlands	Kipkebe
Altitude (m)	2260	2180	1860	1800	1800
Latitude	1^0 6'S	0^0 22'S	0^0 29'S	0^0 35'S	0^0 41'S
Longitude	36^0 39'E	35^0 21'E	35^0 14'E	35^0 5'E	35^0 5'E
Year planted	1991	1986	1989	1974	1978
Plantation age*	17	22	19	34	30
Last prune date	2005	2005	2005	2005	2005

* As at year 2008.

Source: Individual Organisation Records.

3.2: Design of experiments and treatments

The experiments were a factorial two arrangement laid out in a randomised complete block design with five fertiliser rates (0, 75, 150, 225 and 300 Kg N/ha/year) and three plucking frequencies (7, 14 and 21 day rounds) replicated three times at each site (Appendix 3). Each effective plot comprised 60 plants surrounded by a line of tea bushes that served as guard rows. Fertiliser application was done in November every year. First fertiliser application was done in the year 1998. The plots were uniformly managed and were pruned every four years. Prior to the experiments, all the plots were receiving 150 Kg N/ha/year. Plucking was done in different plots as per the plucking treatments, depending on the plot.

3.3: Yields

Yields were recorded on the day plucking was carried out and then converted to Kg made tea per hectare per year (Othieno, 1988) using the formula:

Kg mt/ha/year = (Kg/green leaf) X 13448 X 0.225/60

Where:-

13,448 = Number of bushes per hectare.

0.225 = Conversion factor of green leaf to black tea (Anon, 2007).

60 = Number of plants per plot.

3.4: Processing/manufacture of black tea

On the day all the three plucking intervals coincided in each experiment, a mass of 600 grams of tea leaf was harvested/sampled from each plot and brought to TRFK for miniature CTC processing using recommended methods (Owuor & Reeves, 1986). The leaves were withered over open bed shelves lined with nylon netting material for ambient withering of between 14-18 hours to reduce the moisture content to 70%. The withered leaf was macerated by hand feeding into the miniature CTC machine four times to cut, tear and curl the leaf into "dhool" followed by fermentation for 90 minutes at 26-28^{o}C before firing using a miniature bench top (Sherwood Scientific Cambridge UK) drier set at 90^{o}C to terminate fermentation. Lastly, the processed black tea was subjected to chemical and sensory analysis without sorting.

3.5: Analysis of plain black tea quality parameters and sensory evaluations

3.5.1: Theaflavin analysis

Total theaflavins was determined by the Flavognost method (Roberts, 1958). About 9 grams of black tea leaves was weighed into a 500 ml capacity thermos flask and an infusion made by adding 375 ml of boiling deionised water and shaking done for 10 minutes. Clean infused tea liquor was then obtained by filtering through cotton wool and the hot liquor allowed to cool to room temperature. A volume of 10 ml of the infusion was transferred into a volumetric flask; 10 ml of (IBMK) isobutyl methyl ketone added and then shaken on an orbital shaker for 15 minutes. The mixture was then transferred into a test tube to allow for two layers to separate. Exactly 2 ml of the upper layer was transferred into a test tube and 4 ml of ethanol and 2 ml of Flavognost reagent (2 g diphenyl boric acid-2-aminoethyl ester dissolved in 100 ml of ethanol) added. The mixture was then allowed to stand for exactly 15 minutes, once colour formation was observed the absorbance was quickly read at

625 nm against a blank reading of IBMK/ethanol (1:1v/v) in a CE 393 Digital Grating Spectrophotometer. The theaflavins were calculated at 625 nm.

Theaflavins (μ mol/g) = A_{625nm} X 47.9 X 100/DM.

3.5.2: Determination of thearubigins

The method of (Roberts & Smith, 1963) was used. A volume of 50 ml of the cool, well-shaken and filtered standard tea infusion from theaflavin analysis was mixed with 50 ml of (IBMK) and gently shaken to avoid formation of an emulsion. The two layers were then allowed to separate and a 4 ml portion of the IBMK layer drawn and made up to 25 ml in a volumetric flask with methanol. A volume of 2 ml portion of the aqueous layer was diluted to 10 ml with distilled water and then made up to 25 ml with methanol (Solution B). Twenty-five millilitres of the remaining initial IBMK layer was then taken in a separate flask and mixed with 25 ml of 2.5% aqueous sodium hydrogen carbonate. The mixture was vigorously shaken before the layers were allowed to separate and the aqueous layer discarded. A 4 ml portion of the washed IBMK layer was made to 25 ml with methanol (Solution C).

Two millilitres of a saturated oxalic acid aqueous solution and 6 ml of water were added to a 2 ml portion of the aqueous layer left from the first extraction with IBMK, and diluted to 25 ml with methanol (Solution D). The absorbance A_A, A_B, A_C, A_D of solutions A, B, C and D at 380 and 460 nm was then obtained using a CE 393 Cecil Digital Grating Spectrophotometer with distilled water as the blank (Obanda *et al.,* 2001).

The results were then used to quantify thearubigins as follows: -

Thearubigins (%) = 7.06 X (4(A_B-A_A) X DM%

DM% = dry matter %

3.5.3: Determination of liquor colour and brightness

Total colour and brightness were assayed as outlined by (Roberts & Smith, 1963). Five millilitres of filtered standard tea infusion from theaflavins analysis was pipetted into 45 ml of distilled water in a 100 ml conical flask and shaken well to ensure thorough mixing. The absorbance of this solution was observed at 460 nm and read against distilled water blank. The result was then used to calculate total colour and brightness % in the black tea samples using the formulas below.

Liquor colour = (A_{460nm} X 10)/(DM/100)

DM% = dry matter %

Brightness (%) = (100 x A_C)/(A_A + 2A_B)

3.5.4: Determination of dry matter contents

A mass of 0.200 ± 0.001 grams of the test sample was weighed into vials and placed in an oven set at 103 ± 2^{o}C for 4-5 hrs and the dry matter content calculated from the moisture content loss in mass in accordance with ISO 1570, (1981) for leaf tea.

3.5.5: Sensory evaluation

The black teas were evaluated by professional tea tasters at two tea broking firms in Mombasa city which is the second largest tea auction centre in world. The tasters have long experience in the Kenyan teas. A mass of 20 grams of the unsorted black tea leaves were packed in special aluminium coated sachets and sent to two professional tea testers for sensory evaluations. The teas were evaluated for brightness, briskness, colour, thickness and flavour on a scale of 0 to 20 for Taster A and 0 to 10 for Taster B for each attribute.

3.6: Statistical analyses

The results were analysed using a 5X5X3 factorial design with locations as main treatments, nitrogen NPKS 25:5:5:5 fertiliser rates as sub treatments and harvesting intervals days as sub-sub treatments. The results obtained from the analysis were then processed using (MSTAT-C, 1993) programme for ANOVA (Appendix, 1), while column charts, polynomial and linear regressions were performed using MS-Excel statistical packages.

CHAPTER FOUR

4.0: RESULTS AND DISCUSSION

Clone BBK 35 used in the study is a popular cultivar grown widely in Kenya for manufacture of black tea. It is recognised as high yielding with good tea quality potential (Ng'etich & Stephens, 2001c). In Tanzania it has yielded up to 6000 Kg mt/ha/year (Burges, 1983). In Kenya economic tea farming activities are located at higher altitudes between 1300 m amsl and 2700 m amsl. The lowest altitude field that was identified with well managed clone BBK 35 was at 1800 m amsl, while the highest altitude field was at 2260 m amsl.

4.1: Yield responses to nitrogenous fertiliser rates and geographical area of production

Yield response of clone BBK 35 to varying rates of NPKS 25:5:5:5 fertiliser at five locations are presented in (Table 4.1.1). Yield varied significantly ($P \leq 0.05$) due to nitrogen fertiliser rates. The control 0 Kg N/ha/year produced significantly ($P \geq 0.05$) lower yields. In deed in all the five locations, yields increases were observed with increase in nitrogenous fertiliser rates application (Table 4.1.1 & Figure 4.0.1). At all the locations, data were better represented by quadratic relationship between yields and nitrogenous fertiliser rates (Figure 4.0.1), with all having significant ($P \leq 0.05$) and $r^2 = 0.9$.

Table 4.1.1**:** Effects of region of production and nitrogenous fertiliser rates on yield (Kg mt ha/year) of clone BBK 35 in 2007

	N-Rates (Kg N/ha/year)					
	0	75	150	225	300	Mean locations
Karirana	3278	4192	4834	4875	4597	4355
Timbilil	2323	3334	3903	3808	3767	3427
Changoi	3438	4438	4965	4803	5014	4531
Sotik Highlands	2936	4215	4604	5275	5214	4449
Kipkebe	1681	2794	3553	3772	3848	3129
Mean N rate	2731	3794	4372	4507	4488	
CV (%)			8.15			
LSD,P ≤ 0.05			190			190
Interactions			561			

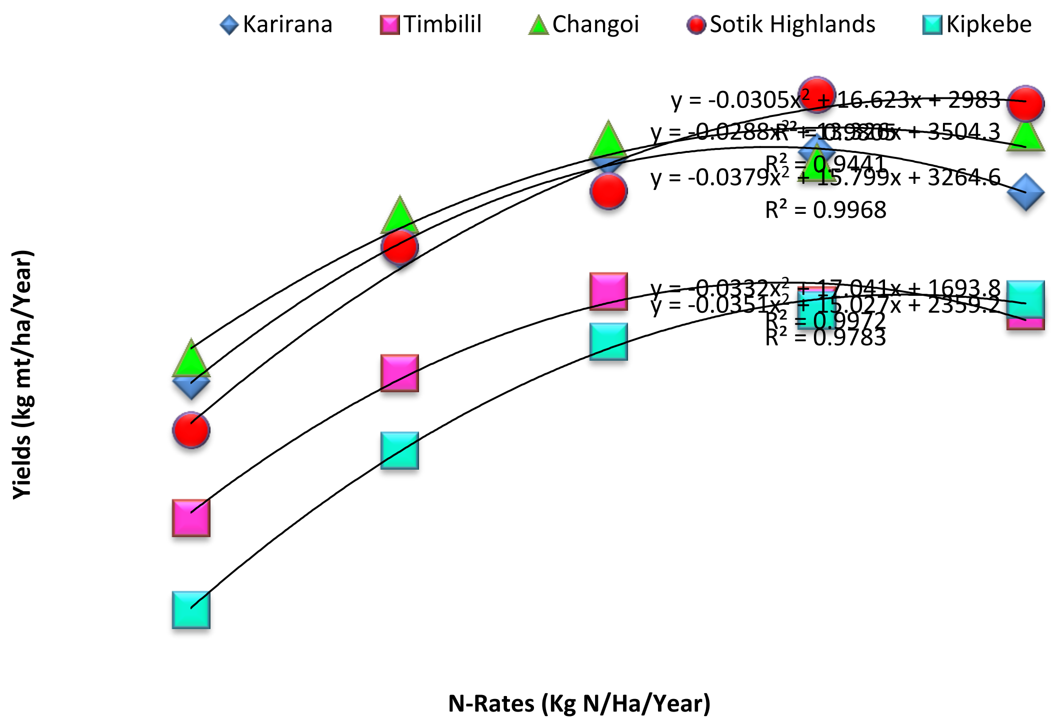


Figure 4.0.1**:** Yield response of BBK 35 to varying nitrogenous fertiliser rates

Yield $_{(Karirana)}$ = $-0.0379x^2+15.799x+3264.6$, ($R^2$ = 0 9968). Max at 248 Kg N/ha/year

Yield $_{(Timbilil)}$ = $-0.0351x^2+15.027x+2359.2$, ($R^2$ = 0.9783). Max at 226 Kg N/ha/year

Yield $_{(Changoi)}$ = $-0.0288x^2+13.326x+3504.3$, ($R^2$ = 0.9441). Max at 244 Kg N/ha/year

Yield $_{(Sotik\ Highlands)}$ = $-0.0305x^2+16.623x+2983$, (R^2 = 0.9805). Max at 362 Kg N/ha/year

Yield $_{(Kipkebe)}$ = $-0.0332x^2+17.041x+1693.8$, ($R^2$ = 0.9972). Max at 263 Kg N/ha/year

These results demonstrate that nitrogenous fertiliser application is important in all tea growing locations of Kenya for realisation of high yields. Similar yield responses to rate of nitrogen had been widely recorded for trials conducted on single locations (Bonheure & Wilson, 1992; Kamau *et al.*, 1998, 2008; Owuor *et al.*, 1997, 2000, 2008b; Ranganathan & Natesan, 1987) and the data used to develop fertiliser use recommendations. It was thought that these responses would be replicated in other tea growing locations. These results demonstrate for the first time, that yields of clone BBK 35 are not stable to regional variations.

Consequently, yields obtained at one location were not replicated at another location. In deed, there were significant ($P \leq 0.05$) interaction effects between rates of nitrogenous fertiliser and geographical area of production (Table, 4.1.1) suggesting that yield responses did not occur in a similar pattern.

This could be due to several factors including temperature (Tanton, 1982) rainfall and rainfall distribution (Othieno *et al.*, 1992), altitude (Obaga *et al.*, 1989; Squire *et al.*, 1993) and sporadic hail damage experienced in the tea growing locations (Ng'etich *et al.,* 2001a; Ng'etich & Stephens, 2001b; Othieno *et al.,* 1992). Although these factors were not monitored in the present study, the extents of their variations may be large at the various geographical locations.

Although there were significant ($P \leq 0.05$) quadratic yield responses to rate of nitrogenous fertiliser in all the locations (Figure 4.0.1), a careful examination of the data reveals that the yield response at Kipkebe was very low. Indeed the difference between the highest and the lowest yield occurred between control 0 Kg N/ha/year and the highest rate 300 kg N/Ha/year was only 1167 Kg N/ha/year, the difference in mean yields between same rates in Sotik Highlands was 2278 Kg N/ha/year. Sotik Highlands and Kipkebe are within 10 km from each other and are both at 1800 m amsl implying that the locations have relatively similar regional conditions. But despite the short distance from each other, the yield responses were very different, with Sotik Highlands producing much higher yields than Kipkebe. This could be due to past management practices and/or inherent soil fertility gradient. However, the maximum responses at these two locations occurred at very high rates of nitrogenous fertiliser compared to the other locations. However, the results (Table 4.1.1 & Figure 4.0.1) show that before extensive plantation of a cultivar, it is necessary for tea growers to assess its performance relative to the other available genotypes (Wachira *et al.,* 2002). The assessment will determine if a given cultivar in relation to other available cultivars is suitable for the location for realisation of high yields.

There may be many micro regional and management factors affecting yield responses. The earlier reported decline in tea yields with rise in altitudes, (Obaga *et al.*, 1989; Squire *et al.*, 1993; Othieno *et al.*, 1992) occurred when management and regional factors were uniform. The data presented in (Table 4.1.1 & Figure 4.0.1) suggest that the present blanket fertiliser recommendations need a review. More trials are needed to develop location specific fertiliser use recommendations of fertiliser rates using more tea cultivars.

4.2: Quality responses to nitrogenous fertiliser rates and location of production

Although sensory evaluation is subjective, it is the most practical method of assessing quality in tea trade; as done in previous studies (Owuor *et al.,* 1997, 2000; Vankatesan *et al.,* 2004, 2005). The plain black tea quality parameters and sensory evaluation variations due to rates of NPKS 25:5:5:5 fertiliser for five locations are presented in (Table 4.1.2 &

Figure 4.0.2). All the quality parameters significantly ($P \leq 0.05$) varied with locations, therefore it is not possible to make black teas with similar quality parameters in all the five locations. This did not follow any pattern as had been observed in earlier studies with altitude (Owuor *et al.,* 1990b; Mahanta *et al.,* 1988). With experimentation in locations far away from each other there might have been too many regional variables changing as explained in the previous sub section. These changes were not uniform and did not follow any pattern, hence the lack of relationship with altitude.

Theaflavins, brightness and sensory evaluation of Taster B scores significantly ($P \leq 0.05$) declined with increase in nitrogenous fertiliser rates (Table 4.1.2). Indeed, at all locations, these quality parameters declined with increasing rates of nitrogenous fertiliser as had been observed in previous studies conducted at single locations (Owuor *et al.,* 1997, 2000, 1987c, 1991). Thus irrespective of geographical area of production, high rate of nitrogen is deleterious to quality. It is therefore important to use nitrogen rates which are a compromise between yields and quality.

Thearubigins and sensory evaluation of Taster A did not vary due to rates of nitrogenous fertiliser (Table 4.1.2); meaning that it is possible to make black teas with similar thearubigins. The lack of significant differences in thearubigins explains why Kenya black teas are generally classified as plain tea. Although Taster A valuations did not reach significant differences, the pattern was similar to that of Taster B.

There were significant variations in theaflavins, total colour, brightness and sensory evaluation of Taster B with locations, (Table 4.1.2) indicating that tea quality change with locations even in the same cultivar when produced in different locations. Thus it is important for tea processors to enhance the production of parameters they can best produce. But it is unlikely they will match these parameters produced at different locations. There were no significant interaction effects between the geographical area of production and nitrogenous fertiliser rates in all the quality parameters assessed indicating that the quality responses followed a similar pattern (Table 4.1.2 & Figure 4.0.2).

Table 4.1.2: Effects of location of production and nitrogen fertiliser rates on black tea quality parameters of clone BBK 35

Item	Locations	N-Rates (kg N/ha/year)					
Theaflavins(μmol/)		0	75	150	225	300	Mean locations
	Karirana	24.01	23.94	23.75	22.81	23.24	23.55
	Timbilil	22.15	21.81	22.09	21.15	19.21	21.42
	Changoi	27.14	26.03	25.10	25.68	24.70	25.73
	Sotik Highlands	20.72	18.81	19.27	17.84	15.57	18.44
	Kipkebe	22.99	20.59	20.53	19.77	18.71	20.52
	Mean N rate	23.54	22.23	22.15	21.45	20.29	
	CV (%)			13.06			
	LSD,P ≤ 0.05			1.68			1.68
Thearubigins (%)	Karirana	17.69	17.51	17.31	16.46	15.98	16.99
	Timbilil	19.37	17.83	17.30	17.05	16.05	17.52
	Changoi	18.41	18.52	16.66	17.05	16.05	17.47
	Sotik Highlands	18.25	18.02	17.55	16.78	15.41	17.20
	Kipkebe	18.48	18.33	17.45	16.79	17.31	17.31
	Mean N rate	18.44	18.04	17.25	16.83	15.94	
	CV (%)			8.45			
	LSD,P ≤ 0.05			NS			0.85
Total colour (%)	Karirana	5.51	5.48	6.11	4.95	5.49	5.30
	Timbilil	5.48	5.43	6.02	4.86	5.04	5.33
	Changoi	5.42	5.41	5.79	4.81	4.97	5.88
	Sotik Highlands	5.12	5.29	5.79	4.72	4.86	4.73
	Kipkebe	4.97	5.03	5.67	4.32	4.77	5.03
	Mean N rate	5.51	5.37	5.28	5.16	4.96	
	CV (%)			7.11			
	LSD,P ≤ 0.05			0.23			0.23
Brightness (%)	Karirana	29.60	28.00	26.96	27.36	25.35	27.45
	Timbilil	25.40	23.38	23.32	22.41	20.97	23.10
	Changoi	26.59	25.99	25.57	24.60	23.75	25.30
	Sotik Highlands	25.01	23.10	20.94	20.94	20.72	22.14
	Kipkebe	25.54	25.21	24.74	24.56	22.87	24.58
	Mean N rate	26.43	25.14	24.31	23.97	22.73	
	CV (%)			11.46			
	LSD,P ≤ 0.05			1.64			1.64
Taster A	Karirana	80.9	74.1	71.4	62.8	61.9	70.2
	Timbilil	90.3	76.8	71.2	69.6	67.2	75.0
	Changoi	72.6	61.3	62.1	59.3	62.0	63.5
	Sotik Highlands	97.3	87.8	78.0	50.2	37.8	70.2
	Kipkebe	85.9	75.4	73.2	57.9	51.2	68.7
	Mean N rate	85.4	75.1	71.2	60.0	56.0	
	CV (%)			34.8			
	LSD,P ≤ 0.05			NS			14.15
Taster B	Karirana	21.0	20.9	19.9	19.8	19.2	20.16
	Timbilil	20.1	19.3	19.1	18.9	18.7	19.2
	Changoi	19.2	18.9	18.8	17.8	17.3	18.4
	Sotik Highlands	19.8	19.3	19.1	19.0	18.1	19.1
	Kipkebe	20.4	19.8	19.6	18.8	18.4	19.4
	Mean N rate	20.1	19.6	19.3	18.8	18.3	
	CV (%)			6.04			
	LSD,P ≤ 0.05			0.68			0.68

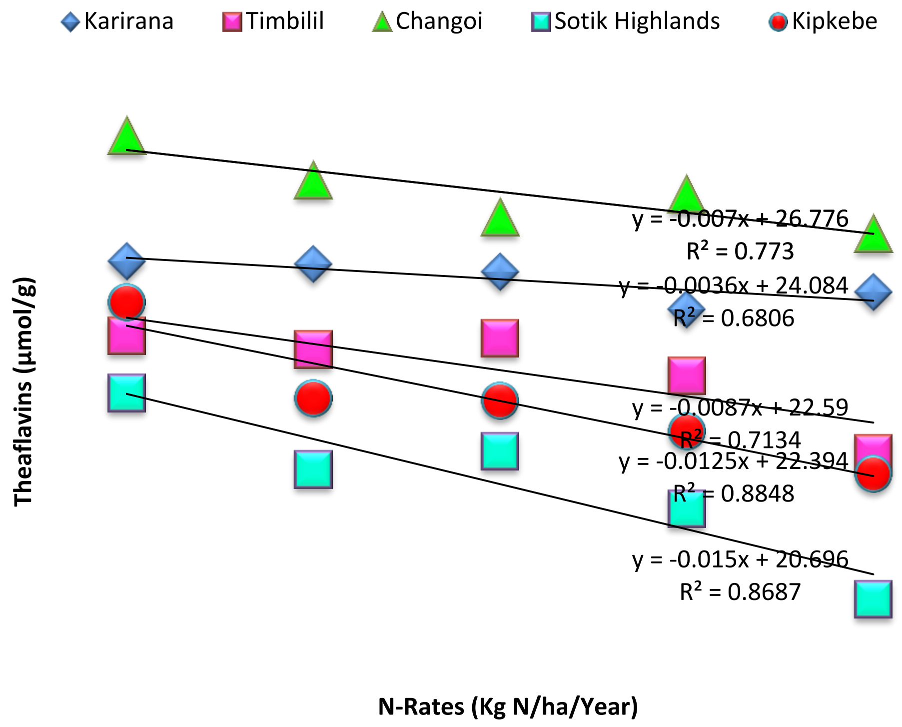


Figure 4.0.2: Changes in theaflavin (µmol/g) levels due to nitrogen fertiliser rates

$TF_{(Karirana)} = -0.0036x+24.084$, ($R^2 = 0.6806$)

$TF_{(Timbilil)} = -0.0087x+22.59$, ($R^2 = 0.7134$)

$TF_{(Changoi)} = -0.007x+26.776$, ($R^2 = 0.773$)

$TF_{(Sotik\ Highlands)} = -0.015x+20.696$, ($R^2 = 0.8687$)

$TF_{(Kipkebe)} =-0.0125x+22.394$, ($R^2 = 0.8848$)

The results presented here show that quality of tea produced in one area can not be reproduced in another area by same cultivar. The extent of variation in quality at different nitrogenous fertiliser rates due to geographical area of production were estimated using theaflavins, brightness, total colour and taster scores (Figure 4.0.2). Theaflavins have been shown to have higher significance to quality than other plain black tea quality parameters, since significant quality relationships between theaflavins and quality have been established (Owuor *et al.*, 2006; Wright *et al.*, 2002). The rates of decline in theaflavins levels were in the order Changoi < Karirana < Timbilil < Kipkebe < Sotik Highlands (Table 4.1.2 &, Figure 4.0.2).

The response of total colour levels to rates of nitrogen appeared sporadic and was neither linear nor quadratic. Generally, the r^2 values were very low below 0.5 for linear Karirana r^2

= 0.048, Timbilil r^2 = 0.260, Changoi r^2 = 0.366, Sotik Highlands r^2 = 0.170 and Kipkebe r^2 = 0.129. While quadratic Karirana r^2 = 0.005, Timbilil r^2 = 0.407 Changoi r^2 = 0.487, Sotik Highlands r^2 = 0.441 and Kipkebe r^2 = 0.258 (Figure 4.0.3) and insignificant.

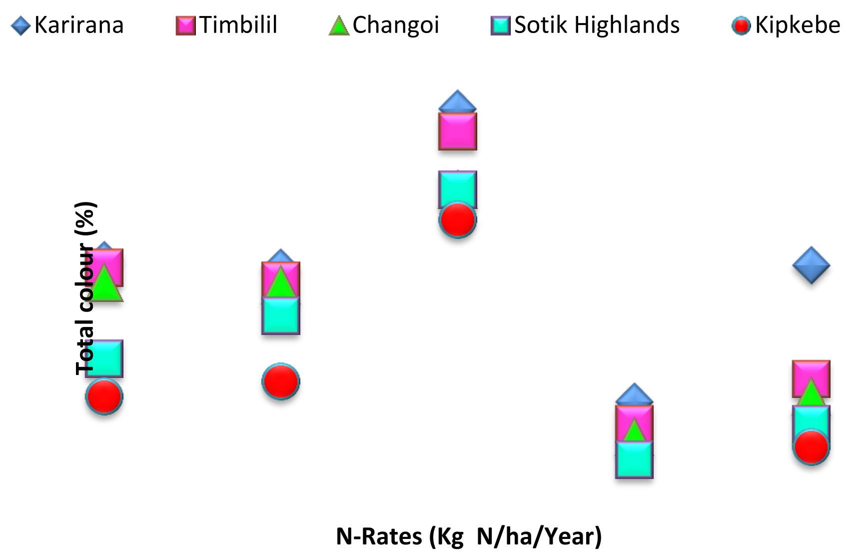


Figure 4.0.3**:** Changes in total colour levels (%) levels due to nitrogen fertiliser rates

The results demonstrate that changes in total colour with rates of nitrogenous fertiliser did not occur in any predictable manner. This aspect may need further experimentation using more cultivars to yield more information. Thearubigins levels usually dictate the total colour of black tea. It is therefore not surprising that both thearubigins and total colour levels did not follow any trend with fertiliser rates. Indeed the response of both with respect to nitrogenous fertiliser rates appeared sporadic.

However, brightness declined significantly ($P \leq 0.05$), $r^2 \geq 0.8$ with increase in rates of nitrogenous fertiliser. The rates of decline depended on locations and followed the order Sotik Highlands > Timbilil > Karirana > Changoi > Kipkebe (Figure 4.0.5). The results demonstrate that black tea losses brightness with rise in nitrogenous fertiliser rates. Despite the variations, the order of brightness was retained for locations at different fertiliser rates. A location producing brighter teas maintained the characteristic over the others irrespective of nitrogenous fertiliser rates and *vice versa*.

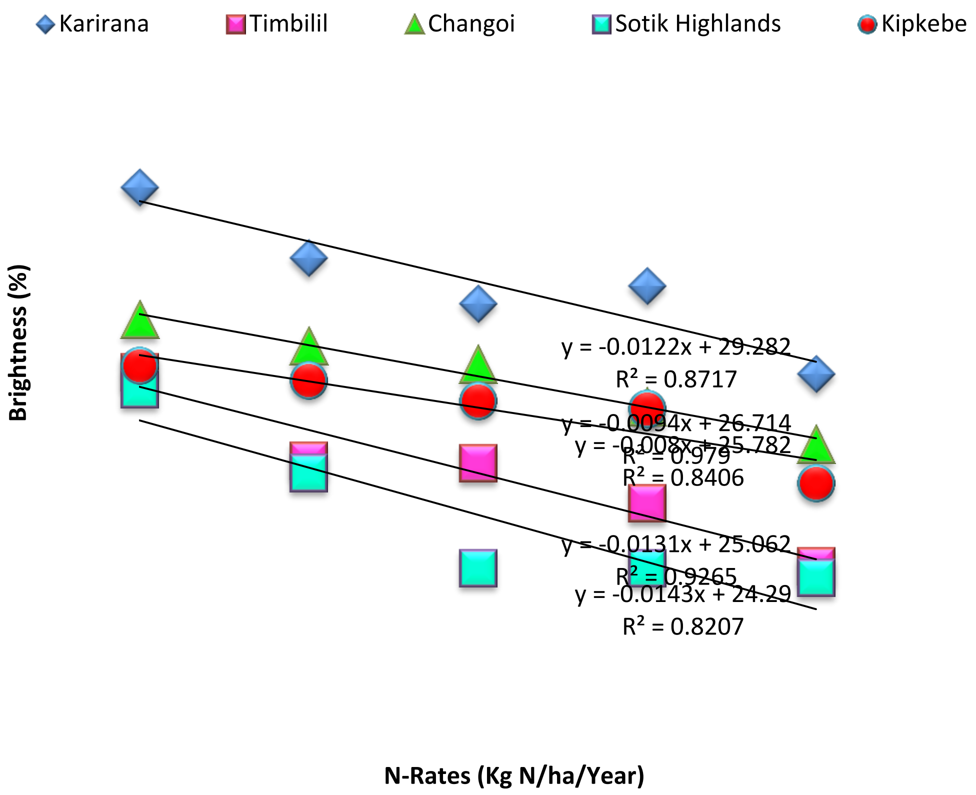


Figure 4.0.4**:** Changes in brightness (%) levels due to nitrogen fertiliser rates

$BR_{(Karirana)} = -0.0122x+29.282$, ($R^2 = 0.8717$)
$BR_{(Timbilil)} = -0.0131x+25.062$, ($R^2 = 0.9265$)
$BR_{(Changoi)} = -0.0094x+26.714$, ($R^2 = 0.9790$)
$BR_{(Sotik\ Highlands)} = -0.0143x+24.29$, ($R^2 = 0.8202$)
$BR_{(Kipkebe)} = -0.008x+25.782$, ($R^2 = 0.8406$)

Although the sensory evaluation scores for Taster A did not significantly decline with increase in nitrogen rates, the pattern of response was the same as for Taster B.

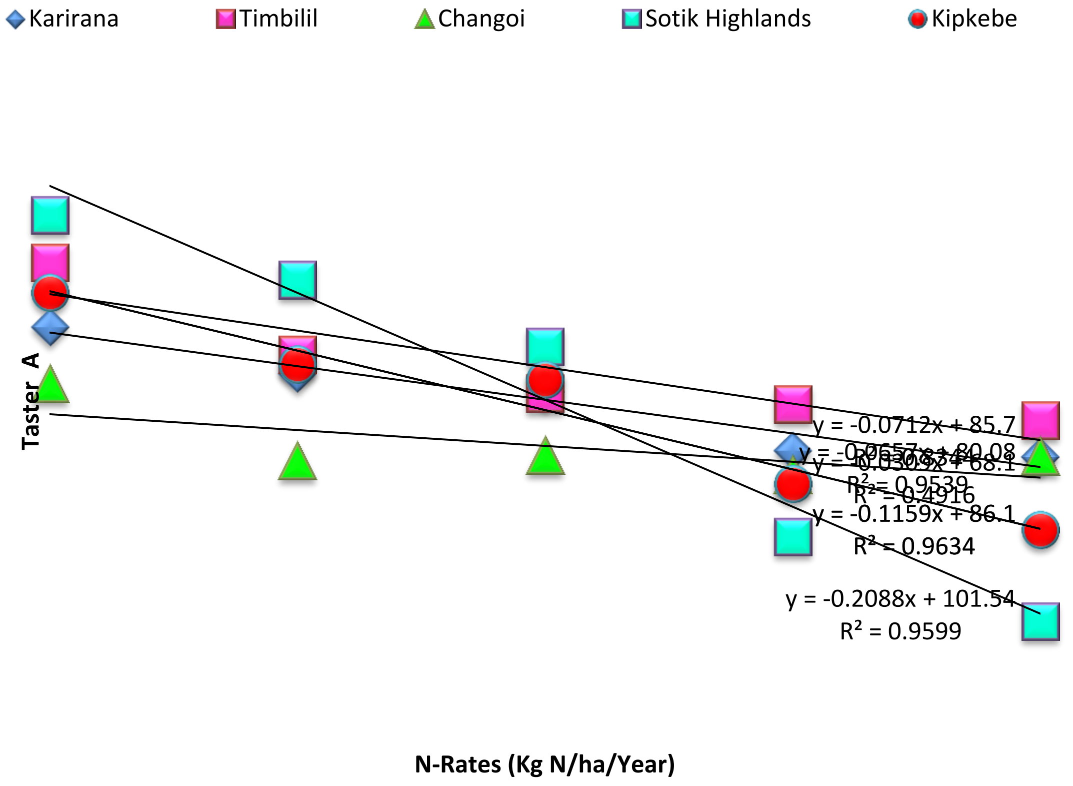


Figure 4.0.5**:** Changes in Sensory evaluation levels of Taster A due to nitrogen fertiliser rates

Taster A $_{(Karirana)}$ = -0.0657x+80.03, (R^2 = 0.9539)

Taster A $_{(Timbilil)}$ = -0.0712x+85.07, (R^2 = 0.8344)

Taster A $_{(Changoi)}$ = -0.0309x+68.01, (R^2 = 0.4916)

Taster A $_{(Sotik\ Highlands)}$ = -0.2088x+101.54, (R^2 = 0.9599)

Taster A $_{(Kipkebe)}$ = -0.1159x+86.1, (R^2 = 0.9634)

Sensory evaluation of Taster B declined with increasing rates of nitrogen (Table 4.1.2 & Figure 4.0.6). Indeed, the decline was very significant explaining the fact that even by sensory evaluation, there is decline in quality of black tea with high rates of nitrogenous fertiliser.

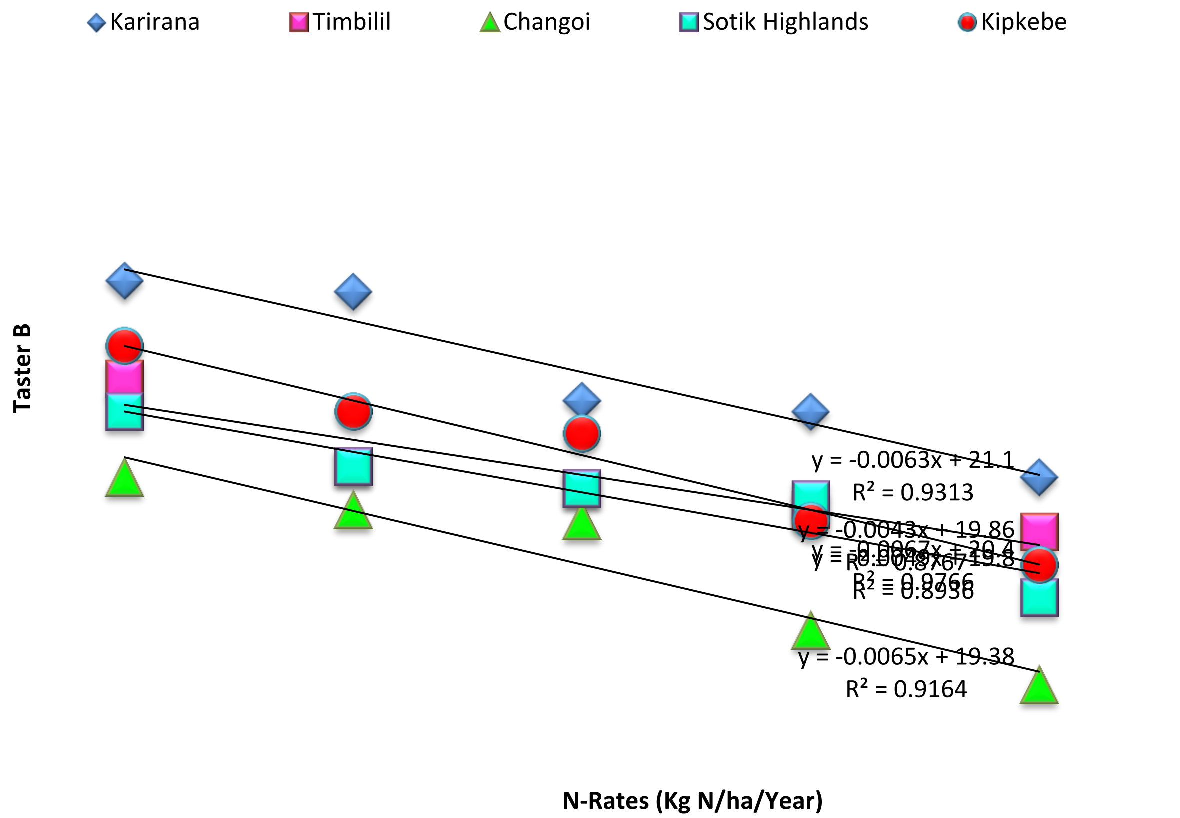


Figure 4.0.6: Changes in Sensory evaluation levels of Taster B due to nitrogen fertiliser rates

Taster B $_{(Karirana)}$ = -0.0063x+21.1, (R^2 = 0.9313)

Taster B $_{(Timbilil)}$ = -0.0043x+19.86, (R^2 = 0.8767)

Taster B $_{(Changoi)}$ = -0.0065x+19.38, (R^2 = 0.9164)

Taster B $_{(Sotik\ Highlands)}$ = -0.0049x+19.8, (R^2 = 0.8936)

Taster B $_{(Kipkebe)}$ = -0.0067x+20.4, (R^2 = 0.9766)

The response of plain black tea quality parameters to nitrogen fertiliser rates followed similar linear patterns at different locations illustrated in (Figures 4.0.2, 4.0.4 & 4.0.6) which fitted a linear regression model with theaflavin, brightness and Taster B having highly significant ($P \leq 0.05$) $r^2 \geq 0.7$ values. As a result there were no significant interaction effects between the response in the parameters between geographical areas of production and nitrogen fertiliser rates.

The data presented here indicate that for both yield and quality, responses to nitrogen vary with geographical area of production. The responses occur such that the areas with good yield response to nitrogen suffer more in quality decline due to high rates of nitrogen fertilisers. Low rates of nitrogenous fertiliser will improve quality at the expense of yield. It is therefore necessary to use rates of nitrogenous fertiliser that are a compromise between yields and quality. However, some locations like Sotik Highlands could accommodate higher rates of nitrogenous fertiliser than the others. For each location, the recommended rates should be that which compromises yields and quality.

4.3: Yield response to plucking intervals and region of production

The yield responses to varying plucking intervals at different locations are presented in (Table 4.1.3). Yield varied significantly ($P \leq 0.05$) with locations but did not vary with plucking intervals. The data presented here indicate that within Kenya, there are significant ($P \leq 0.05$) variations in yields even when one cultivar is subjected to identical plucking practices in different locations (Table 4.1.3). Yields at Timbilil, Changoi and Kipkebe increased with plucking rounds while for Karirana and Sotik Highlands there was a decline in yield response due to increase in plucking rounds. Since the experiments were rain fed, regional conditions governing growth are not uniform in all the five locations (Othieno *et al.,* 1992). As a result there was significant ($P \leq 0.05$) interaction effect observed for yield responses indicating that the response patterns were different at each region (Table 4.1.3 & Figure 4.0.7).

The results demonstrate that the current recommendation of short plucking intervals throughout Kenya may not be appropriate and could be limiting yields in some locations (Appendix, 1). However, the data presented here is only for one year, such short term data can be misleading for a perennial crop like tea. It may need long experimentation time to confirm these yield response data.

Table 4.1.3**:** Effects of plucking intervals and region of production on yield (Kg mt ha/year) of clone BBK 35 in 2007

	Locations					
Plucking round (days)	Karirana	Timbilil	Changoi	Sotik Highlands	Kipkebe	Mean plucking round
7	4443	3217	4282	4572	2988	3900
14	4316	3866	4621	4395	3177	3942
21	4306	4282	4691	4380	3224	4093
Mean location	4355	3427	4531	4449	3129	
CV (%)			8.15			
LSD,$P \leq 0.05$			190			NS
Interactions			324			

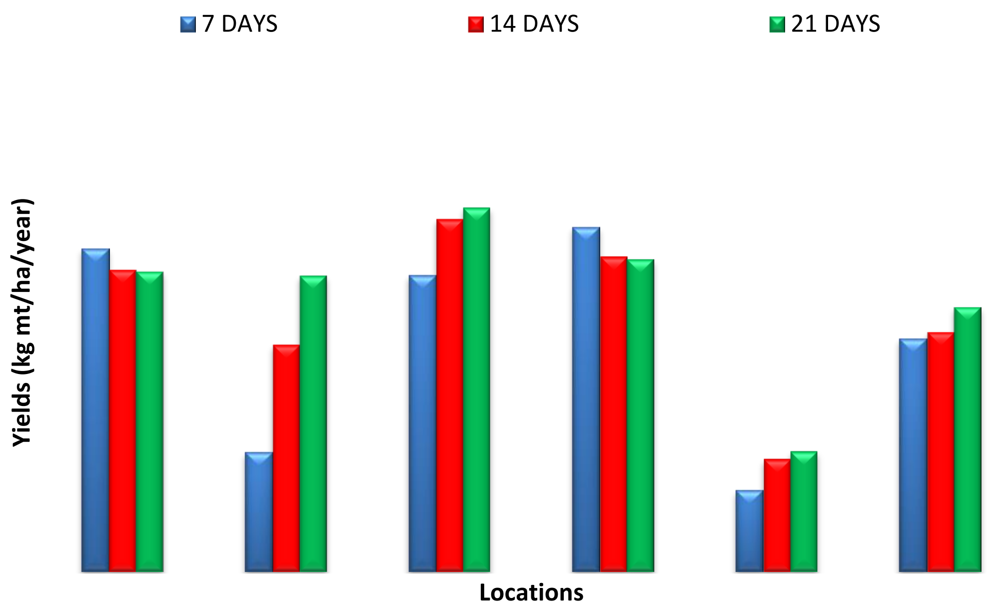


Figure 4.0.7**:** Effects of region of production and plucking rounds on yields

In previous studies, contradicting reports on yield responses to plucking intervals have been reported. Yields decreased in Malawi (Palmer-Jones, 1977; Tanton, 1989), but increased in Kenya with short plucking intervals (Odhiambo & Owuor, 1994). For the 7 days plucking round the yields were in the order: Sotik Highlands > Karirana > Changoi > Timbilil > Kipkebe, for the 14 days the order was Changoi > Sotik Highlands > Karirana > Timbilil > Kipkebe and 21 days order was Changoi > Sotik Highlands > Karirana > Timbilil > Kipkebe (Figure 4.0.7). These results indicate that the highest yield potential for Sotik highlands would be achieved best using the 7 days plucking round while Changoi would respond maximumly to both the 14 and 21 days rounds. In Karirana and Sotik Highlands there was a decline in yield with increasing plucking intervals whereas, in Timbilil Changoi and Kipkebe there was an increase in yield with increasing plucking rounds. This phenomenon was observed in a recent long term 18 year trial (Owuor *et al.*, 2008a) conducted at one site in Kenya using high yielding clone S15/10. Therefore, it is necessary to establish region specific plucking rounds for different tea growing locations for the realisation of high yields (Appendix, 1).

4.4: Quality response to plucking intervals and locations of production

The plain black tea quality parameters variations due to plucking intervals and geographical area of production at the five locations are presented in (Table 4.1.4). All the quality parameters significantly ($P \leq 0.05$) varied with plucking intervals and geographical area of production except Taster A sensory evaluation scores. Thus it is not possible to make black teas from BBK 35 with similar quality potentials within different tea growing locations of Kenya. The responses occurred such that as the plucking intervals increased quality declined. There were no significant interactions for all the quality potentials suggesting that the responses occurred in a similar manner.

Table 4.1.4**:** Effects of plucking intervals and locations of production on the plain black tea quality of clone BBK 35 in 2007

Item	Plucking round(days)	Karirana	Timbilil	Changoi	Sotik Highlands	Kipkebe	Mean plucking round
		Locations					
Theaflavins (µmol/g)	7	25.02	23.66	27.63	20.09	22.19	23.72
	14	23.52	21.48	25.67	18.51	20.32	21.90
	21	22.10	19.12	23.89	16.72	19.03	20.17
	Mean locations	23.55	21.42	25.73	18.44	20.52	
	CV (%)			13.06			
	LSD,P $\leq$ 0.05			1.68			2.60
Thearubigins (%)	7	15.99	16.07	17.34	16.66	16.31	16.49
	14	17.06	17.62	17.62	16.92	17.48	17.31
	21	17.93	18.87	18.87	18.01	18.15	18.11
	Mean locations	16.99	17.52	17.47	17.20	17.31	
	CV (%)			8.45			
	LSD,P $\leq$ 0.05			0.85			1.33
Total colour (%)	7	5.04	4.93	5.66	4.28	4.64	4.91
	14	5.31	5.40	5.79	4.77	5.04	5.26
	21	5.55	5.66	6.19	5.14	5.40	5.59
	Mean locations	5.30	5.33	5.88	4.73	5.03	
	CV (%)			7.11			
	LSD,P $\leq$ 0.05			0.22			0.34
Brightness (%)	7	29.22	26.07	26.89	24.01	26.77	26.59
	14	27.56	22.97	25.57	22.36	24.15	24.52
	21	25.57	20.25	23.44	20.06	22.83	25.43
	Mean locations	27.45	23.10	25.30	22.14	24.58	
	CV (%)			11.46			
	LSD,P $\leq$ 0.05			1.64			2.55
Taster A	7	86.47	94.20	72.13	87.07	78.93	83.76
	14	70.93	72.40	62.87	69.07	71.33	69.32
	21	53.27	58.47	55.40	54.53	55.93	55.52
	Mean locations	70.22	75.02	63.47	70.22	68.73	
	CV (%)			34.78			
	LSD,P $\leq$ 0.05			NS			21.94
Taster B	7	21.33	20.21	19.53	19.93	20.73	20.35
	14	20.00	19.23	18.33	19.33	19.40	19.26
	21	19.13	18.17	17.33	17.19	18.10	18.13
	Mean locations	20.16	19.21	18.40	19.06	19.41	
	CV (%)			6.04			
	LSD,P $\leq$ 0.05			0.68			1.05

As the plucking rounds increased the levels of theaflavins (Figure 4.0.8), brightness (Figure 4.0.10) and Taster B evaluations (Figure 4.0.12) in all the locations declined. However, thearubigins (Figure 4.0.9) and total colour (Figure 4.0.11) levels increased with long plucking rounds. Black teas with high levels of theaflavins and total colour are usually less bright and brisk and are classified as muddy, hence lower quality. The results demonstrate that short plucking intervals ensure production of high quality tea, irrespective of region.

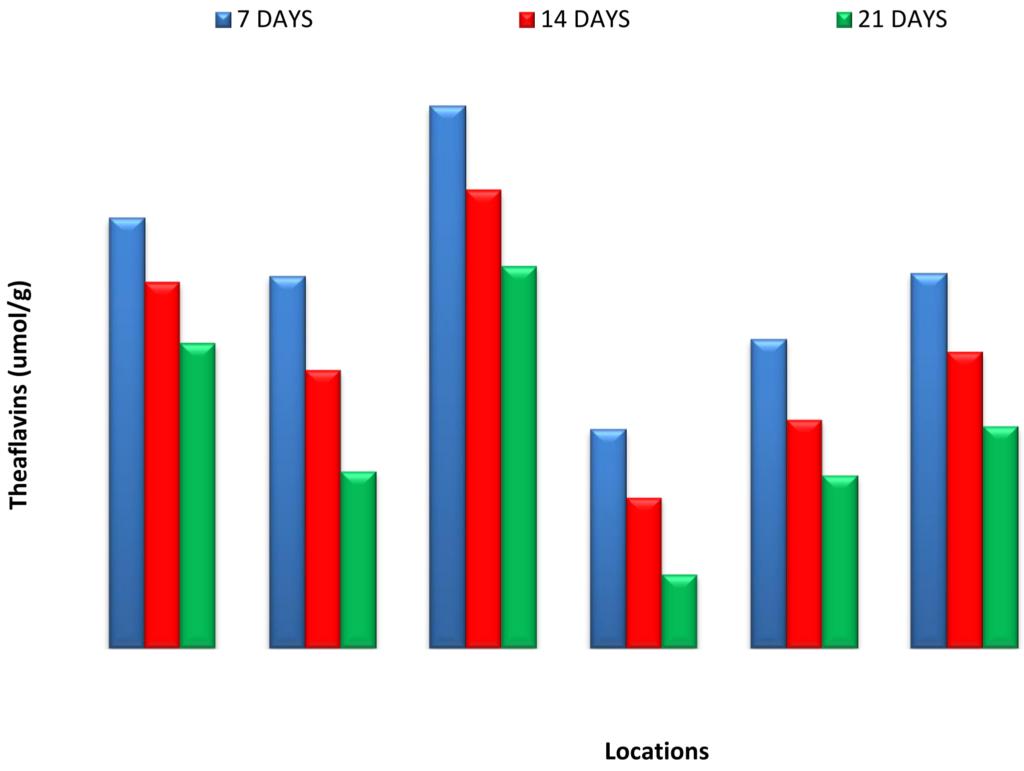


Figure 4.0.8**:** Changes in theaflavin levels (µmol/g) due to plucking rounds

These results are in agreement with the earlier results (Mahanta *et al.*, 1988; Owuor *et al.*, 1997; 2000; 2008a; Owuor & Odhiambo, 1993, 1994). Since plucking was unselective; the quality of the leaf obtained was dependent on the length of the harvesting intervals, such that long plucking intervals might have had higher percentage of mature leaf beyond two leaves and a bud.

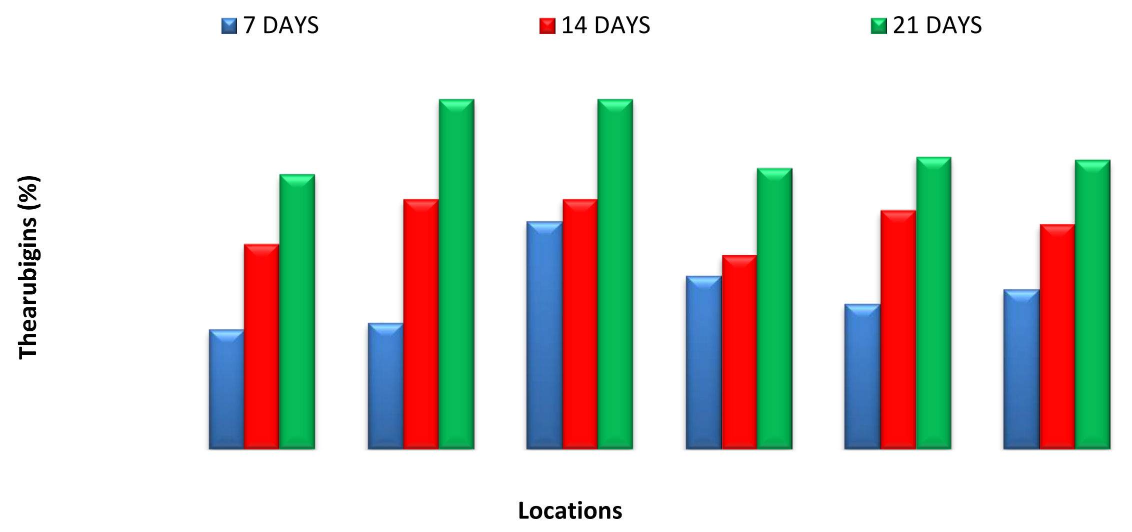


Figure 4.0.9**:** Changes in thearubigins levels (%) due to plucking rounds

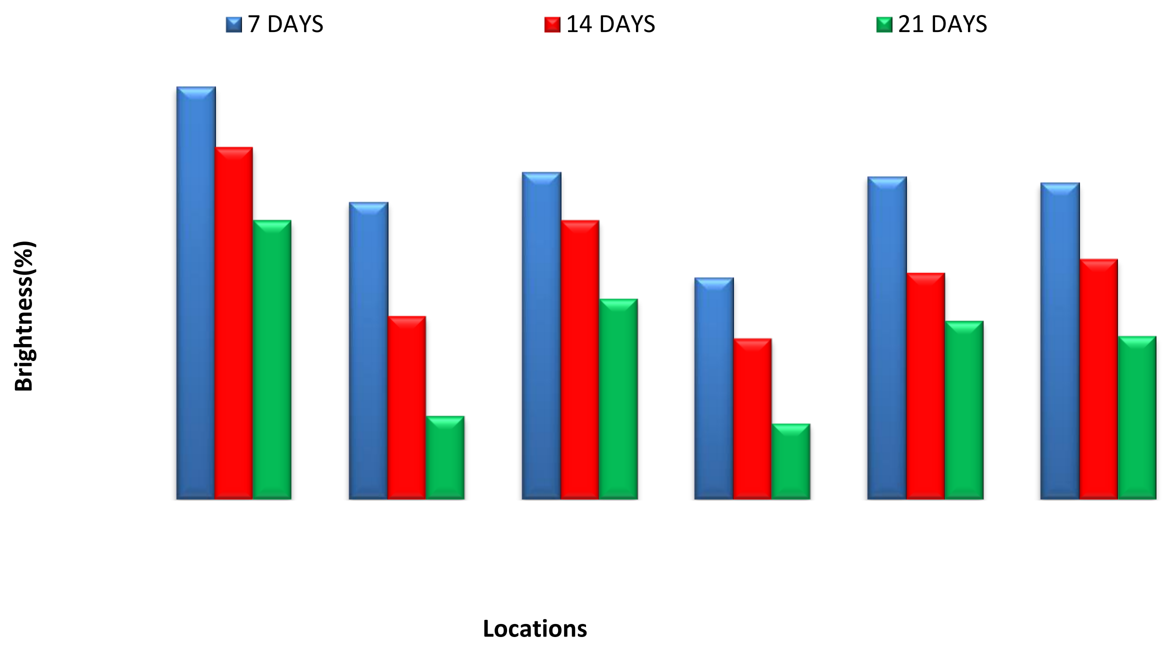


Figure 4.0.10: Changes in brightness (%) levels due to plucking rounds

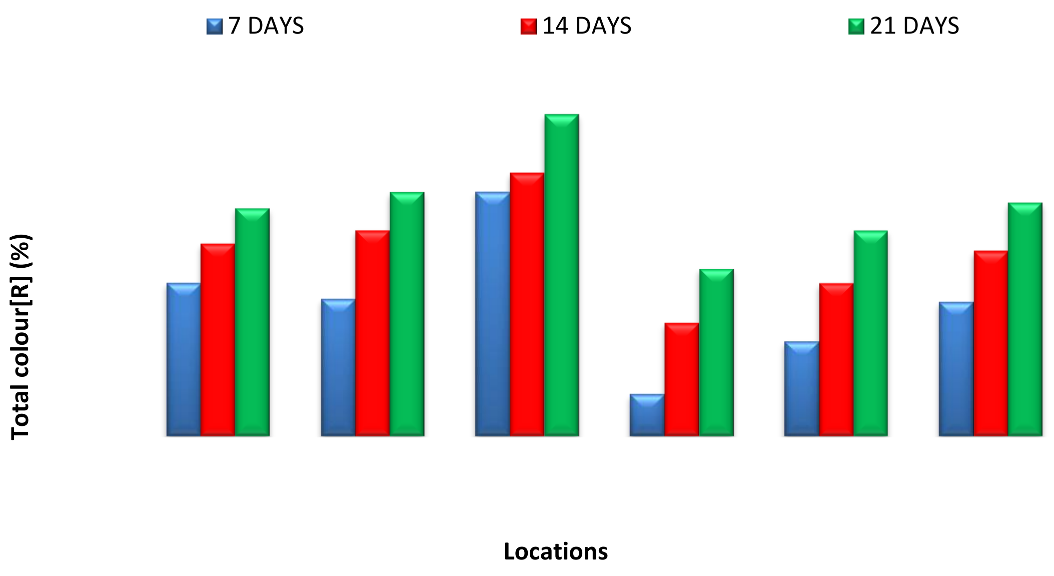


Figure 4.0.11: Changes in total colour levels (%) due to plucking rounds

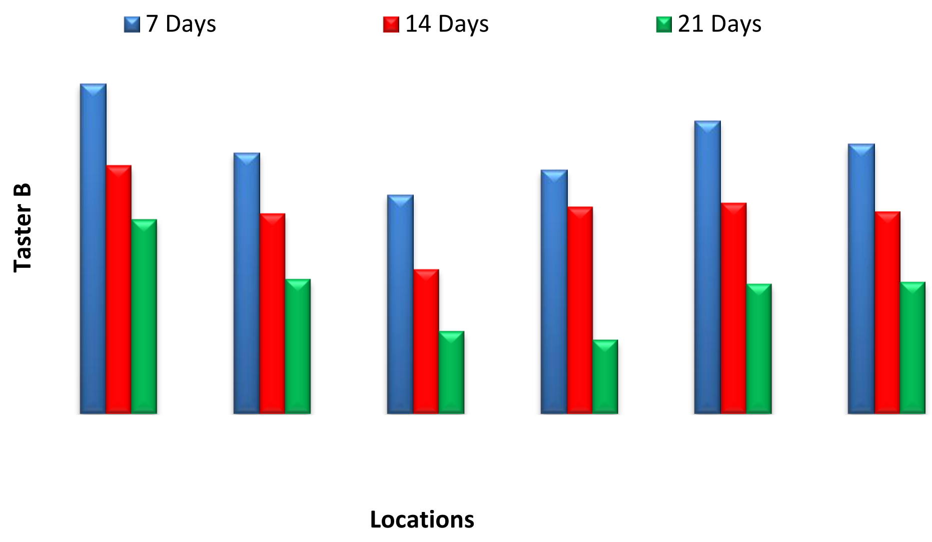


Figure 4.0.12: Changes in taster B sensory evaluation levels due to plucking rounds

The decline of quality at all locations was therefore attributed to an increase in proportion of mature leaf to fine leaf with long plucking intervals. But even where plucking is selective, quality declines with long plucking intervals (Owuor *et al.*, 2000). The results demonstrate that short plucking intervals ensure production of high quality tea. Thus, despite the conflicting results obtained on yields (Tables 4.1.4 & Figure 4.0.7), it is important to use short plucking intervals (Othieno, 1988) throughout Kenya to produce high quality plain black teas. However, for realisation of high profits, there should be rationalisation of yields and quality at different locations. Plucking intervals should be adopted that are a compromise between yields and quality at different locations.

4.5: Yield response to fertiliser rates and plucking rounds

The effects of the nitrogenous fertiliser rates and plucking intervals on yield of BBK 35 cultivar for all locations combined are presented in (Table 4.1.5). Yield significantly ($P \leq 0.05$) varied nitrogenous fertiliser rates, but did not vary with plucking intervals. Consequently, there was no significant interaction suggesting uniform response pattern. Yields significantly ($P \leq 0.05$) increased with long plucking rounds at all fertiliser rates.

Table 4.1.5: Effects of plucking intervals and fertiliser rates on yield (Kg mt/ha/year) of clone BBK 35 in 2007

Plucking round(days)	N-Rates 0	75	150	225	300	Mean Plucking rounds
7	2786	3673	4298	4328	4415	3900
14	2659	3789	4372	4476	4411	3942
21	2748	3921	4445	4715	4638	4093
Mean N-rate	2731	3794	4372	4507	4488	
CV (%)			8.15			
LSD, $P \leq 0.05$			190			NS

The response to nitrogenous fertiliser rates results were similar to previous results obtained at single site studies (Bonheure & Wilson, 1992; Wanyoko, 1983; Owuor, 1989, 1997; Owuor *et al.*, 1990d, 1997, 2000). The results demonstrate the general need for applying nitrogenous fertiliser. However as noted earlier, (Table 4.1.1) the response can vary with localities. Contrary to previous studies (Owuor *et al.*, 1997, 2000; Owuor & Odhiambo, 1993, 1994) yields declined with short plucking intervals. Similar yield increase with long plucking intervals had been recorded in Malawi (Palmer-Jones, 1977; Tanton, 1989) when plucking was done over a short duration. Yield recorded here were for only one year.

4.6: Plain black tea quality response to fertiliser rates and plucking rounds

The effects of the nitrogenous fertiliser rates and plucking intervals on the plain black tea quality parameters are presented in (Table 4.1.6). All the quality parameters significantly ($P \leq 0.05$) varied with plucking intervals and nitrogenous fertiliser rates. There were no significant interactions suggesting uniform response patterns for all the parameters. Thus quality response to nitrogen rates at different plucking intervals occurred in the same pattern.

Quality significantly ($P \leq 0.05$) declined with increase in plucking rounds and nitrogenous fertiliser rates The theaflavins, brightness, Taster A and Taster B declined while for thearubigins and total colour increased with increasing plucking intervals at all fertiliser rates.

These results suggest that indeed high rates of nitrogenous fertiliser application compromised quality as had been observed in earlier studies (Owuor & Othieno, 1996; Owuor & Wanyoko, 1996; Cloughley, 1983; Hilton *et al.*, 1973). Similarly at long plucking intervals, plain black tea quality declined as noted in earlier studies (Mahanta *et al.*, 1988; Owuor & Odhiambo, 1993; Owuor *et al.*, 1997, 2000). In this study, moderate lower rates of nitrogenous fertiliser between 0 and 150 Kg N/ha/year coupled with shorter plucking rounds lead to high returns from tea enterprise.

Table 4.1.6: Effects of plucking intervals and fertiliser rates on the plain black tea quality parameters of clone BBK 35

Item	Plucking round(days)	N-Rates					Mean Plucking rounds
		0	75	150	225	300	
Theaflavins (µmol/g)	7	25.60	23.72	23.89	23.39	21.99	23.72
	14	23.41	22.25	22.01	21.29	20.54	21.90
	21	21.62	20.74	20.54	19.66	18.32	20.17
	Mean N-rate	23.54	21.42	25.73	18.44	20.51	
	CV (%)			13.06			
	LSD,P $\leq$ 0.05			1.67			2.60
Thearubigins (%)	7	17.68	17.39	16.10	16.04	15.16	16.47
	14	18.28	17.85	17.34	16.96	16.11	17.31
	21	19.36	18.88	18.32	17.48	16.55	18.12
	Mean N-rate	18.44	18.04	17.25	16.83	15.94	
	CV (%)			8.45			
	LSD,P $\leq$ 0.05			0.85			1.33
Total colour (%)	7	5.11	5.02	5.00	4.84	4.58	4.91
	14	5.48	5.35	5.26	5.18	5.04	5.26
	21	5.94	5.73	5.58	5.44	5.25	5.59
	Mean N-rate	5.09	5.37	5.28	5.16	4.95	
	CV (%)			7.11			
	LSD,P $\leq$ 0.05			0.22			1.94
Brightness (%)	7	23.45	27.58	26.35	25.72	24.87	26.59
	14	26.06	25.10	24.82	23.76	22.86	24.52
	21	24.78	22.73	21.74	22.44	20.47	22.43
	Mean N-rate	26.43	25.14	24.31	23.97	22.73	
	CV (%)			11.46			
	LSD,P $\leq$ 0.05			1.64			1.97
Taster A	7	101.73	88.93	88.87	74.07	65.20	83.76
	14	85.67	75.73	68.27	59.20	57.73	69.32
	21	68.80	60.60	56.47	46.60	45.13	55.52
	Mean N-rate	85.40	75.09	71.20	59.96	56.02	
	CV (%)			34.78			
	LSD,P $\leq$ 0.05			14.14			17.0
Taster B	7	21.39	20.95	20.40	19.73	19.27	20.35
	14	19.90	19.60	19.53	18.87	18.40	19.26
	21	19.04	18.31	17.97	17.93	17.39	18.13
	Mean N-rate	20.11	19.62	19.30	18.84	18.35	
	CV (%)			6.04			
	LSD,P $\leq$ 0.05			0.68			1.05

CHAPTER FIVE

5.0: CONCLUSIONS

1. This study has revealed that even in one cultivar the yield and quality response patterns to nitrogenous fertiliser rates varied from region to region, therefore optimal rates for different locations need to be established.
2. Yield and quality response to one cultivar with respect to plucking intervals also varied from region to region therefore regional specific plucking intervals need to be determined.
3. Yield and quality response to one cultivar varied due to nitrogenous fertiliser rates and plucking intervals therefore need to establish recommendations that both compromise between yield and quality.

5.1: RECOMMENDATIONS

1. While plucking still remains a labour intensive and expensive undertaking and with, regional variations in terms of yield and quality due to plucking rounds for cultivar BBK 35, these trials indicate that farmers should shorten the plucking rounds so as to realise moderate yield and high quality tea. These would be good compromise between yields and quality, thus enhancing profitability of tea farming.
2. Since yield and quality response varies due to nitrogenous fertiliser rates and plucking intervals for cultivar BBK 35. It is necessary that further research is done using more tea cultivars so that specific agronomic recommendations especially nitrogen rates and plucking intervals can be developed.

5.2: SUGGESTIONS FOR FUTURE STUDY

With the varied responses in yield and plain black tea quality realised with respect to nitrogen fertiliser rates application and plucking intervals with a single cultivar grown in different locations, future studies should identify and quantify how the individual theaflavin and theaflavin digallate equivalents vary with nitrogenous fertiliser rates and plucking intervals.

Secondly, flavoury teas also exist in some parts of the country. Studies need to be conducted to determine the changes in black tea aroma and fatty acids to nitrogen fertiliser rates application and plucking intervals in different locations. Although significant results have been obtained in the study, there is need for economic study to determine the most ideal recommendations.

This study has used only one cultivar. However yield (Wachira *et al.,* 2002) and quality (Owuor *et al.,* 2010) of tea cultivars vary with locations. It is therefore necessary to repeat this study using many cultivars as responses could vary.

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APPENDICES

7.1: Appendix 1: Table of means for all the variables.

Function: FACTOR

Experiment Model Number 10:

Three Factor Randomized Complete Block Design

Data case no. 1 to 225.

Factorial ANOVA for the factors:

Replication (3 REPS) with values from 1 to 3

Factor A (LOCATIONS (1=Karirana, 2=Timbilil, 3=Changoi, 4=Sotik, 5=Kipkebe)) with values from 1 to 5

Factor B (N-RATES (1=0, 2=75, 3=150, 4=225, 5=300) with values from 1 to 5

Factor C (FREQUENCY (1=7, 2=14, and 3=21 days) with values from 1 to 3

Variable 5: TF

Grand Mean = 21.932 Grand Sum = 4934.600 Total Count = 225

T A B L E O F M E A N S

1	4	2	3	5	Total
1	*	*	*	20.807	1560.530
2	*	*	*	22.757	1706.760
3	*	*	*	22.231	1667.310
*	1	*	*	23.550	1059.740
*	2	*	*	21.422	963.990
*	3	*	*	25.729	1157.790
*	4	*	*	18.441	829.830
*	5	*	*	20.517	923.250
*	*	1	*	23.543	1059.450
*	*	2	*	22.235	1000.580
*	*	3	*	22.146	996.570
*	*	4	*	21.447	965.120
*	*	5	*	20.286	912.880
*	1	1	*	24.012	216.110
*	1	2	*	23.938	215.440
*	1	3	*	23.751	213.760
*	1	4	*	22.808	205.270
*	1	5	*	23.240	209.160
*	2	1	*	22.846	205.610
*	2	2	*	21.814	196.330

*	2	3	*	22.088	198.790
*	2	4	*	21.149	190.340
*	2	5	*	19.213	172.920
*	3	1	*	27.141	244.270
*	3	2	*	26.026	234.230
*	3	3	*	25.099	225.890
*	3	4	*	25.676	231.080
*	3	5	*	24.702	222.320
*	4	1	*	20.724	186.520
*	4	2	*	18.806	169.250
*	4	3	*	19.267	173.400
*	4	4	*	17.838	160.540
*	4	5	*	15.569	140.120
*	5	1	*	22.993	206.940
*	5	2	*	20.592	185.330
*	5	3	*	20.526	184.730
*	5	4	*	19.766	177.890
*	5	5	*	18.707	168.360
*	*	*	1	23.717	1778.810
*	*	*	2	21.902	1642.680
*	*	*	3	20.175	1513.110

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*	1	*	1	25.020	375.300
*	1	*	2	23.525	352.870
*	1	*	3	22.105	331.570
*	2	*	1	23.657	354.850
*	2	*	2	21.481	322.220
*	2	*	3	19.128	286.920
*	3	*	1	27.627	414.400
*	3	*	2	25.669	385.040
*	3	*	3	23.890	358.350
*	4	*	1	20.090	301.350
*	4	*	2	18.513	277.700
*	4	*	3	16.719	250.780
*	5	*	1	22.194	332.910
*	5	*	2	20.323	304.850
*	5	*	3	19.033	285.490

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*	*	1	1	25.599	383.990
*	*	1	2	23.413	351.190
*	*	1	3	21.618	324.270

*	*	2	1	23.717	355.750
*	*	2	2	22.252	333.780
*	*	2	3	20.737	311.050
*	*	3	1	23.888	358.320
*	*	3	2	22.014	330.210
*	*	3	3	20.536	308.040
*	*	4	1	23.391	350.860
*	*	4	2	21.291	319.360
*	*	4	3	19.660	294.900
*	*	5	1	21.993	329.890
*	*	5	2	20.543	308.140
*	*	5	3	18.323	274.850

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*	1	1	1	26.407	79.220
*	1	1	2	22.883	68.650
*	1	1	3	22.747	68.240
*	1	2	1	25.213	75.640
*	1	2	2	24.127	72.380
*	1	2	3	22.473	67.420
*	1	3	1	24.830	74.490
*	1	3	2	24.500	73.500
*	1	3	3	21.923	65.770
*	1	4	1	23.630	70.890
*	1	4	2	22.450	67.350
*	1	4	3	22.343	67.030
*	1	5	1	25.020	75.060
*	1	5	2	23.663	70.990
*	1	5	3	21.037	63.110
*	2	1	1	25.040	75.120
*	2	1	2	23.070	69.210
*	2	1	3	20.427	61.280
*	2	2	1	24.043	72.130
*	2	2	2	21.053	63.160
*	2	2	3	20.347	61.040
*	2	3	1	23.690	71.070
*	2	3	2	22.020	66.060
*	2	3	3	20.553	61.660
*	2	4	1	23.490	70.470
*	2	4	2	21.260	63.780
*	2	4	3	18.697	56.090
*	2	5	1	22.020	66.060

*	2	5	2	20.003	60.010
*	2	5	3	15.617	46.850
*	3	1	1	29.437	88.310
*	3	1	2	27.393	82.180
*	3	1	3	24.593	73.780
*	3	2	1	27.817	83.450
*	3	2	2	26.423	79.270
*	3	2	3	23.837	71.510
*	3	3	1	27.263	81.790
*	3	3	2	24.293	72.880
*	3	3	3	23.740	71.220
*	3	4	1	28.047	84.140
*	3	4	2	25.490	76.470
*	3	4	3	23.490	70.470
*	3	5	1	25.570	76.710
*	3	5	2	24.747	74.240
*	3	5	3	23.790	71.370
*	4	1	1	22.470	67.410
*	4	1	2	20.927	62.780
*	4	1	3	18.777	56.330
*	4	2	1	19.850	59.550
*	4	2	2	19.307	57.920
*	4	2	3	17.260	51.780
*	4	3	1	21.107	63.320
*	4	3	2	19.157	57.470
*	4	3	3	17.537	52.610
*	4	4	1	19.970	59.910
*	4	4	2	17.657	52.970
*	4	4	3	15.887	47.660
*	4	5	1	17.053	51.160
*	4	5	2	15.520	46.560
*	4	5	3	14.133	42.400
*	5	1	1	24.643	73.930
*	5	1	2	22.790	68.370
*	5	1	3	21.547	64.640
*	5	2	1	21.660	64.980
*	5	2	2	20.350	61.050
*	5	2	3	19.767	59.300
*	5	3	1	22.550	67.650
*	5	3	2	20.100	60.300
*	5	3	3	18.927	56.780

*	5	4	1	21.817	65.450
*	5	4	2	19.597	58.790
*	5	4	3	17.883	53.650
*	5	5	1	20.300	60.900
*	5	5	2	18.780	56.340
*	5	5	3	17.040	51.120

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	152.629	76.314	9.3050	0.0002
2	Factor A	4	1416.805	354.201	43.1879	0.0000
4	Factor B	4	255.500	63.875	7.7883	0.0000
6	AB	16	75.573	4.723	0.5759	
8	Factor C	2	470.739	235.369	28.6987	0.0000
10	AC	8	12.873	1.609	0.1962	
12	BC	8	7.193	0.899	0.1096	
14	ABC	32	44.710	1.397	0.1704	
-15	Error	148	1213.808	8.201		
	Total	224	3649.828			

Coefficient of Variation: 13.06%

s_ for means group 1: 0.3307 Number of Observations:75
y

s_ for means group 2: 0.4269 Number of Observations:45
y

s_ for means group 4: 0.4269 Number of Observations:45
y

s_ for means group 6: 0.9546 Number of Observations: 9
y

s_ for means group 8: 0.3307 Number of Observations:75
y

s_ for means group 10: 0.7394 Number of Observations:15
y

s_ for means group 12: 0.7394 Number of Observations:15
y

s_ for means group 14: 1.6534 Number of Observations:3
y

Variable 6: TR%

Grand Mean = 17.300   Grand Sum = 3892.480   Total Count = 225

T A B L E   O F   M E A N S

1	4	2	3	6	Total
1	*	*	*	16.492	1236.900
2	*	*	*	17.774	1333.030
3	*	*	*	17.634	1322.550
*	1	*	*	16.990	764.560
*	2	*	*	17.519	788.360
*	3	*	*	17.474	786.310
*	4	*	*	17.202	774.080
*	5	*	*	17.315	779.170
*	*	1	*	18.440	829.800
*	*	2	*	18.040	811.820
*	*	3	*	17.252	776.340
*	*	4	*	16.827	757.210
*	*	5	*	15.940	717.310
*	1	1	*	17.693	159.240
*	1	2	*	17.508	157.570
*	1	3	*	17.311	155.800
*	1	4	*	16.460	148.140
*	1	5	*	15.979	143.810
*	2	1	*	19.368	174.310
*	2	2	*	17.828	160.450
*	2	3	*	17.298	155.680
*	2	4	*	17.049	153.440
*	2	5	*	16.053	144.480
*	3	1	*	18.408	165.670
*	3	2	*	18.524	166.720
*	3	3	*	16.659	149.930
*	3	4	*	17.053	153.480
*	3	5	*	16.723	150.510
*	4	1	*	18.253	164.280
*	4	2	*	18.016	162.140
*	4	3	*	17.547	157.920
*	4	4	*	16.782	151.040
*	4	5	*	15.411	138.700

*	5	1	*	18.478	166.300
*	5	2	*	18.327	164.940
*	5	3	*	17.446	157.010
*	5	4	*	16.790	151.110
*	5	5	*	15.534	139.810
*	*	*	1	16.475	1235.590
*	*	*	2	17.309	1298.180
*	*	*	3	18.116	1358.710
*	1	*	1	15.991	239.870
*	1	*	2	17.056	255.840
*	1	*	3	17.923	268.850
*	2	*	1	16.068	241.020
*	2	*	2	17.623	264.340
*	2	*	3	18.867	283.000
*	3	*	1	17.337	260.060
*	3	*	2	17.462	261.930
*	3	*	3	17.621	264.320
*	4	*	1	16.665	249.980
*	4	*	2	16.924	253.860
*	4	*	3	18.016	270.240
*	5	*	1	16.311	244.660
*	5	*	2	17.481	262.210
*	5	*	3	18.153	272.300
*	*	1	1	17.679	265.180
*	*	1	2	18.285	274.270
*	*	1	3	19.357	290.350
*	*	2	1	17.391	260.860
*	*	2	2	17.853	267.790
*	*	2	3	18.878	283.170
*	*	3	1	16.097	241.460
*	*	3	2	17.340	260.100
*	*	3	3	18.319	274.780
*	*	4	1	16.045	240.680
*	*	4	2	16.957	254.360
*	*	4	3	17.478	262.170
*	*	5	1	15.161	227.410
*	*	5	2	16.111	241.660
*	*	5	3	16.549	248.240

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*	1	1	1	16.530	49.590
*	1	1	2	17.787	53.360
*	1	1	3	18.763	56.290
*	1	2	1	16.877	50.630
*	1	2	2	17.267	51.800
*	1	2	3	18.380	55.140
*	1	3	1	15.820	47.460
*	1	3	2	17.537	52.610
*	1	3	3	18.577	55.730
*	1	4	1	15.640	46.920
*	1	4	2	16.773	50.320
*	1	4	3	16.967	50.900
*	1	5	1	15.090	45.270
*	1	5	2	15.917	47.750
*	1	5	3	16.930	50.790
*	2	1	1	18.383	55.150
*	2	1	2	19.177	57.530
*	2	1	3	20.543	61.630
*	2	2	1	16.233	48.700
*	2	2	2	18.020	54.060
*	2	2	3	19.230	57.690
*	2	3	1	15.823	47.470
*	2	3	2	17.430	52.290
*	2	3	3	18.640	55.920
*	2	4	1	15.440	46.320
*	2	4	2	17.263	51.790
*	2	4	3	18.443	55.330
*	2	5	1	14.460	43.380
*	2	5	2	16.223	48.670
*	2	5	3	17.477	52.430
*	3	1	1	18.763	56.290
*	3	1	2	17.990	53.970
*	3	1	3	18.470	55.410
*	3	2	1	18.443	55.330
*	3	2	2	18.310	54.930
*	3	2	3	18.820	56.460
*	3	3	1	16.173	48.520
*	3	3	2	15.857	47.570
*	3	3	3	17.947	53.840
*	3	4	1	16.590	49.770

*	3	4	2	17.653	52.960
*	3	4	3	16.917	50.750
*	3	5	1	16.717	50.150
*	3	5	2	17.500	52.500
*	3	5	3	15.953	47.860
*	4	1	1	16.823	50.470
*	4	1	2	17.937	53.810
*	4	1	3	20.000	60.000
*	4	2	1	17.913	53.740
*	4	2	2	17.503	52.510
*	4	2	3	18.630	55.890
*	4	3	1	16.667	50.000
*	4	3	2	17.953	53.860
*	4	3	3	18.020	54.060
*	4	4	1	16.870	50.610
*	4	4	2	15.847	47.540
*	4	4	3	17.630	52.890
*	4	5	1	15.053	45.160
*	4	5	2	15.380	46.140
*	4	5	3	15.800	47.400
*	5	1	1	17.893	53.680
*	5	1	2	18.533	55.600
*	5	1	3	19.007	57.020
*	5	2	1	17.487	52.460
*	5	2	2	18.163	54.490
*	5	2	3	19.330	57.990
*	5	3	1	16.003	48.010
*	5	3	2	17.923	53.770
*	5	3	3	18.410	55.230
*	5	4	1	15.687	47.060
*	5	4	2	17.250	51.750
*	5	4	3	17.433	52.300
*	5	5	1	14.483	43.450
*	5	5	2	15.533	46.600
*	5	5	3	16.587	49.760

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	74.163	37.082	17.3450	0.0000

2	Factor A	4	8.278	2.070	0.9680	
4	Factor B	4	176.535	44.134	20.6436	0.0000
6	AB	16	26.765	1.673	0.7825	
8	Factor C	2	101.066	50.533	23.6369	0.0000
10	AC	8	28.121	3.515	1.6442	0.1170
12	BC	8	6.054	0.757	0.3540	
14	ABC	32	25.994	0.812	0.3800	
-15	Error	148	316.408	2.138		
	Total	224	763.384			

Coefficient of Variation: 8.45%

s_ for means group 1: 0.1688 Number of Observations:75
y

s_ for means group 2: 0.2180 Number of Observations:45
y

s_ for means group 4: 0.2180 Number of Observations:45
y

s_ for means group 6: 0.4874 Number of Observations: 9
y

s_ for means group 8: 0.1688 Number of Observations:75
y

s_ for means group 10: 0.3775 Number of Observations:15
y

s_ for means group 12: 0.3775 Number of Observations:15
y

s_ for means group 14: 0.8442 Number of Observations: 3
y

Variable 7: TC (F)

Grand Mean = 5.013 Grand Sum = 1127.830 Total Count = 225

T A B L E O F M E A N S

1	4	2	3	7	Total
1	*	*	*	4.747	356.000
2	*	*	*	5.264	394.780
3	*	*	*	5.027	377.050
*	1	*	*	5.058	227.600
*	2	*	*	5.110	229.950
*	3	*	*	5.342	240.390
*	4	*	*	4.667	210.010

*	5	*	*	4.886	219.880
*	*	1	*	5.287	237.920
*	*	2	*	5.120	230.390
*	*	3	*	5.021	225.940
*	*	4	*	4.917	221.260
*	*	5	*	4.718	212.320
*	1	1	*	5.266	47.390
*	1	2	*	5.200	46.800
*	1	3	*	5.191	46.720
*	1	4	*	4.952	44.570
*	1	5	*	4.680	42.120
*	2	1	*	5.277	47.490
*	2	2	*	5.293	47.640
*	2	3	*	5.006	45.050
*	2	4	*	4.982	44.840
*	2	5	*	4.992	44.930
*	3	1	*	5.706	51.350
*	3	2	*	5.516	49.640
*	3	3	*	5.230	47.070
*	3	4	*	5.146	46.310
*	3	5	*	5.113	46.020
*	4	1	*	5.000	45.000
*	4	2	*	4.687	42.180
*	4	3	*	4.739	42.650
*	4	4	*	4.668	42.010
*	4	5	*	4.241	38.170
*	5	1	*	5.188	46.690
*	5	2	*	4.903	44.130
*	5	3	*	4.939	44.450
*	5	4	*	4.837	43.530
*	5	5	*	4.564	41.080
*	*	*	1	4.638	347.880
*	*	*	2	5.029	377.140
*	*	*	3	5.371	402.810
*	1	*	1	4.829	72.440
*	1	*	2	5.062	75.930
*	1	*	3	5.282	79.230

*	2	*	1	4.680	70.200
*	2	*	2	5.173	77.590
*	2	*	3	5.477	82.160
*	3	*	1	5.029	75.440
*	3	*	2	5.301	79.520
*	3	*	3	5.695	85.430
*	4	*	1	4.228	63.420
*	4	*	2	4.664	69.960
*	4	*	3	5.109	76.630
*	5	*	1	4.425	66.380
*	5	*	2	4.943	74.140
*	5	*	3	5.291	79.360

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*	*	1	1	4.844	72.660
*	*	1	2	5.331	79.970
*	*	1	3	5.686	85.290
*	*	2	1	4.773	71.600
*	*	2	2	5.075	76.130
*	*	2	3	5.511	82.660
*	*	3	1	4.662	69.930
*	*	3	2	5.008	75.120
*	*	3	3	5.393	80.890
*	*	4	1	4.496	67.440
*	*	4	2	4.993	74.890
*	*	4	3	5.262	78.930
*	*	5	1	4.417	66.250
*	*	5	2	4.735	71.030
*	*	5	3	5.003	75.040

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*	1	1	1	4.933	14.800
*	1	1	2	5.293	15.880
*	1	1	3	5.570	16.710
*	1	2	1	4.947	14.840
*	1	2	2	5.183	15.550
*	1	2	3	5.470	16.410
*	1	3	1	5.097	15.290
*	1	3	2	5.057	15.170
*	1	3	3	5.420	16.260
*	1	4	1	4.757	14.270
*	1	4	2	5.007	15.020
*	1	4	3	5.093	15.280

*	1	5	1	4.413	13.240
*	1	5	2	4.770	14.310
*	1	5	3	4.857	14.570
*	2	1	1	4.787	14.360
*	2	1	2	5.303	15.910
*	2	1	3	5.740	17.220
*	2	2	1	4.970	14.910
*	2	2	2	5.343	16.030
*	2	2	3	5.567	16.700
*	2	3	1	4.363	13.090
*	2	3	2	5.183	15.550
*	2	3	3	5.470	16.410
*	2	4	1	4.523	13.570
*	2	4	2	5.083	15.250
*	2	4	3	5.340	16.020
*	2	5	1	4.757	14.270
*	2	5	2	4.950	14.850
*	2	5	3	5.270	15.810
*	3	1	1	5.590	16.770
*	3	1	2	5.680	17.040
*	3	1	3	5.847	17.540
*	3	2	1	5.157	15.470
*	3	2	2	5.460	16.380
*	3	2	3	5.930	17.790
*	3	3	1	4.920	14.760
*	3	3	2	5.153	15.460
*	3	3	3	5.617	16.850
*	3	4	1	4.610	13.830
*	3	4	2	5.260	15.780
*	3	4	3	5.567	16.700
*	3	5	1	4.870	14.610
*	3	5	2	4.953	14.860
*	3	5	3	5.517	16.550
*	4	1	1	4.597	13.790
*	4	1	2	4.903	14.710
*	4	1	3	5.500	16.500
*	4	2	1	4.073	12.220
*	4	2	2	4.563	13.690
*	4	2	3	5.423	16.270
*	4	3	1	4.323	12.970
*	4	3	2	4.703	14.110

*	4	3	3	5.190	15.570
*	4	4	1	4.297	12.890
*	4	4	2	4.787	14.360
*	4	4	3	4.920	14.760
*	4	5	1	3.850	11.550
*	4	5	2	4.363	13.090
*	4	5	3	4.510	13.530
*	5	1	1	4.313	12.940
*	5	1	2	5.477	16.430
*	5	1	3	5.773	17.320
*	5	2	1	4.720	14.160
*	5	2	2	4.827	14.480
*	5	2	3	5.163	15.490
*	5	3	1	4.607	13.820
*	5	3	2	4.943	14.830
*	5	3	3	5.267	15.800
*	5	4	1	4.293	12.880
*	5	4	2	4.827	14.480
*	5	4	3	5.390	16.170
*	5	5	1	4.193	12.580
*	5	5	2	4.640	13.920
*	5	5	3	4.860	14.580

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	10.050	5.025	37.1431	0.0000
2	Factor A	4	11.498	2.875	21.2472	0.0000
4	Factor B	4	8.223	2.056	15.1946	0.0000
6	AB	16	1.687	0.105	0.7792	
8	Factor C	2	20.144	10.072	74.4458	0.0000
10	AC	8	1.118	0.140	1.0331	0.4138
12	BC	8	0.459	0.057	0.4239	
14	ABC	32	2.950	0.092	0.6813	
-15	Error	148	20.023	0.135		
	Total	224	76.153			

Coefficient of Variation: 7.34%

s_ for means group 1:   0.0425   Number of Observations: 75
y

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s_ for means group 2:     0.0548       Number of Observations: 45
 y
s_ for means group 4:     0.0548       Number of Observations: 45
  y
s_ for means group 6:     0.1226       Number of Observations: 9
 y
s_ for means group 8:     0.0425       Number of Observations: 75
 y
s_ for means group 10:     0.0950      Number of Observations: 15
 y
s_ for means group 12:     0.0950      Number of Observations: 15
 y
s_ for means group 14:     0.2124      Number of Observations: 3
 y
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Variable 8: BR%

Grand Mean = 24.515   Grand Sum = 5515.980   Total Count = 225

T A B L E   O F   M E A N S

1	4	2	3	8	Total
1	*	*	*	25.835	1937.610
2	*	*	*	24.350	1826.230
3	*	*	*	23.362	1752.140
*	1	*	*	27.454	1235.430
*	2	*	*	23.098	1039.400
*	3	*	*	25.301	1138.550
*	4	*	*	22.140	996.280
*	5	*	*	24.585	1106.320
*	*	1	*	26.428	1189.250
*	*	2	*	25.137	1131.160
*	*	3	*	24.306	1093.750
*	*	4	*	23.973	1078.780
*	*	5	*	22.734	1023.040
*	1	1	*	29.598	266.380
*	1	2	*	28.004	252.040
*	1	3	*	26.958	242.620
*	1	4	*	27.357	246.210
*	1	5	*	25.353	228.180
*	2	1	*	25.402	228.620

*	2	2	*	23.380	210.420
*	2	3	*	23.323	209.910
*	2	4	*	22.409	201.680
*	2	5	*	20.974	188.770
*	3	1	*	26.587	239.280
*	3	2	*	25.992	233.930
*	3	3	*	25.568	230.110
*	3	4	*	24.604	221.440
*	3	5	*	23.754	213.790
*	4	1	*	25.008	225.070
*	4	2	*	23.100	207.900
*	4	3	*	20.936	188.420
*	4	4	*	20.939	188.450
*	4	5	*	20.716	186.440
*	5	1	*	25.544	229.900
*	5	2	*	25.208	226.870
*	5	3	*	24.743	222.690
*	5	4	*	24.556	221.000
*	5	5	*	22.873	205.860
*	*	*	1	26.592	1994.430
*	*	*	2	24.523	1839.190
*	*	*	3	22.431	1682.360
*	1	*	1	29.223	438.350
*	1	*	2	27.565	413.470
*	1	*	3	25.574	383.610
*	2	*	1	26.073	391.090
*	2	*	2	22.971	344.570
*	2	*	3	20.249	303.740
*	3	*	1	26.887	403.300
*	3	*	2	25.575	383.620
*	3	*	3	23.442	351.630
*	4	*	1	24.006	360.090
*	4	*	2	22.356	335.340
*	4	*	3	20.057	300.850
*	5	*	1	26.773	401.600
*	5	*	2	24.146	362.190
*	5	*	3	22.835	342.530
*	*	1	1	28.440	426.600

*	*	1	2	26.063	390.940
*	*	1	3	24.781	371.710
*	*	2	1	27.581	413.720
*	*	2	2	25.103	376.550
*	*	2	3	22.726	340.890
*	*	3	1	26.351	395.270
*	*	3	2	24.822	372.330
*	*	3	3	21.743	326.150
*	*	4	1	25.721	385.820
*	*	4	2	23.760	356.400
*	*	4	3	22.437	336.560
*	*	5	1	24.868	373.020
*	*	5	2	22.865	342.970
*	*	5	3	20.470	307.050

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*	1	1	1	31.670	95.010
*	1	1	2	29.390	88.170
*	1	1	3	27.733	83.200
*	1	2	1	30.093	90.280
*	1	2	2	28.590	85.770
*	1	2	3	25.330	75.990
*	1	3	1	29.080	87.240
*	1	3	2	27.243	81.730
*	1	3	3	24.550	73.650
*	1	4	1	28.047	84.140
*	1	4	2	27.227	81.680
*	1	4	3	26.797	80.390
*	1	5	1	27.227	81.680
*	1	5	2	25.373	76.120
*	1	5	3	23.460	70.380
*	2	1	1	28.910	86.730
*	2	1	2	24.190	72.570
*	2	1	3	23.107	69.320
*	2	2	1	27.087	81.260
*	2	2	2	22.080	66.240
*	2	2	3	20.973	62.920
*	2	3	1	25.293	75.880
*	2	3	2	24.233	72.700
*	2	3	3	20.443	61.330
*	2	4	1	25.460	76.380
*	2	4	2	22.267	66.800

*	2	4	3	19.500	58.500
*	2	5	1	23.613	70.840
*	2	5	2	22.087	66.260
*	2	5	3	17.223	51.670
*	3	1	1	26.467	79.400
*	3	1	2	26.563	79.690
*	3	1	3	26.730	80.190
*	3	2	1	29.013	87.040
*	3	2	2	26.657	79.970
*	3	2	3	22.307	66.920
*	3	3	1	27.557	82.670
*	3	3	2	25.647	76.940
*	3	3	3	23.500	70.500
*	3	4	1	25.587	76.760
*	3	4	2	24.767	74.300
*	3	4	3	23.460	70.380
*	3	5	1	25.810	77.430
*	3	5	2	24.240	72.720
*	3	5	3	21.213	63.640
*	4	1	1	27.363	82.090
*	4	1	2	24.767	74.300
*	4	1	3	22.893	68.680
*	4	2	1	24.183	72.550
*	4	2	2	23.457	70.370
*	4	2	3	21.660	64.980
*	4	3	1	22.837	68.510
*	4	3	2	21.633	64.900
*	4	3	3	18.337	55.010
*	4	4	1	23.010	69.030
*	4	4	2	21.347	64.040
*	4	4	3	18.460	55.380
*	4	5	1	22.637	67.910
*	4	5	2	20.577	61.730
*	4	5	3	18.933	56.800
*	5	1	1	27.790	83.370
*	5	1	2	25.403	76.210
*	5	1	3	23.440	70.320
*	5	2	1	27.530	82.590
*	5	2	2	24.733	74.200
*	5	2	3	23.360	70.080
*	5	3	1	26.990	80.970

*	5	3	2	25.353	76.060
*	5	3	3	21.887	65.660
*	5	4	1	26.503	79.510
*	5	4	2	23.193	69.580
*	5	4	3	23.970	71.910
*	5	5	1	25.053	75.160
*	5	5	2	22.047	66.140
*	5	5	3	21.520	64.560

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	232.418	116.209	14.7266	0.0000
2	Factor A	4	761.032	190.258	24.1106	0.0000
4	Factor B	4	339.947	84.987	10.7700	0.0000
6	AB	16	50.676	3.167	0.4014	
8	Factor C	2	649.257	324.628	41.1388	0.0000
10	AC	8	34.948	4.368	0.5536	
12	BC	8	23.614	2.952	0.3741	
14	ABC	32	81.448	2.545	0.3225	
-15	Error	148	1167.877	7.891		
	Total	224	3341.217			

Coefficient of Variation: 11.46%

s_ for means group 1: 0.3244 Number of Observations: 75
y

s_ for means group 2: 0.4188 Number of Observations: 45
y

s_ for means group 4: 0.4188 Number of Observations: 45
y

s_ for means group 6: 0.9364 Number of Observations: 9
y

s_ for means group 8: 0.3244 Number of Observations: 75
y

s_ for means group 10: 0.7253 Number of Observations: 15
y

s_ for means group 12: 0.7253 Number of Observations: 15
y

s_ for means group 14: 1.6218 Number of Observations: 3

y

Variable 9: Taster A

Grand Mean = 69.533   Grand Sum = 15645.000   Total Count = 225

T A B L E   O F   M E A N S

1	4	2	3	9	Total
1	*	*	*	55.200	4140.000
2	*	*	*	71.907	5393.000
3	*	*	*	81.493	6112.000
*	1	*	*	70.222	3160.000
*	2	*	*	75.022	3376.000
*	3	*	*	63.467	2856.000
*	4	*	*	70.222	3160.000
*	5	*	*	68.733	3093.000
*	*	1	*	85.400	3843.000
*	*	2	*	75.089	3379.000
*	*	3	*	71.200	3204.000
*	*	4	*	59.956	2698.000
*	*	5	*	56.022	2521.000
*	1	1	*	80.889	728.000
*	1	2	*	74.111	667.000
*	1	3	*	71.444	643.000
*	1	4	*	62.778	565.000
*	1	5	*	61.889	557.000
*	2	1	*	90.333	813.000
*	2	2	*	76.778	691.000
*	2	3	*	71.222	641.000
*	2	4	*	69.556	626.000
*	2	5	*	67.222	605.000
*	3	1	*	72.556	653.000
*	3	2	*	61.333	552.000
*	3	3	*	62.111	559.000
*	3	4	*	59.333	534.000
*	3	5	*	62.000	558.000
*	4	1	*	97.333	876.000
*	4	2	*	87.778	790.000
*	4	3	*	78.000	702.000
*	4	4	*	50.222	452.000
*	4	5	*	37.778	340.000

*	5	1	*	85.889	773.000
*	5	2	*	75.444	679.000
*	5	3	*	73.222	659.000
*	5	4	*	57.889	521.000
*	5	5	*	51.222	461.000

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*	*	*	1	83.760	6282.000
*	*	*	2	69.320	5199.000
*	*	*	3	55.520	4164.000

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*	1	*	1	86.467	1297.000
*	1	*	2	70.933	1064.000
*	1	*	3	53.267	799.000
*	2	*	1	94.200	1413.000
*	2	*	2	72.400	1086.000
*	2	*	3	58.467	877.000
*	3	*	1	72.133	1082.000
*	3	*	2	62.867	943.000
*	3	*	3	55.400	831.000
*	4	*	1	87.067	1306.000
*	4	*	2	69.067	1036.000
*	4	*	3	54.533	818.000
*	5	*	1	78.933	1184.000
*	5	*	2	71.333	1070.000
*	5	*	3	55.933	839.000

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*	*	1	1	101.733	1526.000
*	*	1	2	85.667	1285.000
*	*	1	3	68.800	1032.000
*	*	2	1	88.933	1334.000
*	*	2	2	75.733	1136.000
*	*	2	3	60.600	909.000
*	*	3	1	88.867	1333.000
*	*	3	2	68.267	1024.000
*	*	3	3	56.467	847.000
*	*	4	1	74.067	1111.000
*	*	4	2	59.200	888.000
*	*	4	3	46.600	699.000
*	*	5	1	65.200	978.000
*	*	5	2	57.733	866.000
*	*	5	3	45.133	677.000

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*	1	1	1	103.667	311.000
*	1	1	2	77.667	233.000
*	1	1	3	61.333	184.000
*	1	2	1	90.333	271.000
*	1	2	2	72.333	217.000
*	1	2	3	59.667	179.000
*	1	3	1	84.333	253.000
*	1	3	2	77.667	233.000
*	1	3	3	52.333	157.000
*	1	4	1	76.333	229.000
*	1	4	2	62.333	187.000
*	1	4	3	49.667	149.000
*	1	5	1	77.667	233.000
*	1	5	2	64.667	194.000
*	1	5	3	43.333	130.000
*	2	1	1	104.667	314.000
*	2	1	2	93.667	281.000
*	2	1	3	72.667	218.000
*	2	2	1	98.000	294.000
*	2	2	2	70.333	211.000
*	2	2	3	62.000	186.000
*	2	3	1	94.000	282.000
*	2	3	2	63.333	190.000
*	2	3	3	56.333	169.000
*	2	4	1	95.667	287.000
*	2	4	2	71.000	213.000
*	2	4	3	42.000	126.000
*	2	5	1	78.667	236.000
*	2	5	2	63.667	191.000
*	2	5	3	59.333	178.000
*	3	1	1	92.667	278.000
*	3	1	2	70.667	212.000
*	3	1	3	54.333	163.000
*	3	2	1	71.333	214.000
*	3	2	2	64.333	193.000
*	3	2	3	48.333	145.000
*	3	3	1	77.667	233.000
*	3	3	2	54.667	164.000
*	3	3	3	54.000	162.000
*	3	4	1	64.667	194.000

*	3	4	2	53.000	159.000
*	3	4	3	60.333	181.000
*	3	5	1	54.333	163.000
*	3	5	2	71.667	215.000
*	3	5	3	60.000	180.000
*	4	1	1	107.333	322.000
*	4	1	2	104.000	312.000
*	4	1	3	80.667	242.000
*	4	2	1	110.000	330.000
*	4	2	2	86.000	258.000
*	4	2	3	67.333	202.000
*	4	3	1	104.000	312.000
*	4	3	2	72.667	218.000
*	4	3	3	57.333	172.000
*	4	4	1	59.333	178.000
*	4	4	2	51.333	154.000
*	4	4	3	40.000	120.000
*	4	5	1	54.667	164.000
*	4	5	2	31.333	94.000
*	4	5	3	27.333	82.000
*	5	1	1	100.333	301.000
*	5	1	2	82.333	247.000
*	5	1	3	75.000	225.000
*	5	2	1	75.000	225.000
*	5	2	2	85.667	257.000
*	5	2	3	65.667	197.000
*	5	3	1	84.333	253.000
*	5	3	2	73.000	219.000
*	5	3	3	62.333	187.000
*	5	4	1	74.333	223.000
*	5	4	2	58.333	175.000
*	5	4	3	41.000	123.000
*	5	5	1	60.667	182.000
*	5	5	2	57.333	172.000
*	5	5	3	35.667	107.000

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	26558.907	13279.453	22.7052	0.0000

2	Factor A	4	3083.467	770.867	1.3180	0.2659
4	Factor B	4	25185.467	6296.367	10.7655	0.0000
6	AB	16	11230.844	701.928	1.2002	0.2743
8	Factor C	2	29911.280	14955.640	25.5712	0.0000
10	AC	8	2294.053	286.757	0.4903	
12	BC	8	1078.720	134.840	0.2305	
14	ABC	32	5749.502	179.672	0.3072	
-15	Error	148	86559.760	584.863		
	Total	224	191652.000			

Coefficient of Variation: 34.78%

s_ for means group 1: 2.7925 Number of Observations: 75
y

s_ for means group 2: 3.6051 Number of Observations: 45
y

s_ for means group 4: 3.6051 Number of Observations: 45
y

s_ for means group 6: 8.0613 Number of Observations: 9
y

s_ for means group 8: 2.7925 Number of Observations: 75
y

s_ for means group 10: 6.2443 Number of Observations: 15
y

s_ for means group 12: 6.2443 Number of Observations: 15
y

s_ for means group 14: 13.9626 Number of Observations: 3
y

Variable 10: Taster B

Grand Mean = 19.247 Grand Sum = 4330.482 Total Count = 225

T A B L E O F M E A N S

1	4	2	3	10	Total
1	*	*	*	19.725	1479.349
2	*	*	*	19.034	1427.573
3	*	*	*	18.981	1423.560
*	1	*	*	20.156	907.000
*	2	*	*	19.206	864.270
*	3	*	*	18.400	828.000
*	4	*	*	19.061	857.725

*	5	*	*	19.411	873.487
*	*	1	*	20.110	904.950
*	*	2	*	19.623	883.045
*	*	3	*	19.303	868.623
*	*	4	*	18.844	848.000
*	*	5	*	18.353	825.863
*	1	1	*	21.000	189.000
*	1	2	*	20.889	188.000
*	1	3	*	19.889	179.000
*	1	4	*	19.778	178.000
*	1	5	*	19.222	173.000
*	2	1	*	20.106	180.950
*	2	2	*	19.258	173.320
*	2	3	*	19.111	172.000
*	2	4	*	18.889	170.000
*	2	5	*	18.667	168.000
*	3	1	*	19.222	173.000
*	3	2	*	18.889	170.000
*	3	3	*	18.778	169.000
*	3	4	*	17.778	160.000
*	3	5	*	17.333	156.000
*	4	1	*	19.778	178.000
*	4	2	*	19.303	173.725
*	4	3	*	19.111	172.000
*	4	4	*	19.000	171.000
*	4	5	*	18.111	163.000
*	5	1	*	20.444	184.000
*	5	2	*	19.778	178.000
*	5	3	*	19.625	176.623
*	5	4	*	18.778	169.000
*	5	5	*	18.429	165.863
*	*	*	1	20.350	1526.230
*	*	*	2	19.260	1444.480
*	*	*	3	18.130	1359.772
*	1	*	1	21.333	320.000
*	1	*	2	20.000	300.000
*	1	*	3	19.133	287.000

*	2	*	1	20.215	303.230
*	2	*	2	19.232	288.480
*	2	*	3	18.171	272.560
*	3	*	1	19.533	293.000
*	3	*	2	18.333	275.000
*	3	*	3	17.333	260.000
*	4	*	1	19.933	299.000
*	4	*	2	19.333	290.000
*	4	*	3	17.915	268.725
*	5	*	1	20.733	311.000
*	5	*	2	19.400	291.000
*	5	*	3	18.099	271.487

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*	*	1	1	21.394	320.910
*	*	1	2	19.899	298.480
*	*	1	3	19.037	285.560
*	*	2	1	20.955	314.320
*	*	2	2	19.600	294.000
*	*	2	3	18.315	274.725
*	*	3	1	20.400	306.000
*	*	3	2	19.533	293.000
*	*	3	3	17.975	269.623
*	*	4	1	19.733	296.000
*	*	4	2	18.867	283.000
*	*	4	3	17.933	269.000
*	*	5	1	19.267	289.000
*	*	5	2	18.400	276.000
*	*	5	3	17.391	260.863

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*	1	1	1	22.667	68.000
*	1	1	2	20.667	62.000
*	1	1	3	19.667	59.000
*	1	2	1	22.333	67.000
*	1	2	2	20.667	62.000
*	1	2	3	19.667	59.000
*	1	3	1	21.333	64.000
*	1	3	2	20.000	60.000
*	1	3	3	18.333	55.000
*	1	4	1	20.333	61.000
*	1	4	2	19.333	58.000
*	1	4	3	19.667	59.000

*	1	5	1	20.000	60.000
*	1	5	2	19.333	58.000
*	1	5	3	18.333	55.000
*	2	1	1	21.637	64.910
*	2	1	2	20.160	60.480
*	2	1	3	18.520	55.560
*	2	2	1	20.773	62.320
*	2	2	2	19.000	57.000
*	2	2	3	18.000	54.000
*	2	3	1	19.667	59.000
*	2	3	2	19.333	58.000
*	2	3	3	18.333	55.000
*	2	4	1	19.667	59.000
*	2	4	2	18.667	56.000
*	2	4	3	18.333	55.000
*	2	5	1	19.333	58.000
*	2	5	2	19.000	57.000
*	2	5	3	17.667	53.000
*	3	1	1	20.333	61.000
*	3	1	2	18.667	56.000
*	3	1	3	18.667	56.000
*	3	2	1	20.000	60.000
*	3	2	2	19.000	57.000
*	3	2	3	17.667	53.000
*	3	3	1	19.667	59.000
*	3	3	2	18.667	56.000
*	3	3	3	18.000	54.000
*	3	4	1	19.000	57.000
*	3	4	2	18.333	55.000
*	3	4	3	16.000	48.000
*	3	5	1	18.667	56.000
*	3	5	2	17.000	51.000
*	3	5	3	16.333	49.000
*	4	1	1	20.667	62.000
*	4	1	2	20.000	60.000
*	4	1	3	18.667	56.000
*	4	2	1	20.333	61.000
*	4	2	2	19.667	59.000
*	4	2	3	17.908	53.725
*	4	3	1	20.333	61.000
*	4	3	2	19.667	59.000

*	4	3	3	17.333	52.000
*	4	4	1	19.333	58.000
*	4	4	2	19.333	58.000
*	4	4	3	18.333	55.000
*	4	5	1	19.000	57.000
*	4	5	2	18.000	54.000
*	4	5	3	17.333	52.000
*	5	1	1	21.667	65.000
*	5	1	2	20.000	60.000
*	5	1	3	19.667	59.000
*	5	2	1	21.333	64.000
*	5	2	2	19.667	59.000
*	5	2	3	18.333	55.000
*	5	3	1	21.000	63.000
*	5	3	2	20.000	60.000
*	5	3	3	17.874	53.623
*	5	4	1	20.333	61.000
*	5	4	2	18.667	56.000
*	5	4	3	17.333	52.000
*	5	5	1	19.333	58.000
*	5	5	2	18.667	56.000
*	5	5	3	17.288	51.863

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	25.818	12.909	9.5509	0.0001
2	Factor A	4	72.277	18.069	13.3686	0.0000
4	Factor B	4	83.321	20.830	15.4113	0.0000
6	AB	16	8.701	0.544	0.4023	
8	Factor C	2	184.742	92.371	68.3408	0.0000
10	AC	8	4.145	0.518	0.3834	
12	BC	8	6.244	0.780	0.5774	
14	ABC	32	20.078	0.627	0.4642	
-15	Error	148	200.040	1.352		
	Total	224	605.366			

Coefficient of Variation: 6.04%

s_ for means group 1: 0.1342   Number of Observations: 75

y

s_ for means group 2: 0.1733 Number of Observations: 45

y

s_ for means group 4: 0.1733 Number of Observations: 45

y

s_ for means group 6: 0.3875 Number of Observations: 9

y

s_ for means group 8: 0.1342 Number of Observations: 75

y

s_ for means group 10: 0.3002 Number of Observations: 15

y

s_ for means group 12: 0.3002 Number of Observations: 15

y

s_ for means group 14: 0.6712 Number of Observations: 3

y

Variable 11: Yield

Grand Mean = 3978.889 Grand Sum = 895250.000 Total Count = 225

T A B L E O F M E A N S

1	4	2	3	11	Total
1	*	*	*	3989.333	299200.000
2	*	*	*	3981.093	298582.000
3	*	*	*	3966.240	297468.000
*	1	*	*	4355.644	196004.000
*	2	*	*	3427.578	154241.000
*	3	*	*	4531.867	203934.000
*	4	*	*	4449.400	200223.000
*	5	*	*	3129.956	140848.000
*	*	1	*	2731.622	122923.000
*	*	2	*	3794.956	170773.000
*	*	3	*	4372.044	196742.000
*	*	4	*	4507.200	202824.000
*	*	5	*	4488.622	201988.000
*	1	1	*	3278.778	29509.000
*	1	2	*	4192.111	37729.000
*	1	3	*	4834.556	43511.000
*	1	4	*	4875.444	43879.000
*	1	5	*	4597.333	41376.000
*	2	1	*	2323.222	20909.000

*	2	2	*	3334.778	30013.000
*	2	3	*	3903.222	35129.000
*	2	4	*	3808.778	34279.000
*	2	5	*	3767.889	33911.000
*	3	1	*	3438.444	30946.000
*	3	2	*	4438.000	39942.000
*	3	3	*	4965.000	44685.000
*	3	4	*	4803.333	43230.000
*	3	5	*	5014.556	45131.000
*	4	1	*	2936.111	26425.000
*	4	2	*	4215.667	37941.000
*	4	3	*	4604.444	41440.000
*	4	4	*	5275.889	47483.000
*	4	5	*	5214.889	46934.000
*	5	1	*	1681.556	15134.000
*	5	2	*	2794.222	25148.000
*	5	3	*	3553.000	31977.000
*	5	4	*	3772.556	33953.000
*	5	5	*	3848.444	34636.000

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*	*	*	1	3900.733	292555.000
*	*	*	2	3942.027	295652.000
*	*	*	3	4093.907	307043.000

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*	1	*	1	4443.333	66650.000
*	1	*	2	4316.733	64751.000
*	1	*	3	4306.867	64603.000
*	2	*	1	3217.133	48257.000
*	2	*	2	3199.267	47989.000
*	2	*	3	3866.333	57995.000
*	3	*	1	4282.133	64232.000
*	3	*	2	4621.733	69326.000
*	3	*	3	4691.733	70376.000
*	4	*	1	4572.533	68588.000
*	4	*	2	4395.333	65930.000
*	4	*	3	4380.333	65705.000
*	5	*	1	2988.533	44828.000
*	5	*	2	3177.067	47656.000
*	5	*	3	3224.267	48364.000

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*	*	1	1	2786.667	41800.000

*	*	1	2	2659.400	39891.000
*	*	1	3	2748.800	41232.000
*	*	2	1	3673.867	55108.000
*	*	2	2	3789.733	56846.000
*	*	2	3	3921.267	58819.000
*	*	3	1	4298.400	64476.000
*	*	3	2	4372.400	65586.000
*	*	3	3	4445.333	66680.000
*	*	4	1	4328.867	64933.000
*	*	4	2	4476.867	67153.000
*	*	4	3	4715.867	70738.000
*	*	5	1	4415.867	66238.000
*	*	5	2	4411.733	66176.000
*	*	5	3	4638.267	69574.000

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*	1	1	1	3751.333	11254.000
*	1	1	2	3101.333	9304.000
*	1	1	3	2983.667	8951.000
*	1	2	1	4098.000	12294.000
*	1	2	2	4110.000	12330.000
*	1	2	3	4368.333	13105.000
*	1	3	1	4759.000	14277.000
*	1	3	2	4875.000	14625.000
*	1	3	3	4869.667	14609.000
*	1	4	1	4831.333	14494.000
*	1	4	2	4908.333	14725.000
*	1	4	3	4886.667	14660.000
*	1	5	1	4777.000	14331.000
*	1	5	2	4589.000	13767.000
*	1	5	3	4426.000	13278.000
*	2	1	1	2194.000	6582.000
*	2	1	2	2259.333	6778.000
*	2	1	3	2516.333	7549.000
*	2	2	1	3005.667	9017.000
*	2	2	2	2994.000	8982.000
*	2	2	3	4004.667	12014.000
*	2	3	1	3646.000	10938.000
*	2	3	2	3531.667	10595.000
*	2	3	3	4532.000	13596.000
*	2	4	1	3518.667	10556.000
*	2	4	2	3815.333	11446.000

*	2	4	3	4092.333	12277.000
*	2	5	1	3721.333	11164.000
*	2	5	2	3396.000	10188.000
*	2	5	3	4186.333	12559.000
*	3	1	1	3343.667	10031.000
*	3	1	2	3212.000	9636.000
*	3	1	3	3759.667	11279.000
*	3	2	1	4377.000	13131.000
*	3	2	2	4662.667	13988.000
*	3	2	3	4274.333	12823.000
*	3	3	1	4616.000	13848.000
*	3	3	2	5150.333	15451.000
*	3	3	3	5128.667	15386.000
*	3	4	1	4357.000	13071.000
*	3	4	2	4884.000	14652.000
*	3	4	3	5169.000	15507.000
*	3	5	1	4717.000	14151.000
*	3	5	2	5199.667	15599.000
*	3	5	3	5127.000	15381.000
*	4	1	1	3019.667	9059.000
*	4	1	2	3021.000	9063.000
*	4	1	3	2767.667	8303.000
*	4	2	1	4060.000	12180.000
*	4	2	2	4325.333	12976.000
*	4	2	3	4261.667	12785.000
*	4	3	1	5011.000	15033.000
*	4	3	2	4527.000	13581.000
*	4	3	3	4275.333	12826.000
*	4	4	1	5403.000	16209.000
*	4	4	2	5093.333	15280.000
*	4	4	3	5331.333	15994.000
*	4	5	1	5369.000	16107.000
*	4	5	2	5010.000	15030.000
*	4	5	3	5265.667	15797.000
*	5	1	1	1624.667	4874.000
*	5	1	2	1703.333	5110.000
*	5	1	3	1716.667	5150.000
*	5	2	1	2828.667	8486.000
*	5	2	2	2856.667	8570.000
*	5	2	3	2697.333	8092.000
*	5	3	1	3460.000	10380.000

*	5	3	2	3778.000	11334.000
*	5	3	3	3421.000	10263.000
*	5	4	1	3534.333	10603.000
*	5	4	2	3683.333	11050.000
*	5	4	3	4100.000	12300.000
*	5	5	1	3495.000	10485.000
*	5	5	2	3864.000	11592.000
*	5	5	3	4186.333	12559.000

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	20545.529	10272.764	0.0978	
2	Factor A	4	76218373.022	19054593.256	181.3876	0.0000
4	Factor B	4	102735792.044	25683948.011	244.4948	0.0000
6	AB	16	6299837.600	393739.850	3.7482	0.0000
8	Factor C	2	1552215.262	776107.631	7.3880	0.0009
10	AC	8	5204858.338	650607.292	6.1934	0.0000
12	BC	8	845438.649	105679.831	1.0060	0.4340
14	ABC	32	4889547.307	152798.353	1.4545	0.0711
-15	Error	148	15547260.471	105049.057		
	Total	224	213313868.222			

Coefficient of Variation: 8.15%

s_ for means group 1: 37.4253 Number of Observations: 75
y

s_ for means group 2: 48.3159 Number of Observations: 45
y

s_ for means group 4: 48.3159 Number of Observations: 45
y

s_ for means group 6: 108.0376 Number of Observations: 9
y

s_ for means group 8: 37.4253 Number of Observations: 75
y

s_ for means group 10: 83.6855 Number of Observations: 15
y

s_ for means group 12: 83.6855 Number of Observations: 15
y

s_ for means group 14: 187.1266 Number of Observations: 3
y

Variable 12: TC (R)

Grand Mean = 5.253   Grand Sum = 1181.970   Total Count = 225

T A B L E   O F   M E A N S

1	4	2	3	12	Total
1	*	*	*	4.984	373.820
2	*	*	*	5.454	409.020
3	*	*	*	5.322	399.130
*	1	*	*	5.301	238.540
*	2	*	*	5.328	239.780
*	3	*	*	5.877	264.470
*	4	*	*	4.733	212.980
*	5	*	*	5.027	226.200
*	*	1	*	5.509	247.910
*	*	2	*	5.366	241.470
*	*	3	*	5.280	237.580
*	*	4	*	5.156	232.040
*	*	5	*	4.955	222.970
*	1	1	*	5.508	49.570
*	1	2	*	5.480	49.320
*	1	3	*	5.422	48.800
*	1	4	*	5.121	46.090
*	1	5	*	4.973	44.760
*	2	1	*	5.483	49.350
*	2	2	*	5.429	48.860
*	2	3	*	5.409	48.680
*	2	4	*	5.288	47.590
*	2	5	*	5.033	45.300
*	3	1	*	6.113	55.020
*	3	2	*	6.021	54.190
*	3	3	*	5.788	52.090
*	3	4	*	5.792	52.130
*	3	5	*	5.671	51.040
*	4	1	*	4.948	44.530
*	4	2	*	4.861	43.750
*	4	3	*	4.807	43.260
*	4	4	*	4.724	42.520

*	4	5	*	4.324	38.920
*	5	1	*	5.493	49.440
*	5	2	*	5.039	45.350
*	5	3	*	4.972	44.750
*	5	4	*	4.857	43.710
*	5	5	*	4.772	42.950
*	*	*	1	4.909	368.210
*	*	*	2	5.262	394.680
*	*	*	3	5.588	419.080
*	1	*	1	5.041	75.620
*	1	*	2	5.313	79.690
*	1	*	3	5.549	83.230
*	2	*	1	4.927	73.900
*	2	*	2	5.399	80.980
*	2	*	3	5.660	84.900
*	3	*	1	5.657	84.850
*	3	*	2	5.787	86.810
*	3	*	3	6.187	92.810
*	4	*	1	4.285	64.270
*	4	*	2	4.773	71.600
*	4	*	3	5.141	77.110
*	5	*	1	4.638	69.570
*	5	*	2	5.040	75.600
*	5	*	3	5.402	81.030
*	*	1	1	5.113	76.690
*	*	1	2	5.477	82.150
*	*	1	3	5.938	89.070
*	*	2	1	5.019	75.280
*	*	2	2	5.347	80.210
*	*	2	3	5.732	85.980
*	*	3	1	4.999	74.980
*	*	3	2	5.263	78.950
*	*	3	3	5.577	83.650
*	*	4	1	4.841	72.620
*	*	4	2	5.183	77.750
*	*	4	3	5.445	81.670
*	*	5	1	4.576	68.640
*	*	5	2	5.041	75.620

*	*	5	3	5.247	78.710
*	1	1	1	5.143	15.430
*	1	1	2	5.533	16.600
*	1	1	3	5.847	17.540
*	1	2	1	5.230	15.690
*	1	2	2	5.493	16.480
*	1	2	3	5.717	17.150
*	1	3	1	5.210	15.630
*	1	3	2	5.523	16.570
*	1	3	3	5.533	16.600
*	1	4	1	4.883	14.650
*	1	4	2	5.020	15.060
*	1	4	3	5.460	16.380
*	1	5	1	4.740	14.220
*	1	5	2	4.993	14.980
*	1	5	3	5.187	15.560
*	2	1	1	5.137	15.410
*	2	1	2	5.463	16.390
*	2	1	3	5.850	17.550
*	2	2	1	4.987	14.960
*	2	2	2	5.470	16.410
*	2	2	3	5.830	17.490
*	2	3	1	5.083	15.250
*	2	3	2	5.403	16.210
*	2	3	3	5.740	17.220
*	2	4	1	5.040	15.120
*	2	4	2	5.320	15.960
*	2	4	3	5.503	16.510
*	2	5	1	4.387	13.160
*	2	5	2	5.337	16.010
*	2	5	3	5.377	16.130
*	3	1	1	5.863	17.590
*	3	1	2	6.013	18.040
*	3	1	3	6.463	19.390
*	3	2	1	5.843	17.530
*	3	2	2	5.930	17.790
*	3	2	3	6.290	18.870
*	3	3	1	5.543	16.630
*	3	3	2	5.653	16.960
*	3	3	3	6.167	18.500

*	3	4	1	5.487	16.460
*	3	4	2	5.857	17.570
*	3	4	3	6.033	18.100
*	3	5	1	5.547	16.640
*	3	5	2	5.483	16.450
*	3	5	3	5.983	17.950
*	4	1	1	4.270	12.810
*	4	1	2	4.907	14.720
*	4	1	3	5.667	17.000
*	4	2	1	4.327	12.980
*	4	2	2	4.857	14.570
*	4	2	3	5.400	16.200
*	4	3	1	4.497	13.490
*	4	3	2	4.707	14.120
*	4	3	3	5.217	15.650
*	4	4	1	4.367	13.100
*	4	4	2	4.897	14.690
*	4	4	3	4.910	14.730
*	4	5	1	3.963	11.890
*	4	5	2	4.500	13.500
*	4	5	3	4.510	13.530
*	5	1	1	5.150	15.450
*	5	1	2	5.467	16.400
*	5	1	3	5.863	17.590
*	5	2	1	4.707	14.120
*	5	2	2	4.987	14.960
*	5	2	3	5.423	16.270
*	5	3	1	4.660	13.980
*	5	3	2	5.030	15.090
*	5	3	3	5.227	15.680
*	5	4	1	4.430	13.290
*	5	4	2	4.823	14.470
*	5	4	3	5.317	15.950
*	5	5	1	4.243	12.730
*	5	5	2	4.893	14.680
*	5	5	3	5.180	15.540

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob

1	Replication	2	8.789	4.394	31.5277	0.0000
2	Factor A	4	32.366	8.091	58.0534	0.0000
4	Factor B	4	7.977	1.994	14.3075	0.0000
6	AB	16	1.403	0.088	0.6290	
8	Factor C	2	17.261	8.631	61.9216	0.0000
10	AC	8	1.024	0.128	0.9184	
12	BC	8	0.502	0.063	0.4499	
14	ABC	32	1.817	0.057	0.4075	
-15	Error	148	20.628	0.139		
	Total	224	91.766			

Coefficient of Variation: 7.11%

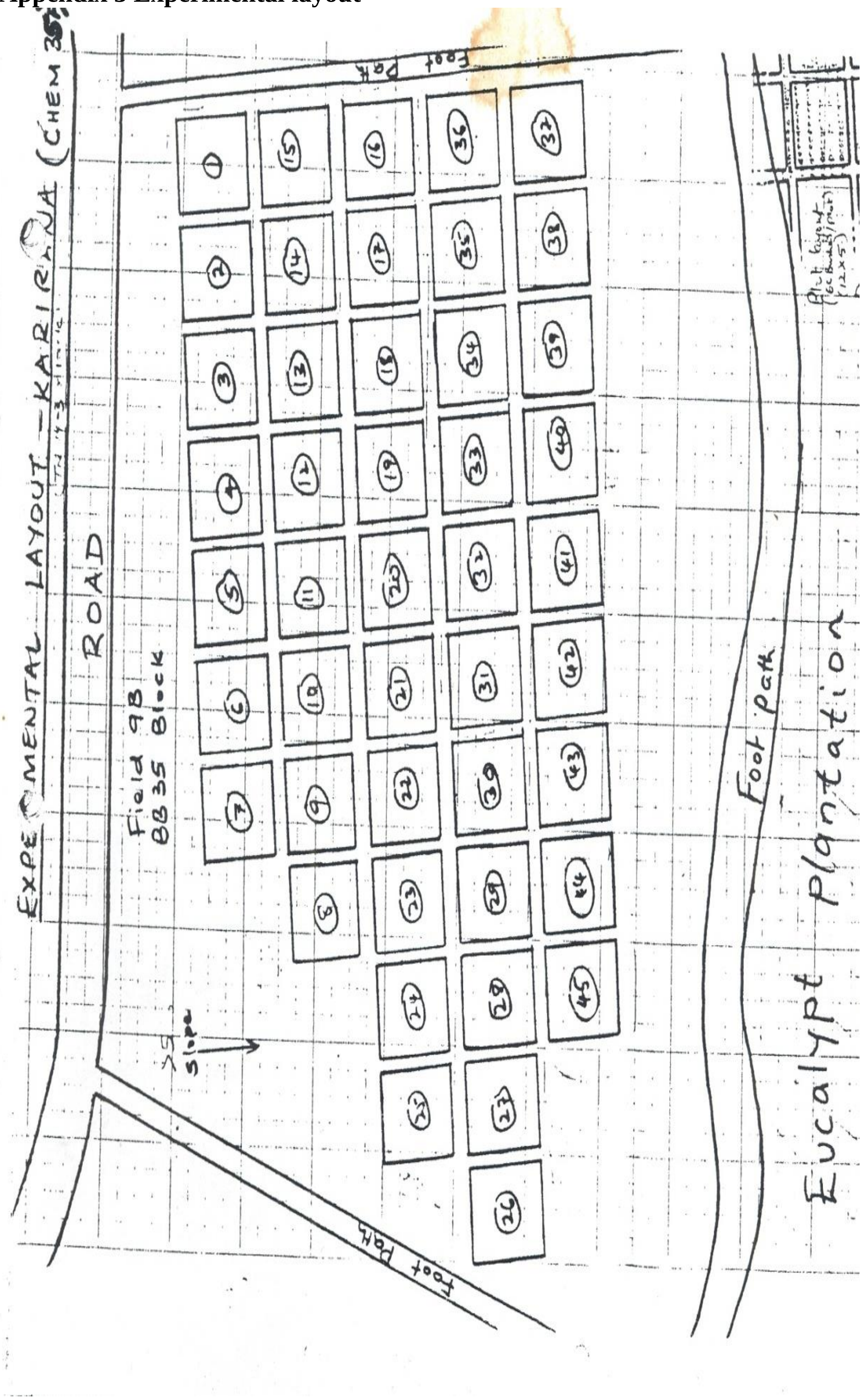
```
s_ for means group 1:     0.0431      Number of Observations: 75
 y
s_ for means group 2:     0.0557      Number of Observations: 45
 y
s_ for means group 4:     0.0557      Number of Observations: 45
 y
s_ for means group 6:     0.1244      Number of Observations: 9
 y
s_ for means group 8:     0.0431      Number of Observations: 75
 y
s_ for means group 10:    0.0964      Number of Observations: 15
 y
s_ for means group 12:    0.0964      Number of Observations: 15
 y
s_ for means group 14:    0.2155      Number of Observations: 3
 y
```

7.2: Appendix 2 Assigned treatments to plots

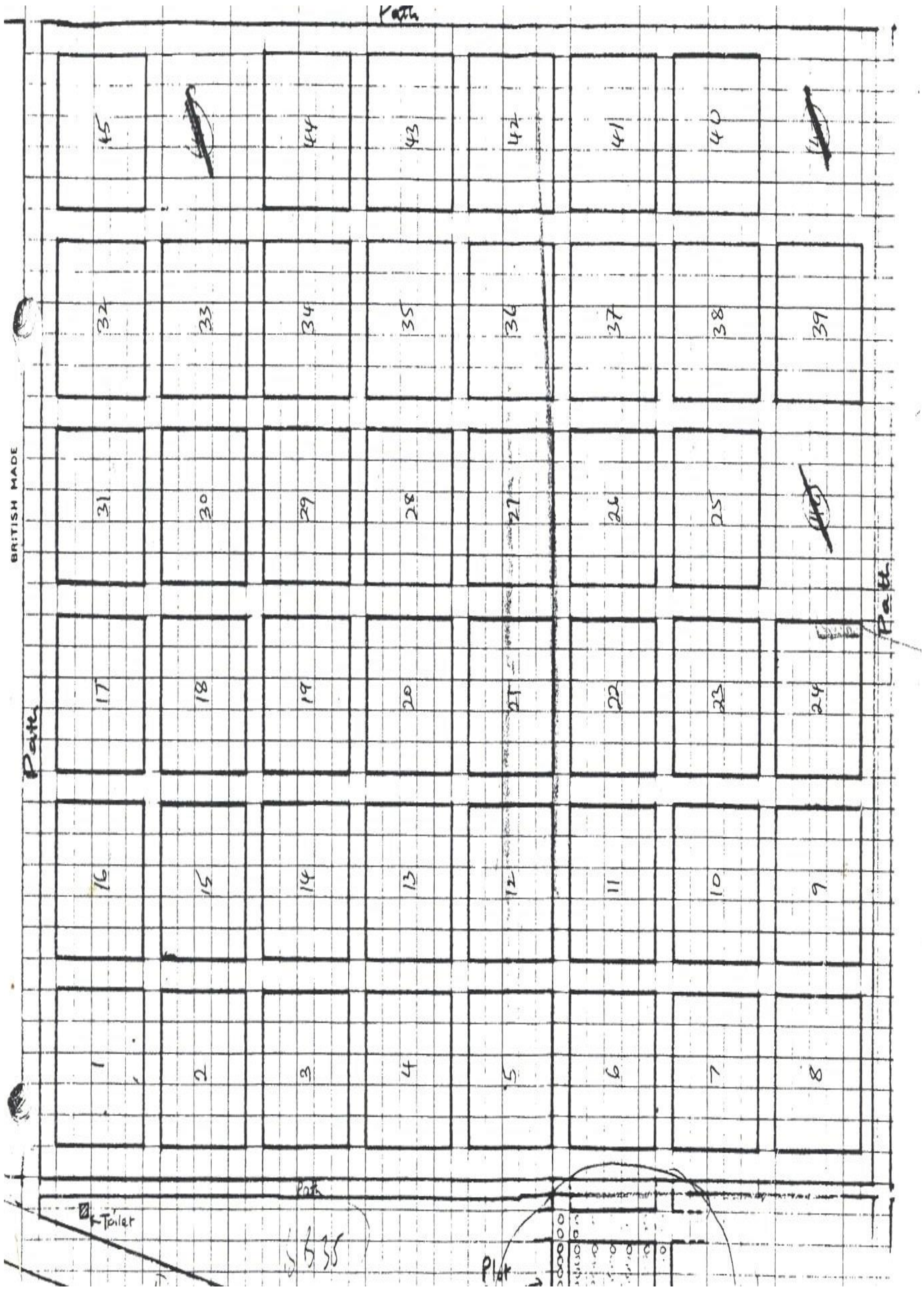
Plot treatment allocation on randomisation (for all the 5 locations)

PLOT NO.	TREATMENT	PLOT NO.	TREATMENT
1	N_{300} Pf $_{7}$	23	N_{150} Pf $_{14}$
2	N_{300} Pf $_{21}$	24	N_{300} Pf $_{7}$
3	N_{150} Pf $_{21}$	25	N_{300} Pf $_{21}$
4	N_{225} Pf $_{14}$	26	N_{150} Pf $_{7}$
5	N_{0} Pf $_{7}$	27	N_{75} Pf $_{7}$
6	N_{75} Pf $_{14}$	28	N_{0} Pf_{7}
7	N_{225} Pf $_{21}$	29	N_{0} Pf $_{14}$
8	N_{300} Pf $_{14}$	30	N_{75} Pf $_{21}$
9	N_{150} Pf $_{7}$	31	N_{225} Pf $_{14}$
10	N_{300} Pf $_{21}$	32	N_{75} Pf $_{14}$
11	N_{225} Pf $_{7}$	33	N $_{225}$ Pf $_{21}$
12	N_{150} Pf $_{14}$	34	N $_{150}$ Pf $_{21}$
13	N_{75} Pf $_{21}$	35	N_{225} Pf $_{7}$
14	N_{0}Pf $_{14}$	36	N_{0} Pf $_{21}$
15	N_{75} Pf $_{7}$	37	N_{150} Pf $_{14}$
16	N_{0} Pf $_{21}$	38	N_{300} Pf $_{14}$
17	N_{75}Pf $_{14}$	39	N_{300} Pf $_{7}$
18	N_{150} Pf $_{21}$	40	N_{75} Pf $_{7}$
19	N_{225}Pf $_{14}$	41	N_{300} Pf $_{21}$
20	N_{225}Pf $_{21}$	42	N_{150} Pf $_{7}$
21	N_{225}Pf $_{7}$	43	N_{0} Pf $_{7}$
22	N_{300}Pf 14	44	N_{75} Pf $_{21}$
		45	N_{0} Pf $_{14}$

7.3: Appendix 3 Experimental layout




KIPKEBE (MAGURA) TEA ESTATE : EXPERIMENTAL LAYOUT : CHEM 35
ROAD
Field No 21 (BB35 Block)
Slope
ROAD
Slope
1
2
3
6
17
18
19
20
6
5
4
25
24
23
22
21
7
8
9
26
27
28
29
12
11
10
30
31
32
33
13
14
15
37
36
35
34
38
39
40
41
45
44
43
42


Path
BRITISH MADE
Path
Path
Path
Toilet
Plot
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
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25
26
27
28
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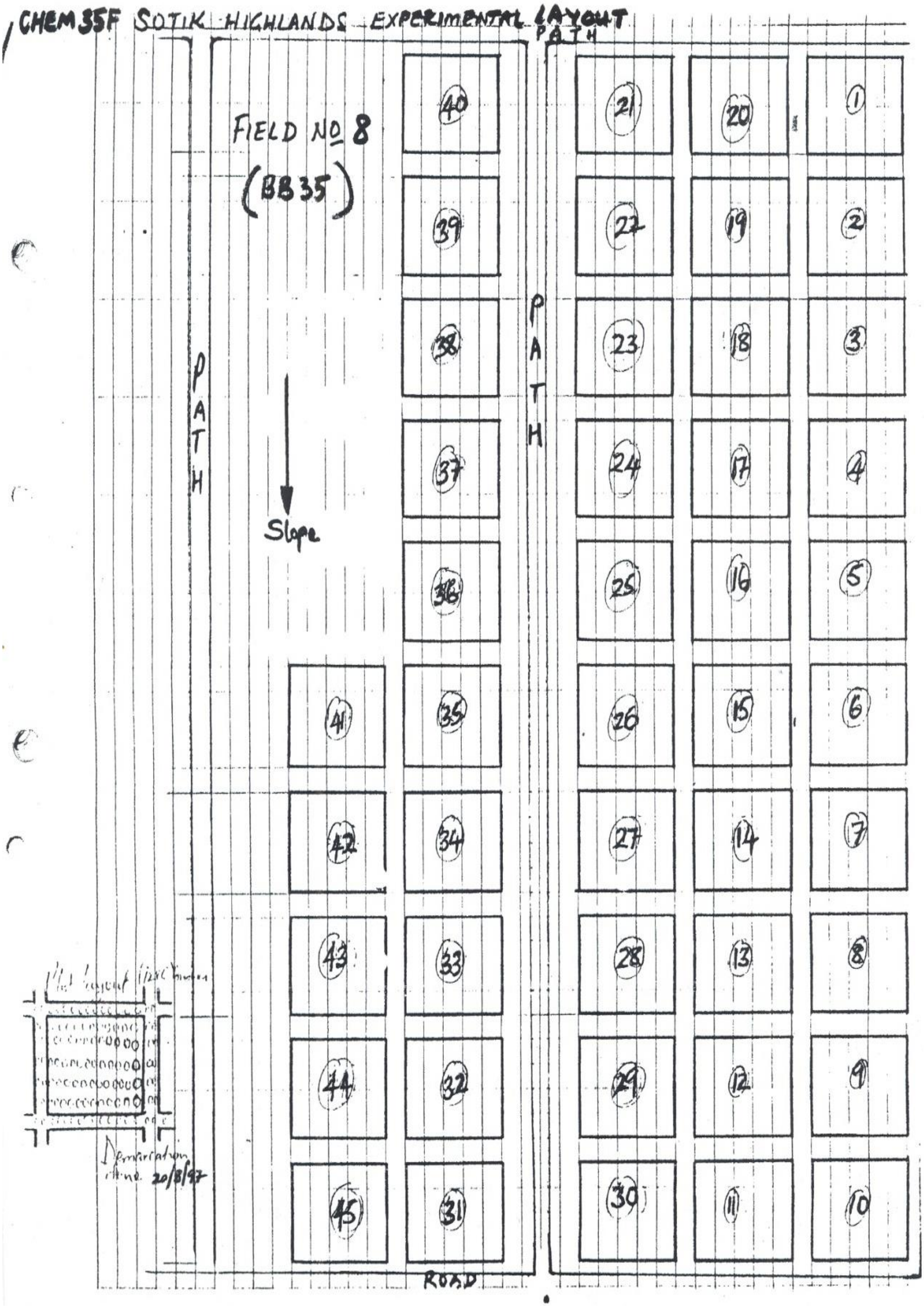
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45


CHEM 35F SOTIK HIGHLANDS EXPERIMENTAL LAYOUT
PATH
FIELD NO 8
(BB35)
Slope
PATH
PATH
ROAD
40
39
38
37
36
35
34
33
32
31
41
42
43
44
45
21
22
23
24
25
26
27
28
29
30
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19
18
17
16
15
14
13
12
11
1
2
3
4
5
6
7
8
9
10


LAYOUT: CHANGOI
BB35 Block
Road
Field No 19
PATH
BK1
BK2
BK3
Foot Path
Slope
Plot layout
(12 x 5) bushes/plot

7.4: Appendix 4: Publications

Owuor, P.O.; Kamau, D.M.; Jondiko E.O. (2009). Responses of clonal tea to location of production and plucking intervals. *Food Chemistry*, **115,** 290-296.

Owuor, P.O.; Kamau, D.M.; Jondiko, E.O. (2010). Responses of clonal tea to location of production and Nitrogenous fertiliser rates. *Journal of Food Agriculture and Environment,* **8(2)**, 682-690.