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Seasonal and Environment Variations of Yields and Yield Components of Tea (*Camellia sinensis*) Cultivars in Kenya

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ABSTRACT

In Kenya, tea is grown in highlands east and west of the Rift Valley at altitudes ranging from 1300 m to 2700 m above mean sea level. These areas vary widely in seasonal and locational environmental factors leading to differences in responses in growth, productivity and quality of tea genotypes. Despite these differences, tea husbandry practices are uniform across tea growing regions in the country. Understanding modes of variations in tea growth parameters and yields to varying environments is crucial for optimization of husbandry practices for tea productivity improvements. Responses in clonal tea growth and yield parameters to season and locations of production effects and their contribution to yields were evaluated, using 20 cultivars in a genotype × environment trial conducted in three locations (Kipkebe, Timbilil and Kangaita). There were yield variations (pd"0.05) between clones, locations and seasons. Tea yield components responses to weather parameters varied with location and season. Shoot growth rates in Kangaita and shoot density in Timbilil linearly correlated (pd"0.05) with yields but varied with season. Yield components and weather parameters contribution to the yield also varied with location and seasons causing significant (pd"0.05) interactions effects. Drought reduced yields while rainfall distribution influenced seasonal yield distribution. Seasonal yield variations were due to shoot growth rate, and shoot dry weight changes but not shoot density. The variations were due to seasonal environmental factors that limited yields rather than factors that increased yields.

INTRODUCTION

Kenyan tea is grown in the highlands, differing widely in elevation, climatic and edaphic factors. The altitude of tea growing areas range from slightly below 1300m above mean sea level (a.m.s.l) in Kirinyaga (*1*) to 2700m a.m.s.l in Olenguruone, Nakuru County (*2*). These are high rainfall highlands in the east and west of the Rift Valley (*3*). The tea production areas lie in close proximity to the equator, consequently growth and production is continuous throughout the year, as opposed to further away from the equator where production is restricted to some times of the year (*4*). Indeed, the crop comprising young shots are harvested at 7 to 21 day (*5*) intervals in all seasons. However, yields and quality at any location fluctuate with weather factors within and between years (*6-8*). The differences in altitude (*9-11*) and weather (*12-14*) factors in various geographical areas of production influence growth (*15, 16*), productivity (*14*) and quality (*2, 17, 18*) of tea. There is normally yield reduction during the dry and cool seasons (*19, 20*).

Although tea crops throughout the year, volume of crop varies both on weekly and seasonal basis, with low crop in the cold (*8*) and dry seasons (*21*). After harvest, the axils in the top most leaves of remaining butts develop to become the next crop (*8*). The quantity of harvest depends on the number of shoots per unit area, their rate of growth and average weight of shoots. The variations in performance of genotypes relative to each other and relative to the environment, and the formulation of the phenomenon in the Genotype by Environment (G x E) interaction concept has been widely documented, especially for tea yields (*14, 15, 22*). Differences in clonal yield response both within and across different environments have been reported in Kenya (*13-15, 22*). Tea yield components, described as the shoot density, shoot replacement cycle/rate and shoot extension rate (growth rate), determine seasonal and genotype yield variations (*23*). Shoot growth rate was reported as the major component causing seasonal fluctuation in yield whereas shoot density determined yield difference between varieties (*20, 24*). It has been suggested that shoot density and shoot weights determines clonal yield differences (*7*), while shoot size at harvest determines yields (*20, 25*). However, shoot size accounted for only 11% of the total variation in weekly yields throughout the season, 89% being accounted for by the number of shoots harvested, which also contributed to yield differences between certain clones (*26*). Later, shoot size was reported to insignificantly determine seasonal yield changes (*8*). These conflicting findings suggest necessity of further studies on growth parameters for better understanding of how the parameters affect tea yields in different environments and genotypes. Paucity of knowledge of the mechanisms by which environmental factors influence tea shoot growth fluctuations had been noted in 1979 to severely limit the development of methods to control these variables (*20*). It was postulated (*27*) that there was possibility of understanding causes of yield variations if relationships between yield and its components could be evaluated. This study evaluated the relationships between yield, its components and environmental factors in clonal tea.

METHODOLOGY

Experimental treatments and design

The experiment was conducted in three tea growing environments located at Kangaita (Kirinyaga), Timbilil (Kericho) and Kipkebe (Sotik) (Table 1). The terrain was all within slopes of 0-15%. The trial was set up on mature tea plots (previously clonal field trial) of the same age and comprised twenty clones viz; TRFK 6/8, TRFK 31/8, AHP S15/10, EPK TN14-3, BBK 35, TRFK 54/40, TRFK12/12, TRFK 12/19, TRFK 31/27, TRFK 11/26, TRFK 57/15, TRFK 7/3, TRFK 7/9, TRFK 56/89, STCK 5/3, TRFK 303/259, TRFK 303/577, TRFK 303/999, TRFK 303/1199 and TRFK 2X1/4 laid out as a factorial three trial in Randomized Complete Block design replicated three times, with clones and sites and seasons as the factors. The fields were managed as per standard management practices in Kenya (*1*).

Data Sampling and recording

Soil chemical and physical analysis

Soil pH, fresh (un-dried) were read off a Jenway 3305 pH meter. Nitrogen content was determined using the Kjeldahl method. To determine the mineral content, soil samples were air dried, ground and sieved through a 2mm. sieve. Extraction of the ground samples was done using the Mehlich III method then analysed for K, P, Ca, Mg, Mn, Na, Cu, Fe and Zn using a plasma atomic emission spectrophotometer (ICPE-9000) from Shimandzu. Sub samples from the disturbed soil samples were subjected to particle size analysis using the pipette method (*28*), taking 63 ìm as the sand/silt boundary.

Location weather

Rainfall, temperatures and accompanying meteorological data were recorded at each site. Daily rainfall was recorded from a standard rain gauge. Ambient temperatures, maximum, minimum, wet and dry bulb were recorded daily at 09.00 h and 15.00 h local time from mercury in glass thermometers (Cassella (London) Ltd., UK). Relative humidity (RH%) was derived from the wet and dry bulb temperature readings (*29*) and, the wet and dry thermometer readings were used to derive Saturated Vapour Pressure Deficit (SVPD).

Yields

Green leaf was harvested at 7-10 day intervals and converted to made tea by multiplying green leaf weight by 0.225 (*1*).

Shoot density (SD), and shoot dry weight (SDWT)

Shoot density was determined by counting the mean of the number of mature harvestable shoots (two leaves and a bud) captured within a 0.25m^2 grid randomly thrown on to the plucking tables (*30*) of five randomly selected bushes at every plucking round. Shoots falling within the grid were harvested, weighed and counted. The leaves were then oven dried at 105^{o}C for 48 hours and weighed. The

Table 1: Geographic location of study sites

Site	Location	Latitude	Longitude	Altitude
Timbilil	TRFK, Timbilil, Kericho	0^o 22'S	35^o 21'E	2180 m amsl
Kipkebe	Kipkebe Tea Company, Sotik, Nyamira	0^o 39'S	35^o 02'E	1800 m amsl
Kangaita	KTDA Kangaita Tea Farm, Kirinyaga	0^{o}30'S	37^{o}16'E	2100 m amsl

SDWT was determined by dividing the dry weight by the number of shoots harvested.

Shoot growth rate (SGR)

The shoot growth rate (mmd^{-1}) was determined by tagging five shoots from each of three randomly selected bushes, plucking the two leaves and a bud and measuring the length from the tip of the axilliary bud to the base, at three day intervals until the new shoot developed into harvestable two leaves and a bud. The growth rate (mmd^{-1}) was derived by dividing the shoot length measured at each interval by the number of days between two successive measurements.

Shoot water potential (SWP)

The shoot water potential of harvestable shoots was measured between the hours of 11.00am and 2.00pm, using the pressure chamber technique (*31*). Fifteen shoots were sampled per plot and comprised three shoots from each of five randomly selected bushes. The shoots were cut, sealed in a polythene bag then transferred one by one to a pressure chamber where one centimetre was cut off the stalk and the shoot immediately inserted into the gas chamber. The key of the compressed nitrogen gas turned on until the first gas bubbles were released from the cut shoot stalk surface and the pressure reading taken. SWP measurements were taken twice per season and averaged to get the mean for each season.

Data analysis

The data was subjected to analysis of variance (ANOVA) using MSTAT-C (Version 2.10) statistical package. The data was analysed as a three factor RCBD with clone (genotype) as the main factor, location (site) as the second factor and season forming the third factor.

RESULTS AND DISCUSSION

Soil characteristics of the study site had been presented in a previous communication (*15*). All sites were suitable for growing tea.

Seasonal weather and geographic locations

The annual weather characteristics of study locations were discussed in an earlier publication (*15*). The seasons, January-March, April-May, June-September and October-December followed the earlier described seasons (*32, 33*) for Kericho, and were designated to facilitate unbiased assessment of "seasonal" yields by allocating equal growing periods to the changing weather patterns in annual growth cycle. The seasons exhibited discernible differences and were from temperature and rainfall patterns as hot dry (January-March), cool wet (April-May), cold wet (June-September), and warm wet (October-December) respectively (Table 3). The seasonal weather varied within and between locations throughout the year (Tables 2 and 3). The highest (maximum) and lowest (minimum) temperatures were recorded in January-March season in all locations.

The weather conditions in January-March season were perfect for development of frost as recorded in Timbilil. Timbilil and Kipkebe recorded the highest diurnal range of e"12°C through all seasons. Kangaita only recorded diurnal range of >12 in January-March season, all the rest being < 6.8°C. Similarly, rainfall and rain days were highest in April-May season in all locations. January-March Season also had the lowest rainfall and fewest rain days. Timbilil recorded same amount of rainfall in June-September and October-December seasons, but Kipkebe recorded slightly different amounts while Kangaita recorded double amount of rainfall in October-December season compared to June-September season. Overall, the seasonal weather patterns though similar, varied in magnitude across locations, which partially explain the variations of yields across the sites recorded earlier (*15*).

Tea yield components

Shoot growth rate (SGR)

Shoot growth rates (Table 4) were lowest ($p \leq 0.05$) in Timbilil throughout the four seasons and highest in Kipkebe except in April-June season when Kangaita was marginally higher than Kipkebe. The growth rates followed the seasonal temperature and rainfall patterns (Tables 2 and 3), with variations at locations following the temperature differences. This illustrates the temperature dependence of tea shoot growth as reported earlier (*9, 16, 34*).

The clones x sites interactions were significant ($p \leq 0.05$) across all seasons except in January-March season, demonstrating the seasonal variation in cultivar shoot growth rate response to location. There were clonal shoot growth rates variations both within and across locations. These variations in clonal growth rates were not consistent across all sites and seasons as demonstrated in the shoot growth rate rankings (Table 5). None of the clones maintained their quartile positions in any location or across the locations in all seasons, which indicated the instability of shoot growth parameter across different environments. The mean location shoot growth rates also varied significantly (p≤0.05) with season and locations with the highest value (1.43 mm/day) in Kipkebe in October-December and lowest value in Timbilil (0.03 mm/day) in January-March. Similar variations had been observed in earlier studies within one location, (*34, 35*), across seasons (*24*) and across locations (*9, 14, 16*). The variations in clonal shoot growth rates with locations and seasons indicate that shoot growth rate is mainly weather controlled and the extent of response to weather was determined by the inherent genetic makeup.

Shoot density (SD)

Shoot density was not measured in January March in Kipkebe. However, shoot density also varied (p≤0.05) with clones, locations and seasons (Table 6). There were clonal variations (p≤0.05) in shoot densities within and between locations, except in October-December season when clonal variations were not significant. The mean location shoot density varied (p≤0.05) with season but the ranking did not vary with season. Kangaita recorded significantly (p≤0.05) the highest and Timbilil the lowest shoot density in all seasons. These showed a similar pattern to earlier results (*9, 16*), that shoot density decline with rise in altitude. Clones and sites interactions were significant (p≤0.05) in all seasons, as demonstrated in the clonal shoot density rankings (Table 7) and confirmed that the clonal shoot density response to environment vary with location. There was no clone that maintained same the quartile position across locations and seasons. However, some clones, for example: TRFK 303/577, TRFK 54/40 and TRFK 31/8, remained in the same quartile in the same location across all seasons. The results suggest that while most genotypes do not have shoot density seasonal stability across locations, some genotypes will have shoot density seasonal stability in a single location.

Shoot dry weight (SDWT)

Shoot dry weights changed (p≤0.05) with genotype, locations and season, except in January-March season (Table 8), when moisture was limiting in all locations (Tables 2, 3). This illustrated the phenomenon that varieties/clones selected for high yields will express their genetic yield potential only under similar environments of their selections. Clones and locations interactions were significant (p≤0.05) in all seasons and clonal contrasts varied with locations. However seasonal variations were not significant. The interactions demonstrate the basis for variations in clonal responses to environment. Locational shoot dry weights were different (p≤0.05) and also varied (p≤0.05) between the seasons. Shoot dry weights were lowest in January–March season and increased to peak in October-December season. This could be related to weather changes through the seasons. Moisture was limiting in January-March

Table 2: Monthly weather parameters at three study locations, Jan – Dec 2012

	Timbilil							Kangaita							Kipkebe						
	Temp(°C)							*Temp(°C)*							*Temp(°C)*						
	max	min	Mean	rain	rain days	rh%	svpd (kPa)	max	Min	mean	rain	rain days	rh%	svpd (kPa)	max	min	mean	rain	rain days	rh%	svpd (kPa)
Jan	25.7	7.7	16.7	0	0	62	1.51	23.5	9	16.25	17.2	3	32	0.95	28.7	11	19.85	0.5	0	47	0.94
Feb	26.3	9.1	17.7	26.8	7	55	1.55	21.4	9.1	15.25	19.7	4	35	1.09	28.4	11.7	20.05	82.9	11	70	0.94
Mar	27.5	8.5	18	27.7	6	63	1.41	23.9	10.3	17.1	40.3	3	36	1.13	28.7	10.1	19.4	50.1	7	70	1.00
Apr	23.3	7.2	15.25	398.4	25	62	0.54	18.8	13.5	16.15	449.6	23	89	0.48	26.7	12.3	19.5	514.4	26	82	0.50
May	22.9	9.8	16.35	391.1	24	71	0.36	19.3	13.5	16.4	692.0	25	96	0.43	27	12.2	19.6	249.4	24	81	0.44
Jun	22.2	9.7	15.95	226.9	20	80	0.44	16.9	12.6	14.75	89.4	16	42	0.51	26	11.2	18.6	178.3	20	85	0.39
Jul	21.7	9.7	15.7	160.9	13	70	0.51	14.6	11.9	13.25	49.1	16	40	0.41	25.6	11.6	18.6	122.6	10	83	0.48
Aug	22.8	9.4	16.1	298.9	18	71	0.51	16.4	10.7	13.55	190.5	14	48	0.32	26.6	11.1	18.85	97.7	11	81	0.61
Sept	22.7	8.7	15.7	239.1	24	71	0.60	17.7	15.3	16.5	121.8	8	44	0.48	24	11.5	17.75	194.5	17	80	0.52
Oct	23.7	10	16.85	269.4	24	73	0.39	18	12.7	15.35	325	11	80	0.33	28.4	12.5	20.45	99.3	16	76	0.53
Nov	24.1	9.7	16.9	227.6	22	80	0.66	18.5	12.4	15.45	234.1	13	70	0.12	27	12.3	19.65	97.1	15	81	0.34
Dec	22.9	9.9	16.4	172.3	15	62	0.74	18.5	11.7	15.1	169.6	17	46	0.42	27.2	12.2	19.7	261.6	17	82	0.42
Total				2439	198						2398	153						1948	174		
Mean	23.8	9.1	16.5			68.3	8.0	19.0	11.9	15.4			54.8	5.3	27.0	11.6	19.3			76.5	0.59

Table 3: Seasonal mean weather parameters in three study locations, 2012.

	Timbilil							Kangaita							Kipkebe						
	Temp(°C)							Temp(°C)							Temp(°C)						
	max	min	Mean	rain	Rain days	rh %	svpd (kPa)	max	Min	mean	rain	Rain days	rh %	Svpd (kPa))	max	min	mean	rain	Rain days	rh %	Svpd (kPa)
Jan Mar	26.5	8.4	17.5	55	13	60.0	1.49	22.9	9.5	16.2	77	10	34.3	1.06	28.6	10.9	19.8	134	18	62.3	0.96
Apr Jun	22.8	8.9	15.9	1016	69	71.0	0.45	18.3	13.2	15.8	1231	64	75.7	0.39	26.6	11.9	19.2	942	70	82.7	0.45
Jul Sept	22.4	9.3	15.8	699	55	70.7	0.54	16.2	12.6	14.4	361	38	44.0	0.40	25.4	11.4	18.4	415	38	81.3	0.54
Oct Dec	23.6	9.9	16.7	669	61	71.7	0.71	18.3	12.3	15.3	729	41	65.3	0.29	27.5	12.3	19.9	458	48	79.7	0.43

season, April-June being the recovery season, while July-September was cold and October-December season was warm and wet therefore conducive for growth. Shoot dry weights were highest in Timbilil probably due to milder weather through the seasons compared to the other sites which experienced high (Kipkebe) and low (Kangaita) temperatures fluctuations, which could have limited growth (Table 2 and 3).

Shoot water potential (SWP)

SWP was measured only January-March, April-June and October-December (Table 9). There were no significant ($p \leq 0.05$) genotypic differences within locations. However, there were variations ($p \leq 0.05$) between locations in January-March and October-December seasons but not April-June season. The tea plants maintained similar water status regardless of genotype. Shoot water potentials followed saturated pressure deficits across the seasons being lowest (-19.97 to -15.86 KPa) in January-March when SVPD was very high, moderately low (-6.09 to -4.58) in July-August and October-December seasons when SVPD was low (Tables 3 and 9). These findings support previous observations (*5*) that shoot water potential of tea shoots were more closely related to vapour pressure deficits than to soil moisture. The observations also suggest that threshold of plant water status for tea shoot survival and growth does not vary with genotypes but is dependent on environment (location and/or season). Shoot water potential may therefore influence variations in tea yields (*19*) across different locations and seasons but not between individual clones. This parameter may therefore be more practical when used to model tea yields across locations and seasons but not on clones. The threshold for plant water status is dependent upon weather attributes that dictate the vapour pressure deficits, and these vary with location and season.

Management practices to optimise seasonal yields may provide better outcomes if measures to reduce the vapour pressure deficits are implemented. All the parameters varied ($p \leq 0.05$ to $p \leq 0.001$) across locations and seasons, illustrating variability in seasonal weather parameters between locations and plant responses to environment. The genotypic variations were in line with earlier observations (*7*). However, shoot density and shoot weights may be important in explaining yields differences between clones.

Yields and seasonal yield distribution

Tea yields showed variations *($p \leq 0.05$)* across genotypes, locations, and seasons (Table 10). The seasonal yields were in the order July-September> October-December> April-June>January-March. Kipkebe produced highest yields in all seasons. In previous studies tea growth rates increase linearly with rise in temperature above base temperature (*9, 36, 37*). Kangaita and Timbilil yields were similar in January-March and July-September seasons and produced the lowest yields in October-December and April-June season, respectively. Clones, locations and seasons interactions were significant *($p \leq 0.05$)* and individual clonal yield ranking varied with locations and seasons (Table 11). Clonal yields ranged from 34 kg mt/ha in clone TRFK 2X1/4 in Timbilil in January March to 1736 kg mt/ha in clone TRFK 303/1199 in Kipkebe in July-September. The clonal yield performance and rankings changed *($p \leq 0.05$)* across sites and seasons. No single clone retained the same quartile position through the four seasons. In Kangaita and Timbilil

Table 4: Effect of genotype, location and season on shoot growth rates (mm/day)

	January-March				April- June				July-September				October-Dec		
Clone	Kgta	Tmbl	Kpkb	*Cln mean*	Kgta	Tmbl	Kpkb	*Cln mean*	Kgta	Tmbl	Kp kb	*Cln mean*	Kgta	Tmbl	
TRFK 7/3	0.08	0.03	0.72	*0.27*	0.31	0.06	0.21	*0.19*	0.53	0.31	0.95	*0.60*	0.47	1.40	1
TRFK 303/577	0.09	0.05	0.67	*0.27*	0.24	0.09	0.30	*0.21*	0.49	0.78	1.37	*0.88*	0.60	1.16	1
AHP TN 14-3	0.06	0.03	0.65	*0.25*	0.23	0.08	0.26	*0.19*	0.42	0.59	1.36	*0.79*	0.43	1.64	2
AHP 2X1/4	0.05	0.02	0.51	*0.19*	0.12	0.08	0.23	*0.15*	0.53	0.52	1.02	*0.69*	0.57	1.48	1
STC 5/3	0.07	0.02	0.66	*0.25*	0.29	0.07	0.19	*0.18*	0.40	0.70	0.83	*0.64*	0.46	1.38	1
TRF 11/26	0.10	0.03	0.74	*0.29*	0.27	0.07	0.20	*0.18*	0.31	0.29	0.68	*0.43*	0.68	0.99	0
TRF 12/19	0.06	0.02	0.68	*0.25*	0.22	0.07	0.17	*0.16*	0.32	0.36	0.68	*0.45*	0.46	1.09	0
TRFK 56/89	0.06	0.03	0.68	*0.26*	0.05	0.07	0.22	*0.11*	0.66	0.66	1.08	*0.80*	0.69	2.18	1
TRFK 12/12	0.06	0.03	0.71	*0.26*	0.30	0.07	0.18	*0.18*	0.40	0.27	0.58	*0.42*	0.52	1.08	0
TRFK 303/999	0.05	0.03	0.67	*0.25*	0.32	0.04	0.24	*0.20*	0.62	0.32	0.93	*0.62*	0.67	1.23	1
AHP S 15/10	0.07	0.02	0.59	*0.26*	0.25	0.07	0.23	*0.18*	0.49	0.18	0.83	*0.50*	0.64	0.87	1
TRFK 57/15	0.06	0.02	0.76	*0.28*	0.30	0.08	0.19	*0.19*	0.33	0.60	1.16	*0.69*	0.79	0.84	1
TRFK 31/27	0.09	0.02	0.74	*0.28*	0.26	0.06	0.19	*0.17*	0.39	0.33	0.81	*0.51*	0.79	0.78	1
TRFK 6/8	0.09	0.03	0.66	*0.26*	0.24	0.06	0.19	*0.16*	0.55	0.24	0.59	*0.46*	0.59	0.97	0
BB 35	0.06	0.03	0.64	*0.24*	0.31	0.08	0.22	*0.21*	0.58	0.49	0.76	*0.61*	0.64	1.30	1
TRFK 31/8	0.06	0.03	0.69	*0.26*	0.20	0.08	0.23	*0.17*	0.38	0.56	0.84	*0.60*	0.45	1.15	1
TRFK 7/9	0.07	0.04	0.69	*0.27*	0.25	0.06	0.18	*0.16*	0.38	0.24	0.61	*0.41*	0.68	1.22	0
TRFK 303/259	0.05	0.02	0.66	*0.25*	0.11	0.08	0.22	*0.14*	0.44	0.32	0.88	*0.55*	0.68	1.12	1
TRFK 303/1199	0.08	0.03	0.72	*0.28*	0.21	0.07	0.22	*0.17*	0.41	0.62	1.00	*0.68*	0.56	1.83	1
TRFK 54/40	0.09	0.03	0.70	*0.27*	0.05	0.09	0.21	*0.12*	0.41	0.41	0.73	*0.52*	0.81	0.94	0
Ste mean	*0.07*	*0.03*	*0.68*		*0.23*	*0.07*	*0.21*		*0.45*	*0.44*	*0.88*		*0.61*	*0.23*	*1*
SSn mean		0.26				0.171				0.591				1.048	
CV%		32.86				27.46				26.69				27.98	
LSD (p≤05)		0.03		NS		0.02		0.04		0.06		0.15		0.11	
CxS		NS				0.08				0.25				0.47	
All 4 seasons															
CV%	33.97														
	Kangaita	Timbilil	Kipkebe												
Site mean	0.34	0.44	0.77												
	Cln	Ste	Ssn	ClnxSte	ClnxSSn	StexSsn	ClnxStexSsn								
LSD (p≤.05)	0.81	0.31	0.04	0.14	0.16	0.06	0.28								

Kgta= Kangaita; Tmbl=Timbilil; Kpkb=Kipkebe; Cln=clone; Ste=site=location; Ssn=season

Table 5: Effect of genotype, location and season on ranking of shoot growth rates

	January-March				April- June				July-September				October-December			
Clone	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***
TRFK 7/3	6b	3a	4a	5a	2a	16d	11c	4a	5a	15c	7b	10b	16d	5a	6b	5a
TRFK 303/577	2a	1a	12c	5a	11c	1a	1a	1a	7b	1a	1a	1a	11c	10b	7b	7b
AHP TN 14-3	11c	3a	17d	14c	13c	3a	2a	4a	10b	6b	2a	3a	20d	3a	1a	2a
AHP 2X1/4	18d	14d	20d	20d	17d	3a	4a	17d	5a	8b	5a	4a	13c	4a	4a	3a
STC 5/3	8b	14d	14c	14c	6b	9b	14c	7b	13c	2a	11c	7b	17d	6b	13c	11c
TRFK 11/26	1a	3a	2a	1a	7b	9b	13c	7b	20d	16d	16d	18d	5a	15c	15c	16d
TRFK 12/19	11c	14c	10b	14c	14c	9b	20d	14c	19d	11c	16d	17d	17d	13c	16d	17d
TRFK 56/89	11c	3a	10b	9b	19d	9b	7b	20d	1a	3a	4a	2a	4a	1a	2a	1a
TRFK 12/12	11c	3a	6b	9b	4a	9b	18d	7b	13c	17d	20d	19d	15c	14c	20d	19d
TRFK 303/999	18d	3a	12c	14c	1a	20d	3a	3a	2a	13c	8b	8b	8b	8b	11c	9b
AHP S 15/10	8b	14d	19d	9b	9b	9b	4a	7b	7b	20d	11c	15c	9b	18d	10b	12c
TRFK 57/15	11c	14d	1a	2a	4a	3a	14c	4a	18d	5a	3a	4a	2a	19d	5a	8b
TRFK 31/27	2a	14d	2a	2a	8b	16d	14c	11c	15c	12c	13c	14c	2a	20d	12c	14c
TRFK 6/8	2a	3a	14c	9c	11c	16d	14c	14c	4a	18d	19d	16d	12c	16d	19d	18d
BB 35	11c	3a	18d	19d	2a	3a	7b	1a	3a	9b	14c	9b	9b	7b	3a	20d
TRFK 31/8	11c	3a	8b	9b	16d	3a	4a	11c	16d	7b	10b	10b	19d	11c	9b	10b
TRFK 7/9	8b	2a	8b	5a	9b	16d	18d	14c	16d	18d	18d	20d	5a	9b	18d	12c
TRFK 303/259	18d	14c	14c	14c	18d	3a	7b	18d	9b	13c	9c	12c	5a	12c	8b	6a
TRFK 303/1199	6b	3a	4a	2a	15c	9b	7b	11c	11c	4a	6b	6b	14c	2a	14c	4a
TRFK 54/40	2a	3a	7b	5a	19d	1a	11c	19d	11c	10b	15c	13c	1a	17d	17d	15c

Letters next to the ranking, down the column indicates quartile position: a=1st quartile; b= 2nd quartile; c=3rd quartile; d=4th quartile

however, clone TRFK 303/577 retained the top position in three seasons and was in the 1st quartile in all four seasons. Clone TRFK 2X1/4 had the lowest position in two seasons in Kangaita. In Kipkebe some clones retained the same ranking in two or three seasons with clone BB35 remaining in the 1st quartile in all four seasons. These observations illustrate the variations in clonal yields and growth responses to environment. Majority of clones showed low yield stability in the location across the seasons (Table 11). Previous reports showed that while trials enable rankings of clones within an environment, same ranking need not occur elsewhere because genotypes respond differently to environment (*14, 38*). Results herein showed that the variation in ranking also occurs in different seasons. Earlier studies showed differences in seasonal variability between estates in Kericho area of Kenya, where some had larger variability than others (*12*). This could be due to a combination of clonal composition in the estates and weather, as demonstrated in this study. Drought and frost occurring in January-March season reduced yields in Timbilil. This raised variability in clonal response to environment (Table 2). Long term data in Kericho showed that annual seasonal yield variability increased mainly in January-June period, which includes most of the dry period and the bush recovery period following the start of the rains (*12*). Yields approximately followed seasonal rainfall and temperature patterns. Indeed, yields increased from January-March to April-June seasons in Kipkebe in response to increase in rainfall and temperatures. In Timbilil and Kangaita yields declined during the same period, which could be attributed to temperature drop, (1.6 and 0.4°C in Timbilil and Kangaita, respectively), and this was similarly reflected in the magnitude of yields decline in the two locations. Variation in the size of tea crop, both on a weekly and seasonal basis are often negligible in the cold and dry seasons (*8, 21*). Similar yield variations in clonal yields both

Table 6: Effect of genotype, location and season on shoot densities (shoots/m²)

	January-March			April- June				July-September				October-December			
Clone	**Kgta**	**Tmbl**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***
TRFK 7/3	77.33	18.67	*48.00*	105.00	15.00	61.67	*60.56*	87.00	33.33	69.33	*63.22*	115.67	64.33	87.67	*89.22*
TRFK 303/577	97.67	26.00	*58.83*	141.00	19.67	70.33	*77.00*	123.67	48.00	72.67	*81.44*	114.67	86.33	71.33	*90.78*
AHP TN 14-3	73.33	27.00	*50.17*	97.33	20.00	57.00	*56.11*	102.67	34.33	66.67	*69.22*	97.67	75.00	81.33	*84.67*
AHP 2X1/4	67.67	23.67	*45.67*	77.67	19.67	64.00	*53.78*	*96.33*	34.67	76.67	*69.22*	105.33	65.33	86.00	*85.56*
STC 5/3	62.00	23.33	*42.67*	100.00	16.00	72.67	*62.89*	114.33	32.33	75.33	*74.00*	116.00	58.00	91.33	*88.44*
TRF 11/26	77.00	25.00	*51.00*	80.00	16.33	69.33	*55.22*	84.33	37.33	63.00	*61.55*	95.67	57.00	81.33	*78.00*
TRF 12/19	74.33	17.33	*45.83*	77.00	13.67	60.67	*50.44*	81.67	38.33	74.00	*64.67*	83.00	59.33	88.67	*77.00*
TRFK 56/89	73.67	34.67	*54.17*	110.67	22.33	44.33	*59.11*	81.00	38.33	63.00	*60.78*	68.67	65.33	85.00	*73.00*
TRFK 12/12	70.00	28.67	*49.33*	96.67	21.00	58.00	*58.56*	67.33	38.00	64.33	*56.56*	83.00	64.33	74.00	*73.78*
TRFK 303/999	62.67	23.33	*42.50*	82.00	26.00	55.67	*54.56*	77.33	41.67	70.33	*63.11*	97.67	79.00	79.00	*85.22*
AHP S 15/10	62.67	21.33	*42.00*	106.67	16.33	52.00	*58.33*	89.00	38.33	66.67	*64.67*	102.67	64.33	93.67	*86.89*
TRFK 57/15	65.00	29.67	*47.33*	100.67	26.00	57.00	*61.22*	105.33	49.33	63.00	*72.56*	103.33	71.33	84.00	*86.22*
TRFK 31/27	78.33	23.67	*51.00*	94.33	12.33	69.33	*58.67*	91.33	37.00	72.67	*67.00*	93.33	58.00	82.67	*78.00*
TRFK 6/8	61.00	19.00	*40.00*	98.00	18.67	64.00	*60.22*	68.33	27.33	65.33	*53.67*	97.67	56.00	83.67	*79.11*
BB 35	58.00	17.67	*37.83*	76.67	17.33	55.67	*49.89*	110.33	31.00	74.00	*71.78*	113.33	65.33	83.67	*87.44*
TRFK 31/8	65.00	22.33	*43.67*	88.67	17.67	59.33	*55.22*	82.00	28.33	66.67	*59.00*	87.00	126.00	88.67	*100.56*
TRFK 7/9	73.33	27.33	*50.33*	94.67	18.67	65.33	*59.56*	98.67	43.33	71.67	*71.22*	106.33	69.33	91.33	*89.00*
TRFK 303/259	67.00	27.00	*47.00*	80.67	17.67	63.00	*53.78*	68.33	54.33	63.33	*62.00*	86.33	115.00	75.00	*92.11*
TRFK 303/1199	86.67	21.00	*53.83*	128.33	21.00	69.33	*72.89*	88.67	53.00	72.00	*67.78*	110.33	70.67	79.33	*86.78*
TRFK 54/40	57.00	20.00	*38.50*	81.67	16.33	65.33	*54.44*	72.00	46.00	65.33	*60.78*	85.33	56.00	82.67	*74.67*
Ste mean	70.18	23.78		*95.58*	*18.58*	*61.70*		*89.68*	*39.22*	68.23		*98.15*	*71.30*	83.52	
Ssn mean		46.98			58.62				65.71				84.32		
CV%		17.17			22.38				17.69				24.63		
LSD (p≤0.05)		2.92	9.22		4.69		12.12		4.16		10.74		7.43		NS
CxS		13.04			20.99				18.61				NS		
All seasons															
CV%	22.65														
	Kangaita	Timbilil	Kipkebe												
Site mean	94.472	43.033	71.15												
	Cln	Ste	Ssn	ClnXSt	ClnxSSn	StxSsn	ClnxStexSSn								
LSD (p≤0.05)	8.4	3.25	3.26	14.56	NS	5.64	NS								

within and between seasons had been reported from in four sites around Kericho (*9, 13*).

The same variations were replicated in this study in locations outside Kericho, a distance ranging from 71 to 245km away from the Kericho site in 20 clones. This demonstrated that clones with similar performance under same management in one location may require different management options to optimise yields in a separate location. Clonal selection programmes should take cognizance of seasonal and locational yield performance for optimization of yields.

Seasonal yield distribution (was uniform in all

Table 7: Effect of genotype, location and season on ranking of shoot densities

	January-March			April- June				July-September				October-December			
Clone	**Kgta**	**Tmbl**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***
TRFK 7/3	4a	18d	*9b*	5a	18d	11c	*5a*	11c	16d	10b	*12c*	2a	12c	6b	*4a*
TRFK 303/577	1a	7b	*1a*	1a	7b	2a	*1a*	1a	4a	5a	*1a*	3a	3a	20d	*3a*
AHP TN 14-3	8b	5a	*7b*	9b	6b	15c	*12c*	5a	15c	11c	*6b*	10b	5a	14c	*13c*
AHP 2X1/4	11c	9b	*13c*	18d	7b	8b	*17d*	7b	14c	1a	*6b*	7b	9b	7b	*11c*
STC 5/3	17d	11c	*15c*	7b	17d	1a	*3a*	2a	17d	2a	*2a*	1a	16d	2a	*6b*
TRF 11/26	5a	8b	*4a*	17d	14c	3a	*13c*	12c	12c	18d	*15c*	13c	18d	14c	*15c*
TRF 12/19	6b	20d	*12c*	19d	19d	12c	*19d*	14c	8b	3a	*10b*	18d	15c	4a	*17d*
TRFK 56/89	7b	1a	*2a*	3a	3a	20d	*8b*	15c	8b	18d	*16c*	20d	9c	8b	*20d*
TRFK 12/12	10b	3a	*8b*	10b	4a	14c	*10b*	20d	11c	16d	*19d*	18d	12c	19d	*19d*
TRFK 303/999	15c	11c	*16d*	14c	1a	17d	*15c*	16d	7b	9b	*13c*	10b	4a	17d	*12c*
AHP S 15/10	15c	14c	*17d*	4a	14c	19d	*11c*	9b	8b	11c	*10b*	9b	12c	1b	*8b*
TRFK 57/15	13c	2a	*10b*	6b	1a	15c	*4a*	4a	3a	18d	*3a*	8b	6b	9b	*10b*
TRFK 31/27	3a	9b	*4a*	12c	20d	3a	*9b*	8b	13c	5a	*9b*	14c	16c	12c	*15c*
TRFK 6/8	18d	17d	*18d*	8b	9b	8b	*6b*	18d	20d	14c	*20d*	10b	19d	10b	*14c*
BB 35	19d	19d	*20d*	20d	13c	17d	*20d*	3a	18d	3a	*4a*	4a	9b	10b	*7b*
TRFK 31/8	13c	13c	*14c*	13c	11c	13c	*13c*	13c	19d	11c	*18d*	15c	1a	4a	*1a*
TRFK 7/9	8b	4a	*6b*	11c	9b	6b	*7b*	6b	6b	8b	*5a*	6b	8b	2a	*5a*
TRFK 303/259	12c	5a	*11c*	16d	11c	10b	*17d*	18d	1a	17d	*14c*	16d	2a	18d	*2a*
TRFK 303/1199	2a	15c	*3a*	2a	4a	3a	*2a*	10b	2a	7b	*8b*	5a	7b	16d	*9b*
TRFK 54/40	20d	16d	*19d*	15c	14c	6b	*16d*	17d	5a	14c	*16d*	17d	19d	12c	*18d*

locations except Timbilil where drought and frost reduced yields in January-March season (Table 12). Further, in Timbilil, seasonal yield proportion in October-December was higher than that of Kipkebe and Kangaita due better rainfall distribution in Kericho with 20 days more than the other two locations. The yield depression in April-May in Timbilil followed temperature pattern, but could also be attributed to the effect of January-March drought depressing the yields of following wet and cool season from April to July. Long term yield data in Timbilil showed that early year drought caused yield decline in April-May period (*12*). Yields declined *(pd"0.05)* in Kipkebe and Kirinyaga in October-December but increased in Timbilil over the same period. The decline in the two locations was attributable to low and poorer rainfall distribution in the July-September season extending to October-December season. The October-December season recorded a 20 day rain day difference between the high and low yielding locations. This phenomenon illustrates the effect of unfavourable weather in the preceding season on the yields of the following season. Mean yield seasonal differences varied between locations in the order 102, 438, and 577kg mt/Ha in Kangaita, Timbilil and Kipkebe, respectively. The findings from Timbilil contrast with previous observations (*12*), that Kericho had the most even yield distribution attributed to seasonal temperature changes and development of large soil water deficits during the dry seasons in contrast to Mufindi in southern Tanzania and Mulanje in Malawi, which had large seasonal variations in yield distribution. Management options should therefore include operations to ameliorate effects of adverse weather for yields optimisation in all seasons.

CONCLUSIONS

Yield components contributions to yield varied with location and season but were not attributable to soil properties. The response of tea yield components to weather factors also varied with location. Genotype yields and yield

Table 8: Effect of genotype, location and season on shoot dry weights (g/shoot)

	January-March			April- June				July-September				October-December			
Clone	**Kgta**	**Tmbl**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***
TRFK 7/3	0.11	0.13	*0.12*	0.10	0.17	0.15	*0.14*	0.13	0.32	0.15	*0.20*	0.14	0.36	0.18	*0.22*
TRFK 303/577	0.10	0.12	*0.11*	0.04	0.13	0.16	*0.11*	0.10	0.29	0.13	*0.17*	0.19	0.32	0.16	*0.23*
AHP TN 14-3	0.12	0.12	*0.12*	0.05	0.17	0.16	*0.13*	0.12	0.41	0.17	*0.24*	0.17	0.42	0.16	*0.25*
AHP 2X1/4	0.09	0.12	*0.11*	0.03	0.15	0.14	*0.11*	0.11	0.28	0.13	*0.17*	0.14	0.37	0.16	*0.22*
STC 5/3	0.13	0.10	*0.12*	0.07	0.12	0.12	*0.11*	0.08	0.32	0.12	*0.17*	0.09	0.37	0.17	*0.21*
TRF 11/26	0.13	0.08	*0.10*	0.07	0.12	0.16	*0.11*	0.11	0.21	0.14	*0.15*	0.19	0.29	0.17	*0.22*
TRF 12/19	0.10	0.11	*0.10*	0.05	0.16	0.15	*0.15*	0.14	0.19	0.13	*0.16*	0.22	0.39	0.17	*0.26*
TRFK 56/89	0.07	0.12	*0.10*	0.04	0.16	0.14	*0.11*	0.17	0.47	0.13	*0.26*	0.30	0.57	0.17	*0.34*
TRFK 12/12	0.15	0.09	*0.12*	0.10	0.14	0.19	*0.14*	0.16	0.29	0.16	*0.20*	0.29	0.35	0.18	*0.27*
TRFK 303/999	0.11	0.15	*0.13*	0.05	0.12	0.19	*0.12*	0.10	0.31	0.16	*0.19*	0.20	0.44	0.18	*0.27*
AHP S 15/10	0.13	0.13	*0.13*	0.09	0.17	0.20	*0.15*	0.14	0.33	0.18	*0.22*	0.18	0.38	0.17	*0.24*
TRFK 57/15	0.09	0.08	*0.09*	0.06	0.10	0.18	*0.11*	0.09	0.22	0.14	*0.15*	0.13	0.34	0.18	*0.22*
TRFK 31/27	0.11	0.12	*0.12*	0.10	0.19	0.14	*0.14*	0.11	0.37	0.14	*0.21*	0.17	0.44	0.16	*0.26*
TRFK 6/8	0.10	0.12	*0.11*	0.06	0.13	0.16	*0.11*	0.18	0.34	0.16	*0.23*	0.20	0.36	0.16	*0.24*
BB 35	0.14	0.15	*0.15*	0.06	0.17	0.16	*0.13*	0.08	0.28	0.15	*0.17*	0.16	0.36	0.17	*0.23*
TRFK 31/8	0.07	0.12	*0.10*	0.07	0.16	0.18	*0.14*	0.18	0.39	0.18	*0.25*	0.20	0.38	0.16	*0.25*
TRFK 7/9	0.09	0.15	*0.12*	0.06	0.17	0.14	*0.12*	0.14	0.38	0.13	*0.22*	0.14	0.49	0.16	*0.26*
TRFK 303/259	0.11	0.11	*0.11*	0.08	0.17	0.14	*0.13*	0.19	0.35	0.17	*0.24*	0.23	0.37	0.18	*0.25*
TRFK 303/1199	0.10	0.16	*0.13*	0.06	0.19	0.14	*0.13*	0.10	0.29	0.13	*0.17*	0.15	0.43	0.15	*0.24*
TRFK 54/40	0.11	0.09	*0.10*	0.09	0.11	0.16	*0.12*	0.16	0.16	0.15	*0.16*	0.31	0.29	0.16	*0.26*
Ste mean	*0.11*	*0.12*		*0.06*	*0.15*	*0.16*		*0.13*	*0.31*	0.15		*0.19*	*0.39*	0.17	
Ssn mean		0.11			0.13				0.20					0.25	
CV%		22.99			22.68				28.76				18.99		0.04
LDS (p≤0.05)		NS	NS		0.01		0.02		0.02		0.05		0.02		
CxS		.04			.05				0.09				0.08		
All seasons															
CV%	23.9														
	Kangaita	Timbilil	Kipkebe												
Site mean	0.128		0.282	0.158											
	Cln	Ste	Ssn	ClnXSt	ClnxSSn	StxSsn	ClnxStexSSn								
LDS (p≤0.05)	0.02	0.01	0.01*	0.04	0.04	0.02	NS								

Table 9: Effect of genotype, location and season on shoot water potential (KPa)

	January-March				April-June				October-December			
Clone	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***
TRFK 7/3	-17.73	-20.07	-16.00	*-17.93*	-6.30	-6.70	-5.83	*-6.28*	-8.57	-5.10	-9.30	*-7.66*
TRFK 303/577	-15.97	-20.20	-15.43	*-17.20*	-6.83	-6.73	-5.77	*-6.44*	-7.67	-4.67	-9.37	*-7.23*
AHP TN 14-3	-16.63	-20.50	-15.73	*-17.62*	-6.23	-6.47	-5.77	*-6.16*	-8.97	-4.97	-9.13	*-7.69*
AHP 2X1/4	-17.37	-20.97	-16.07	*-18.13*	-6.03	-5.73	-5.83	*-5.87*	-8.47	-5.03	-8.67	*-7.39*
STC 5/3	-16.80	-19.47	-14.80	*-17.02*	-6.80	-6.03	-5.83	*-6.22*	-8.87	-4.50	-9.23	*-7.53*
TRF 11/26	-16.37	-19.93	-15.13	*-17.14*	-5.37	-4.67	-5.67	*-5.23*	-7.67	-4.80	-8.90	*-7.12*
TRF 12/19	-18.13	-19.43	-16.83	*-18.13*	-5.77	-6.33	-5.90	*-6.00*	-7.87	-4.80	-7.83	*-6.83*
TRFK 56/89	-16.60	-18.43	-16.20	*-17.07*	-5.33	-5.53	-5.70	*-5.49*	-7.80	-4.57	-8.87	*-7.08*
TRFK 12/12	-14.87	-19.47	-15.77	*-16.70*	-6.33	-5.43	-6.30	*-6.02*	-7.70	-4.53	-8.97	*-7.07*
TRFK 303/999	-17.97	-20.07	-16.97	*-18.33*	-5.80	-4.67	-6.03	*-5.50*	-8.63	-4.63	-8.73	*-7.33*
AHP S 15/10	-17.90	-20.27	-15.97	*-18.04*	-6.43	-5.27	-5.77	*-5.82*	-9.33	-4.87	-8.93	*-7.71*
TRFK 57/15	-18.57	-20.27	-16.03	*-18.29*	-6.67	-5.63	-5.90	*-6.07*	-8.70	-4.70	-9.03	*-7.48*
TRFK 31/27	-16.63	-19.73	-14.07	*-16.81*	-6.40	-6.60	-6.00	*-6.33*	-8.77	-4.17	-9.13	*-7.36*
TRFK 6/8	-18.40	-20.60	-16.77	*-18.59*	-6.37	-5.33	-5.83	*-5.91*	-9.33	-4.60	-8.37	*-7.43*
BB 35	-16.80	-19.83	-14.17	*-16.93*	-6.63	-5.90	-6.13	*-6.22*	-8.13	-4.57	-8.13	*-6.94*
TRFK 31/8	-18.27	-20.57	-16.63	*-18.49*	-5.73	-4.63	-5.80	*-5.39*	-8.50	-4.20	-8.57	*-7.09*
TRFK 7/9	-16.47	-19.43	-17.57	*-17.82*	-4.97	-6.03	-5.97	*-5.66*	-8.73	-4.30	-8.30	*-7.11*
TRFK 303/259	-17.33	-19.00	-16.97	*-17.77*	-6.30	-3.93	-5.80	*-5.34*	-8.87	-4.33	-8.20	*-7.13*
TRFK 303/1199	-17.17	-20.50	-15.40	*-17.69*	-6.20	-5.03	-5.70	*5.64*	-8.70	-4.13	-83.00	*-7.04*
TRFK 54/40	-17.60	-20.57	-14.73	*-17.63*	-5.37	-5.13	-5.87	*5.46*	*-9.33*	-4.13	-8.87	*-7.44*
Ste mean	-17.18	-19.97	-15.86		*-6.09*	*-5.60*	*-5.87*		*-8.53*	*-4.58*	-8.74	
Ssn mean		-17.67				-5.85				-7.28		
CV%		8.73				20.08				7.72		
LSD (p≤0.05)		.06		NS		NS		NS		0.2		NS
CxS		NS				NS				0.9		
All seasons												
CV%	22.65											
	Kangaita	Timbilil	Kipkebe									
Site mean	10.59	10.05	10.16									
	Cln	Ste	Ssn	ClnXSt	ClnxSSn	StxSsn	ClnxStexSSn					
LSD (p≤0.05)	NS	0.25	0.25	NS	NS	0.43	NS					

Table 10: Effect of genotype, location and season on tea yields

	January-March				**April-June**				**July-September**				**October-December**			
	Kgta	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	***Kpkb***	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***
TRFK 7/3	175	172	474	*274*	162	58	887	*369*	235	161	1417	*604.44*	223	255	983	*487*
TRFK 303/577	522	444	641	*536*	454	131	1584	*723*	621	961	1720	*1103*	734	1433	1106	*1091*
AHP TN 14-3	244	262	862	*456*	211	125	1224	*520*	524	363	1421	*769*	356	598	1101	*685*
AHP 2X1/4	161	227	782	*390*	120	34	830	*328*	260	195	1063	*506*	241	277	859	*459*
STC 5/3	164	189	822	*392*	172	88	1357	*539*	286	207	1156	*550*	239	542	762	*514*
TRF 11/26	205	184	696	*362*	170	91	801	*354*	297	267	990	*518*	226	371	696	*431*
TRF 12/19	207	290	719	*405*	139	61	893	*364*	248	383	1173	*601*	264	525	659	*483*
TRFK 56/89	163	313	736	*404*	167	84	873	*375*	375	613	1300	*763*	329	545	757	*544*
TRFK 12/12	247	230	549	*342*	352	115	901	*456*	331	303	1202	*612*	308	454	676	*479*
TRFK 303/999	218	298	635	*384*	181	106	774	*353*	372	481	1219	*691*	343	775	728	*615*
AHP S 15/10	191	229	671	*364*	169	45	1134	*450*	405	295	1411	*704*	264	547	984	*599*
TRFK 57/15	228	192	631	*350*	226	121	850	*399*	467	232	825	*508*	275	473	588	*445*
TRFK 31/27	299	298	590	*396*	310	103	812	*409*	431	297	970	*566*	313	779	638	*577*
TRFK 6/8	124	282	615	*341*	161	80	1021	*421*	296	204	1283	*594*	267	379	794	*480*
BB 35	173	348	1004	*408*	146	105	1247	*499*	298	417	1536	*750*	293	363	1225	*644*
TRFK 31/8	228	313	611	*384*	250	110	971	*444*	392	250	1087	*576*	302	353	684	*446*
TRFK 7/9	221	234	570	*342*	178	129	1247	*518*	295	287	1311	*631*	310	492	1064	*622*
TRFK 303/259	213	396	817	*475*	170	106	1146	*474*	308	310	1352	*657*	338	443	1187	*656*
TRFK 303/1199	355	401	862	*539*	310	174	1252	*578*	527	746	1736	*1003*	417	723	982	*707*
TRFK 54/40	224	325	741	*430*	249	140	495	*294*	247	141	1381	*590*	291	442	984	*572*
Ste mean	*228*	*281*	*701*		*215*	*100*	*1015*		*361*	*356*	*1278*		*317*	*538*	*875*	
Mean season		404				443				665				577		
CV%		24.30				34.60				24.8				26.99		
LDS (p≤0.05)		32			91	55		142		59		152		564		144
CxS		157				245				264				249		
ALL 4 SEASONS																
CV%	28.71															
	Kgta	Tmbl	Kpkb													
Site mean	280	319	967													
	Clone	Site	Ssn	CxS	CxSsn	SxSsn	CxSxSSn									
LDS (p≤0.05)	69	27	31	120	139	54	240									

Table 11: Effect of genotype, location and season on tea yield rankings

	January-March				April-June				July-September				October-December			
Clone	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***	**Kgta**	**Tmbl**	**Kpkb**	***Cln mean***
TRFK 7/3	15c	20d	20d	20d	16d	18d	13c	15c	20d	19d	5a	11c	20d	20d	8b	13c
TRFK 303/577	1a	1a	12c	2a	1a	3a	1a	1a	1a	1a	2a	1a	1a	1a	3a	1a
AHP TN 14-3	5a	12c	2a	4a	8b	5a	6b	4a	3a	7b	4a	3a	3a	5a	4a	3a
AHP 2X1/4	19d	16d	6b	11c	20d	20d	16d	19d	17d	18d	17d	20d	17d	19d	10b	17d
STC 5/3	17d	18d	4a	10b	11c	14c	2a	3a	16d	16d	15c	17d	18d	8b	12c	12c
TRF 11/26	13c	19d	10b	15c	12c	13c	18d	17d	13c	13c	18d	18d	19d	16d	15c	20d
TRF 12/19	12c	10b	9b	7b	19d	17d	12c	16d	18d	6b	14c	12c	15c	9b	18d	14c
TRFK 56/89	18d	6b	8b	8b	15c	15c	14c	14c	8b	3a	10b	4a	6b	7b	13c	11c
TRFK 12/12	4a	14c	19d	17d	2a	7b	11c	8b	10b	9b	13c	10b	9b	12c	17d	16d
TRFK 303/999	10b	8b	13c	12c	9b	9b	19d	18d	9b	4a	12c	7b	4a	3a	14c	7b
AHP S 15/10	14c	15c	11c	14c	14c	19d	8b	9b	6b	11c	6b	6b	16d	6b	6b	8b
TRFK 57/15	6b	17d	14c	16d	7b	6b	15c	13c	4a	15c	20d	19d	13c	11c	20d	19d
TRFK 31/27	3b	9b	17d	9b	3a	12c	17d	12c	5a	10b	19d	16d	7b	2a	19d	9b
TRFK 6/8	20d	11c	15c	19d	17d	16d	9b	11c	14c	17d	11c	13c	14c	15c	11c	15c
BB 35	16d	4a	1a	6b	18d	11c	4a	6b	12c	5a	3a	5a	11c	17d	1a	5a
TRFK 31/8	7b	7b	16d	13c	5a	8b	10b	10b	7b	14c	16d	15c	10b	18d	16d	18d
TRFK 7/9	9b	13c	18d	18d	10b	4a	5a	5a	15c	12c	9b	9b	8b	10b	5a	6b
TRFK 303/259	11c	3a	5a	3a	13c	10b	7b	7b	11c	8b	8b	8b	5a	13c	2a	4a
TRFK 303/1199	2a	2a	3a	1a	4a	1a	3a	2a	2a	2a	1a	2a	2a	4a	9b	2a
TRFK 54/40	8b	5a	7b	5a	6b	2a	20d	20d	19d	20d	7b	14c	12c	14c	7b	10b

Table 12: Seasonal yield distribution by location as proportion of (%) of the annual yield

	Season yield		
Season	**Kangaita**	**Timbilil**	**Kipkebe**
Jan Mar	*20*	*22*	*18*
Apr Jun	*19*	*8*	*26*
Jul Sept	*32*	*28*	*33*
Oct Dec	*28*	*42*	*23*

components varied significantly in their response to environment. These variations give rise to the locational and seasonal yield variations among tea genotypes. Testing of tea cultivars in proposed areas of production should be a compulsory undertaking before the plants area availed to farmers. This shall ensure farmers use cultivars suitable for their areas.

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