RESEARCH ARTICLE

Effects of Blended Fertilizers on Yields of Mature Clonal Tea grown in Kenyan Highlands

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Abstract

Fertilizer requirement for tea production is high since the pluckable portions are succulent shoots, which contain the largest percentage of nutrients. Kenya's tea industry depends predominantly on imported compound NPK fertilizer to replenish nutrients removed through plucking. These fertilizers cannot be easily manipulated for specific soils and tea clones. This has necessitated studies on other fertilizers which can be produced locally in an economical manner so as to boost farmers' profit. The objective of this research was to evaluate two Mavuno fertilizer blends with the aim of identifying optimal levels of application which would maximize tea productivity. This was achieved through determination of seasonal and annual effects on tea yields at different rates of application.

Keywords: *Blended fertilizers, Clonal tea, Fertilizer types, Fertilizer rates,* Seasons.

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Introduction

Tea (*Camellia sinensis* (L.) O. Kuntze), like any other crop, requires optimum nutrition for its growth and production. Nutrient requirements for commercial tea production are particularly high because the harvestable portions of tea are succulent shoots, which contain the largest percentage of nutrients in the plant.[1,2] To continuously produce economically acceptable yields, it becomes mandatory that removed nutrients are replenished into the soil through fertilizer applications.[1]

Fertilizer application is a regular and important field management practice for intensive production of tea.[3-6] Tea fertilizers are available commercially in many physical and chemical forms. Among these are the compound granular fertilizers which contain all of the plant nutrients specified in each granule; and the blended granular fertilizer which is a mixture of dry fertilizer granules or prills or chips, which have no chemical reaction.[7,8] Each physical form of the fertilizer has its own uses and limitations, which provide the basis for selecting the best fertilizer for specific crops or location.

Sources and rates of fertilizers recommended for tea production vary from country to country. In Kenya, the most popular formulation is NPK 25:5:5 or NPK 20:10:10.[9] Research in Kenya tea industry has focused predominantly on the compound NPK fertilizers due to its wide adoption by many small holder tea growers. However, these fertilizers are not readily available locally and cannot be manipulated to suit specific soil and clone. This has necessitated studies on other potential fertilizers which can be found locally.

Knowledge of seasonal yield patterns of mature tea crop is an important component of fertilizer management and can be used to increase nutrient use efficiency (i.e., nutrient recovered/nutrient applied) by matching fertilizer applications with periods of high nutrient requirement or season hence increased nutrient uptake capacity. Kamau et al.[10] described the tea seasons as (1) a warm-dry season (December to March); (2) a cool-wet season (April to August); (3) a warm-wet season (September to November). These seasons have been found to have profound effects on tea yields and therefore when considering applications of blended fertilizers, the choice of season and the rate is of significance important.

Thus this study was designed to investigate the blended fertilizer effects on tea yield as affected by seasons and rates of application.

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Conflict of interest: None

The study was meant to provide better insight on the potential of blended fertilizers in providing required nutrition to tea crop and therefore contributing to higher and economically viable yields.

Materials ans methods

- *The study was conducted in two sites:* Tea Research Institute, Timbilil Estate in Kericho and Kenya Tea Development Agency, Kagochi farm in Nyeri; which represent the geographically different major tea growing regions in Kenya designated as East and West of the Great Rift Valley respectively.

Description of study sites

Timbilil Tea Estate is located at 35° 21′ East longitude and 0° 22′ South latitude with altitude of 2200 m above the sea level. It has to mean annual temperature and rainfall of 16.6°C and 2175mm respectively (Figure 1).

Kagochi Tea Farm is situated at an elevation of 2005 m above the sea level, latitude of 0° 25′ 43″ South and longitude of 37° 7′ 41″ East. It has mean annual temperature and rainfall of 15.4°C and 2040 mm respectively (Figure 2).

The sites were selected based on their strategic positions to represent tea growing areas East and West of Rift, availability of

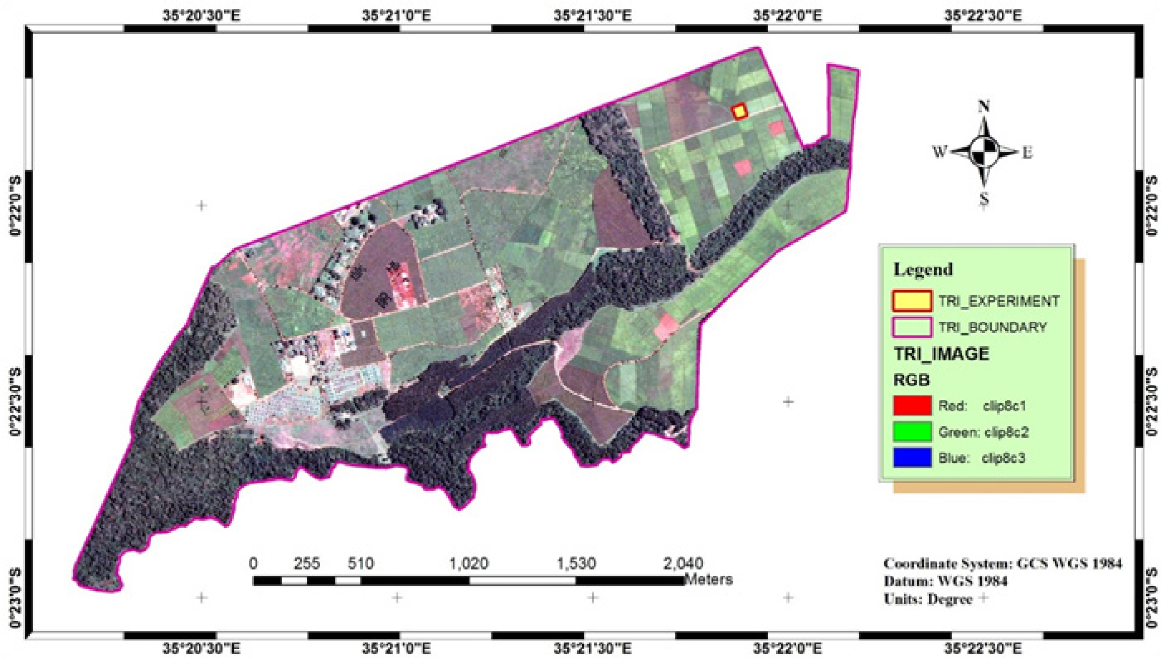


Figure 1: Location of the study sites along the plains of Timbilil, Kericho (Extracted from google earth images)

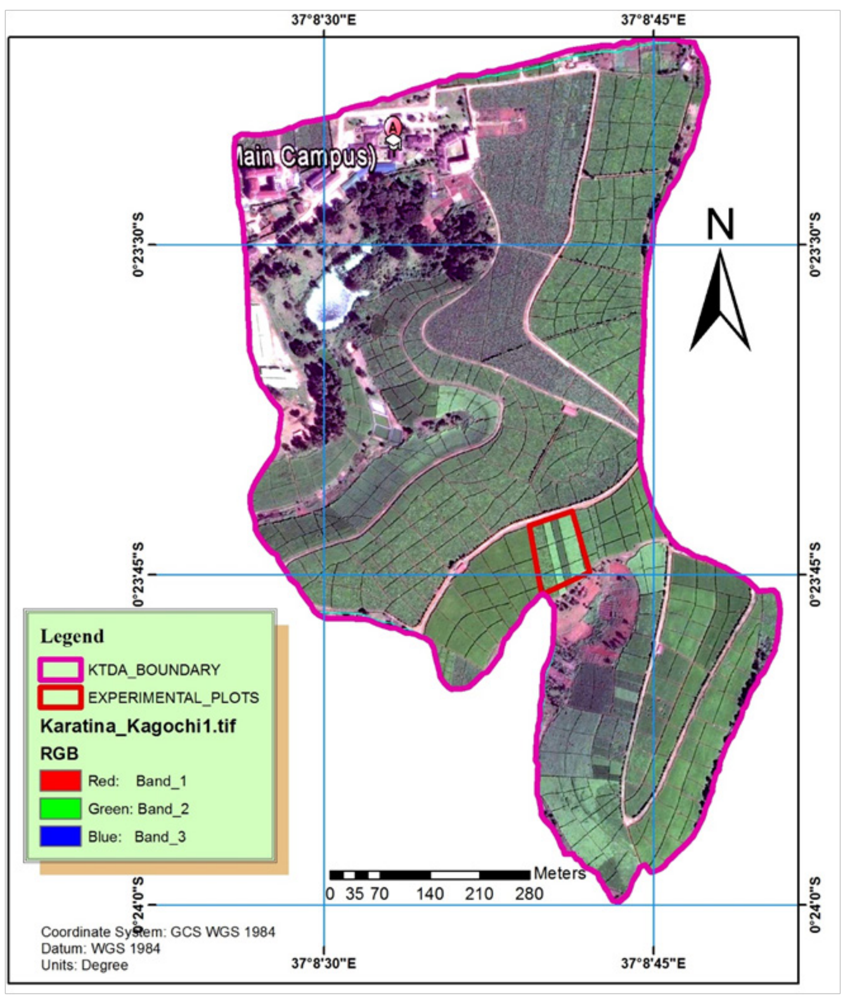


Figure 2: Location of the study sites along the valley of Kagochi, Nyeri (*Extracted from google earth images*)

technical personnel to collect data and required tea clones. The experiments were set up in existing tea fields in the two sites.

Climatic characteristics of the sites

Monthly rainfall and temperature during the experimental periods is shown in Table 1. The shaded area indicate missing values due to faulty thermometers.

Uniformity yield data

Uniformity yield data collected at the two sites prior to treatment application are as summarized in Table 2. The results showed that the yields in the plots were not significantly different, implying that the selected sites were uniform. However, the Kagochi site had higher yields which might have aroused from the productivity differences of the two clones.

Experimental Layout and treatments

The trial was conducted using randomized completely block design (RCBD) with three fertilizer types and four fertilizer application rates replicated three times. Thus;

(a) Fertilizer types

- *Blend "A":* Mavuno-NPKS 25:5:5:4+9Ca+2.6Mg+ Trace Elements (TE).
- *Blend "B":* Mavuno- NPKS 23:5:5:4 +10Ca+3Mg+ Trace Elements (TE).
- *NPK standard:* NPK 26:5:5 as control

(b) Fertilizer application rates (0 (control), 75, 150, and 225 kgN/ha).

Treatment application and management

The trial was set using clone BBK 35 in Timbilil planted in 1988 at a spacing of 4x2.5 ft. and clone TRFK 6/8 in Kagochi planted in 1965 at a spacing of 5x2.5 ft. Seventy (70) plants per plot (7x10) in Kericho and fifty six (56) plants per plot (7x8) in Kagochi were used. The number of plants for effectiveness varied in the sites due to spacing.

The fertilizers were applied annually in rows as per bush calculation based on spacing (Table 3). Management of the plots including plucking, pruning, and weeding was done in conformity with standard procedure.

Tea Yield Determination

Tea productivity was quantified in terms of the weight of 'made tea' per unit land area per year 'Made tea' is obtained after the harvested shoot has gone through the manufacturing process,[11] and the weight is directly related to the fresh weight of plucked shoot (2-3 leaves and a bud) by a factor of 0.225.[12] Therefore, yield components of tea were the number of plucked shoots per unit land area and the mean weight per shoot.[11] Plucking of tea was done in conformity with standard procedure and yield data recorded for three years from 2014 to 2016. The yield were converted to kilograms (kg) made tea per hectare per year (kg MT ha^{-1} y^{-1}) using the following equation[12]:

$$\text{Yield (kgMT ha}^{-1}\text{y}^{-1}) = \frac{n * a * 0.225}{b} \quad (2)$$

Where

- *n:* is green leaf yield per plot,
- *a:* is plant population per hectare,
- 0.225 is the factor converting green leaf to made tea and *b* is the number of plants per plot.

Table 1: Rainfall and temperature for Timbilil and Kagochi in 2014-2016

	Timbilil rainfall			*Timbilil temperature*		
	2014	*2015*	*2016*	*2014*	*2015*	*2016*
January	23.4	1.3	180.6	16.7	16.7	17.7
February	36.1	23.6	23.6	16.9	16.6	17.7
March	211.0	23.1	92.2	17.8	18.7	19.4
April	107.2	357.5	327.1	16.7	17.2	17.9
May	280.0	348.0	353.5	16.7	16.4	17.8
June	228.3	231.3	157.2	16.7	16.5	17.0
July	100.5	145.7	151.7	15.4	16.2	16.3
August	207.0	173.6	184.9	14.3	16.6	16.8
September	180.8	159.2	118.4	14.9	16.9	16.9
October	340.8	203.3	225.9	15.8	18.0	16.2
November	550.7	245.5	78.5	16.8	16.1	17.4
December	137.0	215.8	39.4	17.0	17.0	17.6
	Kangaita rainfall			*Kangaita temperature*		
January	28.3	0		17.05	–	–
February	126	59.54	37.79	18.45	–	–
March	92.8	146.6	114.3	17.65	–	–
April	247.9	382.5	410.12	16.4	–	–
May	445.7	502.9	147.27	16.8	–	–
June	283.9	149.2	90.28	16.3	–	–
July	69.4	117.9	29.3	18.65	–	–
August	239.2	103.1	95.1	–	–	–
September	114.7	13.78	56.42	–	–	–
October	305.2	380.3	20.02	–	–	–
November	223.3	312.7	119.15	–	–	–
December	114.6	159.1	32.76	–	–	–

Table 2: Two factor ANOVA for uniformity tea yields (kg made tea/ha) in the plots at the two sites at the start of the experiment

Plots \Site*	*Kericho*	*Kagochi*	*Means*
1	1373	2163	1768
2	1201	2135	1668
3	1452	2199	1826
4	1403	2200	1802
5	1656	2458	2057
6	1557	2184	1870
7	1621	2190	1906
8	1574	2065	1820
9	1362	2158	1760
10	1225	2094	1659
11	1384	2361	1872
12	1415	2170	2198
Means	1435	2198	(1817)
CV (%)	15.1		
LSD (p = 0.05)	Plots (NS); Site (92)		

* Means of three plots that form a replicate.

Table 3: Amount of fertilizer applied per bush in different N-rates

Fertilizer type	*Rate of application*	*Amount fertilizer applied per bush (g/bush)*	
		Timbilil estate	*Kagochi*
Blend "A"	0	0	0
	75	27.9	34.8
	150	55.7	69.7
	225	83.6	104.5
Blend "B"	0	0	0
	75	30.3	37.9
	150	60.6	75.7
	225	90.9	113.6
NPK standard	0	0	0
	75	26.8	33.5
	150	53.6	67.0
	225	80.4	100.5

Data analysis

Effect of treatments application on seasonal, annual and mean yields of mature tea clone BBK 35 in Kericho and TRFK 6/8 in Kagochi were subjected to the analysis of variance (ANOVA) using the Mstat C computer software package.[12] The Least Significant Difference (LSD) procedure was then used to separate differences among the treatment means.

Results And Discussion

Effects of the Fertilizer Treatments on Annual Tea Yields

Annual and mean yields effect of treatments application on mature tea clone BBK 35 in Kericho and TRFK 6/8 in Kagochi are shown in Figures 3 (a,b,c) and 4.

Responses Due to N-rates

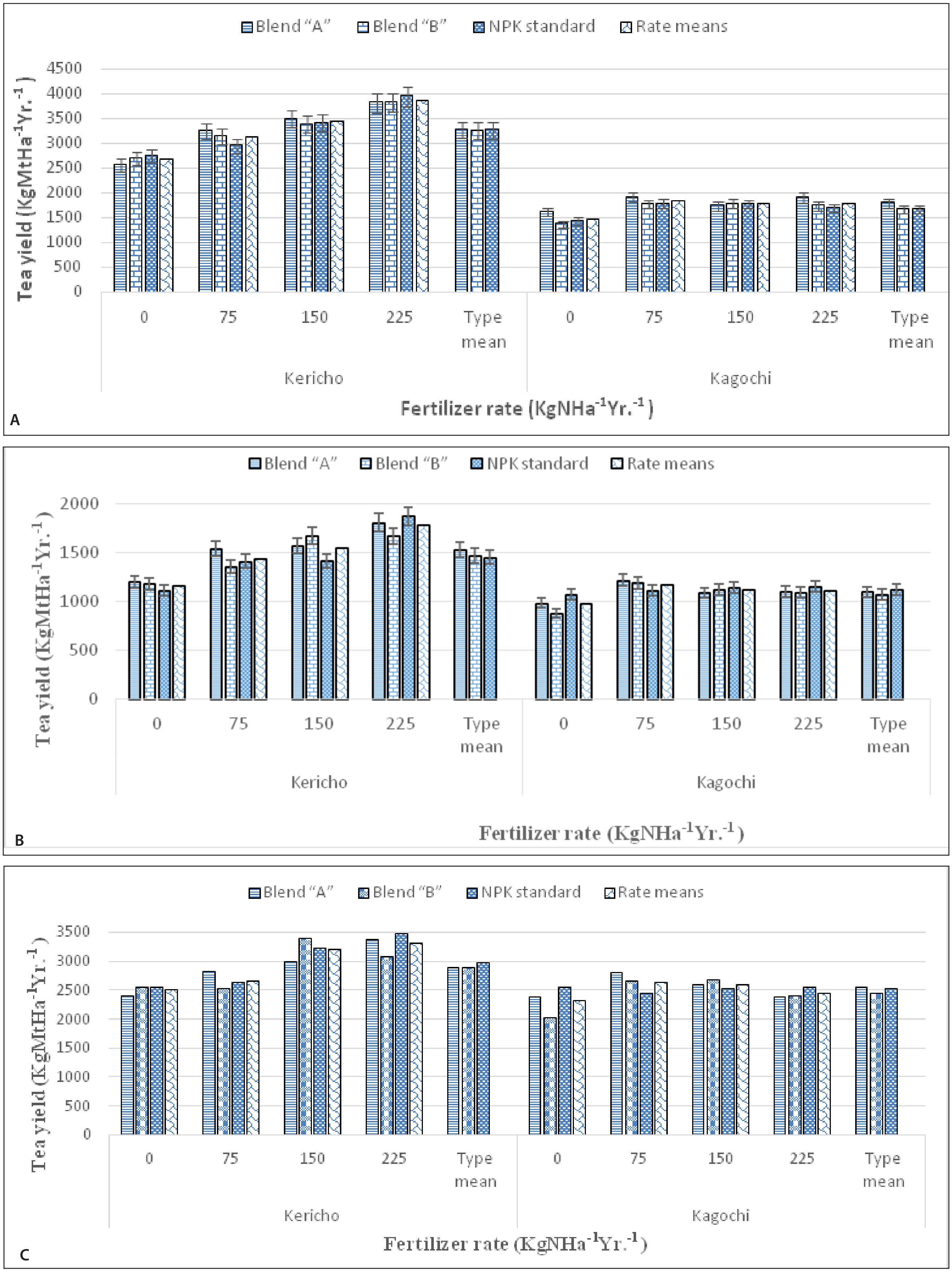
Results from this study indicated that fertilizer rates resulted in significant (P=0.05) annual and mean yield responses except for the year 2016 and mean in Kagochi. In Kericho highest yields of 3817, 3831 and 3952 kg Mt ha^{-1} for blend A, B and NPK standard resulted from highest N-rate of 225 kg N ha^{-1} year^{-1} in 2014 (Figure 3a). During the same year in Kagochi, highest yields of 1909 and 1784 kg Mt ha^{-1} for blend A and NPK standard were observed at the rate of 75 kg N ha^{-1} year^{-1} while 1777 kg Mt ha^{-1} for blend B was observed at the rate of 150 kg N ha^{-1} year^{-1}. In 2015, highest yields of 1811 and 1873 kg Mt ha^{-1} were observed with highest N-rate of 225 kg N ha^{-1} year^{-1} for blend A and NPK standard while for blend B (1675 kg Mt ha^{-1}) was observed at 150 kg N ha^{-1} year^{-1} (Figure 3b). For Kagochi, highest yields of 1218 and 1191 kg Mt ha^{-1} for blend A and B were observed at the rate of 75 kg N ha^{-1} year^{-1}. However, the highest yield of 1153 kg Mt ha^{-1} for NPK standard was observed at the highest rate of 225 kg N ha^{-1} year^{-1}. Highest responses of 3356 and 3470 kg Mt ha^{-1} for blend A and NPK standard were observed with highest N-rate of 225 kg N ha^{-1} year^{-1} in Kericho in 2016 while that of 3385 kg Mt ha^{-1} for blend B was observed at the rate of 150 kg N ha^{-1} year^{-1} (Figure 3c). For Kagochi, it varied non-significantly 75 (2800 kg Mt ha^{-1}), 150 (2674 kg Mt ha^{-1}) and 225 (2547 kg Mt ha^{-1}) kg N ha^{-1} year^{-1} for the three fertilizer types respectively. Mean for 2014-2016 in Kericho showed highest yields of 2895, 2854 and 3099 kg Mt ha^{-1} for blend A, B and NPK standard with highest N-rate of 225 kg N ha^{-1} year^{-1} while in Kagochi, highest yields of 1808 and 1870 kg Mt ha^{-1} for blend A and B were observed at the lowest rate of 75 kg N ha^{-1} year^{-1} and 1810 kg Mt ha^{-1} for NPK standard was observed at 150 kg N ha^{-1} year^{-1} (Figure 4). Lowest yields were observed at 0 (control) for both sites except in 2016 for Kagochi when it was observed at 75 kg N ha^{-1} year^{-1}.

Responses due to N types

Yields were not influenced significantly (P=0.05) by N types. In 2014 in Kericho, the highest yield of 3952 kg Mt ha^{-1} was obtained with NPK standard followed by blend B with 3831 kg Mt ha^{-1} then blend A with 3817 kg Mt ha^{-1}, all at the highest rate of 225 kg N ha^{-1} year^{-1}. However, blend A gave the highest yields of 1909 and 1905 kg Mt ha^{-1} at 75 and 225 kg N ha^{-1} year^{-1} respectively in Kagochi followed by NPK standard with 1784 kg Mt ha^{-1} then blend B with 1777 kg Mt ha^{-1} at 75 and 150 kg N ha^{-1} year^{-1} respectively (Figure 3a). In 2015, the highest yield for Kericho (1873 kg Mt ha^{-1}) was observed with NPK standard followed by blend A (1811 kg Mt ha^{-1}) both at highest rate (225 kg N ha^{-1} year^{-1}) and lastly blend B (1675 kg Mt ha^{-1}) at 150 kg N ha^{-1} year^{-1}. For Kagochi, the highest yield (1218 kg Mt ha^{-1}) was observed with blend A followed by blend B (1191 kg Mt ha^{-1}) both at same rate (75 kg N ha^{-1} year^{-1}) then NPK standard (1153 kg Mt ha^{-1}) at the highest rate of 225 kg N ha^{-1} year^{-1} (Figure 3b). The highest (3470 kg Mt ha^{-1}) and the least (3356 kg Mt ha^{-1}) yield for Kericho in 2016 were observed with NPK standard and blend A at the highest rate (225 kg N ha^{-1} year^{-1}) and in between was blend B (3385 kg Mt ha^{-1}) at 150 kg N ha^{-1} year^{-1}. During the same year in Kagochi, the highest yield (2800 kg Mt ha^{-1}) was observed with the lowest rate (75 kg N ha^{-1} year^{-1}) of blend A followed by blend B (Figure 3c). Mean for Kericho (2014-2016) were in the order NPK standard followed by blend A then B, all at the highest rate while for Kagochi, the highest yield was observed with blend A at 75 kg N ha^{-1} year^{-1} followed by blend B (Figure 4).

Seasonal Variations of Tea Yield as Affected by Blended Fertilizer Application

Seasonal effects of treatments application on yields trait of mature



Figures 3A to C: Effect of Mavuno tea formulations on annual tea yields (Kg mt/ha), 2014, 2015 and 2016

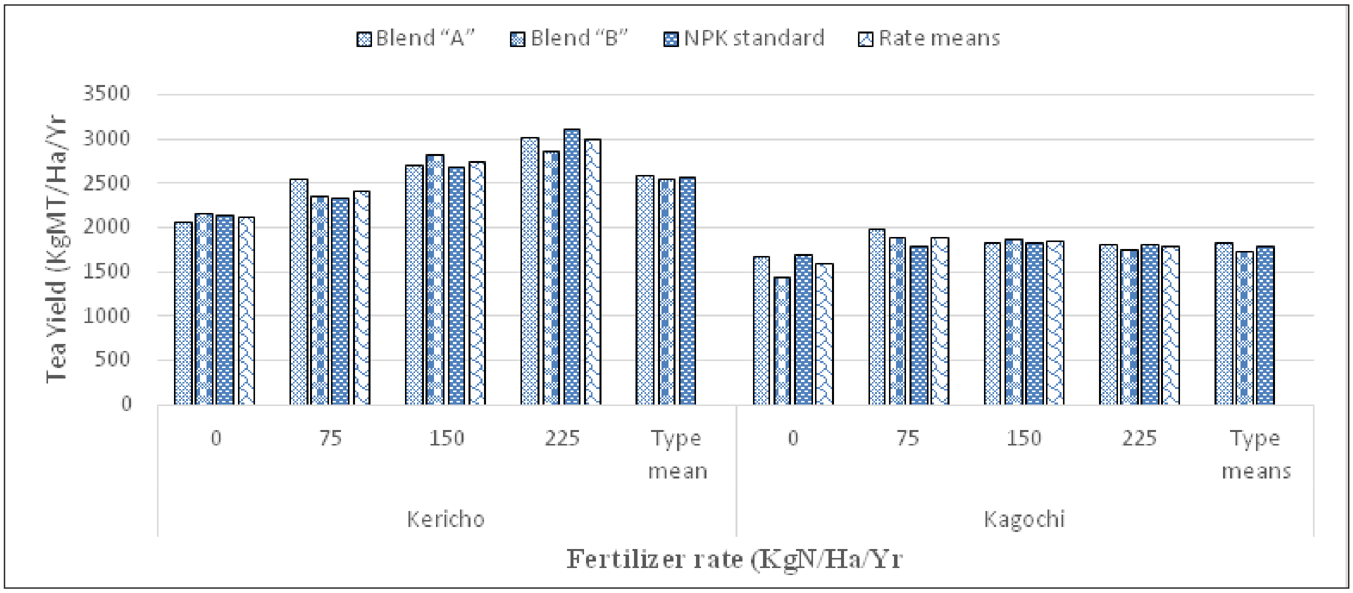


Figure 4: Effect of Mavuno tea formulations on mean tea yields (Kg mt/ha), 2014 – 2016

tea clone BBK 35 in Kericho and TRFK 6/8 in Kagochi are shown in Figure 5a, b, c, d, e and f.

Responses Due to N-rates

From the results, effect of fertilizer N-rates resulted in significant (P=0.05) seasonal yield responses except for 2016 in Kagochi. During the seasons in Kericho, yields generally increased linearly with N-rates. The highest yields for blend A and standard NPK fertilizer in all the seasons of 2014, 2015, warm-dry and warm-wet of 2016 were observed with the highest N-rate of 225 kg N ha^{-1} $year^{-1}$ (Figure 5a, b & c). However, during cold-wet season of 2016, the highest yield was observed with the lowest N-rate of 75 kg N ha^{-1} $year^{-1}$. For blend B, the highest yields were observed with 150 kg N ha^{-1} $year^{-1}$ in 2014 and 2016 except for cold-wet season of 2014 and the whole of 2015 when they were observed with the highest N-rate of 225 kg N ha^{-1} $year^{-1}$.

During the seasons in Kagochi, yields varied with N-rates. The highest yields for blend A except in the cold-wet season were observed with the highest N-rate (225 kg N ha^{-1} $year^{-1}$) in 2014 (Figure 5d). The same was observed in warm-dry season of 2015. The highest yields for blend A in the other seasons of 2015 and all the seasons of 2016 were observed with the lowest N-rate (75 kg N ha^{-1} $year^{-1}$) (Figure 5 e & f). The highest yields for blend B except in cold-wet season of 2014 were observed with 150 kg N ha^{-1} $year^{-1}$ while in 2015, except in cold-wet season, the highest yields observed with the highest N-rate. The highest yields for blend b except for cold-wet season of 2016 were observed with the lowest N-rate (75 kg N ha^{-1} $year^{-1}$). For standard NPK fertilizer in 2014 and warm-wet season of 2015, the highest yields were observed with the highest N-rate (225 kg N ha^{-1} $year^{-1}$) while in 2016, except for warm-wet season, the highest yields were observed with 150 kg N ha^{-1} $year^{-1}$.

Responses Due to N types

The highest yields were observed with standard NPK in all seasons of 2014 in Kericho (Figure 5a). Except for warm-wet season in 2015, the highest yields were observed with blend B fertilizer (Figure 5b). In both years, the observations were at the highest N-rate of 225 kg N ha^{-1} $year^{-1}$. In 2016 the highest yields were observed with different rates of the three fertilizer types in different seasons (Figure 5c).

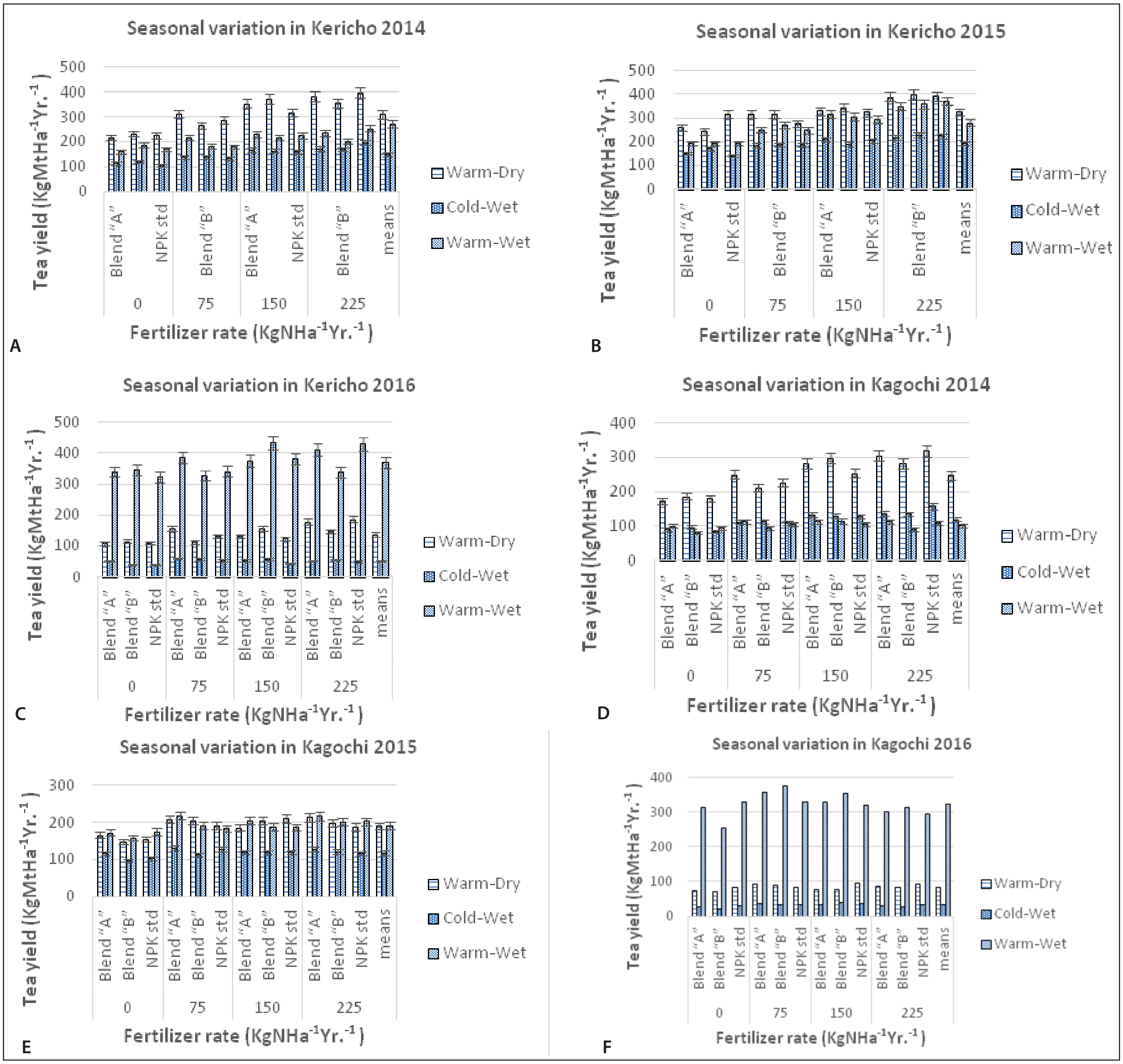
In Kagochi, except for warm-wet season of 2014, the highest yields were observed with standard NPK at the highest N-rate (Figure 5d). However, in 2015, blend A gave the highest yields at different N-rates (Figure 5e). In 2016, standard NPK at 150 kg N ha^{-1} $year^{-1}$ gave the highest yield during warm-dry season while blend B at the same N-rate and at the lowest N-rate (75 kg N ha^{-1} $year^{-1}$) gave the highest yields in the remaining seasons respectively (Figure 5f).

Discussion

From the results, the yields behaved differently as the total level of nitrogen rate increased in the two sites. The yields in Kericho increased linearly with N-rates while in Kagochi the yields diminished with N-rate. The findings in Kericho were corroborated by earlier investigations which showed significant correlation of yield with nutrient levels (NPK) applied.[14] Similar findings on responses due to N-application rates have been reported in other studies[10,15-19] confirming that mature clonal tea requires N-fertilizers to enhance production. However, the findings in Kagochi contradicted these findings.

There were no interactions between the fertilizer types and rates indicating that the responses for the three fertilizers were similar. These results coincide with the findings of Sarwar *et al.*,[20] who reported that ammonium sulphate and urea consistently yield good result in presence of adequate amount of potassium.

The lower annual yields observed in Kagochi in 2015 might have resulted from pruning which was done in August 2015 and reduced rains in the months of February and September (Table 1). The weather and seasonal fluctuations in variables such as rainfall, temperature and humidity, and soil water deficits influence seasonal yield distribution, and hence annual yields.[15,21] Highest yields in both sites were obtained during warm-wet season while lowest yields were obtained during the cold-wet season (Figure 5). The results showed that provided soil moisture is adequate, warm temperatures lead to fast growth which convert to highest yields. The lower yields observed during cold-wet season were corroborated by Owuor's findings who also observed the same in 2011. Nixon et al.[14] also found that low temperatures caused slow growth resulting in lowered yields. Yields were also lower during the warm-dry season. Maritim et al.[22] working in Kericho also found



Figures 5A to F: Seasonal yield responses to the Mavuno tea formulations during 2013-2014, 2014-2015 and 2015-2016 in Kericho (Kg mt/ha)

that yields were low during dry spell. However, the observed lower yields in Kagochi when compared to Kericho could be attributed to plants density. The issue of plant density has been found by other researchers to affect yields.[23]

Conclusion and recommendations

Conclusion

This study has shown that based on the annual and seasonal yields analysis, the three fertilizer types, blend 'A', blend 'B' and standard 'NPK', were similar irrespective of clones and sites. However, blend 'A' was the most consistent fertilizer with high mean yields across the two sites.

Recommendation

Apart from the standard NPK fertilizer, blend 'A' can be considered for use in tea growing in Kenya.

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