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EFFECTS OF BLENDED FERTILIZERS ON YIELDS OF MATURE TEA CLONES TRFK 6/8 AND BBK 35 GROWN IN KENYAN HIGHLANDS

Pengaruh Pupuk Majemuk Terhadap Pertumbuhan Teh Klon TRFK 6/8 dan BBK 35 di Dataran Tinggi Kenya

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ABSTRACT

Kenya's tea industry depends predominantly on imported NPK fertilizers to replenish nutrients removed through plucking. In this respect, two blended fertilizers containing NPKS 25:5:5:4+9Ca+2.6Mg and NPKS 23:5:5:4+10Ca+3Mg with trace elements have been produced in the country. However, contribution of the blended fertilizers to optimal tea yields had not been determined. The study aimed to evaluate the optimal levels of the two blended fertilizers on tea grown in the highlands of Kenya. The blended fertilizers were evaluated in two sites, i.e. Timbilil estate in Kericho and Kagochi farm in Nyeri. The trial was laid out in a randomized complete block design with two blended fertilizers and the standard NPK 26:5:5 as a control. The treatments were applied at four fertilizer rates (0-control, 75, 150 and 225 kg N ha^{-1} yr^{-1}), with three replications. The results showed that application of 225 kg N ha^{-1} yr^{-1} blended fertilizer NPKS 25:5:5:4+9Ca+2.6Mg in Timbilil produced mean yield of 2,995 kg Mt ha^{-1} compared with 3,099 kg Mt ha^{-1} from the standard NPK. In Kagochi, the highest yield was 1,975 kg Mt ha^{-1} obtained from the application of the same blended fertilizer NPKS 25:5:5:4+9Ca+2.6Mg at 75 kg N ha^{-1} yr^{-1}. The highest yields in both sites were obtained during a warm-dry season except in 2015–2016. This study concluded that based on the annual and seasonal yields, the two blended fertilizers and the standard type had the same effectiveness, irrespective of clones and sites. However, the fertilizer rates affected the tea yield.

[**Keywords:** blended fertilizers, fertilizer rates, highland, Kenya, tea, yields]

ABSTRAK

Industri teh Kenya sangat bergantung pada pupuk majemuk NPK impor untuk mengembalikan hara yang hilang akibat pemetikan. Oleh karena itu, dua jenis pupuk majemuk diproduksi di dalam negeri, yaitu NPKS 25:5:5:4+9Ca+2.6Mg dan NPKS 23:5:5:4+10Ca+3 Mg. Namun, kontribusi kedua jenis pupuk majemuk tersebut terhadap hasil teh belum diteliti. Penelitian bertujuan untuk menguji dosis optimal dua pupuk majemuk pada pertanaman teh di dataran tinggi Kenya. Penelitian dilaksanakan di Perkebunan Timbilil, Kericho dan di Kagochi, Nyeri. Penelitian dirancang secara acak lengkap dengan perlakuan dua pupuk majemuk (NPKS 25:5:5:4+9Ca+2.6Mg dan NPKS 23:5:5:4+10Ca+3Mg) dan pupuk NPK standar 26:5:5 sebagai kontrol. Empat dosis pupuk yang diuji yaitu 75, 150, dan 225 kg N ha^{-1} $tahun^{-1}$, serta 0 (kontrol), dengan tiga ulangan. Hasil penelitian menunjukkan bahwa aplikasi pupuk majemuk NPKS 25:5:5:4+9Ca+2.6Mg sebanyak 225 kg N ha^{-1} $tahun^{-1}$ di Timbilil memberikan rata-rata hasil tertinggi, yaitu 2.995 kg Mt ha^{-1} sebanding dengan perlakuan pupuk NPK standar (3.099 kg Mt ha^{-1}). Di Kagochi, hasil tertinggi 1.975 kg Mt ha^{-1} diperoleh dari perlakuan pupuk majemuk NPKS 25:5:5:4+9Ca+2.6Mg sebanyak 75 kg N ha^{-1} $tahun^{-1}$. Hasil tertinggi di kedua lokasi diperoleh pada musim hangat-kering, kecuali tahun 2015–2016. Studi ini menyimpulkan bahwa berdasarkan hasil panen tahunan dan musiman, kedua pupuk majemuk buatan dan NPK standar memiliki tingkat keefektifan yang sama, terlepas dari jenis klon dan lokasi. Dosis pupuk memengaruhi hasil teh.

[**Kata kunci:** dataran tinggi, dosis pupuk, hasil, Kenya, pupuk majemuk, teh]

INTRODUCTION

Tea, like any other crop, requires many nutrients for its growth. Fertilizer requirements for tea production are high because the pluckable portions are succulent shoots, which contain the largest percentage of nutrients in the plant (Sitienei et al. 2013; Venkatesan et al.

2005). In order to continuously produce economically viable yields, it becomes mandatory that the removed nutrients are replenished into the soil through fertilizer applications (Sitienei et al. 2013).

Fertilizer application is a regular field management practice with a significant influence on yield (Cheruiyot et al. 2009; Drinnan 2008). Chemical fertilizers with the ability to replenish depleted nutrients in optimum quantities and forms have been recognized as an important component of sustainable soil fertility management (Ogundijo et al. 2015**.** Such fertilizers are available commercially in many physical and chemical forms. Each physical form has its own uses and limitations, which provide the basis for selecting the best fertilizer for specific crops or locations (Barnes and Fortune 2004). Sources and rates of fertilizers recommended for tea production vary from region to region depending on soil types and weather conditions.

Kenya's tea industry depends predominantly on imported compound NPK fertilizers to replenish nutrients removed through plucking. The most popular formulation is NPK 25:5:5 or NPK 20:10:10 (Owuor et al. 2011). These fertilizers cannot be easily manipulated for specific soils and tea clones (Shoji 2005). In this respect, Athi River Mining Limited has produced Mavuno blended NPK fertilizers with calcium (Ca) and magnesium (Mg) and trace elements. However, the extent to which the blended fertilizers contributed to optimal yields had not been evaluated. This was the knowledge gap that this study sought to address.

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 hence increases nutrient uptake capacity. The three seasons under consideration were described as warm and dry (December–March); cold and wet (April –August); and warm and wet (September–November) (Kamau 2008). These seasons have been found to have profound effects on tea yields and therefore when considering applications of blended fertilizers, the choice of the season and the rate was significantly important. This study was designed to determine annual and seasonal effects of blended fertilizer application on tea yields for sustainable tea production.

MATERIALS AND METHODS

Site Selection and Description

The study was conducted at Tea Research Institute, Timbilil Estate in Kericho County and Kenya Tea Development Authority (KTDA), Kagochi farm in Nyeri County, Kenya. Timbilil Tea Estate is located at 35° 21' East and 0° 22' South at an altitude of 2200 m above sea level. It has mean annual temperature and rainfall of 16.6 ^{0}C and 2175 mm, respectively. Kagochi Tea Farm is located at a latitude of 0° 25' 43" South and longitude of 37° 7' 41" East and an elevation of 2005 m above sea level. It has mean annual temperature and rainfall of 15.4 ^{0}C and 2040 mm, respectively. The areas receive a bimodal type of rainfall with peaks in April to May and October to November.

The study sites were selected using purposeful sampling where land was available and would be allowed for manipulation (Patton 2002). Tea industry in Kenya is divided geographically into two, east and west of Rift valley. Thus, the experimental sites were selected based on their strategic position to represent tea growing areas at east and west of Rift valley and availability of technical personnel to collect data.

Research Design

The trial was established using a randomized completely block design (Clewer and Scarisbrick 2013) with two blended fertilizers (NPKS 25:5:5:4+9Ca+2.6Mg and NPKS 23:5:5:4 +10Ca+3Mg) and standard NPK 26:5:5 as a control; four fertilizer rates (0-control, 75, 150 and 225 kg N ha^{-1} yr^{-1}), and three replications.

Variable Determination

Variables used were three fertilizer types and four fertilizer application rates. The fertilizer types were (1) blended NPKS 25:5:5:4+9Ca+2.6Mg+trace elements (TE) as blend A; (2) blended NPKS 23:5:5:4 +10Ca+3Mg+TE as blend B; and (3) standard NPK 26:5:5 as a control. Fertilizer application rates were 0 (control), 75, 150 and 225 kg N ha^{-1} yr^{1}. These fertilizer description and composition are described in detail on Table 1.

Treatment Application and Management

The trial was set up on a field with clone BBK 35 in Timbilil planted in 1988 at a spacing of 1.22 x 0.76 m. and clone TRFK 6/8 in Kagochi planted in 1965 at a spacing of 1.52 x 0.76 m. The plot size in Timbilil was 7 m x12 m inclusive of net plot of 7 m x 10 m (70 plants), while in Kagochi, the plot size was 8 m x 8 m with a net plot of 7 m x 8 m (56 plants). The number of plants for effective sampling varied in the sites due to spacing. The fertilizers were spread in rows as per characteristics and bush calculation based on spacing as shown on Table 1.

Table 1. Fertilizer description, composition and application rates

Fertilizer description	N composition (%)			Physical properties	pH	Fetilizer rate per year (kg N ha^{-1} yr^{-1})	Fertilizer rate per bush (g)	
	Ammoniacal	Nitrate	Amide				Timbili estate	Kagochi farm
Blended NPKS A containing 25%N:5%P:5%K:4%S+9%Ca +2.6%Mg + B (140 ppm) + Zn (200 ppm) + Cu (89 ppm) + Mo (19 ppm)	2	0	23	Mixture of white, black and brown granules	6.71±0.11	0	0	0
						75	27.9	34.8
						150	55.7	69.7
						225	83.6	104.5
Blended NPKS B containing 23%N:5%P:5%K:4%S+10% Ca+3%Mg + B (140 ppm) + Zn (200 ppm) + Cu (89 ppm) + Mo (19 ppm)	21	0	2	Mixture of white, black and brown granules	3.68±0.02	0	0	0
						75	30.3	37.9
						150	60.6	75.7
						225	90.9	113.6
Standard NPK containing 26%N:5%P:5%K (control)	14	12	0	Grey uniform granules	3.73±0.01	0	0	0
						75	26.8	33.5
						150	53.6	67.0
						225	80.4	100.5

Data Uniformity for Site Selection

Baseline Soil pH

Soil pH is the single most informative measurement that can be made to determine soil characteristics. Availability and toxicity of other elements can be estimated using soil pH. Soil pH at different depths at the two sites prior to treatment application is shown in Table 2. The pH ranged between 3.20 and 3.89 in Timbilil estate and 3.09 and 3.69 in Kagochi farm. These pH ranges are classified as very acidic according to Landon (2014). However, the pH was generally uniform in the two sites before treatment application.

Tea Yields

Uniformity of tea yields in all plots at the two sites prior to treatment are summarized in Table 3. These are green leaves plucked from every plot and converted to equivalent processed tea using a conversion factor. The yields from the selected plots were recorded separately before the treatment and subjected to analysis of variance. The results showed that the yields in all the plots were not significantly different, implying that the selected sites were uniform. However, the Kagochi site had higher yields probably due to productivity differences between the two clones. The number of tea bushes for the plots was similar for each site and therefore any variation in yields could be explained as the experimental error due to slight differences in weighing, soil heterogeneity or tea plucking.

Tea Yield Determination

Yield components of tea are described as the number of plucked shoots per unit land area and the mean weight per shoot (De Costa et al. 2007). Plucking was done in conformity with standard procedures. The fresh tea yields were converted to kilograms (kg) processed yield per hectare per year (kg Mt ha^{-1} yr^{-1}) using the following equation (Anon 2002):

$$\text{Yield (kg Mt ha}^{-1}\text{ yr}^{-1}) = \frac{n + a + 0.225}{b} \quad \ldots\ldots\ldots\ldots (1)$$

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

Data Analysis

Effects of treatment 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 (Russel 1995). The Least Significant Difference (LSD) procedure was then used to separate differences among the treatment means.

RESULTS

Annual and Mean Tea Yields

Effects of fertilizer application on annual and mean yields of mature tea clone BBK 35 in Kericho and TRFK 6/8 in Kagochi are shown in Table 4.

Table 2. Baseline soil pH in Timbilil estate (Kericho) and Kagochi farm (Nyeri), Kenya, at different soil depths and fertilizer rates and types.

Soil depth (cm)	Soil pH at different fertilizer rate (kg N ha^{-1} yr^{-1}) and types												Mean
	0			75			150			225			
	Blended NPKS A	Blended NPKS B	Standard NPK	Blended NPKS A	Blended NPKS B	Standard NPK	Blended NPKS A	Blended NPKS B	Standard NPK	Blended NPKS A	Blended NPKS B"	Standard NPK	
Timbilil													
0-15	3.26	3.50	3.24	3.37	3.20	3.33	3.28	3.51	3.43	3.53	3.30	3.40	3.36
15-30	3.53	3.65	3.43	3.57	3.50	3.58	3.52	3.68	3.67	3.66	3.63	3.46	3.57
40-60	3.71	3.89	3.70	3.87	3.69	3.70	3.80	3.77	3.80	3.72	3.75	3.58	3.75
		Type			Rate			Depth					
CV (%)		3.63			3.63			4.28					
LSD (P<0.05)		NS			N			NS					
Kagochi													
0-15	3.33	3.10	3.14	3.22	3.26	3.12	3.45	3.09	3.26	3.20	3.30	3.11	3.22
15-30	3.33	3.14	3.35	3.51	3.31	3.29	3.21	3.13	3.39	3.23	3.39	3.42	3.31
40-60	3.43	3.40	3.39	3.66	3.38	3.51	3.29	3.27	3.43	3.30	3.47	3.31	3.40
		Type			Rate								
CV (%)		4.35			4.35								
LSD (P<0.05)		NS			NS								

Blended NPKS A = NPKS 25:5:5:4+9Ca+2.6Mg; Blended NPKS B = NPKS 23:5:5:4 +10Ca+3Mg.

Table 3. Two factor ANOVA for uniformity of tea yields in the plots at the two sites in Kenya.

Plots*	Tea yield (kg made tea ha^{-1})		
	Timbilil (Kericho)	Kagochi (Nyeri)	Means
1	1,373	2,163	1,768
2	1,201	2,135	1,668
3	1,452	2,199	1,826
4	1,403	2,200	1,802
5	1,656	2,458	2,057
6	1,557	2,184	1,870
7	1,621	2,190	1,906
8	1,574	2,065	1,820
9	1,362	2,158	1,760
10	1,225	2,094	1,659
11	1,384	2,361	1,872
12	1,415	2,170	2,198
Means	1,435	2,198	(1,817)
CV (%)	15.1		
LSD (P<0.05)	Plots (NS); Site (92)		

*Means of three plots that form a replicate.

Yield Responses Due To Nitrogen Rates

Results from this study indicated that fertilizer rate, site and their interaction resulted in significant (P<0.05) annual and mean yield responses (Table 4). In Timbilil, the highest yields of 3,817, 3,831 and 3,952 kg Mt ha^{-1} were obtained with application of blend A, blend B and standard NPK at highest N-rate of 225 kg N ha^{-1} yr^{-1} in 2014. During the same year in Kagochi, the highest yields of 1,909 and 1,784 kg Mt ha^{-1} for blend A and standard NPK, respectively, were observed at the rate of 75 kg N ha^{-1} yr^{1}, while 1777 kg Mt ha^{-1} for blend B was observed at the rate of 150 kg N ha^{-1} yr^{-1}.

In 2015, the highest yields of 1,811 and 1,873 kg Mt ha^{-1} were observed at the highest N-rate of 225 kg N ha^{-1} yr^{1} for blend A and standard NPK, respectively, while for blend B (1,675 kg Mt ha^{-1}) was observed at 150 kg N ha^{-1} yr^{1} in Timbilil. For Kagochi, the highest yields of 1,218 and 1,191 kg Mt ha^{-1} for blend A and B, respectively, were observed at the rate of 75 kg N ha^{-1} yr^{1}. However, the highest yield of 1,153 kg Mt ha^{-1} for standard NPK was observed at the highest rate of 225 kg N ha^{-1} yr^{1}.

The highest yield responses of 3,356 and 3,470 kg Mt ha^{-1} respectively for blend A and standard NPK were observed with the highest N-rate of 225 kg N ha^{-1} yr^{1} in Timbilil in 2016, while that of 3,385 kg Mt ha^{-1} for blend B was observed at the rate of 150 kg N ha^{-1} yr^{1}. For Kagochi, the yields varied non-significantly at N rate of 75 (2,800 kg Mt ha^{-1}), 150 (2,674 kg Mt ha^{-1}) and 225 (2,547 kg Mt ha^{-1}) kg N ha^{-1} yr^{1} for the three fertilizer types respectively.

Mean tea yields from 2014 to 2016 in Timbilil were highest at 2,995, 2,854 and 3,099 kg Mt ha^{-1} for blend A, blend B and standard NPK with highest N-rate of 225 kg N ha^{-1} yr^{1}. In Kagochi, the highest yields of 1,975 and 1,870 kg Mt ha^{-1} were obtained from blend A and blend B, respectively, at the lowest rate of 75 kg N ha^{-1} yr^{1} and 1,810 kg Mt ha^{-1} for standard NPK at the rate of 150 kg N $ha^{-1}$$yr^{1}$. The control treatment consistently gave low yields for both sites except in 2016 for Kagochi whereby the lowest yields were observed at the treatment rate of 75 kg N $ha^{-1}$$yr^{1}$. In annual and mean results, significant interaction effects were observed implying that application of the blended fertilizers at different N-rates in the two sites behaved differently.

Table 4. Effect of fertilizer application on annual and mean tea yields in Timbilil and Kagochi, Kenya, 2014–2016.

Year	Site	N-rate (kg N ha^{-1} yr^{-1})	Tea yield (kg Mt ha^{-1}) Blended NPKS A	Blended NPKS B	Standard NPK	Means
2014	Timbilil	0	2,563	2,689	2,748	2,667
		75	3,250	3,136	2,951	3,112
		150	3,491	3,388	3,407	3,429
		225	3,817	3,831	3,952	3,867
		Type mean	3,280	3,261	3,265	(3,269)
	Kagochi	0	1,605	1,367	1,436	1,469
		75	1,909	1,772	1,784	1,822
		150	1,740	1,777	1,773	1,763
		225	1,905	1,737	1,699	1,780
		Type mean	1,790	1,663	1,673	(1,709)
			Type	Rates	Location	Rate*Site
		CV (%)	11.1	11.1	12.5	12.5
		LSD (P<0.05)	NS	207*	657*	329*
2015	Timbilil	0	1,204	1,180	1,110	1165
		75	1,538	1,358	1,414	1437
		150	1,571	1,675	1,415	1554
		225	1,811	1,672	1,873	1786
		Type mean	1,531	1,471	1,453	(1485)
	Kagochi	0	985	882	1,076	981
		75	1,218	1,191	1,117	1,175
		150	1,090	1,127	1,146	1,121
		225	1,103	1,094	1,153	1,116
		Type mean	1,099	1,073	1,123	(1,099)
			Type	Rates	Location	Rate*Site
		CV (%)	16.2	16.2	15.3	15.3
		LSD (P≤0.05)	NS	157*	418*	210*
2016	Timbilil	0	2,390	2,550	2,538	2,493
		75	2,807	2,513	2,622	2,647
		150	2,986	3,385	3,216	3,196
		225	3,356	3,058	3,470	3,295
		Type mean	2,885	2,876	2,962	(2,908)
	Kagochi	0	2,373	2,010	2,536	2,307
		75	2,800	2,648	2,441	2,630
		150	2,592	2,674	2,510	2,592
		225	2,372	2,396	2,547	2,439
		Type mean	2,535	2,432	2,509	(2,492)
			Type	Rates	Location	Rate*Site
		CV (%)	14.1	14.1	13.4	13.4
		LSD (P≤0.05)	NS	285*	760*	381*
2014–2016	Timbilil	0	2,052	2,140	2,132	2,108
		75	2,532	2,336	2,329	2,399
		150	2,683	2,816	2,679	2,726
		225	2,995	2,854	3,099	2,982
		Type mean	2,565	2,536	2,560	(2,554)
	Kagochi	0	1,654	1,420	1,683	1,586
		75	1,975	1,870	1,781	1,876
		150	1,808	1,859	1,810	1,825
		225	1,795	1,742	1,800	1,779
		Type mean	1,808	1,723	1,768	(1,766)
			Type	Rates	Location	Rate*Site
		CV (%)	45.6	45.6	11.5	11.5
		LSD (P≤0.05)	NS	185*	526*	264*

*Significant at P≤0.05

Blended NPKS A = NPKS 25:5:5:4+9Ca+2.6Mg; Blended NPKS B = NPKS 23:5:5:4 +10Ca+3Mg.

Yield Responses Due to Fertilizer Types

Tea yields were not significantly influenced ($P<0.05$) by fertilizer types during the experimental period in the two sites (Table 4). However, there was yield improvement with blended fertilizer A as compared to the other treatments. Yields recorded were higher in Timbilil as compared to those in Kagochi in all the years under study. Tea yields from the standard NPK compared well with the yields from the blended fertilizers. Mean yields for Timbilil in 2014–2016 were in the order of blend A, standard NPK and blend B (2,565, 2,560 and 2,536 kg Mt ha^{-1}, respectively), while for Kagochi, the yield per fertilizer types were 1,808, 1,768 and 1,723 kg Mt ha^{-1} for blend A, blend B and standard NPK, respectively.

Seasonal Variations of Tea Yields

Seasonal effects of treatment application on the yields of mature tea clone BBK 35 in Timbilil and TRFK 6/8 in Kagochi are shown in Table 5 and 6. The three seasons under consideration were described as warm and dry (December–March), cold and wet (April–August) and warm and wet (September–November).

Seasonal Yields Due to Nitrogen Rates

Results from this study indicated that the effect of N-rates resulted in significant ($P<0.05$) seasonal yield responses except for 2015–2016 in Kagochi. During the seasons in Timbilil, yields increased linearly with varying N-rates. The highest yields for blend A and standard NPK in all the seasons of 2013–2014, 2014–2015, warm-dry and warm-wet of 2015–2016 were observed with the highest N-rate of 225 kg N ha^{-1} yr^{-1} (Table 5). However, during cold-wet season of 2015–2016, the highest yield was observed with the lowest N-rate of 75 kg N ha^{-1} yr^{-1}. For blend B, the highest yields were observed with 150 kg N ha^{-1} yr^{-1} in 2013–2014 and 2015–2016 except for cold-wet season of 2013–2014 and the whole of 2014–2015 when they were observed with the highest N-rate of 225 kg N $ha^{-1}yr^{-1}$.

In Kagochi, yields varied with N-rates across the seasons. The highest yields for blend A except in the cold-wet season were observed with the highest N-rate (225 kg N ha^{-1} yr^{-1}) in 2013-2014 (Table 6). Similar results were obtained in the warm-dry season of 2015. The highest yields for blend A in the other seasons of 2014–2015 and all the seasons of 2015-2016 were observed with the lowest N-rate (75 kg N $ha^{-1}yr^{-1}$). The highest yields for blend B except for cold-wet season of 2013–2014 were observed with 150 kg N ha^{-1} yr^{-1}, while in 2014–2015, except for cold-wet season, the highest yields were observed with the highest N-rate. The highest yields for blend B except for cold-wet season of 2015–2016 were observed with the lowest N-rate (75 kg N $ha^{-1}yr^{-1}$). For standard NPK fertilizer in 2013–2014 and warm-wet season of 2014–2015, the highest yields were observed with the highest N-rate (225 kg N ha^{-1} yr^{-1}) while in 2015–2016, except for warm-wet season, the highest yields were observed with 150 kg N $ha^{-1}yr^{-1}$. There were rate and season significant interactions for Timbilil in 2013–2014 and 2015–2016 and for Kagochi in 2013–2014 and 2014–2015. This implies that observed effects of N-rates within the seasons behaved differently.

Seasonal Yields Due To Fertilizer Types

Tea yields as affected by different fertilizer types for the three seasons are shown in Table 5 and 6. The seasonal tea yields were not influenced by fertilizer types in both sites. However, in both sites in 2013–2014, in Kagochi in 2014–2015 and in Timbilil in 2015–2016, the seasonal yields of blend A were highest, followed by standard NPK then blend B. Blend B became the highest in 2014–2015 in Timbilil, followed by standard NPK then blend A. While standard NPK had the highest seasonal yield in Kagochi in 2015–2016, followed by blend A and the last was blend B.

DISCUSSION

Tea yields varied as the nitrogen rate increased in the two sites. The yields in Timbilil increased linearly with N-rates, while in Kagochi the yields were observed to diminish or decline with N-rates. The findings in Timbilil were corroborated by earlier investigations by Njogu et al. (2014) which showed a significant correlation of yield with nutrient levels (NPK) on tea and Chimdessa (2016) on maize. Similar findings on responses of tea yield due to N-application rates were also reported by Kamau et al. (2003), Kamau (2011), Owuor et al. (2009), Owuor et al. 2010, Njogu et al. (2014) and Tabu et al. (2015) who all confirmed that mature clonal tea requires N-fertilizers to enhance yield. However, our results in Kagochi contradicted these findings. The lower annual yields observed in Kagochi in 2014–2015 might have resulted from pruning which was done in August 2015 and reduced rains in February and September.

There were no interactions between the fertilizer types and rates indicating that the responses for the three fertilizers were similar. These results agree with the findings of Sarwar et al. (2007), who reported that ammonium sulfate and urea consistently yield good result in presence of adequate amount of potassium.

The weather and seasonal fluctuations in rainfall, temperature and humidity, whereas soil water deficits influenced seasonal yield distribution, and hence annual

Table 5. Seasonal tea yield due to fertilizer application during 2013–2014, 2014–2015 and 2015–2016 in Timbilil, Kenya.

Year	Season	Monthly tea yield (kg Mt ha^{-1}) due to different fertilizer rates (kg N ha^{-1} yr^{-1}) and types												
		0			75			150			225			
		Blended NPKS A	Blended NPKS B	Standard NPK	Blended NPKS A	Blended NPKS B	Standard NPK	Blended NPKS A	Blended NPKS B	Standard NPK	Blended NPKS A	Blended NPKS B	Standard NPK	Means
2013-2014	Warm-dry	218	233	226	313	265	286	354	373	317	383	355	399	310
	Cold -wet	114	121	105	141	141	136	167	163	161	173	170	195	149
	Warm-wet	159	187	169	218	181	180	229	218	226	234	201	253	205
			Type			Rate			Seasons			Rate * Season		
	CV (%)		18.9			18.9			11.1			11.1		
	LSD (P<0.05)		NS			70.6*			35.1*			70.1*		
2014-2015	Warm-dry	260	243	317	315	315	277	330	342	324	389	399	390	325
	Cold -wet	151	170	140	185	188	188	209	190	204	218	230	225	192
	Warm-wet	194	194	192	251	269	249	316	307	295	349	358	372	279
			Type			Rate			Seasons			Rate*Season		
	CV (%)		16.4			16.4			11.0			11.0		
	LSD (P<0.05)		NS			67.4*			38.3*			NS		
2015-2016	Warm-dry	108	114	109	158	111	132	132	157	124	178	147	186	138
	Cold -wet	53	38	41	59	57	54	54	57	43	53	55	50	51
	Warm-wet	340	346	322	385	328	341	375	435	382	412	338	429	370
			Type			Rate			Seasons			Rate * Season		
	CV (%)		29.43			29.43			17.18			17.18		
	LSD (P<0.05)		NS			75.03*			37.0*			73.9*		

*Significant at P<0.05.

Blended NPKS A = NPKS 25:5:5:4+9Ca+2.6Mg; Blended NPKS B = NPKS 23:5:5:4 +10Ca+3Mg.

Table 6. Seasonal tea yield due to fertilizer application during 2013–2014, 2014–2015 and 2015–2016 in Kagochi, Kenya.

Year	Season	Seasonal tea yield (kg Mt ha^{-1}) due to different fertilizer rates (kg N ha^{-1} yr^{-1}) and types												
		0			75			150			225			
		Blended NPKS A	Blended NPKS B	Standard NPK	Blended NPKS A	Blended NPKS B	Standard NPK	Blended NPKS A	Blended NPKS B	Standard NPK	Blended NPKS A	Blended NPKS B	Standard NPK	Means
2013–2014	Warm-dry	174	186	181	250	212	228	283	298	254	306	284	319	248
	Cold -wet	91	97	84	112	113	109	134	130	129	138	135	158	119
	Warm-wet	101	80	94	113	95	106	114	115	105	113	91	111	103
			Type			Rate			Seasons			Rate * Season		
	CV (%)		18.2			18.2			13.4			13.4		
	LSD (P<0.05)		NS			45.9*			28.5*			56.9*		
2014–2015	Warm-dry	166	149	155	208	205	191	186	205	210	214	197	188	190
	Cold -wet	117	98	103	131	114	127	120	120	120	128	121	116	118
	Warm-wet	172	158	175	218	192	183	204	188	187	217	201	203	192
			Type			Rate			Seasons			Rate * Season		
	CV (%)		19.3			19.3			8.83			8.83		
	LSD (P<0.05)		NS			49.0*			19.1*			38.1*		
2015–2016	Warm-dry	75	71	85	94	91	85	76	78	96	88	83	92	84
	Cold -wet	27	22	32	37	35	34	34	41	37	31	29	35	33
	Warm-wet	313	256	331	359	377	330	330	354	319	303	314	297	324
			Type			Rate			Seasons			Rate * Season		
	CV (%)		24.9			24.9			17.5			17.5		
	LSD (P<0.05)		NS			NS			29.0*			NS		

*Significant at P<0.05.

Blended NPKS A = NPKS 25:5:5:4+9Ca+2.6Mg; Blended NPKS B = NPKS 23:5:5:4 +10Ca+3Mg.

yields (Kamau 2008; Matthews and Stephens 1998). The highest yields in both sites were obtained during a warm-wet season, while the lowest yields were obtained during the cold-wet season. The results showed that provided soil moisture is adequate, warm temperatures lead to fast growth and hence high yields. The lower yields observed during a cold-wet season were corroborated by Owuor et al. (2010) findings. Nixon et al. (2001) also found that low temperatures caused slow growth resulting in lowered yields. Tony et al. (2016) while working in Kericho also reported that yields were low during dry seasons. However, the observed lower yields in Kagochi when compared to Timbilil could be attributed to plant density which has been found to affect yields (Tshivhandekano et al. 2013).

CONCLUSION

This study has shown that based on the annual and seasonal yield analyses, the two blended fertilizer types (NPKS 25:5:5:4+9Ca+2.6Mg plus trace elements and NPKS 23:5:5:4+10Ca+3Mg plus trace elements) are similarly effective in promoting annual tea yield as the standard NPK 26:5:5 fertilizer, irrespective of tea clones and sites.

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REFERENCES

Barnes, B. & Fortune, T. (2004) *Blending & Spreading Fertilizer-Physical Properties*.

Cheruiyot, E.K., Mumera, L.M., Ng'etich, W.K., Hassanali, A. & Wachira, F.N. (2009) High fertilizer rates increase susceptibility of tea to water stress. *Journal of Plant Nutrition*. 33 (1), 115–129. Available from: doi:10.1080/01904160903392659.

Chimdessa, D. (2016) Blended fertilizers effects on maize yield and yield components of Western Oromia, Ethiopia. *Agriculture, Forestry and Fisheries*. [Online] 5 (5), 151–162. Available from: doi:10.11648/j.aff.20160505.13.

Clewer, A.G. & Scarisbrick, D.H. (2013) *Practical Statistics and Experimental Design for Plant and Crop science.* Clewer, A.G. & Scarisbrick, D.H. (eds.) Chichester, John Wiley & Sons Ltd.

De Costa, W.A.J.M., Mohotti, A.J. & Wijeratne, M.A. (2007) Ecophysiology of tea. *Brazilian Journal of Plant Physiology*. [Online] (4), 299–332. Available from: doi:10.1590/S1677-04202007000400005.

Drinnan, J.E. (2008) *Fertiliser Strategies for Mechanical Tea Production*. Kingston, Rural Industries Research and Development Corporation. .

Kamau, D.M. (2011) Optimizing productivity of ageing tea plantations: Lessons learnt from Kenya. *Two and a Bud*. 58, 48–57.

Kamau, D.M. (2008) *Productivity and resource use in ageing tea plantations*. Wageningen University.

Kamau, D.M., Owuor, P. & Wanyoko, J.K. (2003) Long term effects of rates and types of nitrogenous fertilizers on high yielding clone AHP S15/10 tea. Pt. 1. Yields and nutrient uptake. *Tea*. 24 (1), 14–20.

Matthews, R.B. & Stephens, W. (1998) The role of photoperiod in determining seasonal yield variation in tea. *Experimental Agriculture*. [Online] 34 (3), 323–340. Available from: doi:10.1017/S0014479798343070.

Nixon, D.J., Burgess, P.J., Sanga, B.N.K. & Carr, M.K. V. (2001) A comparison of the responses of mature and young clonal tea to drought. *Experimental Agriculture*. [Online] 37 (3), 391–402. Available from: doi:10.1017/S001447970100309X.

Njogu, R.N., E., Kariuki, D.K., Kamau, D.M., Wachira, F.N. & Njogu, R.N.E. (2014) Effects of foliar fertilizer application on quality of tea (Camellia sinensis) grown in the Kenyan Highlands. *American Journal of Plant Sciences*. [Online] 5 (5), 2707–2715. Available from: doi:10.4236/ajps.2014.518286.

Ogundijo, D.S., Adetunji, M.T., Azeez, J.O., Arowolo, T.A., Olla, N.O., Adekunle, A.F. & Borek, S. (2015) Influence of organic and inorganic fertilizers on soil chemical properties and nutrient changes in an alfisol of South Western Nigeria. *International Journal of Plant & Soil Science Bangladesh*. [Online] 7 (62), 329–337. Available from: doi:10.9734/IJPSS/2015/18355.

Owuor, O.P., Kamau, D.M. & Jondiko, E.O. (2010) The influence of geographical area of production and nitrogenous fertiliser on yields and quality parameters of clonal tea. *Journal of Food, Agriculture and Environment*. [Online] 8 (2), 682–690. Available from: doi:I: https://doi.org/10.1234/4.2010.1791.

Owuor, P.O., Kamau, D.M. & Jondiko, E.O. (2009) Responses of clonal tea to location of production and plucking intervals. *Food Chemistry*. [Online] 115 (1), 290–296. Available from: doi:10.1016/J.FOODCHEM.2008.11.073.

Owuor, P.O., Othieno, C.O., Kamau, D.M. & Wanyoko, J.K. (2011) Effects of long-term fertilizer use on a high-yielding tea clone AHPS15/10: soil pH, mature leaf nitrogen, mature leaf and soil phosphorus and potassium. *International Journal of Tea Science*. 8 (1), 15–51.

Patton, M.Q. (2002) *Qualitative Research and Evaluation Methods*. 3 ed. Thousand Oaks California, Sage Publications.

Russel, F. (1995) *MSTATC Computer Based Statistical Software Package*.

Sarwar, S., Ahmad, F., Hamid, F., Khan, B. & Khurshid, F. (2007) Effect of different nitrogenous fertilizers on the growth and yield of three years old tea (Camellia sinensis) plants. *Sarhad Journal of Agriculture*. 23 (4), 907–910.

Shoji, S. (2005) Innovative use of controlled availability fertilizers with high performance for intensive agriculture and environmental conservation. *Science in China. Series C, Life sciences / Chinese Academy of Sciences*. [Online] 48 (912), 912–20. Available from: doi:10.1360/062005-282.

Sitienei, K., Home, P.G., Kamau, D.M. & Wanyoko, J.K. (2013) Nitrogen and potassium dynamics in tea cultivation as influenced by fertilizer type and application rates. *American Journal of Plant Sciences*. [Online] 04 (01), 59–65. Available from: doi:10.4236/ajps.2013.41010.

Tabu, I.M., Kekana, V.M. & Kamau, D.M. (2015) Effect of varying ratios and rates of enriched cattle manure on leaf nitrogen content, yield and quality of tea (Camellia sinensis). *Journal of Agricultural Science*. 7 (5), 175–181.

Tony, M., Samson, K., Charles, M., Paul, M., Richard, M., Mark, W., Stomeo, F., Sarah, S., Martina, K. & Francis, W. (2016) Transcriptome-based identification of water-deficit stress responsive genes in the tea plant, *Camellia sinensis*. *Journal of Plant Biotechnology*. [Online] 43 (3), 302–310. Available from: doi:10.5010/JPB.2016.43.3.302.

Tshivhandekano, I., Mudau, F.N., Soundy, P. & Ngezimana, W. (2013) Effect of cultural practices and environmental conditions on yield and quality of herbal plants: Prospects leading to research on influence of nitrogen fertilization, planting density and eco-physiological parameters on yield and quality of field-grown bush tea (Athrixia phylicoides DC.). *Journal of Medicinal Plants Research*. [Online] 7 (34), 2489–2493. Available from: doi:10.5897/JMPR12.1282.

Venkatesan, S., Murugesan, S., Senthur Pandian, V.K. & Ganapathy, M.N.K. (2005) Impact of sources and doses of potassium on biochemical and greenleaf parameters of tea. *Food Chemistry*. [Online] 90 (4), 535–539. Available from: doi:10.1016/j.foodchem.2004.05.014.