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Economic Evaluation of Foliar NPK Fertilizer on Tea Yields in Kenya

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Abstract

Economic evaluation analysis of foliar (NPK) fertilizer on tea yields was investigated on three varieties of tea grown in the Kenyan Highlands. Foliar fertilizers trial was setup on three sites, Meru, Kirinyaga and Kericho, comprising of 36 plots per site. Two foliar fertilizer types, Foliar Fertilizer 1 (FF1) and Foliar Fertilizer 2 (FF2), a positive control of Soil Fertilizer (SF) and a blank (FF0) were used to standardize the method. Yield analysis in Meru site showed significant increase (HSD=4.9, $p \leq 0.05$) after FF1 full rate application. SF had significant yield increases for all its rates from zero rate (HSD= 49, 44, 19, $p \leq 0.05$) for half, full and double rates respectively. FF2 had no yield increase after its application. The economic rates were determined to be full rate for FF1 and SF and half rate for FF2 in Kericho site; half rate for all fertilizer types Kirinyaga site; double rate for FF2 and SF and full rate for FF1 in Meru site. The profitable rates were: double rate for SF across all sites and for FF1 and FF2 in Meru site; full rate for FF1 and half rate for FF2 in Kericho and Kirinyaga sites respectively.

Keywords: tea, yields, economic evaluation, foliar fertilizer

1. Introduction

Tea, *Camellia sinensis*, is the second largest foreign exchange earner hence contributes significantly, 107 billion in 2011, to the Kenyan economy (TBK, 2010). Fertilizer is the second largest tea production cost item after plucking with significant bearing on both yield and quality of tea. Fertilizers increase the growth rate and density of harvested shoots thereby increasing yields (TRFK, 1999). Different tea clones have different genetic potentials to yield and response to nutrients supply. However, the fertilizers applied to the soil either is lost, by being bound by soil or are washed out of the root zone (Njogu et al., 2014a). In addition, nutrient imbalances for tea in the soil occur, rendering the soils moribund hence unsustainable for tea production (Ayiemba & Nyabundi, 2010). Experiments have shown that foliar fertilizer application can increase yield from 12 to 25 percent when compared to soil fertilizer application (Islam et al., 2012).

Tea productivity is 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 (De Costa *et al*., 2007), 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 (Anon, 2002). Therefore, yield components of tea are the number of plucked shoots per unit land area and the mean weight per shoot (De Costa et al., 2007).

Fertilizer recommendations are primarily based on field trials that determine the crop response (yield responses) to various rates of fertilizer applications and must optimize crop yield and quality, maximize profitability and reduce the risk of environmental pollution (Belanger et al., 2000). Data from the trials are fitted to several statistical models to describe relationships between N rates and yields, and solving the models to identify the economic optimum rates (EORs) (Kyveryga et al., 2007). The economic optimum rate is arrived at the point where the marginal cost (MC) of the fertilizer is equal to the marginal revenue (MR) per unit fertilizer (MC=MR) (Kiprono et al., 2010; Kyveryga et al., 2007). The EORs can differ with the growing conditions, locations and the clones and hence, it is important to consider the factors in the local environment that may influence production. These include yield trends and seasonal variations in a particular site. Factors affecting yields include soil properties, site, rainfall, genetic material and age of tea, year of prune, fertilizer types, rates and frequency of application (TRFK, 1999). The combination of these components allow for the estimation of the economically optimum Nitrogen rate (EONR) (Kiprono et al., 2010). To achieve the most with the recommended EONRs some factors are considered; current practice whereby EOR is more often below the current practice and use of proven crop production practices e.g. maintaining soil pH, P and K levels at optimum levels (Kiprono et al., 2010). Several studies have demonstrated the yield benefits of nitrogenous fertilizers in tea (Ayiemba & Nyabundi, 2010).The rate of N fertilizer applied to tea to achieve maximum profit shifts downward when the price of N fertilizer increases. The best rate of N to apply is the economic optimum since the last unit of N fertilizer added would result in additional yield hence paying its cost. This rate maximizes the profits obtained per unit area to farmer (Kiprono et al., 2010).

Production function relates the maximum quantity of output that can be produced given the quantities of the inputs employed and is expressed as;

$$Q = f(L, K) \quad (1)$$

Where Q is the quantity of output, L is the quantity of labor used, and K is the quantity of capital employed. The maximum quantity of output depends on the quantities of labor and capital employed. This function shows the maximum total physical product (TPP) that can be obtained using different combinations of quantities of inputs. Two other important concepts are the average physical product (APP) which is the output-input ratio for each level of variable input usage (APP= Q/L), and the marginal physical product (MPP) of an input which is the addition to TPP resulting from the addition of one unit of input, when the amounts of other inputs are constant and is expressed as $MPP = \Delta Q/\Delta L$. There are three stages involved in production; (1) increasing marginal returns where increase in inputs increase the output (TPP) at an increasing rate, (MPP>0, APP is rising and MPP>APP), (2) diminishing marginal returns whereby increase in inputs still increases total output but at a decreasing rate, (MPP>0, but APP is falling, MPP<APP), and (3) diminishing total returns where increase in input decreases total output (MPP<0, TPP is falling). Stage 2 is the relevant part of the production function for profitable production to take place (Colman & Young, 1989). To characterize productivity of inputs, marginal and average products are used where average physical product (APP), is the amount of output per unit of labor while marginal physical product (MPP) is the rate at which total output changes as the quantity of input is changed.

The level of physical output cannot always be used to predict the optimum fertilizer ratios to be used. Therefore, to determine the highest profit ratio or economic optimum fertilizer ratio to use, TPP, MPP, and APP are translated into total value product (TVP), marginal value product (MVP), and average value product AVP by multiplying the output by the market price of made tea being the current average auction price per kilogram (Kg) of made tea (Kiprono et al., 2010). Sustainability in tea production can be ensured by utilization of optimum amounts of fertilizers and this can be achieved through application of nutrients through foliage rather than soil, which has not been tested in Kenya. Moreover, no economic evaluation of foliar fertilizers has been done in tea production in Kenya.

2. Methodology

2.1 Experimental Sites

The trial was set up in September 2010, and comprised of three experimental sites which represent the geographically different major tea growing regions in Kenya (East and West of the Great Rift Valley) –Timbilil estate, TRFK, Kericho, clone TRFK 31/8; KTDA-Kangaita farm, Kirinyaga, clone TRFK 6/8; Michimikuru Ltd Co. farm, Meru, clone EPK D99/10. Each site comprised of 36plots laid in a randomized complete block design with three replications of three fertilizer types; two NPK foliar fertilizers (FF1 and FF2) and the convectional NPK soil applied fertilizer (SF).

Table 1. Location, elevation and climatic characteristics of experimental sites

Site	Clone	Latitude	Longitude	Elevation (m)	Mean Annual Temp (ºC)	Mean Annual Rainfall (mm)
Kericho	TRFK 31/8	0º 22’ S	35º 32’E	2180	16.6	2175
Kirinyaga	TRFK 6/8	0º 26’ S	37º 15’E	2020	15.5	2040
Meru	EPK DPP/10	0º 11’N	37º 51’E	1950	17.3	2379

* Source: Tea Research Foundation of Kenya weather reports.

2.2 Fertilizers and Their Application Rates

Two foliar fertilizers and one soil applied fertilizer were used in the fertilizer trial; *Maj Tea foliar* fertilizer, a water soluble formulation with the elemental composition; NPK 24:24:18 + Trace elements 0.9 MgO, 0.1625 Fe(EDTA), 0.16 Cu, 0.08 Zn, 0.0325 B, 0.0012 Mo, and 0.08 Mn (EDTA). The pH of a 10% solution was 3-4, with a density of 1.40; *T-foliar* SPS fertilizer and plant booster containing NPK 20:5:5 + S+ MgO + Trace Elements; and the soil chemically compounded fertilizer containing NPK 25:5:5. The fertilizers were coded as Foliar Fertilizer 1 (FF1) for Maj Tea foliar, Foliar Fertilizer 2 (FF2) for T-foliar and Soil Fertilizer (SF) for NPK 25:5:5. FF1 was applied at a rate of 1liter per hectare every 2 months, FF2 at a rate of 3liters per hectare every 3 months and SF applied once per year. These were considered as the Full rates of application for the respective foliar fertilizers.

The application rates for the respective foliar fertilizers were varied; Nil, Half rate, Full rate and Double rates and respectively coded as, $FF1_0$, $FF1_{½}$, $FF1_1$, $FF1_2$, and $FF2_0$, $FF2_{½}$, $FF2_1$, $FF2_2$, for Maj and T foliar fertilizer respectively, and 0, 75, 150, and 225 Kg N/ha/year for SF which was treated as the positive control. The amount of fertilizers applied for both foliar and soil fertilizers were calculated based on the number of bushes per plot and the spacing of the tea bushes. The average amounts applied per plot for each fertilizer type are shown in Table 2.

2.3 Tea Yield Measurements

The young flush of two leaves and a bud from the demarcated plots were picked and weighed per plot after every 10 to 14 days, depending on available crop. The weight for green leaf yield of each of the plots was recorded on site and converted to made tea yields using a conversion factor of 0.225 (Anon, 2000).

2.4 Statistical Analysis

All the determinations were carried out in triplicate and the data were subjected to one-way analysis of variance

(ANOVA) whereby analysis for each variable was separately done i.e. by fertilizer type (Blank, FF1, FF2, and SF) and by rates of application (zero, half, full and double). This was followed by the Tukey-Kramer range test to establish the honest significant difference (HSD) in means between the various group means at $p \leq 0.05$ confidence level. HSD is minimum distance between two group means that must exist before the difference between the two groups is considered statistically significant.

2.5 Economic Analysis

The production parameters of interest were; TPP, APP = Q/X= f(X) X, and MPP=ΔTPP/ΔX. TVP, AVP and MVP values were obtained by multiplying the corresponding values of TPP, APP and MPP with 2011's average auction price per Kg of made tea for Kenyan tea, which stood at KES 264.43. In this study, the prices of the treatments were KES 150/500 cm^3 for FF1, KES 250/1000 cm^3 for FF2 and KES 3,000 per 50 kg bag of SF (from KTDA price estimates). Fixed cost of production included the application costs, KES 100 per person per application for any treatment. Assumption was made that two people were used to apply every time.

3. Results

3.1 Tea Yields

Pair wise comparison of yields by types of fertilizers and rates of applications (Table 3) showed that in Kericho and Meru, there was significant increase in yields between zero fertilizer and $SF_{1/2}$, SF_1 and SF_2 with honestly significant difference (HSD) values of 16.8, 16.4 and 10.4 and 49.3, 22.4, 19.3at $p \leq 0.05$ for Kericho and Meru sites respectively. In Meru site, a significant increase in yields of 4.9 was obtained between zero and $FF1_1$ fertilizers. In Kirinyaga site, no significant increases in yields were obtained from any of the fertilizers at the different rates of application. In Kericho, full rates had the highest yield mean difference for FF1 (217 Mt/Ha) as compared to zero rates, while the double rates lead to decreased yields from full rates (-205Mt/Ha) which indicates the diminishing returns of FF1 beyond full rates. For FF2, the half rates had the highest yields with a mean difference of 236 Mt/Ha from zero fertilizer. The full rates and double rates led to decrease yields as compared to half rates of FF2 (-154 Mt/Ha and - 152Mt/Ha respectively) due to diminishing returns of the fertilizer, while SF's half rates had the highest mean difference from zero(631 Mt/Ha). Full and double rates led to diminished returns when compared to half rates (-15 Mt/Ha and -240 Mt/H respectively). In Kirinyaga site, half rates had higher yields mean differences for all the fertilizers when compared to the zero rates with diminished returns resulting beyond this rate. In Meru site, full rates had the highest yield mean difference for FF1 (161 Mt/Ha) against zero rates, with double rates showing diminished returns (-90 Mt/Ha). FF2, the double rates had the highest yield mean difference (327 Mt/Ha) while for SF the half rates had the highest yield mean difference as compared to zero (890 Mt/Ha) with full and double rates leading to diminished returns (-485 Mt/Ha and -541 Mt/Ha respectively).

Table 2. Amounts of fertilizer applied

Sites	Treatments	Rates	Amounts of fertilizer applied (g)	Amounts of N,P,K in each rate (g)		
				N (g)	P (g)	K (g)
KERICHO	FF1	Half	10.5	2.5	2.5	1.9
		Full	21	5.1	5.1	3.8
		Double	42	10.0	10.0	7.6
	FF2	Half	23	4.64	1.16	1.16
		Full	46	9.25	2.31	2.31
		Double	92	18.5	4.63	4.63
	SF	Half	390	97.5	19.5	19.5
		Full	780	194.9	39.0	39.0
		Double	1169	292.3	58.5	58.5
KIRINYAGA	FF1	Half	10.6	2.6	2.6	1.9
		Full	22	5.2	5.2	3.9
		Double	43	10.4	10.4	7.9
	FF2	Half	23	4.64	1.16	1.16
		Full	46	9.28	2.32	2.32
		Double	92	18.6	4.6	4.6
	SF	Half	418	104.5	20.9	20.9
		Full	836	209.0	41.8	41.8
		Double	1254	313.6	62.7	62.7
MERU	FF1	Half	13	3.1	3.1	2.3
		Full	26	6.1	6.1	4.6
		Double	52.5	12.5	12.5	9.4
	FF2	Half	27	5.6	1.4	1.4
		Full	55	11.1	2.8	2.8
		Double	111	22.3	5.6	5.6
	SF	Half	502	125.4	25.1	25.1
		Full	1003	250.7	50.1	50.1
		Double	1505	376.4	75.3	75.3

Table 3. Analysis of Yields by types of fertilizer and rates of application in Kericho, Kirinyaga and Meru sites

Site	Group (X_1) vs. Group(X_2)	Group Means (Mt/Ha)		Mean Dif (X_2- X_1)	HSD
		X_1	X_2	(Mt/Ha)	
Kericho	ZERO vs. $FF1_{1/2}$	1045	1115	70	1
	ZERO vs. $FF1_1$	1045	1262	217	3
	ZERO vs. $FF1_2$	1045	1057	12	0
	$FF1_{1/2}$ vs. $FF1_1$	1115	1262	147	2
	$FF1_{1/2}$ vs. $FF1_2$	1115	1057	-58	1
	$FF1_1$ vs. $FF1_2$	1262	1057	-205	3
	ZERO vs. $FF2_{1/2}$	1045	1281	236	2
	ZERO vs. $FF2_1$	1045	1126	81	1
	ZERO vs. $FF2_2$	1045	1129	84	1
	$FF2_{1/2}$ vs. $FF2_1$	1281	1126	-154	2
	$FF2_{1/2}$ vs. $FF2_2$	1281	1129	-152	2
	$FF2_1$ vs. $FF2_2$	1126	1129	2	0
	ZERO vs. $SF_{1/2}$	1045	1676	631	16.7996*
	ZERO vs. SF_1	1045	1661	616	16.3995*
	ZERO vs. SF_2	1045	1436	391	10.4125*
	$SF_{1/2}$ vs. SF_1	1676	1661	-15	0
	$SF_{1/2}$ vs. SF_2	1676	1436	-240	6.3871*
	SF_1 vs. SF_2	1661	1436	-225	5.9870*
Kirinyaga	ZERO vs. $FF1_{1/2}$	953	1003	50	1
	ZERO vs. $FF1_1$	953	931	-22	1
	ZERO vs. $FF1_2$	953	928	-26	1
	$FF1_{1/2}$ vs. $FF1_1$	1003	931	-72	2
	$FF1_{1/2}$ vs. $FF1_2$	1003	928	-75	2
	$FF1_1$ vs. $FF1_2$	931	928	-3	0
	ZERO vs. $FF2_{1/2}$	953	1035	82	1
	ZERO vs. $FF2_1$	953	868	-85	1
	ZERO vs. $FF2_2$	953	908	-45	1
	$FF2_{1/2}$ vs. $FF2_1$	1035	868	-167	2
	$FF2_{1/2}$ vs. $FF2_2$	1035	908	-127	2
	$FF2_1$ vs. $FF2_2$	868	908	40	1
	ZERO vs. $SF_{1/2}$	953	1241	288	3
	ZERO vs. SF_1	953	1001	48	1
	ZERO vs. SF_2	953	1081	128	2
	$SF_{1/2}$ vs. SF_1	1241	1001	-240	3
	$SF_{1/2}$ vs. SF_2	1241	1081	-160	2
	SF_1 vs. SF_2	1001	1081	80	1
Meru	ZERO vs. $FF1_{1/2}$	988	1027	39	1
	ZERO vs. $FF1_1$	988	1149	161	4.8984*

ZERO vs. $FF1_2$	988	1059	71	2
$FF1_{1/2}$ vs. $FF1_1$	1027	1149	121	4
$FF1_{1/2}$ vs. $FF1_2$	1027	1059	32	1
$FF1_1$ vs. $FF1_2$	1149	1059	-90	3
ZERO vs. $FF2_{1/2}$	988	1019	31	0
ZERO vs. $FF2_1$	988	1131	143	2
ZERO vs. $FF2_2$	988	1315	327	5
$FF2_{1/2}$ vs. $FF2_1$	1019	1131	112	2
$FF2_{1/2}$ vs. $FF2_2$	1019	1315	296	4
$FF2_1$ vs. $FF2_2$	1131	1315	184	3
ZERO vs. $SF_{1/2}$	988	1878	890	49.2607*
ZERO vs. SF_1	988	1393	405	22.4275*
ZERO vs. SF_2	988	1337	349	19.3243*
$SF_{1/2}$ vs. SF_1	1878	1393	-485	26.8333*
$SF_{1/2}$ vs. SF_2	1878	1337	-541	29.9365*
SF_1 vs. SF_2	1393	1337	-56	3

Starred values *represent significant differences at $P \leq 0.05$.

Pair wise comparison by site showed clone TRFK 31/8 and clone EPK D99/10 had significantly higher yields ($p \leq 0.05$) than clone TRFK 6/8. Correlation between first mature leaf data and yields are presented in Table 8. In Kericho, yields correlated significantly with N% r=0.453 ($p \leq 0.01$), showing that N uptake influenced yields. Nitrogen availability affects yield of tea. Its applications should be carefully managed, particularly in tea, to optimize marketable yield while minimizing environmental effects. Yields increase with higher use of nitrogen up to high levels with proportional increase in economic returns. Similar trends were noted for the other nutrients; with P% r=-0.332 ($p \leq 0.05$), K% r=-0.373 ($p \leq 0.05$) and with Mn% r=-0.372 ($p \leq 0.05$). In Kirinyaga, there were no significant correlations between nutrients and yields.

3.2 Economic Analysis

In the economic analysis studies, the economic optimum rate and the most profitable rate for each fertilizer in each site was established for foliar fertilizers (FF1 and FF2) and soil fertilizer (SF) on yield of tea in the three tea growing zones as shown in Table 4. Kericho site: For the SF fertilizer, despite the full rates and the half rates having the same Marginal Physical Product (MPP) value of 3, the Total Value Product (TVP) value for full rates (KES 365,420) was higher than the TVP value for half rates (KES 315,920) hence the full rates was the optimum application rate for this treatment. For FF1, the full rates had the highest MPP, MVP and TVP values: 1.7, 375 and, KES 251,900 respectively, as compared to other rates, hence it was the economic rate of application for this clone. On the other hand, FF2 half rate has the highest MPP, MVP and TVP values: 3.7, 821, and 281,600 respectively, hence it became the economic rate of application for this clone.

For Kirinyaga site, it was observed that for all the treatments applied to this clone, the MPP and MVP were highest at half rate: 3.5 and 768.5 for SF, 0.7 and 146.7 for FF1 and 1.1 and 240.5 for FF2 making this the economic rate for application of all the fertilizers. In Meru site, for all the fertilizers, SF, FF1 and FF2, the optimum rate to apply is the double rate. This is because they had the highest MPP and MVP values: 7.9 and 1736.5 for SF, 1.3 and 290.4 for FF1 and 3.7 and 806.7 for FF2.

Table 4. Productivity of clones TRFK 31/8, TRFK 6/8 & EPK D99/10 at different fertilizers and rates of application

	TYPE	RATES	AMT OF FERTILIZER(g)	No. OF BAGS	TOTAL COST (KES)	TPP Kg Mt/ha	MPP	APP	MVP	TVP(Gross earnings)	AVP	Gross income /ha/yr
TRFK 31/8	SF	0	0	0	0	1000	0	0	0	220000	0	220000
		75	779.6	0.02	448	1436	3	19	662	315920	4212	315472
		150	1559	0.03	490	1661	3	11	660	365420	2436	364930
		225	2338.6	0.05	544	1785	1.7	8	364	392700	1745	392156
	FF1	0	0	0	0	1000	0	0	0	220000	0	220000
		half	10.5	0.02	1402	1017	0.2	14	50	223740	2983	222338
		full	21	0.03	1405	1145	1.7	8	375	251900	1679	250496
		double	42	0.06	1409	1057	-1.2	5	-258	232540	1034	231131
	FF2	0	0	0	0	1000	0	0	0	220000	0	220000
		half	23	0.02	1205	1280	3.7	17	821	281600	3755	280395
		full	46	0.04	1210	1126	-2.1	8	-452	247720	1651	246510
		double	92	0.08	1221	1054	-1	5	-211	231880	1031	230659
TRFK 6/8												
	SF	0	0	0	0	953	0	0	0	209660	0	209660
		75	418.1	0.01	425	1215	3.5	16	769	267300	3564	266875
		150	836.1	0.02	450	1001	-2.9	7	-628	220220	1468	219770
		225	1254.2	0.03	475	1241	3.2	6	704	273020	1213	272545
	FF1	0	0	0	0	953	0	0	0	209660	0	209660
		half	10.6	0.02	1402	1003	0.7	13	147	220660	2942	219258
		full	22	0.03	1405	1030	0.4	7	79.2	226600	1511	225195
		double	43	0.06	1409	928	-1.4	4	-299	204160	907	202751
	FF2	0	0	0	0	953	0	0	0	209660	0	209660
		half	23	0.02	1205	1035	1.1	14	241	227700	3036	226495
		full	46	0.04	1210	868	-2.2	6	-490	190960	1273	189750
		double	93	0.08	1221	908	0.5	4	117	199760	888	198539
EPK D99/10												
	SF	0	0	0	0	923	0	0	0	203060	0	203060
		half	501.5	0.01	430	1370	6	18	1311	301400	4019	300970
		full	1002.9	0.02	460	1393	0.3	9	67.5	306460	2043	306000
		double	1505.5	0.03	490	1985	7.9	9	1737	436700	1941	436210
	FF1	0	0	0	0	923	0	0	0	203060	0	203060
		half	13	0.02	1403	998	1	13	220	219560	2927	218157
		full	26	0.04	1406	960	-0.5	6	-112	211200	1408	209794
		double	53	0.07	1411	1059	1.3	5	290	232980	1035	231569
	FF2	0	0	0	0	923	0	0	0	203060	0	203060
		half	27	0.02	1206	1018	1.3	14	279	223960	2986	222754
		full	55	0.05	1212	1040	0.3	7	64.5	228800	1525	227588
		double	111	0.09	1225	1315	3.7	6	807	289300	1286	288075

The profitability of the three fertilizers under study was analyzed in Table 4 above, by obtaining the gross profit/ha/year for a particular rate. In this case, the cost of production included the prices of the fertilizers and the cost of labor. For the soil SF the profitable rate was found to be the double rate for all the three clones. Double rates gave the highest gross profit/ha/year at KES 392,156, KES 272,545, and KES 436,210 for the three sites. FF1's profitable rate was the full rates for Kericho and Kirinyaga sites at a gross profit/ha/year of KES 250,496 and KES 225,195 respectively and double rates for Meru site (KES 231,569). FF2 profitable rate was the half rates for clones TRFK 31/8 with gross income/ha/year KES 280,395 and TRFK 6/8, KES 226,495 while clone EPK D99/10's was the double rates, at a gross income of KES 288,075. The rate of fertilizer applied to tea to achieve maximum profit shifts downward when the price of fertilizer increases.

4. Discussion

The present study confirms that different clones have different nutritional needs and differ in their abilities to absorb nutrients even when the agronomic practices are similar, which is depicted in their yield response to varying fertilizer application rates and the fertilizer types applied as well. This was demonstrated herein where two sites Kericho (clone TRFK 31/8) and Meru (clone EPK D99/10) showed significant yield increases while in

Kirinyaga site (clone TRFK 6/8) there is no response to any of the fertilizer types applied. Previous studies corroborate these findings where they reported varying response in yield, shoot population density, and growth of tea genotypes to different environments including temperature and altitude (Ng'etich & Stephens, 2001; Omwoyo et al., 2014; Owour et al., 2011). Clone TRFK 31/8 and clone EPK D99/10 are known to be cold and drought resistant while clone TRFK 6/8 is not and this may explain the unresponsiveness of clone TRFK 6/8 during this trial period which was occasioned by cases of hail, frost and drought. From Table 2, the composition of the 3 fertilizers types differed markedly with the SF fertilizers having higher amounts of the NPK as compared to the foliar fertilizers which could explain the higher yields. For instance, in Kericho, the composition of applied fertilizers for half rates was 2.5 g N, 1.5 g K and 1.9 g P for FF1; 4.6 g N, 1.2 g K and 1.2 g P for FF2; and 97.5 g N, 19.5 g P, and 19.5 g K for SF. The rate of change in yields indicated that although the fertilizers were applied at different times and rates, and yields varied significantly, the overall patterns (month to month) of change in yields were similar for each site. This was corroborated by (Drinnan, 2008), who reported that though yields varied significantly between farms and between years, the overall patterns of growth were quite similar in his study. Aside from the nutrients applied, weather elements also greatly influence yields, produced from month to month (Owour et al., 2011), as was observed in this study. There were severe cases of frost and drought which led to very low or no yields in some months. From on-site weather stations, the relative humidity was particularly low, which could have led to 'banjhi' buds, thereby explaining the low yields. Results from a parallel investigation showed significant correlation of yield with nutrient levels (NPK) applied (Njogu *et al.*, 2014a), and also significant increases in levels of total polyphenols for foliar fertilizer applied plots more than SF, and this was notwithstanding the considerable lower amounts of foliar fertilizers applied as compared to the control SF by a factor of 1:5:107 (FF1:FF2: SF) per hectare (Njogu et al., 2014b).

Studies have shown little direct relationship between attainable yield and the most economic which may be due to large variations in residual soil N due to continuous application of nitrogenous fertilizer over the years (Kiprono et al., 2010), which could have hindered accurate attainment of EONR especially for the foliar fertilizers. However, the findings herein can be utilized in the harmonizing the rates (through adjusting the actual amounts of fertilizers applied upwards) in order to establish a universal optimal rate for foliar fertilizers that does not compromise on quality. This would in turn reduce the frequency of application (FF1 was applied every 2 months, FF2 every 3 months as compared to SF applied yearly) and consequentially maximize productivity and profitability.

5. Conclusion

There was significant yield increases after application of FF1 full rate (HSD=4.9, $p \leq 0.05$), SF's half, full and double rates (HSD= 49, 44, 19, $p \leq 0.05$ respectively) in Meru site, and SF's half, full and double rates (HSD= 17, 16, 10 $p \leq 0.05$ respectively) in Kericho site. Yields vary largely due to genotypes, environment and management.

The most economic fertilizer rates differed with growing conditions and clones. The economic rates were determined to be full rate for FF1 and SF and half rate for FF2 in Kericho site; half rate all fertilizer types Kirinyaga site; double rate for FF2 and SF and full rate for FF1 in Meru site. The profitable rates were: double rate for SF across all sites and for FF1 and FF2 in Meru site; full rate for FF1 and half rate for FF2 in Kericho and Kirinyaga sites respectively.

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