Optimization of *Camellia sinensis* Crop Productivity by Use of Blended Fertilizers

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Abstract: Tea (*Camellia sinensis*) is the top foreign exchange earner in Kenya. Its demand is relatively high and this has triggered increased production. Manufacturing companies have also stiff competitions amongst themselves on the aspect of branding. However, for quality assurance and high productivity, the nature of fertilizer in regard to its nutrients has played a major role. This study investigated the effects of blended NPK (Nitrogen:phosphorus:potassium) fertilizer on tea crop productivity in different growing regions of Kenya. The optimum sustainable rate of fertilizer application was also determined. Different rates of 0, 75, 150 and 225 Kg/ha/Yr (kilogram per hectare per year) were used. A randomized complete block design was applied and the sample clone was Tea Research Foundation of Kenya (TRFK) 6/8. The samples, composed of two leaves and a bud, were randomly picked, dried and ground into powder. Each sample was heated to ash in a muffle furnace, cooled and digested using 50% double acid of HNO₃ and HCl with H₂O₂. Desorption was done using HCl and samples allowed to settle before being aspirated into an Inductively Coupled Plasma - Optical Emission Spectrometer (ICP-OPS). They were reweighed and digested for determination of total percentage nitrogen.; This was followed by distillation before titration with ammonium borate solution and HCl. Data analysis was done using MSTAT statistical package. The results revealed that the percentage accumulation of elements was highest when blended fertilizer was applied at a lower rate of 75 Kg N/ha/Yr compared to standard compounded fertilizer, which required higher rates of up to 225 Kg N/ha/Yr. for accumulation of nutrients. Blended fertilizer was therefore found to be more economical and highly yielding than Standard compounded fertilizer, as a lower rate of application still led to higher accumulation of elements which is directly proportional to higher yield and quality in tea.

Keywords: Camellia Sinensis, Fertilizer, Tea, Productivity, Desorption

1. Introduction

Kenya is a major producer of black tea (*Camellia sinensis*). Currently, it is ranked first before China and India in tea production. The country’s tea has won international acclaim for its taste and aroma [1]. It has been proved to have higher levels of antioxidants [2, 3, 4]. Consequently, there is stiff competition among companies when it comes to brand [5].

One of the best bet practices for intensive production of tea is regular application of fertilizers. [6, 7, 8]. Tea fertilizers is available commercially in many physical and chemical forms [9]. 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 pills or chips, which have no chemical reaction [10, 11]. 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 [9].

The quality of tea also influences both local and international markets. The parameter mainly depends on the standard of the green leaf, and this is affected by the type of fertilizer used [5]. Hence, there is need for evaluation of blended fertilizers to establish their effectiveness in order to fully adopt them. In this study, a blended NPK (nitrogen,
phosphorus, potassium) fertilizer with a formulation of 29:5:5 from one of the leading fertilizer producing companies in Kenya, MEA, was evaluated. Fertilizer blending (bulk blending) is a technical process that offers a customized balance by adjusting fertilizer inputs to crop requirements. In the right proportion, the blend must provide major nutrients (nitrogen, phosphorus, potassium), Secondary nutrients (calcium, sulphur, molybdenum, sodium) and micro-nutrients (iron, manganese, molybdenum, copper, boron, zinc, cobalt) [12].

Although Kenya is the leading producer of tea, processing costs compounded with lowered prices discourage growers. Hence, farmers continually seek better production techniques which would increase yields and reduce the costs of production. Some of these techniques include Best Management Practices (BMP) for fertilizer application. This is because fertilizer is the second most expensive input after plucking costs [13]. Thus, in order to make fertilizer production more economically viable, it would be prudent to use readily available fertilizer formulations with high efficacy. The study focused on effects of MEA blended NPK fertilizer (29:5:5) formulation on the yield and nutrients of Camellia sinensis crop compared to the standard compounded fertilizer NPK (25:5:5) formulation [9].

Mineral substances contained in green Camellia sinensis leaf and in finished products, constitutes about 5-6% of dry matter. Among them are potassium, phosphorus, calcium, magnesium, Sulphur, iron, manganese and fluoride [14]; [15]; [16]. There is a direct correlation between the quality of tea and the content therein of soluble mineral substances. For instance, studies indicate that high rates of sulphate of ammonia improve the quality of green Camellia sinensis [16]. With the aging of the plant, total number of minerals increases while the most valuable part of the soluble mineral substances reduces [16]. The potassium content in the Camellia sinensis leaf is 50-60% of all mineral substances. The crop has a moderate to high requirement for potassium [17]. However, high levels of potassium reduces the amounts of aflavins and arubigins in leaves leading to reduction in quality [17]; Phosphorus content in Camellia sinensis ranges from 15-20% of weight of all mineral substances [15]. The top two-leaves-and-bud part (2+B) has higher content of phosphorus compared to the lower coarse of the leaves and stems [18].

Nitrogen is a critical nutrient for Camellia sinensis production as yield depends mainly on the Camellia sinensis foliage [19]. Yields increase with increased use of nitrogen fertilizer up to optimum levels, with proportional increase in economic returns [5]. Optimal Nitrogen rates of Camellia sinensis vary depending on clones, location and usually range from 75 to 150 Kg N/ha/yr. However, it has been reported that the quality of made tea from clones and hybrid seedlings is highest at a nitrogen application level of 100Kg N/ha. As Nitrogen levels increased above this level the quality decreased [16]. Caffeine content in Camellia sinensis has been reported to increase in line with growth rate, which is also influenced by application of Nitrogen and Potash fertilizers [2]. Its availability affects yield of Camellia sinensis, and its applications should be carefully managed, to optimize marketable yield while minimizing environmental effects.

The range of NPK formulae already familiar to the Kenyan Camellia sinensis industry (25:5:5) [9], contain nitrogen in two forms, ammonium and nitrate, often in the ratio 2:1. It is not known whether the forms of these nutrients, have any influence on the value for Camellia sinensis. In the current situation where compound fertilizers are available at varying formulations and competitive prices, it is not envisaged that farmers would like to make their own mixtures. In addition, there is a commercial company (MEA Ltd), which specializes in the bulk blending of fertilizer and can produce any formulation desired by the farmer [20, 21]

2. Materials and Methods

2.1. Study Area

The research study was conducted in one of the Kenya Agricultural and Livestock Organization (KALRO) institutes, Tea Research Institute (TRI) in Kericho County.

2.2. Research Design

A completely randomized block design of a 10 by 8 plot size with 80 plants per plot, including guard rows [99 plants] with three replications of each fertilizer rates: 0, 75, 150, and 225Kg N/ha/year, was used. The clone which was planted in Kericho was TRFK 6/8 with spacing of 5x2.5 ft. the experimental treatments are shown on tables 2 and 3.

| Fertilizer rate Kg N/ha | Treatment Code |
|------------------------|----------------|
| 0                      | NPK 0 (1M)     |
| 75                     | NPK 75 (2M)    |
| 150                    | NPK 150 (3M)   |
| 225                    | NPK 225 (4M)   |

Table 1. Experimental treatments.

Key: M-MEA; S-standard

| Code | Plot (rep 1) | Code | Plot (rep 2) | Code | Plot (rep 3) | Code |
|------|-------------|------|-------------|------|-------------|------|
| 4M   | 9           | 2S   | 17          | 1M   | 18          |
| 2S   | 10          | 1M   | 18          | 3S   | 3           |
| 1M   | 11          | 4S   | 19          | 2M   | 20          |
| 4S   | 12          | 3S   | 21          | 2M   | 22          |
| 3M   | 13          | 3S   | 23          | 4M   | 24          |
| 3S   | 14          | 2M   | 15          | 1S   | 23          |
| 2M   | 15          | 1S   | 23          | 4M   | 24          |
| 3M   | 16          | 3S   | 23          | 4M   | 24          |

Table 2. Experimental Plan and Treatment randomization.

2.3. Collection of Samples

A total of 16 Camellia sinensis samples were used for the research study. The leaf samples were collected in the Field No. 5B in Tea Research Institute (TRI)-Kericho by hand plucking of 2 leaves and a bud of young Camellia sinensis, in conformity with standard practice of Good Agricultural
particles were obtained. 0.1g of each milled sample was poured into the reservoir. Ammonia was distilled in to the before lifting it, and the hydroxide (caustic soda) was run into the still and quickly replaced with the stopper to avoid the ammonia gas escaping after which water was finally poured into the flask. The distillate was then ready for titration. The process of distillation; continued until all the samples were finished. The blank was prepared by dissolving the catalyst in 1ml of concentrated Sulphuric acid and heated until the catalyst had dissolved. It was removed and cooled after which 2ml of distilled water was then added and the solution was distilled. The sample distillate was subjected to titration as follows. 0.3g Analar borax was weighed accurately and dissolved in distilled water then diluted to 50ml. 10ml of borax solution was pipetted into a conical flask, and 1 drop of the Conway indicator was added into the flask and titrated with HCl (N/28 HCl). The end point was judged by comparing the color change with the color of 50ml of reference solution plus one drop of Conway indicator. HCl was run until the two solutions showed the same color. N/28 HCl was run into the sample distillate in the conical flask until the indicator just turned pink. The blank distillate was titrated last.

2.7. Data Analysis

The data obtained was analyzed using MSTAT statistical package and Microsoft Excel for calculation of averages and graphical representation.

3. Results and Discussion

Table 3 below shows the accumulation of nitrogen phosphorus and potassium in two-leaves-plus-bud (2+ B) samples. These results were also presented in form of a bar graph as shown in figure 1.

Based on these the results, the highest percentage accumulation of nitrogen in the two leaves and a bud samples occurred when MEA blended fertilizer NPK 29:5:5 formulation was applied at the rate of 75 Kg N/ha/Yr. and when the Standard compounded fertilizer 25:5:5 formulation was applied at the rate of 150 Kg N/ha/Yr.

Table 3. Accumulation of nitrogen, phosphorus and potassium in two-leaves-and-bud aerial part of Camellia sinensis.

| Fertilizer type | MEA  | STD  |
|-----------------|------|------|
| Nitrogen (N)    |      |      |
| 0               | 4.212| 4.090|
| 75              | 4.227| 3.387|
| 150             | 4.192| 4.017|
| 225             | 4.021| 4.003|
| Phosphorus (P)  |      |      |
| 0               | 0.843| 0.900|
| 75              | 0.927| 0.873|
| 150             | 0.847| 0.847|
| 225             | 0.853| 0.927|
| Potassium (K)   |      |      |
| 0               | 1.940| 2.120|
| 75              | 2.367| 2.243|
| 150             | 2.167| 2.013|
| 225             | 2.110| 2.54  |
| Mean fertilizer type | 2.392| 2.330 |
Nitrogen in the MEA Blended fertilizer accumulated at a lower rate compared to that of the standard NPK fertilizer (figure 1). This is, therefore, more economical to any Camellia sinensis grower. Moreover, higher accumulation of nitrogen in the two leaves and a bud has a great impact to Camellia sinensis yield, as nitrogen is responsible for the vegetative growth of the crop to enable growth of more tender shoots that will be plucked. Furthermore, it was observed that the highest percentage accumulation of Phosphorus in the two leaves and a bud was when MEA blended fertilizer was applied at the rate of 75 Kg P/Ha/Yr compared to Standard compounded Fertilizer applied at the rate of 225 Kg P/Ha/Yr (table 3). Besides, its impact on normal growth and maturity, accumulation of Phosphorus at a lower rate is still economically viable to any Camellia sinensis farmer.

The highest percentage accumulation of Potassium in two leaves and a bud was when MEA blended fertilizer was applied at the rate of 150 Kg K/Ha/Yr which is a lower rate too compared to that of Standard fertilizer which was applied at the rate of 225 Kg K/Ha/Yr. This accumulation further increases plant resistance to diseases allowing the farmer to harvest more.

![Figure 1. Graphical representation of results for two leaves and a bud samples.](image)

There was an equivalent highest percentage accumulation of Nitrogen in mature leaf samples for fertilizers at the rate of 225 Kg N/Ha/Yr (table 4 and figure 2). This implies that nitrogen only accumulated in the mature leaf after a longer period of fertilizer application or with a higher rate of treatment. Accumulation of nitrogen on the mature leaf has very little significance on the yield of Camellia sinensis. Its significance comes in during Nitrogen mobility from the mature leaves to the tender shoots, where it will then lead to vegetative growth of the tender shoots for higher yield. Therefore, this has minimal if no negative economic impact to the farmer.

The highest percentage accumulation of Phosphorus and Potassium in mature leaf was when MEA blended fertilizer was applied at a lower rate of 75 Kg P/Ha/Yr. than that of Standard fertilizer which was applied at the rate of 225 Kg P/Ha/Yr.

![Figure 2. Graphical representation of results for mature leaf samples.](image)

| Fertilizer type | Fertilizer rates | MEA | STD |
|----------------|-----------------|-----|-----|
| Nitrogen (N)   | 0               | 2.992 | 2.547 |
|                | 75              | 2.714 | 2.727 |
|                | 150             | 2.173 | 2.770 |
|                | 225             | 2.985 | 3.053 |
| Phosphorus (P) | 0               | 0.725 | 0.660 |
|                | 75              | 0.943 | 0.633 |
|                | 150             | 0.986 | 0.627 |
|                | 225             | 0.650 | 0.647 |
| Potassium (K)  | 0               | 1.940 | 2.120 |
|                | 75              | 2.219 | 2.243 |
|                | 150             | 2.867 | 2.013 |
|                | 225             | 2.110 | 2.540 |
| Mean fertilizer type | | 1.942 | 1.882 |

Generally, the highest percentage accumulation of the Standard fertilizer in two leaves and a bud were those of Phosphorus and Potassium, while the lowest percentage accumulation of the standard fertilizer in two leaves and a bud was that of Nitrogen. This negatively affects the yield of Camellia sinensis as Nitrogen is responsible for vigorous vegetative growth to obtain more tender shoots that are hence plucked and the lower the Nitrogen accumulation, the lower the yield and quality.

MEA blended fertilizer, unlike the Standard fertilizer, allowed for the accumulation of Nitrogen in the tender shoots (two leaves and a bud). This is important because accumulation of more nitrogen in the tender shoots that are plucked, leads to production of high quality Camellia sinensis, higher Camellia sinensis yield and vigorous vegetative growth with a greener color.

From the mean obtained, as shown in the tables 3 and 4, MEA blended fertilizer had a higher mean of percentage accumulation of nutrients in both 2 + B and mature leaf samples, which is directly proportional to higher yields. Furthermore, table 3 showed that there was highest percentage accumulation of elements in the two leaves and a bud when it was treated with MEA Blended fertilizer at the rates of 75, 75 and 150 Kg N/Ha/Yr. whereas when the two leaves and a bud were treated with Standard fertilizer, there
was highest percentage accumulation of elements in the following treatment rates; 150,225 and 225 Kg N/ha/year.

Highest percentage accumulation of elements in the mature leaf when treated with MEA blended fertilizer, was seen in the following treatments; 225, 75 and 75 Kg N/ha/Yr. whereas when the mature leaf was treated with Standard fertilizer, the highest percentage accumulation of elements was seen in the following treatments; 225,225 and 150 Kg N/ha/Yr. This means, there was highest percentage accumulation of elements in the 2 + B when MEA blended NPK 29:5:5 fertilizer was applied at an average lower rate of 112 Kg N/ha/Yr. compared to Standard compounded NPK 25:5:5 fertilizer which required averagely higher rates of treatment of up to 200 Kg N/ha/Yr. for accumulation. MEA Blended fertilizer averagedly accumulated in the mature leaf at a rate of 125 Kg N/ha/Yr, while STD fertilizer accumulated at a rate of 200 Kg N/ha/Yr.

Lastly, previous findings on NPK Fertilizer application have shown that the quality of made tea is highest when NPK fertilizer is applied at a rate of at most 100 Kg N/ha/Yr.; From the results above, MEA Blended fertilizer was found to be closer to this rate compared to the Standard fertilizer which was double.

4. Conclusion

In conclusion, MEA Blended fertilizer is highly yielding yet more economically viable than the Standard compounded fertilizer, as there is higher percentage accumulation of elements when the MEA blended fertilizer is applied at an average lower rate of 112 Kg N/ha/Yr. compared to Standard compounded fertilizer, which had to be applied at an average treatment of 200 Kg N/ha/Yr. to bring the same effect. A sustainable rate of 75 Kg N/ha/Yr. was also obtained for the MEA Blended fertilizer, as it is closer to the recommended rate of NPK Fertilizer application of 100Kg N/ha/Yr.

Tea growers should take into consideration the use of Blended NPK 29:5:5 fertilizer formulations for higher yields at a lower cost of production. Additionally, further studies should be done on the blended fertilizers with different fertilizer formulations to optimize productivity of *Camellia sinensis*.

**List of Abbreviations and Acronyms**

| Abbreviation | Description |
|--------------|-------------|
| 2 + B        | 2 leaves and a bud |
| TRI          | Tea Research Institute |
| TRFK         | Tea Research Foundation of Kenya |
| ICP-OES     | Inductively Coupled Plasma - Optical Emission Spectrometer |
| KALRO       | Kenya Agricultural and Livestock Research Organization |
| NPK          | Nitrogen: Phosphorus: Potassium |
| STD          | Standard |
| LSD          | Least Significant Differences |
| C.V          | Coefficient of Variance |
| GAP          | Good Agricultural Practices |
| BMP          | Best Management Practices |
| KTDA         | Kenya Tea Development Agency |
| N/ha/yr      | Nitrogen Per Hectare Per Year |
| P/ha/yr      | Phosphorus Per Hectare Per Year |
| K/ha/yr      | Phosphorus Per Hectare Per Year |

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**References**

[1] S. Van Der Wal. Sustainability issues in the tea sector: A comparative analysis of six leading producing countries. 2008.

[2] A. B. Sharangi. Medicinal and therapeutic potentialities of tea (*Camellia sinensis* L.). Food Research International Volume 42, Issues 5–6, June–July 2009, Pages 529-535.

[3] N. P. Seeram, S. M. Henning., Niu, Y., Lee, R., Scheuller, H. S., & Heber, D. (2006). Catechin and caffeine content of green tea dietary supplements and correlation with antioxidant capacity. Journal of Agricultural and Food Chemistry, 54 (5), 1599–1603.

[4] L.-S. Lee, S.-H. Kim, Y.-B. Kim, Y.-C. Kim. Quantitative analysis of major constituents in green tea with different plucking periods and their antioxidant activity. Molecules, 2014, 19 (7), 9173–9186.

[5] N. K. Fageria, V. C Baligar. Enhancing nitrogen use efficiency in crop plants. Advances in Agronomy, 2005, 88, 97–185.

[6] Cheruiyot, E.; Mumera, L.; Ng’etich, W.; Hasanali, A.; Wachira, F. (2009). High Fertilizer Rates Increase Susceptibility of Tea to Water Stress. Journal of Plant Nutrition 33: 115-129.

[7] Drinman, E. (2008) Fertilizer Strategies for Mechanical Tea Production. RIRDC Publication No. 08/030.

[8] 5 Owuor, P. O.; Othieno, C. O.; Kamau, D. M.; Wanyoko, J. K. (2012). Effects of long-term fertilizer use on a high yielding tea clone AHP S15/10: Soil pH, mature leaf nitrogen, mature leaf and soil phosphorus and potassium. International Journal of Tea Science, 8 (1): 15-51.

[9] Sitienei K, Kamiri HW, Nduru GM, Kamau DM, Nyabundi WK, Morogo M. Effects of Blended Fertilizers on Yields of Mature Clonal Tea grown in Kenyan Highlands. International Journal of Tea Science 2019; 14 (1):36-43.

[10] Barnes B. and Fortune T. (2014). Blending & Spreading FertilizerPhysical Properties.

[11] Beegle D. (1985). Comparing Fertilizer Materials. Agronomy sheet 6. Penn State extension.

[12] E. Anitha, V. Praveena, N. G. Ramesh Babu And P. Manasa Enumeration Of Foliar Fertilizer Efficiency In India’s Top Commercial Crop-Tea International Journal Of Innovative Research In Science, Engineering And Technology. Vol. 2, Issue 12, December 2013.
[13] D. J. Connor, R. S. Loomis, K. G Cassman. Crop ecology: productivity and management in agricultural systems. Cambridge University Press, 2011.

[14] M. Salahinejad, F. Aflaki. Toxic and essential mineral elements content of black tea leaves and their tea infusions consumed in Iran. Biological Trace Element Research, 2010, 134 (1), 109–117.

[15] T. Karak, R. M Bhagat. Trace elements in tea leaves, made tea and tea infusion: A review. Food Research International, 2010, 43 (9), 2234–2252.

[16] P. O. Owuor, D. M., Kamau, S. M., Kamunya, S. W. M.; Somba, M. A. Uwimana, A. W. Okal; B. O. Kwach. Effects of genotype, environment and management on yields and quality of black tea. In Genetics, Biofuels and Local Farming Systems 2011, pp. 277–307. Springer.

[17] B. K. Yadav, A. S. Sidhu. Dynamics of potassium and their bioavailability for plant nutrition. In Potassium solubilizing microorganisms for sustainable agriculture, Springer, 2016 pp. 187–201.

[18] S. B. Sharma, R. Z. Sayyed, M. H. Trivedi, T. A. Gobi. Phosphate solubilizing microbes: sustainable approach for managing phosphorus deficiency in agricultural soils. SpringerPlus, 2013, 2 (1), 587. Z.-H. Wang.; S. X. Li.; B. A. Stewart. Responses of crop plants to ammonium and nitrate N. In Advances in agronomy. 2013, Vol. 118, pp. 205–397.

[19] R. N. Roy, A. Finck, G. J. Blair; H. L. S. Tandon. Plant nutrition for food security. A Guide for Integrated Nutrient Management. FAO Fertilizer and Plant Nutrition Bulletin, 2006, 16, 368.

[20] B. R. Bunt. Media and mixes for container-grown plants: a manual on the preparation and use of growing media for pot plants. Springer Science & Business Media, 2012.

[21] O. Miserque and E. Pirard. Segregation of the Bulk Blend Fertilizers. Chemometrics and Intelligent Laboratory Systems. 2004, 74 (1), pp. 215-224.