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Effects of foliar fertilisers containing magnesium, copper and zinc on yield and quality of mature tea

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Abstract: Tea production in Zimbabwe has been steadily declining over years mainly due to soil acidification which leads to poor solubility and availability of plant nutrients. There is therefore need to supplement soil nutrients with foliar fertilizers to improve on quantity and quality of tea. In order to address this, an experiment was conducted at Southdown estate, Chipinge, Zimbabwe, to assess the effect of foliar fertilizers containing copper, magnesium and zinc on yield and quality of tea (Benjani variety).The experiment was laid out in a randomized complete block design with 3 replications. The treatments were; no foliar fertilizer application (control), 1% copper sulphate, 1.25kgzinc oxide, 1.25kg magnesium oxide and a combination of 1.25kgmagnesium oxide +1.25kgzinc oxide and 1% copper sulphate.Application of zinc oxide resulted in the highest tea shoot yield which was 70% higher than that of the foliar fertilizer that contained copper sulphate which recorded the least tea shoot weight. However magnesium oxide did not have a significant effect on yield of tea. Zinc oxide also resulted in the highest tea shoot densityof 25.75shoots/m^2 which was 27% more than that of copper sulphate which recorded the least shoot density. Tea quality parameters (brightness, briskness, colour of liquor, strength of liquor and milk take) were affected significantly ($P<0.05$) by the different foliar fertilizers. 1% copper sulphate gave the highest scores for most quality parameters followed by zinc oxide and then magnesium oxide whilst no foliar fertilizer application (control) gave the lowest total score. It can be concluded that application of 1% copper sulphate is only ideal when aiming on improving quality of tea but it results in yield reduction of tea. It is recommended that farmers usezinc oxide as foliar fertilizer to improve both yield and quality of tea.
Keywords: Tea, foliar fertilizers, yield, quality

INTRODUCTION

The Zimbabwean tea growing sector comprises of large scale farms supported by surrounding smallholder out-grower schemes [1]. Tea growing has been reported to give highly competitive returns in most countries. Most small scale farmers prefer tea to other land uses because of a number of reasons, including that of higher returns, lower risk, use of barren or sloppy lands and long term returns [2]. As a result, tea production seems an attractive venture for smallholder farmers as it provides work and income throughout the year for many years. In Zimbabwe, tea industry plays a vital role in the economy. The total land under tea in Zimbabwe currently stands at about 10 000 hectares. Tea production is responsible for a total direct employment of about 17 000, supporting up to 76 000 people in Zimbabwe [3]. Zimbabwe exports 77, 2% of the total tea produced in the country, bringing in up to $4, 5 million worth of foreign currency annually. Tea production in Zimbabwe makes up about 1, 3% of the total global tea and is amongst the world's leaders in productivity [4].

Despite the profitability associated with tea production, tea production in Zimbabwe, especially by smallholder farmers has been steadily declining in recent years with a majority of farmers abandoning tea production as a commercial enterprise in favour of annual crops like sweet potatoes, sugar beans, maize and horticultural crops. The decline in quality and quantity of tea is as a result of serious productivity challenges which include drought stress and high costs of inputs [1]. In Zimbabwe the major challenge in tea production is soil acidification [1, 5] which leads to poor solubility and availability of plant nutrients. Tea soils mostly become acidic due to fertilization with nitrogenous fertilizers which include ammonium nitrate and urea [6]. Soil pH survey done to tea soils in Zimbabwe and Malawi by Nyasulu [5] showed a low pH status in Zimbabwean soils. The majority of Zimbabwean soils showed some pH levels below 4.5 which lead to unavailability of nutrients such as copper, magnesium and zinc to the crop. It has been reported that most tea plantations in Zimbabwe are deficient in micronutrients such as sulphur, zinc, boron, copper, iron and magnesium and this contributes to a reduction in yield and quality of tea [7].

In Zimbabwe, the current fertilizer recommendations for tea production mainly focuses on the macronutrients which are nitrogen, potassium and phosphorous while very little attention is given to

nutrients like magnesium, zinc and copper. There is need to find ways to replenish these micro nutrients since they do play a pivotal role in improving yield and quality of tea[8] since neglecting them leads to their deficiencies in tea plantations [9]. The objective of this study was to determine the effects of copper, magnesium and zinc foliar fertilizers on yield and quality traits of tea in Zimbabwe.

MATERIALS AND METHODS

The experiment was carried out at Southdown Estate (32°42' S, 20°27'E, and 765m above sea level), located 41km east of Chipinge town along eastern border road. Temperature for this area ranges from a minimum of 15^0C in winter to a maximum of 29^0C in summer. Southdown Estate is in Natural region 1; the average rainfall received is 1 305mm/annum. The area is characterised by sandy loam soils on higher slopes and black clay soils on the lower valleys. The soils are acidic, pH ranging from 3 to 5 resulting in a relatively poor nutrient status. These soils are not suitable for cultivation and are largely used for forestry and the growing of tree crops, especially tea and coffee [10].

The experiment was laid in a Randomised Complete Block Design (RCBD) with 4 replicates and slope was the blocking factor. The experiment consisted of 5 treatments (Table 1). Each experimental plot comprised of a total of 111 bushes with an in-row spacing of 0.75m and inter- row spacing of 1.2m giving a plant population of 11 111plants/ ha. To guard against drift, there were 4 border rows which separated one plot from another.

Table 1: Treatment combinations of different foliar fertiliser application

Treatment	Description
1	No fertiliser application (control)
2	1% copper sulphate(4.35kg Cu ha^{-1})
3	1.25kg/ha zinc oxide(1kgZn ha^{-1})
4	1.25kg/ha magnesium oxide(1kgMg ha^{-1})
5	1% copper sulphate (4.35kgCu ha^{-1}), 1.25kg/ha zinc oxide (1kgZn ha^{-1}), 1.25kg/ha magnesium oxide(1kgMg ha^{-1})

In the experiment, mature tea of a high yielding variety Benjani was used. The crop was planted in 1980. The tea was under a three year pruning round so as to maintain the plucking table height of (60 – 100cm). Copper was applied as copper sulphate, zinc as zinc oxide while magnesium was applied as magnesium sulphate (Table 1). Application of the different foliar fertilizers was done using a knapsack calibrated according to Rattan [11] and this was done to ensure even distribution of the foliar fertilizers and the application of the correct dose. Spraying was done once a month starting from July 2013 to November 2013. Spraying of the foliar fertilizers was done in the morning to prevent it from volatilization due to heat in the afternoon and was also done immediately after plucking. No surfactants were used in this experiment. Besides the foliar fertilizers applied, Compound T (26:6:10) was applied twice at a rate of 500kgs (130kgsN) per hectare as a basal fertiliser in November 2012 and February 2013 using the broadcasting method. The tea was exclusively rain fed and the total rainfall received for the 5 months under study was 511mm.The experimental plots were kept weed free. Harvesting was done using shear machines on tender shoots which are 2 leaves and a bud and 3 leaves and a bud. Harvesting was done at every 12^{th} or 13^{th} day after foliar fertilizer spray. The plucked shoots were weighed and transported to the factory. Processing was done at Southdown Estates factory. The freshly plucked shoots were loaded in withering troughs. Ambient air was passed through the leaves for 18 hours to bring about adequate physical and chemical withering. The withered leaves were passed through a mini CTC (Crush, Tear and Curl) machine for maceration (disruption of the intracellular compartments). The macerated leaf (dhool) was fermented (oxidised by an oxidative enzyme called polyphenol oxidase) for 30, 90 and 120 minutes at 20, 25 and 30 ˚C. Fermentation was done in environmentally controlled units. Fermentation was terminated by drying in a miniature fluid bed dryer to a final moisture content of 3%.

From each experimental plot, leaf samples were collected at random from 20 bushes and these leaf samples comprised of the second and the third leaf from the top of the shoots. The samples were sent to TRFCA for nutrient analysis; macronutrients (N, P, K and Mg) and micro nutrients (B, Cu, Fe and Zn). The nutrients were analysed using standard methods of analysis adopted from the Laboratory.

DATA COLLECTION AND ANALYSIS

Tea shoot weight (kg/ha) was determined using a scale at each plucking round of which there were a total of 11 plucking rounds in this experiment. Only the harvestable shoots (2 leaves and a bud and 3 leaves and a bud). The weighed mass was converted to made tea yield by multiplying the unprocessed tea weight by 22%, according to Grice [12]

Tea shoot density was also determined. Firstly a $50cm^2$ quadrant was thrown randomly on the plucking table in each plot and the number of harvestable shoots in the quadrant was counted. The quadrant was thrown 4 times in each plot and the average number of harvestable shoots was calculated. Shoot density was then calculated using the following formula:

$$\text{Shoot density/m}^2 = \frac{\text{number of shoots}}{\text{land area}}$$

Made tea quality

A sample of 2kg green leaf from each plot was collected every month from July to November. Each of the samples was processed into black tea in the Mini Processing Unit at Southdown estate factory. From the processed tea a sample of 100g from each plot was taken for sensory evaluation and this was done by professional tea tasters of Southdown Estate. The parameters that were evaluated are: brightness, briskness, colour of infusion, colour with milk and strength of the tea. The evaluation was done using a tea tasters scoring scale (Table 2).

Table-2: Black Tea Score Sheet

Briskness	5. Very brisk 4. Brisk 3. Fairly brisk 2. Not brisk 1. Coarse
Brightness	5. Very bright 4. Bright 3. Fairly bright 2. Dull 1. Greenish
Strength of Liquor	5. Pungent 4. Strong 3. Fair strength 2. Soft 1. Harsh
Colour of Liquor	5. Coppery 4. Very bright 3. Bright 2. Fairly bright 1. Dull
Milk take	5. Creamy 4. Very thick 3. Thick 2. Fairly thick 1. light

Adapted from Clowers and Mitini-Nkhoma (1987)

Analysis of variance was done on data on yield (shoot weight and shoot density) using Genstat 14th edition. Score data on quality (briskness, brightness, strength of liquor and milk take) was first transformed using the square root transformation prior to analysis. Separation of means was done using least significance difference (LSD) at 5% level of significance.

RESULTS

Effects of different foliar fertilisers on shoot weight

There was a significant difference ($p<0.05$) on foliar fertilisers on the shoot weight of tea. Zinc oxide resulted in the highest yield of 1362kgs/ha. Yields from the no foliar fertiliser application(control), magnesium oxide and a combination of magnesium oxide, zinc oxide and copper sulphate were statistically similar. Copper sulphate produced the lowest yield of 800kgs/ha (Fig1).High shoot weight due to zinc oxide could be explained by the fact that zinc is responsible for the synthesis of the enzyme IAA which responsible for the growth of shoots in tea [13]. Also zinc increases the rate of carbohydrate metabolism in photosynthesis in tea therefore increase growth and development of tea. Zinc also mobilise photosynthates towards the harvested shoots in tea this increases the mass of harvestable shoots [14]. Shoot weight was significantly reduced by applications of copper sulphate (Fig 1). Perhaps, copper sulphate caused the accumulation of copper to toxic levels in tea plants therefore reducing yield. Excess copper levels in tea plants inhibit photosynthesis by altering source –sink relationship. This produces a feedback inhibition on photosynthesis leading to production of insufficient photosynthates for growth and development of tea shoots [15].

In this experiment application of 1.25kg/ha magnesium oxide did not have a significant effect on shoot weight (Fig 1). This may be because the application rate was too low to correct the deficiencies of magnesium in the experiment. Nonetheless, Magnesium has been reported by several authors to increase yield in tea [12, 13, 16]. Magnesium is a mineral constituent in the chlorophyll molecule that regulates photosynthesis; it also acts as an activator of many enzyme systems. Magnesium also plays specific roles in dry matter formation and carbon partitioning to sink organs [17].

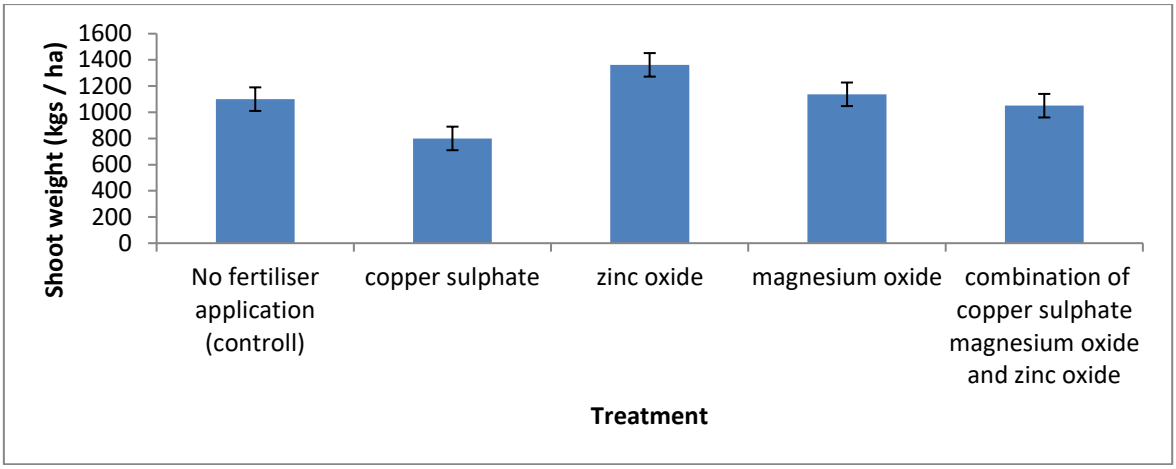

Fig-1: Effects of different foliar fertilisers on shoot weight.

Effects of different foliar fertilisers on shoot density of tea.

There was a significant difference ($p<0.05$) on foliar fertilisers on the shoot density of tea. Zinc oxide produced the highest shoot density of 25.75shoots/m^2. Shoot density from the control (no fertiliser application), magnesium oxide and a combination of magnesium oxide, zinc oxide and copper sulphate were statistically similar. Copper sulphate produced the lowest number of shoots/m^2 (20.25shoots/m^2) (Fig2).

Density of tea shoots were significantly increased by application of 1.25kg/ha zinc oxide (Fig 2). Since zinc is responsible for the healthy development of the tea shoots that are to be harvested for processing.Zinc is responsible for the synthesis of RNA, proteins and tryptophan (precursor of IAA) which contribute to the growth of plants. Also Zn increases the rate of carbohydrate metabolism in photosynthesis in tea therefore increase growth and development of new shoots in tea [14]. A number of reports haveindicated positive yield response to zinc in tea [18, 19, 20]. Shoot density was significantly reduced by applications of copper sulphate (Fig 2). Copper sulphate foliar treatments tended to have an inhibitory effect on the development of shoots which has caused the decline in the number of shoots and therefore yield in plots where copper sulphate was applied. Copper has been reported to be a photosynthesis inhibitor which influences electron transport, photophosphorylation and the dark reactions of photosynthesis [21]. The inhibitory effect of copper was also found on the activity of several enzymes responsible for the dark reactions of photosynthesis such as ribulose 1, 5 biphosphate carboxylase in barley and phosphoenol pyruvate carboxylase in maize [22]. Also a reduction in shoot density was also observed by Barua and Dutta [16] due to copper application on tea. Leaf scorch was observed in copper treatments which also lead to reduction in shoot population showing that the concentration of copper sulphate was detrimental to shoot development. Excess copper accumulation leads to the production of reactive oxygen species which react with cellular components leading to the oxidation of nucleic acids and peroxidation of lipids which results in enzyme inactivation, mutation and cell death [23].

In this study application of 1.25kg/ha magnesium oxide did not have a significant effect on shoot density of tea (Fig 2) suggesting that perhaps the concentration applied was very low. Elsewhere, Magnesium has been reported by several authors to increase shoot density in tea [12, 13, 16]. Magnesium is a mineral constituent in the chlorophyll molecule that regulates photosynthesis; it also acts as an activator of many enzyme systems.

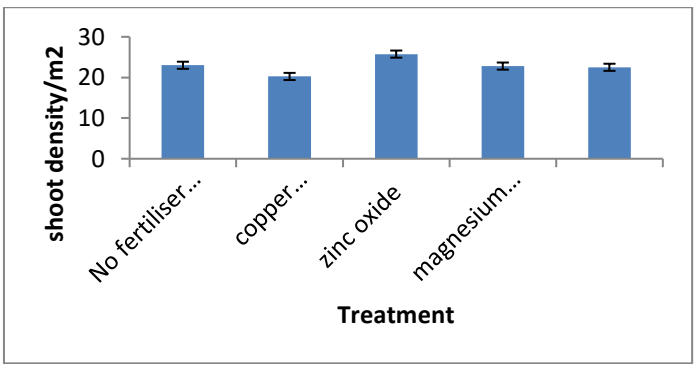

Fig-2: Effects of different foliar fertilisers on the mean shoot density of tea.

Effects of different foliar fertilisers on made tea quality

There was a significant difference ($p<0.05$) on foliar fertilizers on the quality of made tea (brightness, briskness, colour of liquor, milk take) (Table 3). Application of copper sulphate showed the greatest effect on quality followed by zinc oxide and magnesium sulphate (Table 3). The increase in quality by copper sulphate and zinc oxide could be due to the increase in the levels of theaflavins and thearubins. Theaflavins and thearubins (TR) are the chemicals responsible for the taste and appearance of black tea. Theaflavins is responsible for the astringency, brightness, and briskness of the black tea, while thearubins contribute to the mouth feeling (thickness) and strength of the tea [24, 25]. Copper and zinc has been reported to increase the levels of flavins and polyphenol oxidase in tea leaves. Polyphenol oxidase is the enzyme that catalyses the transformation of flavonols to theaflavins during the fermentation of black tea in the manufacturing process. Copper and zinc are vital components of polyphenol oxidase therefore they are important elements in the formation of theaflavins and thearubins during fermentation of black tea and this could explain their significant effect on quality. A positive correlation of copper and total phenol content which improves tea quality in tea was also found in tea samples of Nigerian tea [26]. Copper and zinc were also found to raise tea quality in Iranian tea [13].

The quality of tea also increased due to magnesium oxide treatments. It was found that a sufficient supply of magnesium in nutrient solution increased concentrations of free amino acids, notably theanine in young shoots and roots of tea. The free amino acids in young tea shoots are important chemical constituents, remarkably influencing the quality of tea [27].

Table-3: Effects of different foliar fertilisers on made tea quality

Treatment	Briskness	Brightness	Colour of liquor	Strength of liquor	Colour with milk	Total
No foliar application (control)	(1.510) 2.551^{ab}	(1.500) 2.549^{a}	(4.100) 3.017^{a}	(4.000) 3.000^{ab}	(4.200) 2.669^{ab}	15.31^{a}
Copper sulphate	(2.462) 2.732^{c}	(1.850) 2.617^{c}	(4.752) 3.123^{d}	(3.900) 2.983^{a}	(4.710) 2.664^{a}	17.68^{d}
Zinc Oxide	(1.545) 2.558^{b}	(1.625) 2.574^{b}	(4.515) 3.085^{b}	(4.100) 3.017^{bc}	(4.408) 2.673^{bc}	16.19^{b}
Magnesium oxide	(1.475) 2.545^{a}	(1.475) 2.545^{a}	(4.607) 3.100^{c}	(4.225) 3.037^{c}	(4.535) 2.678^{c}	16.42^{c}
Copper sulphate + Zinc Oxide + Magnesium oxide	(1.500) 2.550^{ab}	(1.575) 2.564^{ab}	(4.600) 3.098^{c}	(4.150) 3.025^{bc}	(4.500) 2.675^{bc}	16.32^{bc}
LSD	0.00893	0.02100	0.01018	0.18230	0.00799	0.20150
P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Means without brackets are the transformed means. Means with the same letters in each column are not statistically different at 5% level of significance.

CONCLUSIONS

Zinc oxide significantly raised the yield of tea. However, Copper sulphate decreased the yield of tea contrary to the hypothesis of the study. Also a mixture of copper sulphate, magnesium oxide and zinc oxide failed to increase the yield. Application of Copper sulphate increased the made tea quality.

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