Research Article

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Standardization of micronutrient dosage to improve yield and quality of cocoa (*Theobroma cacao* L.) grown under coconut ecosystem in Tamil Nadu

V. Jegadeeswari*, G. Amitha Kunikullaya and J. Suresh

Department of Fruit Science, HC & RI (W), TNAU, Tiruchirappalli, Tamil Nadu, India

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Abstract

A study on standardization of micronutrient dosage to improve growth, yield and quality of cocoa (*Theobroma cacao* L.) was carried out at farmer's field, Anaimalai, Pollachi, Coimbatore district to find out a suitable micronutrient combination for cocoa grown in coconut gardens as intercrop. The experiment was conducted with eight treatments and three replications laid out in Randomized Block Design (RBD). Micro-nutrients used in this experiment were 0.5% $ZnSO_4$, 0.3% $FeSO_4$ and 0.1% Boraxin different combinations. Foliar spray was given thrice, first spray at the time of flowering and consecutive two sprays at 45 days interval to cocoa trees intercropped under coconut plantation. Observations on yield and quality parameters were recorded in cocoa. The pod characters namely pod length (22.2 cm) and pod girth (30.6 cm) were recorded maximum in the treatment combination($ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%) + Borax (0.1%)). The treatment ($FeSO_4$ (0.3%)) registered maximum pod weight of 256.6 g. Treatments comprising of boron by itself and in combinations was found to improve the bean characters. The highest dry bean yield (2499.93g)per tree was recorded in (Borax (0.1%)).

***Keywords*:** Cocoa, Micronutrients, Yield, Quality.

Introduction

Cocoa (*Theobroma cacao* L.), is the only species of commercial importance in the genus Theobroma. Dried cocoa bean is the raw material in the manufacture of chocolate, confectioneries and cosmetic products. Micronutrients play a vital role in crop production as it is directly involved in plant metabolism and manifest adverse effects on plant growth when being deficient. Micronutrients, in addition to its contribution in plant growth also impart disease resistance in various crop species. Stimulation of root growth by Zn may account for some observed cases of disease resistance (Duffy, 2007). Zinc has been reported to alleviate Phytophthora diseases. Low Zn levels in soils and leaf tissues were associated with a high incidence of Phytophthora pod rot (or black pod) of cocoa in Papua New Guinea (Nelson *et al.*, 2011).Cocoa requires macronutrients such as nitrogen, potassium, phosphorus, calcium and magnesium and a constant supply of micronutrients such as copper, manganese, boron, zinc, iron and molybdenum for its growth and development (Prasad, 2006).

The deficit of micronutrient like zinc (Zn), boron (B) and iron (Fe) leads to complex disorders in cocoa plantations (Baligar and Fageria, 2005). Foliar application of micronutrients can facilitate rapid translocation and impart protection against a wide range of abiotic stress (Waraich *et al.*, 2012). Zn and B are important for plant reproduction and growth. It also maintains osmotic potential of the plant (Rout and Sahoo, 2015). Standardisation of micronutrient combination for cocoa grown under coconut plantations of Tamil Nadu is essential to upsurge the yield and quality parameters. With this context, the study on "Standardization of micronutrient dosage to improve yield and quality of cocoa (*Theobroma cacao* L.) grown under coconut ecosystem" was taken up.

**Corresponding author: jegadeeswari.v@gmail.com*

Materials and Methods

The experiment was conducted at farmer's field, Sethumadai, Anaimalai region of Pollachi, Coimbatore, Tamil Nadu. The farm is geographically situated at 10058" North latitude, 76093" East longitude and at an altitude of 258 m above mean sea level (MSL). The layout of the experiment was in RBD design with three replications (15 tress/replication) and total number of experimental units was four. The stage of application was at the time of flowering with a frequency of 45 days (3 sprays per crop). The quantity of spray fluid per plant was 1.5-2 litres. The recommended dose of NPK was 100:40:100 g NPK/plant/year.

Treatments	Treatment details
T1	Recommended dose of NPK+$ZnSO_4$ (0.5%)
T2	Recommended dose of NPK+$FeSO_4$ (0.3%)
T3	Recommended dose of NPK+Borax (0.1%)
T4	Recommended dose of NPK+$ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%)
T5	Recommended dose of NPK+$FeSO_4$ (0.3%) + Borax (0.1%)
T6	Recommended dose of NPK+Borax (0.1%) +$ZnSO_4$ (0.5%)
T7	Recommended dose of NPK+$ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%) + Borax (0.1%)
T8	Control (Recommended dose of NPK)

Pod and bean characters were analyzed. The total number of pods harvested in each harvest from each tree was numbered in the field itself and the total number of pods was recorded and expressed as numbers. Yield of dry beans from each tree was worked out as the product of the mean dry weight of the beans per pod and the total number of pods per tree and expressed in grams. Pod value was recorded as the number of pods to produce one kg of dry beans. The pod value was obtained using the yield data. The total number of cherelles in each tree in each season was counted and expressed in numbers.

Quality parameters such as fat content was determined by petroleum ether extraction method in Soxhlet apparatus and expressed in percentage (Elain Apshara *et al*., 2009).Total phenol was estimated using Folin-Ciocalteau reagent method (Bray and Thorpe, 1954). The result was expressed as mg equivalent for pyrocatechol per gram. Total carbohydrates were estimated following the anthrone method (Sadasivam and Manickam, 2008) and expressed in percent. The soluble protein content was described by Lowry *et al*. (1951) and expressed as mg g^{-1}.

Results and Discussion

Pod and bean characters

The pod characters such as pod length and girth was found to be the highest in the treatment T_7 - $ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%) + Borax (0.1%) which recorded 22.2 cm and 30.6 cm respectively (Table 1). Maximum weight of the pod (256.6 g) was recorded by T_2 - $FeSO_4$ (0.3%). T_3 - Borax (0.1%) registered the maximum bean length of 2.64cm and number of pods harvested per tree (53.67). Foliar application of micronutrients increased the fruit size as it improved the innate physiology of fruit through enhanced transfer of water and nutrients vital for their proper growth and development (Dutta and Banik, 2007). Foliar-feeding during flowering and fruit development stages was observed to increase yield and nutrient-use efficiency. Boron plays acrucial role in accumulation of more photosynthates which is directly correlated with weight, size and volume of fruits (Meena *et al.,* 2014) in aonla. The findings were also in tune with the findings of Goswami *et al.* (2012) in guava, Banik *et al.* (1997) in mango and Yadav *et al.* (2013) in Peach.

Beans are the economically important produce of cocoa. Bean length, girth, fresh and dry weight has influence on the total yield and pod value of cocoa. The treatment T_5 - $FeSO_4$ (0.3%) + Borax (0.1%) recorded maximum bean girth (3.65cm). Maximum number of beans, single fresh bean weight, single dry bean weight, fresh bean weight per pod and dry bean weight per pod were observed in the treatments with boron solely or in combination (Table.2). Application of Borax (0.1%) registered the highest dry bean yield per tree (2499.93g) and the estimated dry bean yield per hectare (1249.97 kg). The lowest

Table 1. Effect of micronutrients on pod characters

Treatments	Length of the pod (cm)	Girth of the pod (cm)	Weight of the pod (g)	Number of pods harvested per tree per season
T_1 - $ZnSO_4$ (0.5%)	15.41	23.45	197.51	40.17
T_2 - $FeSO_4$ (0.3%)	20.34	26.42	256.62	45.33
T_3 - Borax (0.1%)	15.97	25.00	213.58	53.67
T_4 - $ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%)	18.12	23.26	207.64	46.33
T_5 - $FeSO_4$(0.3%) + Borax (0.1%)	17.63	21.91	173.87	41.00
T_6 - Borax (0.1%) + $ZnSO_4$ (0.5%)	15.22	22.22	154.14	42.00
T_7 - $ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%) + Borax (0.1%)	22.27	30.65	221.82	45.83
T_8 –Control	16.51	21.63	186.35	32.17
Mean	**17.71**	**24.25**	**200.77**	**43.41**
SEd	**0.89**	**0.70**	**7.01**	**0.89**
SE (M)	**0.88**	**3.49**	**11.09**	**2.18**
CD (0.05)	**2.12 ****	**1.67 ****	**16.59 ****	**2.11 ****

*** - Highly significant * - Significant*

Table 2. Effect of micronutrients on bean characters

Treatments	Length of the bean (cm)	Girth of the bean (cm)	Number of beans per pod	Fresh bean weight per pod (g)	Dry bean weight per pod (g)
T_1 - $ZnSO_4$ (0.5%)	2.23	3.14	43.67	95.09	26.63
T_2 - $FeSO_4$ (0.3%)	2.02	2.98	42.35	93.25	22.02
T_3 - Borax (0.1%)	2.64	3.54	52.34	123.14	46.58
T_4 - $ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%)	2.14	3.34	48.43	101.78	34.38
T_5 - $FeSO_4$ (0.3%) + Borax (0.1%)	2.44	3.65	56.35	110.14	46.77
T_6 - Borax (0.1%) + $ZnSO_4$ (0.5%)	2.32	3.54	46.91	95.49	37.98
T_7 - $ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%) + Borax (0.1%)	2.44	3.51	52.61	118.21	53.66
T_8 –Control	2.06	3.22	42.76	91.04	25.65
Mean	**2.27**	**3.36**	**48.06**	**103.20**	**36.79**
SEd	**0.05**	**0.05**	**1.10**	**1.90**	**0.93**
SE (M)	**0.07**	**0.08**	**1.83**	**4.31**	**4.08**
CD (0.05)	**0.11 ****	**0.13 ****	**2.62 ****	**4.50 ****	**2.20**

*** - Highly significant * - Significant*

pod value (18.37) was registered by T_7 ($ZnSO_4$ - 0.5% + $FeSO_4$ - 0.3% + Borax - 0.1%) (Table 3.) Reproductive phase is more sensitive to boron levels than vegetative growth phase. Maintenance of high boron levels in reproductive parts is an effective boron management method for enhancement of yield in horticultural crops (Raja, 2009). Boron is associated with carbohydrate and hormonal metabolism (Romheld and Marschner, 1991), this could be the reason for improvement of bean characters in the present study. The improvement in yield due to micro-elements may be due to enhanced photosynthesis, reduction in fruit drop, higher fruit size and fruit weight in aonla (Singh, 2012). Foliar application of zinc prior to anthesis may be very useful for improvement offruit yield in citrus (Swietlik, 1999). Similar results were also recorded in cashew (Lakshmipathi *et al.,* 2015).

Table 3. Effect of micronutrients on yield characters

Treatments	Dry bean yield per tree (g)	Pod value	Dry bean yield per hectare (Kg)	Number of cherelles per tree
T_1 - $ZnSO_4$ (0.5%)	1069.99	37.57	535.00	102.07
T_2 - $FeSO_4$ (0.3%)	998.33	45.75	499.17	99.51
T_3 - Borax (0.1%)	2499.93	21.19	1249.97	77.62
T_4 - $ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%)	1593.19	29.04	796.60	84.83
T_5 - $FeSO_4$ (0.3%) + Borax (0.1%)	1917.59	21.31	958.80	90.89
T_6 - Borax (0.1%) + $ZnSO_4$ (0.5%)	1595.54	26.99	797.77	88.59
T_7 - $ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%) + Borax (0.1%)	2459.52	18.37	1229.76	85.21
T_8 –Control	825.35	38.83	412.68	106.71
Mean	**1623.37**	**29.88**	**810.60**	**91.93**
SEd	**25.99**	**0.81**	**21.03**	**1.47**
SE (M)	**14.71**	**3.48**	**113.59**	**3.51**
CD (0.05)	**61.46 ****	**1.93 ****	**49.74****	**3.49 ****

*** - Highly significant * - Significant*

The combination of all the micronutrients significantly increases the yield of the plants. This might be due to the contribution of boron in pollination (Lee and Kim, 1991), zinc in growth promoting substances (Shivanandam *et al.,* 2007) and role of iron in electron transport chain (Meshcheryakov and Alekhina, 1971). Pod value is the number of pods needed to obtain one kg of dry beans. Lower pod value is preferred in cocoa to increase the bean yield (Karthikkumar, 2014). From the study, it is observed that treatments in combination with boron possessed lower pod value.

Cherelle wilt is stated to be physiological thinning mechanism of the plant, by which the size of the crop is regulated with the available food reserves in the tree (Murray, 1975). Number of cherelles (77.62) were decreased by the application of borax 0.1% by reducing the Cherelle wilt. Similar results of high fruit retention with foliar application of Zn and Boron exclusively or in combination have been reported in acid lime (Saurav *et al*., 2022). Zinc and Boron decrease the abscission layer formation, thereby lowering the chances of flower and fruit drop (Smith and Johnson, 1969). In present study also, application of micronutrients decreased the percent of cherelles by reducing the cherelle wilt. The decrease in fruit fall by application of micronutrient has also been reported in fruits like almond (Sotomayor and Castro, 1997) and aonla (Shukla, 2011).

Quality parameters

The highest values for quality characteristics like fat content (46.21 per cent), total phenols (78.68 mg equivalent for pyrocatechol per gram), total carbohydrates (22.61 per cent) were recorded in the treatmentT_7- $ZnSO_4$ (0.5%)+$FeSO_4$ (0.3%) + Borax (0.1%)and protein content (21.8 per cent) was recorded in T_6- Borax (0.1%) + $ZnSO_4$ (0.5%) (Table 4).

Table 4. Effect of micronutrients on quality characters

Treatments	Fat content (percent)	Total phenols content (mg equivalent for pyrocatechol/ gram)	Total carbohydrates (percent)	Protein content (percent)
T_1 - $ZnSO_4$ (0.5%)	43.12	67.44	19.72	18.32
T_2 - $FeSO_4$ (0.3%)	43.74	68.35	19.86	17.71
T_3 - Borax (0.1%)	45.27	72.20	21.92	17.82
T_4 - $ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%)	44.86	75.72	19.25	18.69
T_5 - $FeSO_4$ (0.3%) + Borax (0.1%)	44.79	70.12	21.35	21.38
T_6 - Borax (0.1%) + $ZnSO_4$ (0.5%)	43.91	74.12	20.72	21.82
T_7 - $ZnSO_4$ (0.5%) + $FeSO_4$ (0.3%) + Borax (0.1%)	46.21	78.68	22.61	20.45
T_8 –Control	42.11	68.31	18.97	16.21
Mean	**44.36**	**71.47**	**20.63**	**19.01**
SEd	**0.96**	**2.20**	**0.64**	**0.48**
SE (M)	**0.46**	**1.42**	**0.46**	**0.70**
CD (0.05)	**2.28 ***	**5.22 ****	**1.53 ****	**1.15 ****

** - *Highly significant* * - *Significant*

Enhancement of secondary metabolites on application of micronutrients in turn increased the physiological factors such as photosynthetic pigments (Chlorophyll a, b), proteins and phenols.(Shitole and Dhumal, 2012).In mango, the enhancement in fruit quality could be due to the catalytic action of micronutrients at higher concentration. Hence, the foliar application of micronutrients quickened the absorption of macronutrients in the tissues and organs of the mango plants, decreased the nutritional deficiencies and improved the fruit quality (Anees *et al.,* 2011).

Conclusion

The treatment 3 and treatment 7 are statically on par in nature with respect to yield. Quality parameters like fat content, total phenols content, total carbohydrates and protein content were analyzed and the highest value was recorded in T_7 ($ZnSO_4$ - 0.5%+$FeSO_4$ - 0.3% + Borax - 0.1%) and showed positive influence on morphological, physiological and biochemical parameters thereby increasing the nutrient uptake and disease resistance which in turn increased the yield of cocoa. In coconut, foliar spray of $FeSO_4$ 1% + $ZnSO_4$ 1% + Borax 0.5% not only enhanced the flowering but also gave quality nuts with maximum leaf nutrient status. Iron, zinc and boron contents in coconut leaves were increased appreciably due to the foliar application of micronutrients. From the study, it can be concluded that foliar spray of micronutrient combination ($ZnSO_4$ - 0.5%+$FeSO_4$- 0.3% + Borax - 0.1%) with first spray at the time of flowering and subsequent sprays at 45 days interval found to significantly improve the yield and quality of cocoa.

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