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Micronutrient Formulations for Cocoa on the DTPA Extractable Micronutrient Status in Coconut Intercropping Systems

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Cocoa is an inevitable intercrop of coconut plantations in southern states of India. Micronutrient deficiency in cocoa plantations is a potential yield depressing factor which warrants immediate attention. Ubiquitous deficiency of micronutrients is noticed to the tune of 17% of DTPA Fe, DTPA Mn in 7.5%, DTPA Zn in 71.2% and DTPA Cu in 32.5% in the cocoa growing locations. Hence micronutrient mixture was developed at Coconut Research Station, Aliyarnagar so as to elicit the impact of application of micronutrient mixture on DTPA extractable micronutrient status and on the productivity of cocoa. Experiments included testing various grades of micronutrient formulations applied in soil along with foliar spray. Results revealed that micronutrient mixture grade 3 resulted in higher available DTPA status by 10-35% compared to other formulations. However grade 3

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showed higher status of DTPA extractable micronutrients and it showed statistical parlance with grade 4. Foliar application of micronutrients did not create noteworthy impact on soil fertility status.

Keywords: Cocoa; micronutrient mixture; DTPA micronutrients; foliar application.

1. INTRODUCTION

Coconut is an important horticultural crop which has a significant bearing on the livelihood security of small and marginal famers in Tamil Nadu. Cocoa, an intercrop of coconut plantations spreading over an area of 5000 ha in the state, more concentrated in the districts of Coimbatore, Theni and Kanyakumari, has been dwindling in the recent past because of an array of cultural and socio-economic factors, thus widening the gap between demand and supply [1]. The global cocoa demand is on the rise and considering the diminishing income of cocoa farmers, increasing cocoa productivity is highly imperative. Cocoa turned out to be a succumb victim to an array of micronutrient deficiencies especially due to that of iron and zinc. Interveinal chlorosis, rosetting of leaves, sickle leaves (Fig. 1) and cherelle wilt are the common images of cocoa plantations in Tamil Nadu, pulling down the productivity by 40 – 60% [1].

Managing soil fertility to attain acceptable crop yields without adverse effects on the environment is a global challenge to agricultural land-use systems [2,3]. The key crop growth limiting factors are low soil moisture, low soil organic matter and deficiencies in soil phosphorus (P), potassium (K) and magnesium (Mg) [4,5]. Soil suitability and soil fertility are highly imperative for improving the productivity of cocoa in the coconut intercropping system. In the benchmark survey conducted by Sudhalakshmi, [1], ubiquitous deficiencies of micronutrients in soil was witnessed to the tune of 17% of DTPA Fe, DTPA Mn in 7.5%, DTPA Zn in 71.2% and DTPA Cu in 32.5% of the cocoa growing locations. In the monocropping system, the cocoa bushes have very high nutrient requirement for growth and yield, increasing very rapidly in the first 5 years and then reaching a plateau after that with subsequent increases depending mainly on export of nutrients in increased yield. Even then, the nutrient requirements are reduced if husks of the pods which form a very substantial portion of the nutrients removed are recycled to the fields. Cocoa responds well to fertilizer applications if the management factors, soil and climatic conditions are favourable for good growth and yield and if the soils cannot supply the nutrients required on time [6]. Hence the research was carried out to elicit the impact of micronutrient application on DTPA micronutrient status in soil [7-9].

Fig. 1. Micronutrient disorders in cocoa plantations of Tamil Nadu

2. MATERIALS AND METHODS

Micronutrient concentration in the index leaf samples and the dry matter production, micronutrient requirement of cocoa plant was arrived at as 100-25-50-25-10 g of $FeSO_4$, $MnSO_4$, $ZnSO_4$, $CuSO_4$ and borax respectively. Amalgamating the above nutrient requirement and the fertility status of the cocoa growing locations, four grades of micronutrient mixtures (Grade 1- 4) were formulated with $FeSO_4$, $MnSO_4$, $CuSO_4$, $ZnSO_4$, borax, gypsum as filler material and were test verified under calcareous (Farmer's field at a village – Marichanaickenpalayam) and non-calcareous (Field No. B9, CRS, Aliyarnagar) conditions in CCRP accessions. The field at Marcihanaickenplayam was slightly alkaline in reaction, electrical conductivity was harmless with low status of available nitrogen, medium status of phosphorus and high status of potassium. Organic carbon content was high, DTPA Fe and Zn were deficient; DTPA Cu and Mn were sufficient with free $CaCO_3$ content of 6.48%. The soil at Coconut Research Station, Aliyarnagar (Field No. B9) had neutral pH, electrical conductivity was harmless, available nitrogen and potassium were low, phosphorus was medium, organic carbon was medium, DTPA Fe and Mn were sufficient and free $CaCO_3$ was 1.45%.

Experiments were laid out in Randomized Block Design with each treatment replicated thrice as shown below.

Treatments:

T_1	:	Control (Without micronutrient application)
T_2	:	MN mixture Grade 1 @ 100 g per plant
T_3	:	MN mixture Grade 2 @ 100 g per plant
T_4	:	MN mixture Grade 3 @ 100 g per plant
T_5	:	MN mixture Grade 4 @ 100 g per plant
T_6	:	Foliar spray of $FeSO_4$ and $ZnSO_4$ @ 0.5%
T_7	:	Foliar spray of $FeSO_4$ and $ZnSO_4$ @ 1.0%

Samples were collected from cocoa basins and the DTPA extractable micronutrients was analysed employing Lindsay and Norvell, 1978. Data was subjected to statistical scrutiny adopting WASP [10].

3. RESULTS AND DISCUSSION

3.1 Initial Characteristics of the Experimental Site

Initial characteristics of the experimental site is presented in Table 1. The field at Marcihanaickenplayam was slightly alkaline in reaction, electrical conductivity was non-saline with low status of available nitrogen, medium status of phosphorus and high status of potassium. Organic carbon content was high, DTPA Fe and Zn were deficient; DTPA Cu and Mn were sufficient with free $CaCO_3$ content of 6.48%. The soil at Coconut Research Station, Aliyarnagar (Field No. B9) had neutral pH, electrical conductivity was harmless, available nitrogen and potassium were low, phosphorus was medium, organic carbon was medium, DTPA Fe and Mn were sufficient and free $CaCO_3$ was 1.45%.

3.2 Differential Effect of Micronutrients on DTPA Extractable Micronutrients in Soil

3.2.1 DTPA Fe

DTPA Fe content of soil ranged from 2.61 to 3.74 ppm in location 1 and 9.04 to 10.49 ppm in location 2. The mean content of DTPA Fe in soil was higher in location 2 than in location 1 which may be attributed to the calcareous nature of location 1 leading to fixation of iron as siderite. The content was higher with MN mixture Grade 4 followed by Grade 3 in location 1 and Grade 3 followed by Grade 4 in location 2. The content was lowest with foliar spray of micronutrients @ 0.5% in location 1 and in control in location 2. Irrespective of the sampling sites, foliar spray of micronutrients did not reveal spectacular increase in DTPA Fe content of soil (Table 2).

3.2.2 DTPA Mn

DTPA Mn content of the soil ranged from 5.09 to 5.90 ppm in location 1 and 3.85 to 4.02 ppm in location 2 across different treatments. The mean content of DTPA Mn in soil was higher in location 1 than in location 2. Although the content of DTPA Mn was higher with MN mixture Grade 3 in both the sampling sites, statistical parlance was observed for the differential effect of treatments. This may be due to the fact that all the grades contain equal percentage of Mn and the soils of both the locations are sufficient in DTPA Mn. Except in control, there was a gradual shot up in DTPA Mn with increasing years of application (Table 3).

3.2.3 DTPA Zn

DTPA Zn content of soil ranged from 0.889 to 1.812 ppm in location 1 and 0.178 to 0.697 ppm in location 2. The mean content of DTPA Zn in soil was higher in location 1 than in location 2. Application of MN mixture grade 3 @ 100 g per plant resulted in higher DTPA Zn content in both the locations and was closely followed by MN mixture grade 4. Increased DTPA Zn content in the soil receiving MN mixture grade 3 may be attributed to the higher percentage of Zn in the mixture. Depletion of DTPA Zn content was witnessed in control. Foliar application of micronutrients did not register a hike in Zn content in the soil. Despite the application of $ZnSO_4$, although an increase in DTPA Zn content has been witnessed, it failed to cross the critical level of 1.2 ppm in location 2 (Table 4).

3.2.4 DTPA Cu

DTPA Cu content of the soil samples ranged from 1.59 to 1.89 ppm in location 1 and 0.119 to 0.484 ppm in location 2. The mean content of DTPA Cu in soil was higher in location 1 than in location 2. In location 1, application of MN mixture grade 2 resulted in higher DTPA Cu content and was followed by MN mixture grade 3 whilst that was achieved with grade 3 in location 2. Comparatively lower DTPA Cu content in grade 4 may be ascribed to the lesser percentage of Cu in grade 4. Foliar treatments failed to record appreciably higher level of DTPA Cu content compared to the control (Table 5).

3.2.5 Hot water soluble boron

Hot water soluble boron content ranged from 0.2361 to 0.4181 ppm in location 1 and 0.5380 to 0.8371 ppm in location 2. The mean content of hot water soluble boron (HWS B) was higher in location 2 than in location 1. Soils were sufficient in HWS B in both the locations. Micronutrient mixture grade 4 registered higher boron content in location 1 and was followed by grade 3 while that was achieved with grade 3 followed by grade 4 in location 2. Inspite of the sufficiency of boron in soil and uniform content across different grades of MN mixtures, the differential effect of treatments in the experiment may be ascribed to the interaction effect of other micronutrients complementing and retarding the content of hot water soluble boron in soil (Table 6).

Development of nutrient formulae hold great promise in improving the yield of cocoa. The formula fertilizer N, P, K, Ca and Mg 12.9: 11.4: 16.8: 10.6: 4.8 balanced, dose 1.120 g/tree, application 2 weeks after pruning and fertilizer application planting system is well applied to productive cocoa, but not recommended on non-productive cocoa plants (Nurdin et al., 2023). Micronutrient malnutrition or hidden hunger remains a major global challenge for human health and wellness. The problem results from soil micro- and macro-nutrient deficiencies combined with imbalanced fertilizer use. Micronutrient-embedded NPK (MNENPK) complex fertilizers have been developed to overcome the macro- and micro-element deficiencies to enhance the yield and nutritive value of key crop products. Applying a multi-element foliar fertilizer improved the nutritional quality of eggplant fruit, with a significant increases in the concentration of Fe (+ 26%), Zn (+ 34%), K (+ 6%), Cu (+ 24%), and Mn (+ 27%), all of which are essential for human health. Increasing supply of essential micronutrients during the plant reproductive stages increased fruit yield, as a result of improved yield parameters. Foliar fertilizing with a multi-nutrient product such as MNENPK at eggplant flowering and fruiting stages, combined with the recommended-doses of NPK fertilizers is the optimal strategy to improve the nutritional quality

Table 1. General characteristics of the experimental fields

Parameter	Marichanaickenpalayam (Calcareous location)	CRS, Aliyar Nagar (B9) (non–calcareous location)
	Location 1	Location 2
pH	8.39	6.49
Electrical conductivity (dSm^{-1})	0.11	0.06
$KMnO_4$ –N (kg ha^{-1})	238	210
Olsen – P (kg ha^{-1})	14.9	13.2
1NNH_4OAc K (kg ha^{-1})	371.8	92.0
Organic carbon (%)	0.85	0.50
DTPA Fe (ppm)	3.71	9.18
DTPA Mn (ppm)	5.36	3.85
DTPA Cu (ppm)	1.59	0.196
DTPA Zn (ppm)	0.92	0.121
Free $CaCO_3$ (%)	6.48	1.45

Table 2. Differential effect of micronutrient treatments on DTPA Fe (ppm) content in calcareous and non-calcareous soil conditions

Treatments	Location 1			Location 2		
	2017	**2018**	**Pooled mean**	**2017**	**2018**	**Pooled mean**
T_1- Control (Without micronutrient application)	2.71	2.69	2.70	9.18	9.04	9.11
T_2 - MN mixture Grade 1 @ 100 g per plant	2.86	2.96	2.91	9.26	9.42	9.34
T_3 - MN mixture Grade 2 @ 100 g per plant	2.91	3.42	3.17	9.42	9.58	9.50
T_4 - MN mixture Grade 3 @ 100 g per plant	2.89	3.67	3.28	9.37	10.49	9.93
T_5 - MN mixture Grade 4 @ 100 g per plant	2.93	3.74	3.34	9.44	9.72	9.58
T_6 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 0.5%	2.61	2.69	2.65	9.24	9.26	9.25
T_7 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 1.0%	2.68	2.72	2.70	9.25	9.19	9.22
CD (P = 0.05)	**0.1362**	**0.1535**	**0.1043**	**NS**	**0.2319**	**NS**

Table 3. Differential effect of micronutrient treatments on DTPA Mn (ppm) in calcareous and non-calcareous soil conditions

Treatments	Location 1			Location 2		
	2017	**2018**	**Pooled mean**	**2017**	**2018**	**Pooled mean**
T_1- Control (Without micronutrient application)	5.43	5.19	5.31	3.85	3.89	3.87
T_2 - MN mixture Grade 1 @ 100 g per plant	5.54	5.68	5.61	3.91	3.99	3.95
T_3 - MN mixture Grade 2 @ 100 g per plant	5.81	5.82	5.82	3.94	4.02	3.98
T_4 - MN mixture Grade 3 @ 100 g per plant	5.85	5.90	5.88	3.96	4.02	3.99
T_5 - MN mixture Grade 4 @ 100 g per plant	5.86	5.89	5.88	3.87	4.01	3.94
T_6 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 0.5%	5.09	5.53	5.31	3.85	3.91	3.88
T_7 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 1.0%	5.18	5.49	5.34	3.89	3.96	3.93
CD (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4. Differential effect of micronutrient treatments on DTPA Zn (ppm) in calcareous and non- calcareous soil conditions

Treatments	Location 1			Location 2		
	2017	2018	Pooled mean	2017	2018	Pooled mean
T_1- Control (Without micronutrient application)	0.920	0.889	0.905	0.199	0.178	0.189
T_2 - MN mixture Grade 1 @ 100 g per plant	1.014	1.121	1.068	0.432	0.572	0.502
T_3 - MN mixture Grade 2 @ 100 g per plant	1.146	1.246	1.196	0.519	0.594	0.557
T_4 - MN mixture Grade 3 @ 100 g per plant	1.721	1.812	1.767	0.655	0.697	0.676
T_5 - MN mixture Grade 4 @ 100 g per plant	1.642	1.796	1.719	0.606	0.642	0.624
T_6 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 0.5%	0.971	1.048	1.010	0.204	0.526	0.365
T_7 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 1.0%	0.989	1.086	1.038	0.219	0.241	0.230
CD (P = 0.05)	**0.0603**	**0.0646**	**0.1343**	**0.0547**	**0.0256**	**0.0434**

Table 5. Differential effect of micronutrient treatments on DTPA Cu (ppm) in calcareous and non-calcareous soil conditions

Treatments	Location 1			Location 2		
	2017	2018	Pooled mean	2017	2018	Pooled mean
T_1- Control (Without micronutrient application)	1.59	1.61	1.60	0.121	0.119	0.120
T_2 - MN mixture Grade 1 @ 100 g per plant	1.61	1.70	1.66	0.271	0.284	0.278
T_3 - MN mixture Grade 2 @ 100 g per plant	1.86	1.89	1.88	0.342	0.471	0.407
T_4 - MN mixture Grade 3 @ 100 g per plant	1.74	1.77	1.76	0.416	0.484	0.450
T_5 - MN mixture Grade 4 @ 100 g per plant	1.62	1.64	1.63	0.246	0.251	0.249
T_6 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 0.5%	1.61	1.72	1.67	0.168	0.186	0.177
T_7 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 1.0%	1.64	1.74	1.69	0.177	0.194	0.186
CD (P = 0.05)	**0.0810**	**0.2153**	**0.1652**	**0.0325**	**0.0395**	**0.0486**

Table 6. Differential effect of micronutrient treatments on HWS - B (ppm) in calcareous and non- calcareous soil conditions

Treatments	**Location 1**			**Location 2**		
	2017	**2018**	**Pooled mean**	**2017**	**2018**	**Pooled mean**
T_1- Control (Without micronutrient application)	0.2361	0.2458	0.2410	0.5380	0.6116	0.5748
T_2 - MN mixture Grade 1 @ 100 g per plant	0.3186	0.3216	0.3201	0.6185	0.6314	0.6250
T_3 - MN mixture Grade 2 @ 100 g per plant	0.3241	0.4017	0.3629	0.7251	0.7261	0.7256
T_4 - MN mixture Grade 3 @ 100 g per plant	0.3461	0.4181	0.3821	0.8371	0.8371	0.8371
T_5 - MN mixture Grade 4 @ 100 g per plant	0.3726	0.3921	0.3824	0.8255	0.8316	0.8286
T_6 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 0.5%	0.2812	0.2965	0.2889	0.5689	0.6744	0.6217
T_7 - Foliar spray of $FeSO_4$ & $ZnSO_4$ @ 1.0%	0.2941	0.3056	0.2999	0.5800	0.6826	0.6313
CD (P = 0.05)	**0.0533**	**0.0420**	**0.0161**	**0.0827**	**0.0898**	**0.0851**

of eggplant fruits and increase crop yields, both of which will contribute to reduce micronutrient malnutrition and hunger globally (Bana et al., 2022).

4. SUMMARY AND CONCLUSIONS

Cocoa is an important intercrop of coconut plantations in India. Participation of every nutrient is imperative to reap maximum benefit from cocoa. Micronutrient deficiency manifests itself as interveinal chlorosis, resetting of leaves, reduced pod yield and complete crop failure. Ubiquitous deficiencies of micronutrients is witnessed in cocoa growing soils of Tamil Nadu. Various micronutrient mixtures were formulated to elicit their impact on the soil micronutrient status. Of the various formulations, micronutrient formulation grade 3 was beneficial in enhancing the soil micronutrient status.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sudhalakshmi C. Soil site suitability criteria for intercropping cocoa in coconut gardens of Tamil Nadu. Madras Agricultural Journal. 2021;108(7-9):313–320.
2. Tittonell P, Giller KE. When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. Field Crop. Res. 2013;143:76-90.
3. Wessel M, Quist PMF, Wessel. Cocoa production in West Africa, a review and analysis of recent developments. NJAS - Wageningen J. Life Sci. 2015;74-75.
4. Afrifa AA, Frimpong KO, Acquaye S, Snoeck D, Abekoe MK. Soil Nutrient Management Strategy Required for Sustainable and Competitive Cocoa Production in Ghana Some Key Information on Nutrient and Their Availability Required for Cocoa. 16th International Cocoa Conference. 2009;16-21.
5. Kongor JE, Boeckx P, Vermeir P, van de Walle D, Baert G, Afoakwa EO, Dewettinck K. Assessment of soil fertility and quality for improved cocoa production in six cocoa growing regions in Ghana. Agrofor. Syst. 2018;93:1455-1467.
6. Ooi LH, Chew PS. Some important agronomic and agricultural practices in cocoa estates. TDMB Plantation Management Seminar, Kuala Trengganu; 1985.
7. Anim-Kwapong GJ, Frimpong EB. Vulnerability of Agriculture to Climate Change-Impact of Climate Change on Cocoa Production. in: Vulnerability and Adaptation Assessment under the Netherlands Climate Change Studies Assistance Programme Phase 2 (NCCSAP2), 2, Cocoa Research Institute of Ghana, New Tafo-Akim. 2009;263-298.
8. Bationo André, Ngaradoum Djimasbé, Youl Sansan, Lompo François, Fening Joseph Opoku (Eds.), 1, Springer, Cham. 2018; 287-299.
ISBN 978-3-319-58788-2.
9. Dossa EL, ArthurA, Dogbe W, Mando A, Snoeck D, Afrifa AA, Acquaye S. Improving Fertilizer Recommendations for Cocoa in Ghana Based on Inherent Soil Fertility Characteristics. In Improving the Profitability, Sustainability and Efficiency of Nutrients through Site Specific Fertilizer Recommendations in West Africa Agro-Ecosystems.
10. Jangam AK, Thali P. WASP-Web Agri Stat Package 2.0. ICAR Research Complex for Goa, Ela, Old Goa, Goa. 403 402. India; 2004.

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