Int.J.Curr.Microbiol.App.Sci (2019) *8*(11): 2694-2705

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 8 Number 11 (2019)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2019.811.308

Micronutrient Dynamics on Addition of a Thermochemical Digestate Fertilizer Produced from Food Waste in Banana Intercropped in Coconut Gardens in an Entisol of Kerala

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Keywords

Thermochemical digestate fertilizer (TCDF), FYM: farm yard manure, Bunch weight, number of hands, number of fingers

Article Info

Accepted:
17 October 2019
Available Online:
10 November 2019

A B S T R A C T

A field experimental study was conducted to assess the impact of thermochemical digestate fertilizer produced from food waste on available soil and plant micronutrients in banana (*Musa spp.* cultivar *Njalipoovan*) in an Entisol of Kerala. The initial soil test showed that the soil is in low in OC% (0.26-0.42 %), available boron (0.13-0.17 mg kg^{-1}), available zinc (0.18-0.26 mg kg^{-1}), available copper (0.21-0.25 mg kg^{-1}). The available iron (2.92-3.54 mg kg^{-1}) and available manganese (1.08-1.35 mg kg^{-1}) was in the sufficiency range. The experiment was laid in randomized block design (RBD) with 8 treatments and three replications. The application of FTCDF (10 kg Thermochemical digestate fertilizer from food waste) resulted in sustained availability of nutrients all throughout the growing period. The availability of Fe was reduced due to the application of FTCDF due to formation of strong organo metallic bonds that are more resistant to disintegration. The source of fertilizers didn't affect the pattern of micronutrient uptake, showing the preferential requirement of micronutrients during different growth stages. The foliar micronutrients concentration was high during the initial 2 to 4 months of planting due to requirement of micronutrients for development during vegetative phase. After 4 MAP the foliar nutrient concentration was reduced due to mobilisation of nutrient for bunch emergence and fruit filling. On maturity of bunches, during harvesting the foliar nutrient concentration slightly increases due to slowing down of nutrient translocation to the bunches. There was no significant difference in the number of fingers produced between treatments. The number of hands produced in treatment that received FTCDF was superior to other treatments. The yield of treatments that received FTCDF recorded the highest yield of 19.8 kg. The treatments HTCDF+FS, QTCDF+FS, FS, POP and STB were comparable in yield. The use of TCDF in place of FYM can effectively increase the yield of banana intercropped in coconut gardens in Onattukara sand tracts due to sustained nutrient availability and better nutrient retention and uptake all throughout the cropping season.

Introduction

Banana (*Musa* sp. cultivar *Njalipoovan*) is one of the most important intercrops grown in coconut gardens in Kerala by small and marginal farmers (Varkey and Pushkaran, 1992). The tolerance to pest and diseases and tolerance to partially shaded conditions prevalent in coconut gardens makes the variety popular among the farmers of Kerala (KAU, 2017). Mostly the banana cultivar Njalipoovan is grown as an intercrop under coconut garden with a heavy application of inorganic fertilizers or with the application of only cattle manure and bone meal with less concern on micronutrient application. This prevailing situation causes nutrient imbalances in soil and impairs the growth and yield of banana (Agegnehu *et al.,* 2017). The Onattukara soils belonging to *UsticQuartzipsamments*, with sandy texture makes the soils highly prone to leaching loss of nutrients and low water holding capacity (Mini and Usha, 2015). These production constraints can effectively be overcome by the judicious application of inorganic and organic fertilizers (Indira and Nair, 2008).

It is well documented that the application of organic matter modifies the soil physical properties of sandy soils positively and enhances the nutrient and water retention capacity of soil (Carpenter *et al.,* 2000). This in turn increases the nutrient uptake of the crops and results in higher crop productivity. The application of plant nutrients based on soil test in requisite forms and quantities will increase the availability of nutrients and prevents nutrient loss to water bodies and hence prevents environmental pollution as reported by Panchbhai *et al.,* (2014) in banana. Moreover, the application of fertilizers and organics on a soil test basis will increase the soil productivity and help in reducing the production cost and result in economic sustainability of farmers as suggested by Kukulies *et al.,* (2011). The population explosion combined with a rapid transition to urbanization caused waste disposal to become a major problem (Vij, 2012). The majority of waste that is biodegradable are left untreated creating harmful environmental and health problems (Ferronato *et al.,* 2017).

The methods of waste management utilizing bioconversion processes like vermicomposting are an effective way of waste treatment and conversion to valuable products in an eco-friendly manner (Wani and Rao, 2013). The longer time required for composting of waste derived from different sources and the need for large areas create handling problems (Lewis and Brown, 2010). This technique of thermochemical digestate fertilizer can overcome the handling problems efficiently. Quality fortified thermochemical fertilizer (TCDF) can be prepared within a short span of 8-14 hours. The TCDF produced by rapid method of thermochemical digestion was free from pathogens and was superior in quality (Sudharmaidevi *et al.,* 2017). The fortification was done with micronutrients like zinc and borax and addition of groundnut cake and coir pith to decrease the moisture content and maintain a free flowing nature to the fertilizer.

The TCDF increased the yield of vegetable and fruit crops when grown in Ultisolsas reported by Leno and Sudharmai (2018).

Moreover, the presence of humic acid-like substance from the TCDF and improvement in growth of roots in vegetable crops were reported. In this light, a humic acid-based liquid fertilizer was developed from the thermochemical digestate by extraction with KOH (0.25 M) and making 2% dilution of the extract in 75 % Hoagland nutrient solution at that gave high yield in vegetable crops. The present study was conducted to study the effect of thermochemical digestate fertilizer and the foliar spray derived from thermochemical fertilizer on micronutrient dynamics of banana, Njalipoovan cultivar grown in Onatttukara sandy tracts as intercrop in coconut garden.

Materials and Methods

The experiment was carried out in farmers' fields during the year 2016 May to April 2017.The experimental field located at Kattanam, Onattukara region of Kerala, was located at the latitude of 9^0 14′ 42.288″ N and longitude of 76^0.32 25.44″ E. The soil was loamy sand *UsticQuartzipsamments*. The initial soil test results showed low OC% (0.26-0.42 %). The micronutrients except Fe (2.92-3.54 mg kg^{-1}), and Mn (1.08-1.35 mg kg^{-1}) were low as given in Table 1. The experiment was laid out in randomized block design with three replications per treatment. The plot size was 12 x 6 m with 5 banana suckers of equal weights (free from pests and diseases) planted pertreatment in the interspaces of coconut. The treatments are as given

POP: FYM 10 kg + Fertilizer recommendation of KAU(200:200:400N:P_2O_5:K_2O)

STB: Soil test-based application of fertilizer and micronutrients (256 :256 :512 g N:P_2O_5 :K_2O + 50 g Mg SO_4 + 25 g borax + 50 g $ZnSO_4$).

FTCDF : 10 kg TCDF +200:200:400N:P_2O_5 :K_2O g plant^{-1}

HTCDF : 5kg TCDF +200:200:400N:P_2O_5 :K_2O g plant^{-1}

QTCDF: 2.5 kg TCDF +200:200:400N:P_2O_5 :K_2O g plant^{-1}

HTCDF + FS :5kg TCDF +200:200:400 N:P_2O_5 :K_2O g plant^{-1}+ 1% foliar spray
QTCDF+FS: 2.5kg TCDF+200: 200:400 N:P_2O_5 :K_2O g plant^{-1}+ 1% foliar spray

FS:1% foliar Spray+ FYM +200:200: 400N:P_2O_5 :K_2O g plant^{-1}

Analysis of Soil and plant tissue

The soil samples were collected from 0-15 cm depth prior to the start of the experiment. Subsequent samplings were done at 2 months, 4 months after planting and at harvest. Plant tissue analysis was conducted using the index leaf (Prével, 1980). The index leaf samples were collected simultaneously with soil sample collection before split dose of fertilizer application. The soil pH was determined using a 1:2.5 (w/v) soil/water extract using pH meter. The soil organic carbon (Walkley and Black, 1934) and available N was determined distillation (Subbiah and Asija, 1956).

The available phosphorus was determined by spectrophotometry, available Ca, Mg, K (extraction with neutral normal ammonium acetate) and 0.1 N HCl extractable Fe, Mn, Zn and Cu by atomic absorption spectrophotometry (A Analyst 400, PerkinElmer Inc., USA) (Jackson, 1973) and B by Azomethine-H method (Gupta, 1979). The leaf samples were oven-dried at 60 ^oC and 1g sample was digested using nitric-perchloric (9: 4) acids and estimation of individual elements was carried out.

Statistical analysis

All experiment data was analyzed using Data analytical package Web Agri Stat Package (WASP) ver.2.0 applying the techniques of analysis of variance. The F values for treatments were compared with the table values. If the effects were significant, critical differences at the 5% significance level were calculated for effective comparison among the means.

Results and Discussion

Soil micronutrients dynamics

The soil in the experimental site is sandy loam and situated in a high rainfall zone wherein the annual precipitation is around 3000 mm. This makes the soil highly prone to leaching loss of nutrients. The initial soil analysis showed a deficiency of Zn, B, and Cu. The available nitrogen level was medium, soil available P, and soil available K were low. The secondary nutrients were also low as shown in Table 1.

The release of micronutrients nutrients into the soil solution during the initial 2 months were influenced by the fertilizers sources applied. The release of nutrients from the treatment that received FTCDF and STB compared to other treatments during the first phase since in these treatments either fortification with micronutrients or soil test based application of micronutrients are involved wherein the nutrient release from inorganic source of fertilizer are comparatively faster than organic forms as shown in Figure 1. The soil Mn concentration remained high all throughout the growing season due to the initial high concentration in soil and increased solubility due to the decrease of pH on the addition of nitrogen fertilizers (Kirby, 1968) as in Figure 2. Since all the treatment combinations consisted and organic fraction and inorganic nutrients either in the form of fortification or as FYM addition in varying amounts micronutrients were continuously supplied into the soil solution following a similar pattern of nutrient release.

Although the nutrient release pattern was almost similar the soil solution nutrient concentration varied depending on the quantity of TCDF applied into the soil. The availability of micronutrients in soil solution was significantly high in FTCDF all throughout the cropping season due to sustained nutrient release. Moreover during fortification the thermochemical digestate is added with coirpith to control the moisture and change the lumpy nature that will aid in improving the water holding capacity and nutrient retention in sandy soil (Sivakumar *et al.,* (2000); Arthur *et al.,* (2012)).

Sustained nutrient release from FTCDF can be attributed to the formation of stable complexes due to the chelation between functional groups of organic compounds and metals increasing ion concentration in soil solution (Madrid, 1999).The Fe concentration in soil solution decreased with the application of FTCDF as seen in Figure 3, due to high affinity of stability Fe to organic matter and formation of stable bonds (Behera *et al.,* 2011) having high. Later the Fe availability slowly increases in solution due to gradual release from the organo metallic complexes as in Figure 4.

Plant micronutrient dynamics

The nutrients were accumulated in leaf in the series Fe > Mn > Zn > B > Cu which is similar to the sequence reported by Souza *et al.,* (2016), Leno and Sudharmai (2018) as given in Table 2.The source of fertilizers didn’t affect the pattern of micronutrient uptake, showing the preferential requirement of micronutrients during different growth stages.

The foliar micronutrients concentration was high during the initial 2 to 4 months of planting due to requirement of micronutrients for development of leaves and proper psuedostem growth (Yadav, *et al.,* 2010).

After 4 MAP the foliar nutrient concentration was reduced due to mobilisation of nutrient for bunch emergence and fruit filling. On maturity of bunches, during harvesting the foliar nutrient concentration slightly increases due to slowing down of nutrient translocation to the bunches.

Table.1 Initial soil physicochemical properties

Sl.No	Parameter	Units	0-30 cm
1	Bulk density	Mg m^{-3}	1.38-1.40
2.	WHC	%	15.43-16.06
3.	pH		5.1 - 5.3
4.	EC	d sm^{-1}	0.10-0.15
5	OC	%	0.26-0.42
6	N	kg ha^{-1}	223.3- 291.8
7	P	kg ha^{-1}	11.10 – 14.50
8	K	kg ha^{-1}	67.1- 73.2
9	Ca	kg ha^{-1}	34.9 – 35.9
10	Mg	kg ha^{-1}	11.8 - 12.5
11	S	kg ha^{-1}	1.14 - 1.56
12	B	mg kg^{-1}	0.13 -0.17
13	Fe	mg kg^{-1}	2.92-3.54
14	Cu	mg kg^{-1}	0.21 -0.25
15	Zn	mg kg^{-1}	0.18- 0.26
16	Mn	mg kg^{-1}	1.08- 1.35

Fig.1

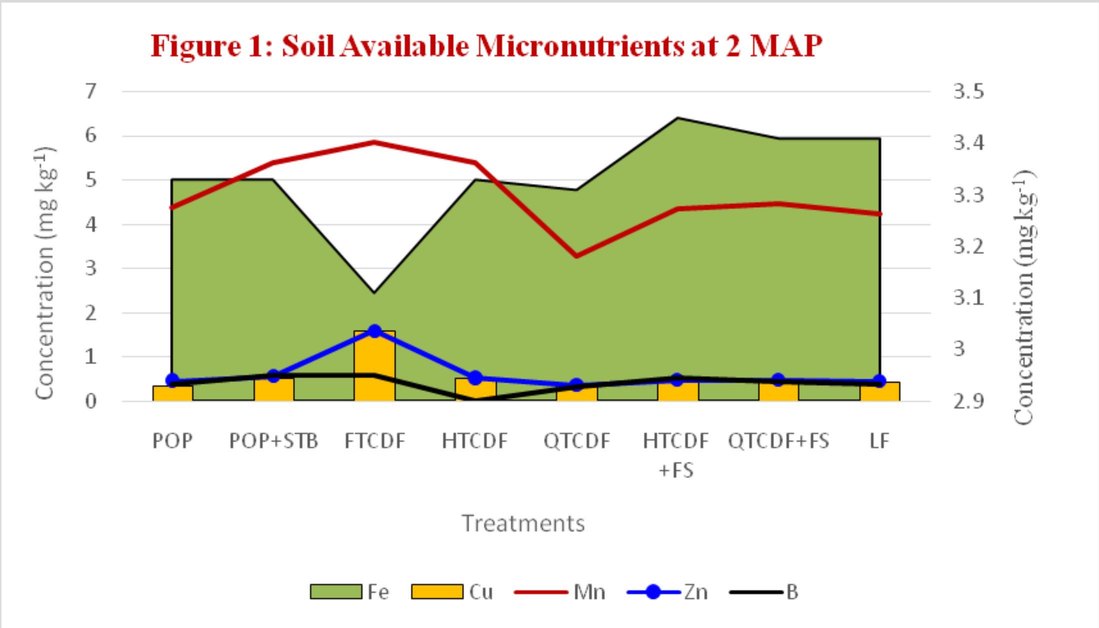

Table.2 Treatment effect on Micronutrient concentration of index leaf

Months after planting	Treatments	B (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})
2MAP	POP	10.24^{c}	19.33^{b}	7.21^{a}	1094.93^{a}	336.93
	STB	14.41^{a}	24.83^{a}	8.30^{a}	1103.87^{a}	305.20
	FTCDF	15.26^{a}	24.70^{a}	8.23^{a}	925.60^{b}	342.53
	HTCDF	9.13^{d}	16.87^{b}	6.32^{b}	1151.60^{a}	297.87
	QTCDF	8.95^{d}	16.43^{b}	5.89^{b}	1145.90^{a}	225.50
	HTCDF+ FS	13.77^{b}	18.90^{b}	7.13^{a}	1185.40^{a}	298.33
	QTCDF +FS	10.94^{c}	17.23^{b}	6.15^{b}	1167.93^{a}	280.87
	FS	10.55^{c}	20.33^{a}	7.66^{a}	1121.27^{a}	297.53
	C.D(0.05)	1.48	5.01	1.17	102.48	N/A
4 MAP	POP	8.58^{b}	21.6^{c}	6.88^{b}	1025.83^{b}	299.13
	STB	9.42^{b}	27.27^{b}	6.78^{b}	1078.10^{a}	234.07
	FTCDF	11.27^{a}	31.90^{a}	8.04^{a}	956.50^{b}	304.73
	HTCDF	8.35^{b}	18.50^{d}	5.88^{b}	1149.17^{a}	310.07
	QTCDF	8.69^{a}	18.43^{d}	4.85^{c}	1143.47^{a}	221.03
	HTCDF+ FS	12.48^{a}	20.90^{c}	6.74^{b}	1116.30^{a}	227.20
	QTCDF +FS	10.28^{a}	19.57^{d}	5.95^{b}	1165.50^{a}	216.40
	FS	8.97^{b}	21.33^{c}	7.81^{a}	1152.17^{a}	296.40
	C.D (0.05)	1.64	2.52	1.06	116.34	N/A
6 MAP	POP	10.49^{a}	17.83^{b}	6.81^{b}	1057.83^{a}	302.13
	STB	11.27^{a}	23.67^{a}	6.74^{b}	1063.43^{a}	270.40
	FTCDF	11.78^{a}	25.40^{a}	8.33^{a}	955.17^{b}	307.73
	HTCDF	8.59^{c}	17.93^{b}	6.14^{b}	1147.83^{a}	229.73
	QTCDF	8.63^{c}	15.60^{b}	5.16^{c}	1142.13^{a}	217.37
	HTCDF+ FS	12.39^{a}	17.73^{b}	6.71^{b}	1148.30^{a}	230.20
	QTCDF +FS	10.30^{b}	16.77^{b}	5.57^{b}	1130.83^{a}	246.07
	FS	10.72^{a}	19.03^{b}	7.10^{a}	1184.17^{a}	266.07
	C.D (0.05)	1.32	4.79	1.21	112.25	N/A
Harvest	POP	10.36	20.60	6.75	1208.93	238.23
	STB	11.14	25.50	7.68	1214.53	223.13
	FTCDF	11.71	24.23	8.61	939.60	243.79
	HTCDF	9.10	19.20	5.94	1265.60	215.80
	QTCDF	8.46	17.10	5.02	1259.90	210.10
	HTCDF+ FS	11.90	20.00	6.31	1299.40	232.93
	QTCDF +FS	11.39	18.70	5.84	1281.93	232.13
	FS	10.43	21.00	6.31	1235.27	263.13
	C.D(0.05)	N/A	N/A	1.054	103.19	N/A

*POP(Package of practice recommendation, STB: Soil test based nutrient application FTCDF : 10 kg TCDF +NPK HTCDF : 5kg TCDF +NPKQTCDF: 2.5 kg TCDF +NPK: HTCDF + FS : 5kg TCDF +NPK+ Foliar spray :QTCDF +FS: 2.5kg + NPK+ 1% foliar spray FS: 1% foliar Spray+ NPK

Table.3 Effect of treatments on the yield attributes of banana

Characters	Bunch weight (kg)	No. of fingers	No. of hands
POP	15.1^{b}	186.6	8.3^{b}
STB	16.1^{b}	188.3	9.0^{b}
TCDF	19.8^{a}	210.3	10.6^{a}
HTCDF	7.6^{c}	190.0	6.2^{d}
QTCDF	6.8^{c}	168.0	6.0^{d}
HTCDF+ FS	15.7^{b}	192.6	8.1^{c}
QTCDF +FS	15.1^{b}	188.3	7.8^{c}
FS	15.2^{b}	187.3	8.6^{b}
C.D(0.05)	2.5	N/A	0.8

Fig.2

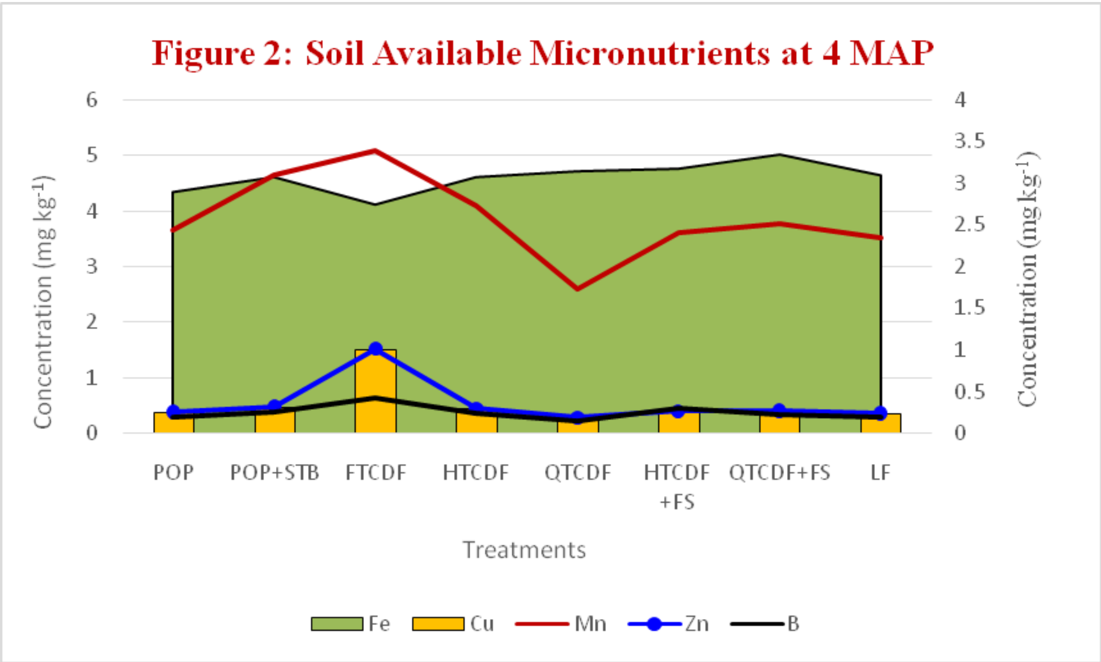

Fig.3

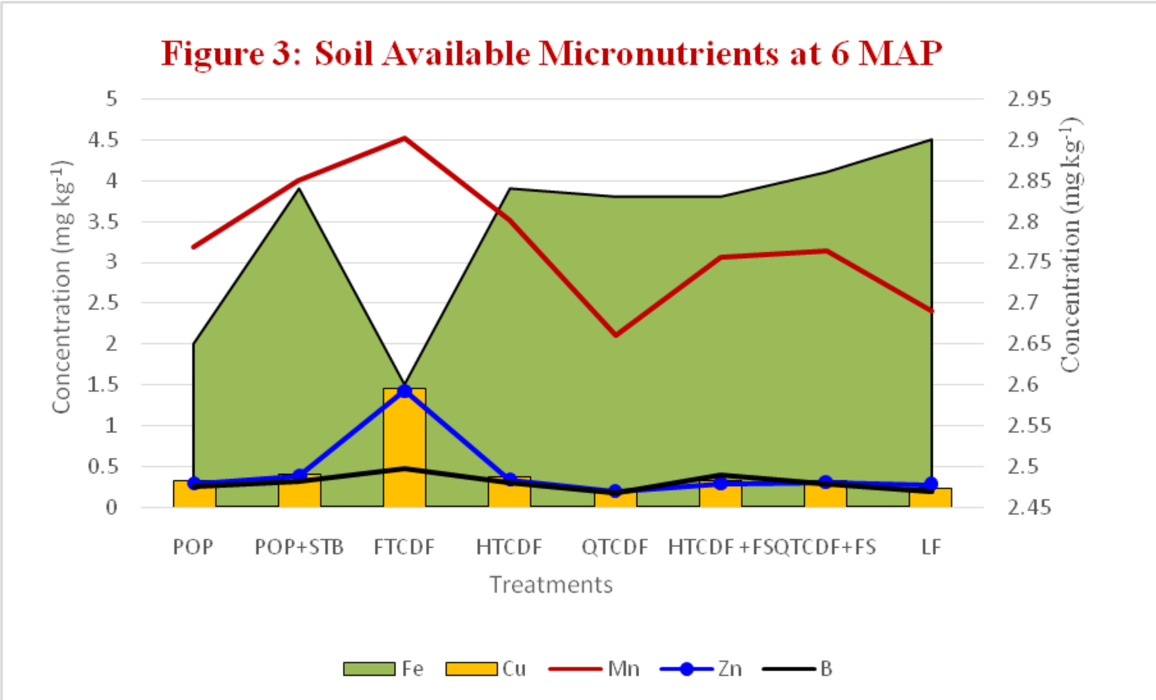
Figure 3: Soil Available Micronutrients at 6 MAP
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Concentration (mg kg-1)
2.95
2.9
2.85
2.8
2.75
2.7
2.65
2.6
2.55
2.5
2.45
Concentration (mg kg-1)
POP
POP+STB
FTCDF
HTCDF
QTCDF
HTCDF +FS
QTCDF+FS
LF
Treatments
Fe
Cu
Mn
Zn
B

Fig.4

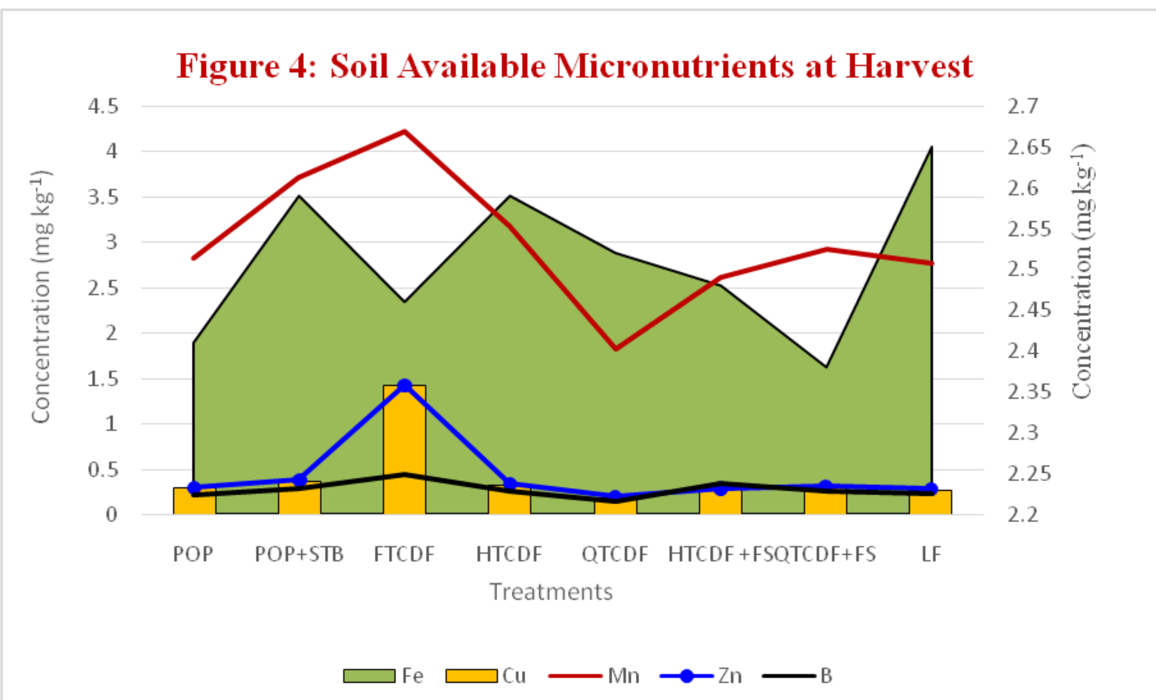
Figure 4: Soil Available Micronutrients at Harvest
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Concentration (mg kg-1)
2.7
2.65
2.6
2.55
2.5
2.45
2.4
2.35
2.3
2.25
2.2
Concentration (mg kg-1)
POP
POP+STB
FTCDF
HTCDF
QTCDF
HTCDF +FS
QTCDF+FS
LF
Treatments
Fe
Cu
Mn
Zn
B

There was a significant difference between the amounts of nutrients accumulated in the leaves on the basis of the source of fertilizer. The highest foliar nutrient concentration was recorded in treatments that received FTCDF and STB as in Table 2. The treatment that received FS was comparable with treatment HTCDF+FS and QTCDF + FS. This may be attributed to nutrient supply from soil and the foliar spray solution.

In addition the foliar spray contains humic acid extract from the thermochemical digestate that will increase the number of leaves produced and increases the nutrient uptake (El-Shenawi *et al.,* 2015). The foliar micronutrient concentration in banana for the treatment that received POP and STB fertilizers were comparable to treatment that received FTCDF since both treatments included an organic source in form of farm yard manure and an inorganic source in form of N, P, K fertilizers ensuring sustained availability of nutrients (Al Busaidi, 2013). The application of nitrogenous fertilizer sources increases the micronutrient availability to crops due to the lowering of pH (Borges *et al.,* 2006). The application of FYM and organic sources of nutrients aided in better root growth and micronutrient uptake by the plants (Chaudhary and Narwal, 2005). The FTCDF registered high foliar nutrient concentration because there was sustained release of nutrients due to the addition of coir pith that has the property of chelation of micronutrients followed by the slow release thereafter (Kadalli *et al.,* 2001). The sustained release of micronutrients might have caused greater absorption of nutrients at critical growth stage.

Effect on the yield of banana

The bunch yield and the bunch weight of banana were increased by application of micronutrients (Robinson, 2012). The bunch yield was highest in the treatment that received FTCDF as given in Table 3. The higher bunch weight may be attributed to increased and sustained release of micronutrients during the critical stages of growth and fruit filling. The application of TCDF increased the WHC, root growth and nutrient uptake that promotes better growth and yield. (Sivakumar *et al.,* 2000).

The yield obtained by application of STB, POP, HTCDF +FS, QTCDF +FS and FS was comparable because all the soil deficient micronutrients like Zn, B, Cu were supplied through either soil application of micronutrients or farm yard manure or foliar spray.

The spraying of micronutrients like Zn and B is known to increase the bunch weight by increasing the chlorophyll content and resultant photosynthetic assimilation in banana (Torres, 2016).

The significant increase in bunch weight of banana on application of micronutrients was in agreement with the findings of Pareek (2016). The treatments that received HTCDF and QTCDF registered the lowest yield even though there was no significant difference in the number of fingers produced.

The fruit filling, number of hands and the fruit weight was adversely affected due to the insufficient supply of micronutrients like boron and zinc that plays pivotal role in flowering and fruit set (Ganie *et al.,* 2013).

The application of FTCDF increased the number of hands and bunch weight of banana. The availability of micronutrients was enhanced on application of FTCDF.

The foliar nutrient concentration was significantly high in FTCDF due to sustained micronuitrient release that coincided with the critical crop growth stages that enhanced the absorption. Thermochemical digestate fertilizer can be used as an efficient substitute to the farm yard manure application. The application of thermochemical digestate fertilizer at 10 kg per plant can increase the water holding capacity, nutrient retention and uptake by banana.

Acknowledgment

The authors acknowledge Kerala Agricultural University for providing financial assistance and laboratory facilities for carrying out the research. The technical advice given by Dr. Ravi Bhat, Principal Scientist and Head, ICAR- Central Plantation crops research Institute is highly appreciated. The assistance provided by Sainath N, Ph.D. scholar, Kerala Agricultural University is also immensely appreciated.

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How to cite this article:

Priya, U. K., S. Visveswaran, C. R. Sudharmaidevi and Naveen Leno 2019. Micronutrient Dynamics on Addition of a Thermochemical Digestate Fertilizer Produced from Food Waste in Banana Intercropped in Coconut Gardens in an Entisol of Kerala. *Int.J.Curr.Microbiol.App.Sci.* 8(11): 2694-2705. doi: https://doi.org/10.20546/ijcmas.2019.811.308