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Influence of humic substance enriched with micronutrients on micronutrients content and uptake by maize

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Abstract
This investigation aimed to improve the fertilizer value of humic acid by enriching with selected micronutrients and there by to increase the growth and yield of maize. It was conducted during *Kharif* 2017 at College of Agriculture, Vishweshwaraiah Canal Farm, Mandya. The design followed was RCBD with ten treatments replicated thrice. The humic substance required for the experiment was extracted using 0.1 N NaOH from FYM with and without micronutrients and designated as enriched humic substance (EHS) and humic substance (HS), respectively. EHS and HS was tested at two levels i.e., 2.5 and 5 litres ha^{-1} at basal and 30 DAS combinations. The results revealed that among the different treatments, T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) recorded significantly higher total Fe, Mn, Zn and Cu content (272.31, 140.19, 60.37 and 22.98 mg kg^{-1}, respectively). Whereas lower Fe, Mn, Zn and Cu content was recorded for the treatment with RDF alone (T_1). Significantly higher Fe, Mn, Zn and Cu uptakes (2713.50, 1426.24, 554.38 and 218.68g ha^{-1}, respectively) were observed for T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) over all other treatments. Whereas lower Fe, Mn, Zn and Cu uptakes (2043.94, 901.07, 267.71 and 119.19 g ha^{-1}, respectively) were recorded for the treatment with RDF alone (T_1).

Keywords: Humic substance enriched, micronutrients, micronutrients content, uptake, maize

Introduction
Humic substance (HS) assumes a major part in maintaining soil fertility and plant sustenance. It enhances the physical, chemical and biological properties of the soil and impacts plant development. In view of its atomic structure, it gives various advantages to crop production. It keeps up soil structure, helping with exchanging the nutrients from the soil to the plant, upgrades the water holding capacity, improves seed germination, enhances water availability, root penetration and advances microorganisms population in the soils. Humic substance however isn't a fertilizer, yet considered as complementary to fertilizer (Mackowiak *et al*., 2001) [5].
Micronutrients have received a lot of significance in crop generation during these years due to their inadequacies in various parts of the nation. Keeping this in mind the end goal to upgrade the growth and yield of maize, humic substance can be an alternative and utilized as a supplement to chemical fertilizers. Enrichment of humic substance with micronutrients can improve fertilizer value of humic substance. In this manner including enrichment humic substance as soil application is the principle advantage that the plant will have the capacity to retain and use the nutrients in solution more effectively.
Among cereals, maize (*Zea mays* L.) is an essential food and feed crop which positions third after wheat and rice on the planet. It is a crop having high return potential and called by the name queen of cereal crop. This product has substantially higher grain protein content than our staple food rice. India is the fifth biggest producer of maize on the planet contributing 3 for each penny of the worldwide generation. The area and production of maize in India is 9.4 million ha and 23 million tones, respectively (Anon., 2015) [2]. In Karnataka maize is grown in an area of 1.28 million ha with a production of 4.08 million tonnes (Anon., 2014) [1]. The crop is chiefly cultivated for commercial purpose with different uses. Thus, crop is having immense request from diversified part, which makes it to exploit under various agro procedures. Hence, considering the above facts, an attempt has been made to test the efficacy of micronutrients

enriched humic substance using maize as test crop and the present work was carried out.

Material and Methods

A field experiment was conducted during *Kharif* 2017 at College of Agriculture, V. C. Farm, Mandya to study the influence of humic substance enriched with micronutrients on micronutrients content and uptake by maize. Soil of the experimental site (Table 1) was sandy loam in texture and neutral in reaction with pH 7.28. Electrical conductivity was 0.41 dS m^{-1} and organic carbon status was found to be high (9.80 g kg^{-1}). The available nitrogen status was low (242.06 kg ha^{-1}), phosphorus was high (107.72 kg $P_2O_5ha^{-1}$) and potassium was medium (213.54 kg K_2O ha^{-1}). The exchangeable Ca and Mg status was adequate and the available sulphur status was high. Among the micro nutrients boron status was in deficient range (0.38 mg kg^{-1}) while Fe, Mn, Zn and Cu were sufficient (8.32, 5.78, 0.94, 0.81 mg kg^{-1}, respectively).

Table 1: Initial soil properties of the experimental plot.

Parameters		Values
Particle size distribution	Sand (%)	69.24
	Silt (%)	23.88
	Clay (%)	6.88
	Texture	Sandy loam
pH (1:2.5)		7.28
EC (dS m^{-1}) (1:2.5)		0.41
OC (g kg^{-1})		9.80
Available Nitrogen (kg ha^{-1})		242.06
Available Phosphorus (kg ha^{-1})		107.72
Available Potassium (kg ha^{-1})		213.54
Exchangeable Calcium (c mol (p+) kg^{-1})		7.50
Exchangeable Magnesium (c mol (p+) kg^{-1})		3.80
Available Sulphur (mg kg^{-1})		26.50
DTPA-Iron (mg kg^{-1})		8.32
DTPA-Manganese (mg kg^{-1})		5.78
DTPA-Copper (mg kg^{-1})		0.81
DTPA-Zinc (mg kg^{-1})		0.94
Boron (mg kg^{-1})		0.38

Treatment details

$T_{1:}$ RDF (150:75:40 kg ha^{-1} NPK)
$T_{2:}$ RDF + FYM @ 10 t ha^{-1}
$T_{3:}$ T_2 + HS @ 2.5 L ha^{-1} as basal
$T_{4:}$ T_2 + HS @ 5 L ha^{-1} as basal
$T_{5:}$ T_2 + HS @ 2.5 L ha^{-1}30 DAS
$T_{6:}$ T_2 + HS @ 5 L ha^{-1}30 DAS
$T_{7:}$ T_2 + EHS @ 2.5 L ha^{-1} as basal
$T_{8:}$ T_2 + EHS @ 5 L ha^{-1} as basal
$T_{9:}$ T_2 + EHS @ 2.5 L ha^{-1} 30 DAS
$T_{10:}$ T_2 + EHS @ 5 L ha^{-1}30 DAS

- RDF: Recommended Dose of Fertilizers-50% N + 100% P and K as basal dose and 25% N each, one at 20 DAS and another at 30 DAS
- $ZnSO_4$@ 10 kg $ha^{-1}$is common for all the treatments except T_1
- HS: Humic Substance without micronutrients enrichment
  EHS: Humic Substance with micronutrients enrichment

Results and Discussion

Micronutrients content and uptake by maize grain

The effects of various treatments on total micronutrients (Fe, Mn, Zn and Cu) content and uptake by grains after the harvest of maize are presented in Table 2.

Among the different treatments, T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) recorded significantly higher Fe, Mn, Zn and Cu content (40.23, 10.05, 26.10 and 3.28 mg kg^{-1}, respectively) followed by treatment T_8 (T_2 + Enriched HS @ 5 L ha^{-1} as basal) (38.45, 8.82, 23.00 and 3.01 mg kg^{-1}, respectively). Whereas lower Fe, Mn, Zn and Cu content (29.89, 4.74, 15.62 and 1.74 mg kg^{-1}, respectively) was recorded for the treatment with RDF alone (T_1).

Significantly higher Fe, Mn, Zn and Cu uptakes (306.63, 76.58, 198.96 and 25.00 g ha^{-1}, respectively) were observed for T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) over all other treatments and it was followed by T_9 treatment (T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS) (274.42, 60.42, 165.89 and 21.17 g ha^{-1}, respectively). Whereas lower Fe, Mn, Zn and Cu uptakes (177.18, 28.12, 92.58 and 10.34 g ha^{-1}, respectively) were recorded for the treatment with RDF alone (T_1).

Further, significant increase in the micronutrients (Fe, Mn, Cu and Zn) content and uptake by maize grains were recorded in the enriched treatments (T_7 to T_{10}) when compared to corresponding non enriched treatments (T_3 to T_6).There was a significant increase in micronutrients (Fe, Mn, Cu and Zn) uptake for enriched treatments and non-significant increase in micronutrients content of grains with 30 DAS treatments compared to corresponding basal treatments.

Micronutrients content and uptake by maize stover

The effects of various treatments on total micronutrients (Fe, Mn, Zn and Cu) content and uptake by stover after the harvest of maize are presented in Table 3.

Among the different treatments, T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) recorded significantly higher Fe, Mn, Zn and Cu content (232.08, 130.14, 34.27 and 19.70 mg kg^{-1}, respectively) followed by treatment T_8 (T_2 + Enriched HS @ 5 L ha^{-1} as basal) (229.39, 122.93, 31.71 and 18.99 mg kg^{-1}, respectively). Whereas lower Fe, Mn, Zn and Cu content (210.85, 98.61, 19.78 and 12.30 mg kg^{-1}, respectively) was recorded for the treatment with RDF alone (T_1).

Significantly higher Fe, Mn, Zn and Cu uptakes (2406.87, 1349.66, 355.42 and 194.68 g ha^{-1}, respectively) were observed for T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) over all other treatments and it was followed by T_9 treatment (T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS) (2303 g ha^{-1}) for Fe and T_8 (T_2 + Enriched HS @ 5 L ha^{-1} as basal) for Mn, Zn and Cu (1224.29, 315.85 and 189.17 g ha^{-1}, respectively). Whereas lower Fe, Mn, Zn and Cu uptakes (1866.76, 872.96, 175.13 and 108.85 g ha^{-1}, respectively) were recorded for the treatment with RDF alone (T_1)

Further, significant increase in the micronutrients (Fe, Mn, Cu and Zn) content and uptake by maize stover were recorded in the enriched treatments (T_7 to T_{10}) when compared to corresponding non enriched treatments (T_3 to T_6) and there was a significant increase in micronutrients (Fe, Mn, Cu and Zn) uptake and non-significant increase in micronutrient content of stover except for Cu with 30 DAS treatments compared to corresponding basal treatments.

Total uptake of micronutrients by maize

The effects of various treatments on total micronutrients (Fe, Mn, Zn and Cu) uptake by maize are presented in Table 4 and Fig 1. Significantly higher total Fe, Mn, Zn and Cu uptakes (2713.50, 1426.24, 554.38 and 218.68 g ha^{-1}, respectively) were observed for T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) over all other treatments and it was followed by T_9 treatment (T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS) for Fe and

Cu (2578.03 and 210.18 g ha^{-1}, respectively) and T_8 (T_2 + Enriched HS @ 5 L ha^{-1} as basal) for Mn and Zn(1283.89 and 471.32 g ha^{-1}, respectively). Whereas lower Fe, Mn, Zn and Cu uptakes (2043.94, 901.07, 267.71and 119.19 g ha^{-1}, respectively) were recorded for the treatment with RDF alone (T_1).

Table 2: Effect of humic substance enriched with micronutrients on micronutrients content and uptake by maize grains.

Treatments		Fe		Mn		Zn		Cu	
		Content (mg kg^{-1})	**Uptake (g ha^{-1})**	**Content (mg kg^{-1})**	**Uptake (g ha^{-1})**	**Content (mg kg^{-1})**	**Uptake (g ha^{-1})**	**Content (mg kg^{-1})**	**Uptake (g ha^{-1})**
T_1	RDF (150:75:40 kg NPK ha^{-1})	29.89	177.18	4.74	28.12	15.62	92.58	1.74	10.34
T_2	RDF (150:75:40 kg NPK ha^{-1}) + FYM @ 10 t ha^{-1}	31.72	195.62	5.07	31.25	16.97	104.66	2.00	12.35
T_3	T_2 + HS @ 2.5 L ha^{-1} as basal	33.48	213.37	5.99	38.19	18.28	116.44	2.30	14.65
T_4	T_2 + HS @ 5 L ha^{-1} as basal	35.33	232.32	6.98	45.93	19.85	130.50	2.49	16.35
T_5	T_2 + HS @ 2.5 L ha^{-1}30 DAS	34.06	228.99	6.44	43.31	18.91	127.14	2.39	16.07
T_6	T_2 + HS @ 5 L ha^{-1}30 DAS	35.36	251.49	7.13	50.70	20.06	142.68	2.56	18.18
T_7	T_2 + Enriched HS @ 2.5 L ha^{-1} as basal	36.52	237.19	8.07	52.44	21.70	140.96	2.79	18.12
T_8	T_2 + Enriched HS @ 5 L ha^{-1} as basal	38.45	259.85	8.82	59.60	23.00	155.46	3.01	20.32
T_9	T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS	37.17	274.42	8.18	60.42	22.47	165.89	2.87	21.17
T_{10}	T_2 + Enriched HS @ 5 L ha^{-1}30 DAS	40.23	306.63	10.05	76.58	26.10	198.96	3.28	25.00
	S. Em±	0.189	3.808	0.070	0.899	0.149	2.144	0.021	0.265
	CD at 5%	0.562	11.314	0.207	6.672	0.443	10.370	0.064	3.787

Table 3: Effect of humic substance enriched with micronutrients on micronutrients content and uptake by maize stover.

Treatments		Fe		Mn		Zn		Cu	
		Content (mg kg^{-1})	**Uptake (g ha^{-1})**	**Content (mg kg^{-1})**	**Uptake (g ha^{-1})**	**Content (mg kg^{-1})**	**Uptake (g ha^{-1})**	**Content (mg kg^{-1})**	**Uptake (g ha^{-1})**
T_1	RDF (150:75:40 kg NPK ha^{-1})	210.85	1866.76	98.61	872.96	19.78	175.13	12.30	108.85
T_2	RDF (150:75:40 kg NPK ha^{-1}) + FYM @ 10 t ha^{-1}	215.08	1950.10	100.80	913.86	21.43	194.32	13.42	121.70
T_3	T_2 + HS @ 2.5 L ha^{-1} as basal	218.08	2016.78	105.78	978.29	23.02	212.84	14.59	134.93
T_4	T_2 + HS @ 5 L ha^{-1} as basal	221.05	2134.83	109.94	1061.72	25.71	248.30	16.04	154.94
T_5	T_2 + HS @ 2.5 L ha^{-1}30 DAS	219.19	2163.16	107.18	1057.69	23.83	235.17	14.99	147.97
T_6	T_2 + HS @ 5 L ha^{-1}30 DAS	222.97	2263.09	111.06	1127.36	26.35	267.45	17.00	172.58
T_7	T_2 + Enriched HS @ 2.5 L ha^{-1} as basal	226.15	2189.42	115.24	1115.59	29.05	281.21	18.34	177.52
T_8	T_2 + Enriched HS @ 5 L ha^{-1} as basal	229.39	2284.93	122.93	1224.29	31.71	315.85	18.99	189.17
T_9	T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS	227.31	2303.60	116.67	1182.50	29.42	298.06	18.65	189.01
T_{10}	T_2 + Enriched HS @ 5 L ha^{-1}30 DAS	232.08	2406.87	130.14	1349.66	34.27	355.42	19.70	194.68
	S. Em±	0.482	30.391	0.389	14.417	0.160	5.040	0.100	3.369
	C. D. at 5%	1.432	90.298	1.156	42.834	0.475	15.220	0.298	10.098

Significant increase in the nutrient content and uptake was may be due to increase in yield which was mainly associated with higher uptake of all the micronutrients. They also reported that humic acid application @ 8 L ha^{-1} along with recommended dose of fertilizers recorded higher concentration and uptake of N, P, K, Ca, Zn and Mn in tomato leaves. Similar results were obtained in maize by Khan *et al.* (2014) [4].

Nardi *et al.* (2002) [6] found that humic substances plays a beneficial role in Fe acquisition by plants, which is due to its complexing properties which increase the availability of micronutrients from sparingly soluble hydroxides. The effects of humic substances onion uptake appear to be selective and variable in relation to their concentration and the pH of the medium, they work on the metabolism of a plant and promote nutrient uptake or plant growth by acting as a hormone.

Enhanced uptake of nutrients due to application of fortified humic acid along with RDF applied to soil was reported by Elayaraja *et al.* (2011) [3]. Micronutrients supplied through humic acid are not only essential for plant growth, yield and quality of crops, but also important like other macro nutrients in spite of their requirement in minor quantity. They also help in uptake of major nutrients and also play a vital role in enhancing the growth of plants by acting as catalysts in promoting organic reactions during cell development, respiration, photosynthesis, chlorophyll formation, enzyme activity, hormones synthesis etc.

Table 4: Effect of humic substance enriched with micronutrients on total uptake of micronutrients by maize.

Treatments		Fe	Mn	Cu	Zn
		(g ha^{-1})			
T_1	RDF (150:75:40 kg NPK ha^{-1})	2043.94	901.07	119.19	267.71
T_2	RDF (150:75:40 kg NPK ha^{-1}) + FYM @ 10 t ha^{-1}	2145.72	945.11	134.05	298.98
T_3	T_2 + HS @ 2.5 L ha^{-1} as basal	2230.16	1016.48	149.58	329.27
T_4	T_2 + HS @ 5 L ha^{-1} as basal	2367.15	1107.65	171.29	378.81
T_5	T_2 + HS @ 2.5 L ha^{-1}30 DAS	2392.15	1101.01	164.04	362.32
T_6	T_2 + HS @ 5 L ha^{-1}30 DAS	2514.58	1178.05	190.77	410.13
T_7	T_2 + Enriched HS @ 2.5 L ha^{-1} as basal	2426.61	1168.03	195.64	422.17
T_8	T_2 + Enriched HS @ 5 L ha^{-1} as basal	2544.78	1283.89	209.49	471.32
T_9	T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS	2578.03	1242.91	210.18	463.95
T_{10}	T_2 + Enriched HS @ 5 L ha^{-1}30 DAS	2713.50	1426.24	218.68	554.38

	S. Em±	31.19	27.18	4.93	11.04
	CD at 5%	92.67	80.76	14.64	32.79

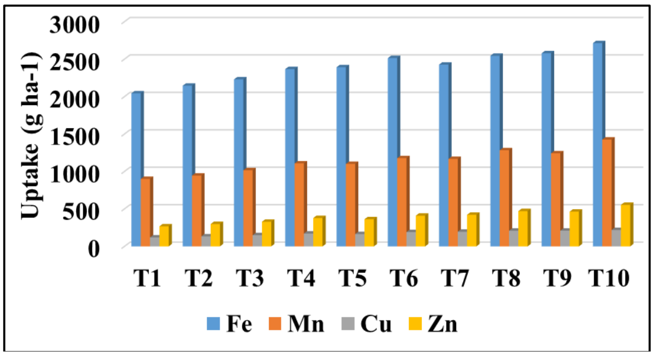

Fig 1: Effect of humic substance enriched with micronutrients on total uptake of Fe, Mn, Cu and Zn by maize

Conclusion and practical utility

Humic substance extracted from farm yard manure incubated with micronutrients can be used as a rich nutrient source in improving micronutrient content and uptake by maize. From the results obtained, it can be concluded that the use enriched humic substance along with RDF and FYM increased micronutrient content and uptake by maize. The treatment T_{10} (T_2 + Enriched HS @ 5 L ha^{-1}30 DAS) was found better.

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