

Assimilation of Macronutrients by Maize as Influenced from Humic Substance Enriched with Micronutrients

ABSTRACT

The aim of the current investigation was to determine if maize had the ability to assimilate macronutrients under the effect of humic substance that was enriched with micronutrients. A field experiment was conducted with 10 treatments replicated thrice using RCBD this in the College of Agriculture's V C Farm in Mandya, Karnataka, India during *Kharif* 2017. The findings showed that the treatment getting RDF + FYM @ 10 t ha⁻¹ together with Enriched HS @ 5 L ha⁻¹ 30 DAS had substantially greater macronutrient content and absorption in grains and stover than the treatment receiving RDF + FYM @ 10 t ha⁻¹ along with Enriched HS @ 2.5 L ha⁻¹ 30 DAS. Whereas lower macronutrients content was recorded for the treatment with RDF alone. Among different treatments, T₁₀ treatment (T₂ + Enriched HS @ 5 L ha⁻¹ 30 DAS) recorded significantly higher total uptake of N, P, K, Ca, Mg and S (225.30, 58.44, 91.03, 96.04, 60.86 and 59.47 kg ha⁻¹, respectively). Whereas lower N, P, K, Ca, Mg and S uptake (141.90, 26.94, 40.28, 46.24, 22.37 and 22.27 kg ha⁻¹, respectively) were recorded for the treatment with RDF alone (T₁).

Keywords: Humic substance; macronutrients; maize; farm yard manure; enrich.

1. INTRODUCTION

“Soil scientists, agronomists, and farmers have recognized the importance of maintaining soil humus content in order to improve productivity in recent years. Farmers consider the use of bulky organic manures as an organic matter source to be a burden because it requires extensive labour for transportation and application to soil. Furthermore, the use of bulky organic manures causes the spread of weed seeds on the land, and weed control would be a major issue” [1]. In this case, the extraction and use of humic substances from large organic manures may help to address a number of issues associated with the use of large organic manures.

Current agricultural practices increase the rate of humic substances utilization and destruction. Any adjustments in normal conditions will bring about changes in humus content of the soil. Irrigation practices, drainage systems, deforestation, frequent tillage, and intensive cultivation are examples of these advancements. Every one of these changes causes a quick and noticeable change in the soil's humus balance. As a result, numerous soil management programmes have recently been developed in order to increase or

possibly maintain the status of humic substances in the soil.

“Although humic substance is not a fertilizer, it is considered complementary to fertilizer” [2]. The application of such particles to the soil or by foliar application in conjunction with a sufficient quantity of conventional fertilizers improves the efficiency of applied chemical fertilizers while also advancing the conversion of inaccessible types of supplements to accessible forms. It has chelating properties, promotes plant development, and has a positive impact on the development of various groups of microorganisms. Humic substance was discovered to boost the content and total quantity of nitrogen in plants. Humic acids, in small doses, act as sensitizing agents, helps in increasing the permeability of the cell membrane and resulting in increased absorption of supplements by plants, and are a source of accessible iron also [3].

Micronutrients have gained prominence in crop production in recent years as a result of widespread shortfalls in various sections of the country. Scientists from every state in the country have also reported a crucial response in yields to micronutrients use. With the end objective of

improving maize growth and output, humic substance can be used as an alternative and addition to chemical fertilizers. Humic substance enrichment with micronutrients can boost humic substance fertiliser value. The primary advantage of introducing enriched humic substance as soil application is that the plant will be able to store and utilise the nutrients in solution more efficiently. Unfortunately, the research available on this subject under Indian conditions is limited. So, little effort was made to enrich humic substance with micronutrients and to know its efficacy in improving macronutrient assimilation by maize.

“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 crops” [4]. “It is a multipurpose crop that gives nourishment to people, sustain for creatures (particularly poultry and domesticated animals) and crude material for the industries. This product has substantially higher grain protein content than our staple food rice. Maize is an overwhelming feeder of nutrients thus it is an exceptionally effective converter of solar energy into dry biomass. India is the fifth largest 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 tonnes, respectively. In Karnataka maize is grown in an area of 1.28 million ha with a production of 4.08 million tonnes” [5]. The crop is chiefly cultivated for commercial purpose with different uses. Thus, crop is having immense potential 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 effect of humic substance enriched with micronutrients in assimilation of macronutrients by maize.

2. MATERIALS AND METHODS

2.1 Location of Experimental Site

The field experiment was conducted at B block, College of Agriculture, Vishwesharaiah Canal Farm, Mandya. It falls under the region III and agro climatic zone VI (Southern dry zone) of Karnataka. Geographically the experimental site was located at 12° 34.31' North latitude and 76° 49.8' East longitude at 697 meter above mean sea level.

2.2 Climatic Conditions

The actual rainfall of the station during crop growing period was 522.5 mm. The major portion of the rainfall is received in the month of September (216.0 mm). The mean maximum air temperature ranged from 30.3 °C to 31.2 °C. The highest mean maximum air temperature was recorded during the month of September (31.2 °C). The mean minimum air temperature ranged from 19.2 °C to 20.4 °C. The highest mean minimum temperature was recorded during October (20.4 °C).

2.3 Characteristics of Soil of Experimental Plot

A composite soil sample was collected from the experimental site before start of experiment. The soil was air dried, powdered and then passed through 2 mm sieve and was analysed for physical and chemical properties.

Soil of the experimental site 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 P₂O₅ ha⁻¹) and potassium was medium (213.54 kg K₂O ha⁻¹). The exchangeable Ca and Mg status was adequate and the available sulphur status was high. Among the micro nutrients boron was deficient while Fe, Mn, Zn and Cu were sufficient (Table 1).

2.4 Preparation and Extraction of Humic Substance Enriched with and without Micronutrients

Calculated amount of FYM was incubated with and without micronutrients separately for two weeks maintaining proper moisture (60 %). The micronutrients (Zn, Fe and Mn) were added at 200 mg kg⁻¹ each and Cu was added at 20 mg kg⁻¹ on dry weight basis to FYM and thoroughly mixed with the FYM. The salts used for micronutrients were ZnSO₄·H₂O, FeSO₄·7H₂O, MnSO₄·H₂O and CuSO₄·5H₂O, respectively.

After two weeks of incubation the humic substance was extracted from the FYM with and without micronutrients separately following the method proposed by Schnitzer and Skinner [6].

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	

Table 2. Methods followed for the analysis of plant sample

Parameter	Method	Reference
Nitrogen	Kjeldahl digestion and distillation method	Piper [7]
Phosphorus	Diacid digestion and colorimetry using vanadomolybdate reagent	Piper [7]
Potassium	Flame photometry	Piper [7]
Calcium and Magnesium	Complexometry using versenate solution	Piper [7]
Sulphur	Turbidometry	Bardsley and Lancaster [8]
Micronutrient cations (Fe, Mn, Zn & Cu)	Atomic absorption spectrophotometry	Lindsay and Norwell [9]

2.5 Experimental Details

Before taking up the experiment with maize during *Kharif* 2017, paddy was grown under irrigated condition in the experimental plot. Ten treatments replicated thrice using RCBD. Treatment details are as follow

- T₁** : RDF (150:75:40 kg ha⁻¹ NPK)
T₂ : RDF + FYM @ 10 t ha⁻¹
T₃ : T₂ + HS @ 2.5 L ha⁻¹ as basal
T₄ : T₂ + HS @ 5 L ha⁻¹ as basal
T₅ : T₂ + HS @ 2.5 L ha⁻¹ 30 DAS
T₆ : T₂ + HS @ 5 L ha⁻¹ 30 DAS
T₇ : T₂ + EHS @ 2.5 L ha⁻¹ as basal
T₈ : T₂ + EHS @ 5 L ha⁻¹ as basal
T₉ : T₂ + EHS @ 2.5 L ha⁻¹ 30 DAS
T₁₀ : T₂ + 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

ZnSO₄ @ 10 kg ha⁻¹ is common for all the treatments except T₁

HS: Humic Substance without micronutrients enrichment

EHS: Humic Substance with micronutrients enrichment

2.6 Analysis of Plant Samples

Representative plant samples from each treatment were collected following destructive sampling technique, dried in a hot air oven at 65 °C, powdered using micro Willey mill and stored for nutrient analysis. The samples were analysed for nutrient content by following standard analytical methods as given in Table 2.

2.7 Nutrient Uptake by Crop

Nutrient content in grains and stover was determined by following standard analytical methods and expressed in percentage. Nutrient uptake (kg ha^{-1}) by grain or stover was calculated for each treatment using the following formula

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{nutrient concentration} \times \text{yield of grain or stover}}{100}$$

2.8 Statistical Analysis

The data collected from the experiment at different growth stages were subjected to statistical analysis as described by Gomez and Gomez [10]. The level of significance used in “F” test was $P = 0.05$. Critical difference (CD) values were calculated for the $P = 0.05$ whenever “F” test was found significant.

3. RESULTS AND DISCUSSION

3.1 Macro nutrients Content and Uptake by Maize Grain

3.1.1 Primary nutrients

Among the different treatments, T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) recorded significantly higher N, P and K content (1.66, 0.43 and 0.32 %, respectively) followed by treatment T_9 (T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS) (1.60, 0.39 and 0.29 %, respectively). Whereas lower N, P and K content (1.32, 0.28 and 0.20 %, respectively) was recorded for the treatment with RDF alone (T_1) (Table 3).

Similarly, among different treatments, T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) recorded significantly higher N, P and K uptake (126.77, 32.52 and 24.66 kg ha^{-1} , respectively) followed by treatment T_9 (T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS) (117.89, 29.04 and 20.87 kg ha^{-1} , respectively). Whereas lower N, P and K uptake (78.44, 16.61 and 11.66 kg ha^{-1} , respectively) were recorded for the treatment with RDF alone (T_1).

Further, increase in the nutrients (N, P and K) 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) and there was a significant increase in nutrients (N, P and K) content and uptake with 30 DAS treatments compared to corresponding basal treatments.

3.1.2 Secondary nutrients

The effects of various treatments on total secondary nutrients (Ca, Mg and S) content and uptake by grains after the harvest of maize are presented in Table 4.

Among the different treatments, T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) recorded significantly higher Ca, Mg and S content (0.32, 0.26 and 0.33 %, respectively) followed by treatment T_9 (T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS) (0.29, 0.23 and 0.29 %, respectively). Whereas lower Ca, Mg and S content (0.16, 0.10 and 0.15 %, respectively) was recorded for the treatment with RDF alone (T_1).

Similarly, among different treatments, T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) recorded significantly higher Ca, Mg and S uptake (24.14 , 20.07 and 24.90 kg ha^{-1} , respectively) followed by treatment T_9 (T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS) (20.88 , 16.60 and 20.92 kg ha^{-1} , respectively). Whereas lower Ca, Mg and S uptake (9.38 , 6.13 and 8.69 kg ha^{-1} , respectively) were recorded for the treatment with RDF alone (T_1).

Further, increase in the nutrients (Ca, Mg and S) 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) and there was a significant increase in nutrients (Ca, Mg and S) content and uptake with 30 DAS treatments compared to corresponding basal treatments except for Ca content in grains.

3.2 Nutrients Content and Uptake by Maize Stover

3.2.1 Primary nutrients

The effects of various treatments on total primary nutrients (N, P and K) content and uptake by stover after the harvest of maize are presented in Table 5.

Among the different treatments, T_{10} treatment (T_2 + Enriched HS @ 5 L ha^{-1} 30 DAS) recorded significantly higher N, P and K content (0.95, 0.25 and 0.64 %, respectively) followed by treatment T_9 (T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS) (0.89, 0.23 and 0.60 %, respectively). Whereas lower N, P and K content (0.72, 0.12 and 0.32 %, respectively) was recorded for the treatment with RDF alone (T_1).

Similarly, among different treatments, T₁₀ treatment (T₂ + Enriched HS @ 5 L ha⁻¹ 30 DAS) recorded significantly higher N, P and K uptake (98.53, 25.93 and 66.38 kg ha⁻¹, respectively) followed by treatment T₉ (T₂ + Enriched HS @ 2.5 L ha⁻¹ 30 DAS) (90.51, 23.68 and 60.57 kg ha⁻¹, respectively). Whereas lower N, P and K uptake (63.46, 10.33 and 28.61 kg ha⁻¹, respectively) were recorded for the treatment with RDF alone (T₁).

Further, significant increase in the nutrients (N, P and K) content and uptake by maize stover were recorded in the enriched treatments (T₇ to T₁₀) when compared to corresponding non enriched treatments (T₃ to T₆) and there was a significant increase in nutrients (N, P and K) content and uptake with 30 DAS treatments compared to corresponding basal treatments.

3.2.2 Secondary nutrients

The effects of various treatments on total secondary nutrients (Ca, Mg and S) content and uptake by stover after the harvest of maize are presented in Table 6.

Among the different treatments, T₁₀ treatment (T₂ + Enriched HS @ 5 L ha⁻¹ 30 DAS) recorded significantly higher Ca, Mg and S content (0.69, 0.39 and 0.33 %, respectively) followed by treatment T₉ (T₂ + Enriched HS @ 2.5 L ha⁻¹ 30 DAS) (0.64, 0.37 and 0.30 %, respectively). Whereas lower Ca, Mg and S content (0.42, 0.18 and 0.15 %, respectively) was recorded for the treatment with RDF alone (T₁).

Similarly, among different treatments, T₁₀ treatment (T₂ + Enriched HS @ 5 L ha⁻¹ 30 DAS) recorded significantly higher Ca, Mg and S uptake (71.91, 40.78 and 34.57 kg ha⁻¹, respectively) followed by treatment T₉ (T₂ + Enriched HS @ 2.5 L ha⁻¹ 30 DAS) (64.52, 37.22 and 30.12 kg ha⁻¹, respectively). Whereas lower Ca, Mg and S uptake (36.86, 16.24 and 13.58 kg ha⁻¹, respectively) were recorded for the treatment with RDF alone (T₁).

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

Treatments	N		P		K	
	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)
T ₁ RDF (150:75:40 kg NPK ha ⁻¹)	1.32	78.44	0.28	16.61	0.20	11.66
T ₂ RDF (150:75:40 kg NPK ha ⁻¹) + FYM @ 10 t ha ⁻¹	1.40	86.56	0.30	18.72	0.21	13.17
T ₃ T ₂ + HS @ 2.5 L ha ⁻¹ as basal	1.47	93.85	0.34	21.65	0.24	15.07
T ₄ T ₂ + HS @ 5 L ha ⁻¹ as basal	1.54	101.05	0.36	23.67	0.25	16.45
T ₅ T ₂ + HS @ 2.5 L ha ⁻¹ 30 DAS	1.51	101.73	0.36	24.42	0.27	17.92
T ₆ T ₂ + HS @ 5 L ha ⁻¹ 30 DAS	1.57	111.91	0.39	27.50	0.27	20.19
T ₇ T ₂ + Enriched HS @ 2.5 L ha ⁻¹ as basal	1.50	97.66	0.36	23.17	0.25	16.02
T ₈ T ₂ + Enriched HS @ 5 L ha ⁻¹ as basal	1.55	105.00	0.38	25.46	0.26	17.80
T ₉ T ₂ + Enriched HS @ 2.5 L ha ⁻¹ 30 DAS	1.60	117.89	0.39	29.04	0.29	20.87
T ₁₀ T ₂ + Enriched HS @ 5 L ha ⁻¹ 30 DAS	1.66	126.77	0.43	32.52	0.32	24.66
S. Em±	0.005	1.590	0.004	1.033	0.005	1.150
CD at 5%	0.015	6.725	0.011	3.139	0.016	3.456

Table 4. Effect of humic substance enriched with micronutrients on secondary nutrients content and uptake by maize grains

Treatments	Ca		Mg		S	
	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)
T ₁ RDF (150:75:40 kg NPK ha ⁻¹)	0.16	9.38	0.10	6.13	0.15	8.69
T ₂ RDF (150:75:40 kg NPK ha ⁻¹) + FYM @ 10 t ha ⁻¹	0.17	10.27	0.13	7.81	0.17	10.70
T ₃ T ₂ + HS @ 2.5 L ha ⁻¹ as basal	0.21	13.39	0.15	9.56	0.21	13.16
T ₄ T ₂ + HS @ 5 L ha ⁻¹ as basal	0.25	16.66	0.19	12.27	0.23	15.34
T ₅ T ₂ + HS @ 2.5 L ha ⁻¹ 30 DAS	0.22	15.00	0.20	13.68	0.26	17.26
T ₆ T ₂ + HS @ 5 L ha ⁻¹ 30 DAS	0.27	20.18	0.22	15.99	0.28	20.39
T ₇ T ₂ + Enriched HS @ 2.5 L ha ⁻¹ as basal	0.22	14.50	0.16	10.39	0.22	14.08
T ₈ T ₂ + Enriched HS @ 5 L ha ⁻¹ as basal	0.26	17.35	0.19	12.84	0.25	16.68
T ₉ T ₂ + Enriched HS @ 2.5 L ha ⁻¹ 30 DAS	0.29	20.88	0.23	16.60	0.29	20.92
T ₁₀ T ₂ + Enriched HS @ 5 L ha ⁻¹ 30 DAS	0.32	24.14	0.26	20.07	0.33	24.90
S. Em±	0.004	0.966	0.003	0.953	0.003	1.022
CD at 5%	0.012	2.910	0.010	2.900	0.010	3.076

Table 5. Effect of humic substance enriched with micronutrients on NPK content and uptake by maize stover

Treatments		N		P		K	
		Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)
T ₁	RDF (150:75:40 kg NPK ha ⁻¹)	0.72	63.46	0.12	10.33	0.32	28.61
T ₂	RDF (150:75:40 kg NPK ha ⁻¹) + FYM @ 10 t ha ⁻¹	0.76	68.61	0.14	13.00	0.39	35.66
T ₃	T ₂ + HS @ 2.5 L ha ⁻¹ as basal	0.79	73.36	0.16	15.10	0.44	40.37
T ₄	T ₂ + HS @ 5 L ha ⁻¹ as basal	0.84	81.46	0.19	18.02	0.50	48.29
T ₅	T ₂ + HS @ 2.5 L ha ⁻¹ 30 DAS	0.83	81.91	0.21	20.40	0.55	54.61
T ₆	T ₂ + HS @ 5 L ha ⁻¹ 30 DAS	0.88	89.66	0.22	21.97	0.57	58.10
T ₇	T ₂ + Enriched HS @ 2.5 L ha ⁻¹ as basal	0.82	79.06	0.17	16.77	0.46	44.55
T ₈	T ₂ + Enriched HS @ 5 L ha ⁻¹ as basal	0.86	85.99	0.20	19.60	0.52	52.14
T ₉	T ₂ + Enriched HS @ 2.5 L ha ⁻¹ 30 DAS	0.89	90.51	0.23	23.68	0.60	60.57
T ₁₀	T ₂ + Enriched HS @ 5 L ha ⁻¹ 30 DAS	0.95	98.53	0.25	25.93	0.64	66.38
S. Em±		0.005	1.777	0.003	0.402	0.006	1.587
CD at 5%		0.013	5.348	0.010	1.194	0.017	4.784

Table 6. Effect of humic substance enriched with micronutrients on secondary nutrient content and uptake by maize stover

Treatments		Ca		Mg		S	
		Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)
T ₁	RDF (150:75:40 kg NPK ha ⁻¹)	0.42	36.86	0.18	16.24	0.15	13.58
T ₂	RDF (150:75:40 kg NPK ha ⁻¹) + FYM @ 10 t ha ⁻¹	0.44	40.20	0.23	21.15	0.18	16.32
T ₃	T ₂ + HS @ 2.5 L ha ⁻¹ as basal	0.52	47.78	0.27	24.66	0.23	20.96
T ₄	T ₂ + HS @ 5 L ha ⁻¹ as basal	0.56	54.09	0.31	29.94	0.24	22.86
T ₅	T ₂ + HS @ 2.5 L ha ⁻¹ 30 DAS	0.52	59.10	0.34	33.23	0.27	26.32
T ₆	T ₂ + HS @ 5 L ha ⁻¹ 30 DAS	0.59	58.52	0.34	34.43	0.28	28.71
T ₇	T ₂ + Enriched HS @ 2.5 L ha ⁻¹ as basal	0.56	53.90	0.27	26.46	0.24	22.92
T ₈	T ₂ + Enriched HS @ 5 L ha ⁻¹ as basal	0.58	51.32	0.32	31.53	0.26	25.57
T ₉	T ₂ + Enriched HS @ 2.5 L ha ⁻¹ 30 DAS	0.64	64.52	0.37	37.22	0.30	30.12
T ₁₀	T ₂ + Enriched HS @ 5 L ha ⁻¹ 30 DAS	0.69	71.91	0.39	40.78	0.33	34.57
S. Em±		0.005	1.164	0.005	0.854	0.004	0.879
CD at 5%		0.016	3.477	0.015	2.558	0.011	2.602

Table 7. Effect of humic substance enriched with micronutrients on total uptake of macronutrients by maize

Treatments		N	P	K	Ca	Mg	S
		(kg ha ⁻¹)					
T₁	RDF (150:75:40 kg NPK ha ⁻¹)	141.90	26.94	40.28	46.24	22.37	22.27
T₂	RDF (150:75:40 kg NPK ha ⁻¹) + FYM @ 10 t ha ⁻¹	155.17	31.72	48.82	50.47	28.96	27.02
T₃	T ₂ + HS @ 2.5 L ha ⁻¹ as basal	167.21	36.75	55.44	61.17	34.22	34.13
T₄	T ₂ + HS @ 5 L ha ⁻¹ as basal	182.50	41.70	64.74	70.75	42.22	38.20
T₅	T ₂ + HS @ 2.5 L ha ⁻¹ 30 DAS	183.65	44.82	72.54	74.10	46.91	43.59
T₆	T ₂ + HS @ 5 L ha ⁻¹ 30 DAS	201.57	49.47	78.29	78.70	50.42	49.10
T₇	T ₂ + Enriched HS @ 2.5 L ha ⁻¹ as basal	176.72	39.94	60.57	68.40	36.85	37.00
T₈	T ₂ + Enriched HS @ 5 L ha ⁻¹ as basal	190.99	45.06	69.94	68.67	44.38	42.25
T₉	T ₂ + Enriched HS @ 2.5 L ha ⁻¹ 30 DAS	208.40	52.72	81.44	85.38	53.82	51.03
T₁₀	T ₂ + Enriched HS @ 5 L ha ⁻¹ 30 DAS	225.30	58.44	91.03	96.04	60.86	59.47
	S. Em±	2.82	1.87	2.66	3.70	2.12	2.19
	CD at 5%	8.38	5.55	7.90	10.99	6.31	6.51

Further, significant increase in the nutrients (Ca, Mg and S) content and uptake by maize stover were recorded in the enriched treatments (T₇ to T₁₀) when compared to corresponding non enriched treatments (T₃ to T₆) and there was a significant increase in nutrients (Ca, Mg and S) content and uptake with 30 DAS treatments compared to corresponding basal treatments except for Ca content in stover.

3.3 Total Uptake of Nutrients by Maize

The effects of various treatments on total macro nutrients (N, P, K, Ca, Mg and S) uptake by maize are presented in Table 7.

Among different treatments, T₁₀ treatment (T₂ + Enriched HS @ 5 L ha⁻¹ 30 DAS) recorded significantly higher total uptake of N, P, K, Ca, Mg and S (225.30, 58.44, 91.03, 96.04, 60.86 and 59.47 kg ha⁻¹, respectively) followed by treatment T₉ (T₂ + Enriched HS @ 2.5 L ha⁻¹ 30 DAS) (208.40, 52.72, 81.44, 85.38, 53.82 and 51.03 kg ha⁻¹, respectively). Whereas lower N, P, K, Ca, Mg and S uptake (141.90, 26.94, 40.28, 46.24, 22.37 and 22.27 kg ha⁻¹, respectively) were recorded for the treatment with RDF alone (T₁).

Significant increase in the nutrient content and uptake may be due to increase in yield which was mainly associated with higher uptake of all the nutrients. Higher uptake of nutrients can be attributed to increased root biomass as influenced by microbial activity, more solubility and availability of nutrients as influenced by humic substance which increased the growth, yield and dry matter production ultimately increased nutrient demand and flux. Humic substance prevents P fixation in the soil by formation of humophospho complexes which are easily available to the plants and finally increased the P uptake by plants [11].

Hussein and Hassan [12] also found increased N uptake by corn with soil application of humus. Paul et al. (2017) proved that humic acid extracted from FYM was responsible for enrichment in qualitative parameters through increasing the uptake of P, K and S within the plant. Nardi et al. [13] found that "humic substances play a beneficial role in nutrient acquisition by plants, which is due to its complexing properties which increase the availability of nutrients from sparingly soluble hydroxides. The effects of humic substances on ion uptake appear to be selective in relation to

their concentration and the pH of the medium, they work on the metabolism and promote nutrient uptake or plant growth by acting as a hormone". Asri et al. [14] also revealed that "the relative increase in NPK uptake by plants grown with application of humic substance". Similar results were obtained in maize by Khan et al. [15].

The uptake of secondary nutrients was found increasing which might be due to decrease in losses of nutrients due to leaching and fixation. Moreover, SSP is the source of secondary nutrients thus might have contributed to their uptake by crop efficiently. Soil application of humic substance was significantly effective on the uptake of Mg [16]. Better nutrient content and uptake of major and trace elements by application of humic acid along with recommended dose of fertilizer in groundnut was recorded by Thenmozhi [17].

4. CONCLUSION

By the results, it can be clearly concluded that humic substance enriched with micronutrients is efficient in improving the potentiality of maize in assimilation of macronutrients there by higher yield can be achieved. Further, soil application of Enriched HS @ 5 L ha⁻¹ 30 DAS along with RDF and FYM proven the best treatment in achieving higher macronutrient content and uptake by both grain and stover of maize which can be clearly correlated with improved biomass in turn the growth and yield of maize.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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