Original Research Article

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

Abstract

The present study aimed to know the potentiality of maize to assimilate macronutrients with the influence of humic substance enriched with micronutrients. For this, a field experiment was carried out in College of Agriculture, V C Farm, Mandya, Karnataka, India. The results revealed that significantly higher macronutrients content and uptake in grains and stover was observed for the treatment with RDF + FYM @ 10 t ha^{-1} along with Enriched HS @ 5 L ha^{-1} 30 DAS) followed by 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, T_{10} treatment (T_2 + 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 T_9 (T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS). 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 (T_1).

Key words: Humic substance, Macronutrients, Maize, Farm yard manure, Enrich

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. 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 (Mackowiak *et al*., 2001). 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 (Senn and Kingman, 1973).

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. 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 (Anon., 2015). 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.

Materials and Methods

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^{o} 34.31' North latitude and 76^{o} 49.8' East longitude at 697 meter above mean sea level.

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).

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 P_2O_5 ha^{-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 was deficient while Fe, Mn, Zn and Cu were sufficient (Table 1).

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

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 $ZnSO_4.H_2O$, $FeSO_4.7H_2O$, $MnSO_4.H_2O$ and $CuSO_4.5H_2O$, 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 (1968).

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

$\mathbf{T_1}$	: RDF (150:75:40 kg ha^{-1} NPK)
$\mathbf{T_2}$	: RDF + FYM @ 10 t ha^{-1}
$\mathbf{T_3}$	: T_2 + HS @ 2.5 L ha^{-1} as basal
$\mathbf{T_4}$	: T_2 + HS @ 5 L ha^{-1} as basal
$\mathbf{T_5}$	: T_2 + HS @ 2.5 L ha^{-1} 30 DAS
$\mathbf{T_6}$	: T_2 + HS @ 5 L ha^{-1} 30 DAS
$\mathbf{T_7}$	: T_2 + EHS @ 2.5 L ha^{-1} as basal
$\mathbf{T_8}$	: T_2 + EHS @ 5 L ha^{-1} as basal
$\mathbf{T_9}$	: T_2 + EHS @ 2.5 L ha^{-1} 30 DAS
$\mathbf{T_{10}}$	: T_2 + EHS @ 5 L ha^{-1} 30 DAS

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.

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

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

Table 2: Methods followed for the analysis of plant sample.

Parameter	Method	Reference
Nitrogen	Kjeldahl digestion and distillation method	Piper (1966)
Phosphorus	Diacid digestion and colorimetry using vanadomolybdate reagent	Piper (1966)
Potassium	Flame photometery	Piper (1966)
Calcium and Magnesium	Complexometry using versenate solution	Piper (1966)
Sulphur	Turbidometry	Bardsley and Lancaster (1965)
Micronutrient cations (Fe, Mn, Zn & Cu)	Atomic absorption spectrophotometery	Lindsay and Norwell 1978

Results and Discussion

Macroutrients content and uptake by maize grain

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.

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.

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**

Nutrients content and uptake by maize stover

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, T_{10} treatment (T_2 + 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 T_9 (T_2 + 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 (T_1).

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

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, T_{10} treatment (T_2 + 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 T_9 (T_2 + 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 (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 (71.91, 40.78 and 34.57 kg ha^{-1}, respectively) followed by treatment T_9 (T_2 + 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 (T_1).

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

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, T_{10} treatment (T_2 + 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 T_9 (T_2 + 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 (T_1).

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 nutrients. Higher uptake of nutrients cab be attributed to increased root biomass as influenced 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 assailable by the plants and finally increased the P uptake by plants (Raina and Goswami, 1988).

Hussein and Hassan (2011) 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.* (2002) found that humic substances plays 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.* (2015) 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*. (2014).

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 sources 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 (Turan *et al*., 2011). 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 (2001).

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})					
T_1	RDF (150:75:40 kg NPK ha^{-1})	141.90	26.94	40.28	46.24	22.37	22.27
T_2	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
T_3	T_2 + HS @ 2.5 L ha^{-1} as basal	167.21	36.75	55.44	61.17	34.22	34.13
T_4	T_2 + HS @ 5 L ha^{-1} as basal	182.50	41.70	64.74	70.75	42.22	38.20
T_5	T_2 + HS @ 2.5 L ha^{-1} 30 DAS	183.65	44.82	72.54	74.10	46.91	43.59
T_6	T_2 + HS @ 5 L ha^{-1} 30 DAS	201.57	49.47	78.29	78.70	50.42	49.10
T_7	T_2 + Enriched HS @ 2.5 L ha^{-1} as basal	176.72	39.94	60.57	68.40	36.85	37.00
T_8	T_2 + Enriched HS @ 5 L ha^{-1} as basal	190.99	45.06	69.94	68.67	44.38	42.25
T_9	T_2 + Enriched HS @ 2.5 L ha^{-1} 30 DAS	208.40	52.72	81.44	85.38	53.82	51.03
T_{10}	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**

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.

References

Anonymous (2015) Area, production and productivity of maize in India. Directorate of Maize Reasearch.

Asri, F. O., Demirtas E, I. and Ari, N. (2015) Changes in fruit yield, quality and nutrient concentrations in response to soil humic acid applications in processing tomato**.** *Bulgarian Journal of Agriculture Sci*ence **21**(3), 585-591.

ASRI, F. O., DEMIRTAS E, I. AND ARI, N. (2015) Changes in fruit yield, quality and nutrient concentrations in response to soil humic acid applications in processing tomato**.** *Bulgarian Journal of Agriculture Science* **21**(3), 585-591.

Bardsley, C. E. and Lancaster, J. D. (1965) In, *Methods of soil analysis*, Part 2. Eds. Black, C. A., Evans, D. D., White, J. L., Jusminger, L. E. and Clark, F. E. Madison, *American Society Agronomy* pp. 1102-1116.

Hussein. and Hassan, A. (2011) Effect of different levels of humic acids on the nutrient content, plant growth, and soil properties under conditions of salinity. *Soil and Water Research* **6**(1), 21-29.

Khan, M. Z., Akhtar, M., Eahmad, S., Khan, A. and Khan, R. U. (2014) Chemical composition of lignitichumic acid and evaluating its positive impacts on nutrient uptake, growth and yield of maize. *Pakistan Journal of Chemistry* **4**(1), 19-25.

Lindsay, W. L. and Norvel, W. A. (1978) Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Science Society of America Journal* **42**, 421-428.

Mackowiak, C., Grossl, P. And Bugbee, B. (2001) Beneficial effects of humic acid on micronutrient availability to wheat. *Soil Science Society of America Journal* **65**(6), 1744-1750.

Nardi, S. D., Pizzeghello, A., Muscolo and Vianello, A. (2002) Physiological effects of humic substances on higher plants. *Soil Biology and Biochemistry* **34**, 1527-1536.

Piper, C. S. (1966) *Soil and Plant Analysis*, Hans Publishers, Bombay, pp. 368.

Raina, J. N. and Goswami, K. P. (1988) Effect of fulvic acid and fulvates on growth and nutrient uptake by maize plant. *Jornal of Indian Society of Soil Science* **36**, 264-268.

Schnitzer, M. and Skinner, S. I. M. (1968) Alkali versus acid extraction of soil organic matter. *Soil Science* **105**, 392-396.

Senn, T. L. and Kingman (1973) A review of humus and humic acids. Research Series No. 145, S. C. Agricultural Experiment Station Clemson, South Carolina, USA.

Thenmozhi, S. (2001) Effect of humic acid on growth, yield, quality and content and uptake of nutrients by groundnut (VRI-2). *M.Sc. (Agri) Thesis*, TNAU, Coimbatore.

Turan, M. A., Asik, B. B., Katkat, A. V. and Celik, H. (2011) The effects of soil –applied humic substances to the dry weight and mineral nutrient uptake of maize plants under soil-salinity conditions. *Ntulae botanicae horti agrobotanici cluj-napoca,* **39**(1), 171-177.