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Yield of cowpea and uptake of nutrients and soil chemical status as influenced by STCR fertilizer dose with humic acid and multi-micronutrient mixture in Southern Dry Zone (Zone 6) of Karnataka

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Abstract

A field experiment was conducted to validate the cowpea STCR equation developed for Zone 5 in Zone 6 and to assess its performance with foliar application of humic acid and multi-micronutrient mixture during *Kharif* 2016 on sandy loam soil at college of Agriculture, V.C. Farm, Mandya. The experimental results revealed that significantly higher total N uptake was observed in T₁₂ (142.58 kg ha⁻¹), total P uptake of 14.58 kg ha⁻¹ in T₁₃ and total K uptake in T₁₁ (127.62 kg ha⁻¹). The uptake of all the micronutrients were higher in the treatments with foliar application of MM with humic acid at 30 and 45 DAS, followed by foliar application of MM alone. Available nutrient status of soil after the harvest of the crop showed a significant effect due to treatments. Higher nitrogen status was reported in T₁₁ (257.13 kg ha⁻¹) followed by T₁₂ (250.85 kg ha⁻¹) and least was in control (175.69 kg ha⁻¹). Higher soil P status was recorded in the treatment having RDF + FYM (86.76 kg ha⁻¹) followed by T₃ receiving STCR fertilizer dose with 50% RDP without FYM (85.23 kg ha⁻¹). Higher K status of the soil was recorded in T₅ (235.34 kg ha⁻¹) with STCR (50% RDP) with FYM. However, lowest was recorded in control (155.89 kg ha⁻¹).

Keywords: STCR, Humic acid (HA), Multi-micronutrient mixture (MM).

Introduction

In India, pulses can be produced with a minimum use of resources and hence, it becomes less costly than animal protein. In comparison to other vegetables, pulses are rich in protein which are less expensive and can be cultivated as an inter-crop and also as mixed crop. Pulses are mostly cultivated under rainfed conditions and do not require intensive irrigation facility and this is the reason why pulses are grown in areas left after satisfying the demand for cereals/cash crops. Even in such conditions, pulses give better returns. Pulses also improves soil fertility and physical structure, fit in mixed or inter-cropping system, crop rotations and dry farming and provide green pods for vegetable and nutritious fodder for cattle as well.

Cowpea is a legume mainly grown in tropical and subtropical regions in the world for vegetable and grains and to lesser extent as a fodder crop. It serves also as cover crop and improves soil fertility by fixing atmospheric nitrogen. Since fertilizer is a costly input, the scientific and efficient utilization of this input is very important. In this input utilization, STCR approach plays a vital role as a comprehensive approach of fertilizer utilization, wherein fertilizer will be applied based on the yield target, to a particular soil test values.

A recent survey by ICRISAT indicated that soils in many states in India are deficient in micronutrients such as boron and zinc (Wani *et al.*, 2012) [17]. Application of small quantities (0.5 to 2 kg ha⁻¹) has resulted in 40-120 per cent increase in grain yield. Hence, making these micronutrient fertilizers easily available to smallholder farmers in remote areas will go a long way in enhancing productivity and production of pulses. Under a mission to boost productivity of rainfed agriculture through science-led interventions in Karnataka (called the Bhoochetana project) the improved management practices (including application of micronutrients) have increased the yield by 31-57 per cent in green gram, 26-38 per cent in pigeonpea and 27- 39

per cent in chickpea during 2010-11. Similarly in 2011-12, black gram and green gram grain yields increased by 33-42 per cent in response to improved management when compared to farmers management (Wani *et al.*, 2012) [17]. The positive response to application of multi-micronutrient mixture was observed in cowpea by Mahriya and Meena (1999) [10].

Studies on the direct and indirect effects of humic substances on plant growth have repeatedly shown positive effects on plant biomass as long as there is sufficient mineral nutrition. Stimulation of root growth is generally more apparent than stimulation of shoot growth (Chen and Aviad, 1990; Nardi *et al.*, 1996 and Abad, 1991) [4, 12, 1]. This stimulatory effects of humic substances have been directly correlated with enhanced uptake of macronutrients, such as nitrogen, phosphorus, sulfur (Chen and Aviad, 1990) [4] and micronutrients, i.e. Fe, Zn, Cu and Mn (Chen *et al.*, 1999) [5].

Material and methods

Field experiment was conducted during *Kharif* 2016 on Validation and performance of cowpea STCR equation with humic acid and multi- micronutrient mixture in Southern Dry Zone (Zone 6) of Karnataka at College of Agriculture, Vishweshwaraiah Canal (V. C.) Farm, Mandya, Karnataka. The experiment consists of 13 treatment combinations with T1: Absolute control, T2: RDF + FYM, T3: STCR only (P maintenance dose i.e. 50% RDP), T4: STCR actual dose (no P), T5: STCR (50% RDP) + FYM, T6: T5 + HA (500 ppm foliar spray at 30 and 45 DAS), T7: T5 + HA (1000 ppm foliar spray at 30 and 45 DAS), T8: T5 + MM1 (Foliar spray at 30 and 45 DAS), T9: T5 + MM2 (Foliar spray at 30 and 45 DAS), T10: T5 + HA (500 ppm) + MM1 (Foliar spray at 30 and 45 DAS), T11: T5 + HA (1000 ppm) + MM1 (Foliar spray at 30 and 45 DAS), T12: T5 + HA (500 ppm) + MM2 (Foliar spray at 30 and 45 DAS), T13: T5 + HA (1000 ppm) + MM2 (Foliar spray at 30 and 45 DAS).

The quantity of fertilizer through STCR approach was calculated by using STCR equations for a cowpea yield target of 15 q ha⁻¹.

$$\begin{aligned} \text{F.N.} &= 11.02 \text{ T} - 0.43 \text{ S.N (KmnO}_4 - \text{N)} \\ \text{F.P}_2\text{O}_5 &= 10.77 \text{ T} - 2.725 \text{ S.P}_2\text{O}_5 \text{ (Olsen's - P}_2\text{O}_5) \\ \text{F.K}_2\text{O} &= 8.48 \text{ T} - 0.466 \text{ S.K}_2\text{O (NH}_4\text{OAC - K}_2\text{O)} \end{aligned}$$

The recommended dose of fertilizer i.e. 25-50-25 kg NPK per hectare was applied with 7.5 tonnes of FYM. For STCR treatments, the following fertilizer dose was applied based on the treatment details. Humic acid and micronutrient mixture was applied upon dilution according to treatment details. Agritone (4% HA) was diluted in water to get 500 and 1000 ppm, respectively.

Humic acid and micronutrient mixture

Nutrient	Initial status (kg ha ⁻¹)	Actual STCR dose	Applied STCR dose *
N	200.7	79	50
P ₂ O ₅	68.32	-24.62	25
K ₂ O	179.5	43.553	43.5

* Applied dose of N is less than the actual dose because a upper limit of 200 per cent of the RDF was fixed in low fertile soils. However in case of P fertilizer dose, applied dose is higher than the actual as high fertility soils gives negative value or zero, 50 per cent of RDF is applied as maintenance dose (Prakash *et al.*, 2007).

Micronutrient carrier and quantity used for foliar application

Micronutrient	MM1 (g ha ⁻¹)	MM2 (g ha ⁻¹)
Fe ₂ SO ₄ .7H ₂ O	210	420
MnSO ₄ .5 H ₂ O	66	66
ZnSO ₄ .7H ₂ O	380	760
CuSO ₄ .7H ₂ O	84	50
Borax	190	190

The Humic acid and MM solution was prepared at the rate of 400 liters per ha. Citric acid was used to completely dissolve the micronutrient salts and then the pH of the solution was adjusted to pH 6.5 using KOH. The foliar spray of HA and MM was carried out at 30 and 45 DAS.

Table 1: Initial Physico-chemical properties of soil at the experimental site

Sl. No	Parameter	Method	Value
Physical Properties			
1	Sand (%)	International pipette method	87.17
2	Silt (%)		1.50
3	Clay (%)		9.75
4	Textural class		Sandy loam
5	Bulk density (Mg m ⁻³)		1.40
Chemical properties			
1	pH(1:2.5)	Potentiometry	6.85
2	EC _{2.5} (dS m ⁻¹)	Conductometry	0.14
3	Organic carbon (g kg ⁻¹)	Wet digestion	6.80
4	Available N (kg ha ⁻¹)	Alkaline potassium permanganate distillation method	200.70
5	Available P ₂ O ₅ (kg ha ⁻¹)	Olsens extractant method, Colorimetry	68.32
6	Available K ₂ O (kg ha ⁻¹)	Ammonium acetate extractant method, Flame photometry	179.50
7	Available Ca (cmol (p ⁺) kg ⁻¹)	Ammonium acetate extractant method, Versenate titration method	4.80
8	Available Mg (cmol (p ⁺) kg ⁻¹)		1.60
9	Available S (mg kg ⁻¹)	CaCl ₂ extraction, Turbidimetry	12.75
10	DTPA Fe (mg kg ⁻¹)	Atomic absorption spectrophotometry	11.82
11	DTPA Zn (mg kg ⁻¹)		1.86
12	DTPA Mn (mg kg ⁻¹)		11.80
13	DTPA Cu (mg kg ⁻¹)		0.52
14	Hot water soluble Boron (mg kg ⁻¹)	Hot water extraction method and colorimetry using Azomethine-H	0.38

The physico-chemical properties of composite soil sample collected before laying out the experiment are presented in Table 1.

The soil was sandy loam in texture with 87.17, 1.5, and 9.75 per cent sand, silt and clay, respectively and bulk density of 1.4 Mg m^{-3} . The soil was neutral in reaction (pH 6.85) and low in soluble salts (0.14 dS m^{-1}). The soil was medium in organic carbon (6.8 g kg^{-1}) content, low in available nitrogen (200.7 kg ha^{-1}) and high in available P_2O_5 (68.32 kg ha^{-1}),

while it was medium in K_2O (179.5 kg ha^{-1}) and high in sulphur (12.75 mg kg^{-1}). The exchangeable calcium and magnesium content of soil was 4.80 and $1.60 \text{ cmol kg}^{-1}$, respectively. The DTPA extractable micronutrient content viz., zinc, iron, copper, manganese and boron were 1.86, 11.82, 0.52, 11.8 and 0.38 mg kg^{-1} , respectively.

Results

Table 2: Effect of STCR based fertilizer recommendation along with foliar application of humic acid and multi-micronutrient mixture on grain and haulm yield of cowpea

Treatment	Grain yield(kg ha^{-1})	Haulm yield (kg ha^{-1})
T ₁ - Absolute control	1015.66	1992.22
T ₂ - RDF + FYM	1422.22	2513.33
T ₃ - STCR	1522.09	2875.92
T ₄ - STCR (no P)	1239.90	2337.03
T ₅ - STCR (50% RDP) + FYM	1522.22	2907.40
T ₆ - T ₅ + HA 500 ppm	1526.67	3007.40
T ₇ - T ₅ + HA 1000 ppm	1529.90	3016.29
T ₈ - T ₅ + MM1	1532.93	3029.26
T ₉ - T ₅ + MM2	1537.32	3036.29
T ₁₀ - T ₅ + HA 500 ppm + MM1	1541.92	3061.11
T ₁₁ - T ₅ + HA 1000 ppm + MM1	1545.25	3081.85
T ₁₂ - T ₅ + HA 500 ppm + MM2	1550.61	3096.29
T ₁₃ - T ₅ + HA 1000 ppm + MM2	1547.80	3060.74
S. Em±	66.21	141.95
CD (P=0.05)	193.24	414.32

The grain yield of cowpea in control was $1015.66 \text{ kg ha}^{-1}$, which increased significantly due to application of RDF + FYM ($1422.22 \text{ kg ha}^{-1}$) fertilizers. While application of STCR based fertilizer dose (50% RDP) only or along with foliar spray of HA and MM (T₃ and T₅-T₁₃) significantly increased the seed yield of cowpea compared to control ($1015.66 \text{ kg ha}^{-1}$) and T₄ ($1239.90 \text{ kg ha}^{-1}$) but they were statistically at par with each other. The maximum seed yield of $1550.61 \text{ kg ha}^{-1}$ was recorded in the treatment that received STCR based fertilizer dose (50% RDP) along with foliar spray of HA @ 500 ppm and MM2 at 30 and 45 DAS (T₁₂). Significantly higher haulm yield of $3096.29 \text{ kg ha}^{-1}$ was obtained due to T₁₂ followed by $3081.85 \text{ kg ha}^{-1}$ in T₁₁. These treatments were significantly superior than control ($1992.22 \text{ kg ha}^{-1}$), RDF + FYM ($2513.33 \text{ kg ha}^{-1}$) and T₄ ($2337.03 \text{ kg ha}^{-1}$). (Table 2) Data presented in Table 3 indicated the total uptake of primary and secondary nutrients by the crop. N uptake ranged

from 77.40 to $142.58 \text{ kg ha}^{-1}$. Significantly higher N uptake of $142.58 \text{ kg ha}^{-1}$ was observed in T₁₂ with STCR (50% RDF) + HA 500 ppm + MM2 which was significantly higher than T₁, T₂ and T₄. Total P uptake increased from 6.90 kg ha^{-1} in control to 14.58 kg ha^{-1} in T₁₃ due to application of STCR based fertilizer dose (50% RDP) with HA 1000 ppm and MM2. Total potassium uptake ranged from 57.82 to $127.62 \text{ kg ha}^{-1}$. Higher K uptake of $127.62 \text{ kg ha}^{-1}$ was observed in T₁₁ with STCR dose + HA 1000 ppm + MM1 which was significantly higher than T₁, T₂, T₃, T₄ and T₅.

The total calcium uptake increased from 50.13 kg ha^{-1} in control to 93.64 kg ha^{-1} in T₉. Higher Mg uptake of 139 kg ha^{-1} was observed in T₈ (STCR dose with MM1) which was significantly higher than the treatments without HA and MM (T₁ to T₅). Higher S uptake of 8.88 kg ha^{-1} was seen in T₉ which was significantly higher than all other treatments except T₁₃ (8.06 kg ha^{-1})

Table 3: Effect of STCR fertilizer dose with humic acid and multi-micronutrient mixture on total uptake of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur (kg ha^{-1})

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (kg ha^{-1})	Mg (kg ha^{-1})	S (kg ha^{-1})
T ₁ - Absolute control	77.40	6.90	57.82	50.13	70.15	3.04
T ₂ - RDF + FYM	119.11	13.37	93.18	81.66	106.08	6.32
T ₃ - STCR	129.04	11.77	105.74	79.36	109.72	7.47
T ₄ - STCR (no P)	101.93	8.83	85.77	50.81	73.41	5.88
T ₅ - STCR (50% RDP) + FYM	134.27	12.68	113.84	65.01	110.40	7.29
T ₆ - T ₅ + HA 500 ppm	135.38	12.36	117.50	91.41	118.63	6.89
T ₇ - T ₅ + HA 1000 ppm	138.94	12.63	114.88	77.12	137.54	7.53
T ₈ - T ₅ + MM1	137.35	13.83	123.01	86.62	139.00	7.82
T ₉ - T ₅ + MM2	138.18	14.12	124.98	93.64	120.57	8.88
T ₁₀ - T ₅ + HA 500 ppm + MM1	135.87	13.89	126.42	74.27	126.67	7.37
T ₁₁ - T ₅ + HA 1000 ppm + MM1	138.38	13.20	127.62	87.97	122.10	7.26
T ₁₂ - T ₅ + HA 500 ppm + MM2	142.58	14.51	126.61	86.23	122.37	7.59
T ₁₃ - T ₅ + HA 1000 ppm + MM2	138.57	14.58	125.31	79.09	118.21	8.06
S.Em±	4.55	0.50	4.57	5.60	7.20	0.33
CD (P=0.05)	13.29	1.47	13.34	16.35	21.01	0.97

Table 4: Effect of STCR fertilizer dose with humic acid and multi-micronutrient mixture on total uptake of micronutrients (g ha⁻¹)

Treatment	Fe (g ha ⁻¹)	Mn (g ha ⁻¹)	Zn (g ha ⁻¹)	Cu (g ha ⁻¹)	B (g ha ⁻¹)
T ₁ – Absolute control	407.41	113.81	43.02	26.26	65.32
T ₂ – RDF + FYM	715.92	190.77	68.58	37.09	105.09
T ₃ – STCR	916.86	228.28	72.47	40.73	123.27
T ₄ – STCR (no P)	792.05	161.64	65.14	34.15	84.55
T ₅ – STCR (50% RDP) + FYM	977.03	233.82	80.01	43.68	128.01
T ₆ – T ₅ + HA 500 ppm	1037.78	230.10	83.05	43.25	132.72
T ₇ – T ₅ + HA 1000 ppm	1061.61	213.31	84.35	43.33	134.27
T ₈ – T ₅ + MM1	1314.03	297.08	101.26	56.56	177.73
T ₉ – T ₅ + MM2	1392.20	288.55	103.97	53.06	177.75
T ₁₀ – T ₅ + HA 500 ppm + MM1	1342.47	300.91	103.93	55.70	179.59
T ₁₁ – T ₅ + HA 1000 ppm + MM1	1380.28	300.14	104.65	58.60	181.85
T ₁₂ – T ₅ + HA 500 ppm + MM2	1425.34	295.32	108.26	55.00	181.43
T ₁₃ – T ₅ + HA 1000 ppm + MM2	1417.72	294.11	107.12	55.12	179.81
S. Em±	50.74	15.09	3.57	2.28	5.19
CD (P=0.05)	148.09	44.05	10.42	6.65	15.14

Table 4 indicated the total uptake of micronutrients by cowpea crop. Application of STCR fertilizer dose with HA and MM significantly increased the uptake of all micronutrients. Fe uptake ranged from 407.41 g ha⁻¹ (control) to 1425.34 g ha⁻¹. Higher Fe uptake of 1425.34 g ha⁻¹ was observed in T₁₂ with STCR (50% RDP) + FYM + HA 500 ppm + MM2. Significantly higher Mn content of 300.91 g ha⁻¹ was observed in T₁₀ which was significantly higher than all treatments without MM application (T₁ to T₇). Copper uptake increased from 26.26 g ha⁻¹ in control to 58.60 g ha⁻¹ in T₁₁ which was higher than all other treatments. Higher boron uptake of 181.85 g ha⁻¹ was seen in treatment T₁₁ with STCR (50% RDF) + HA 1000 ppm + MM1 which was significantly higher than the treatments without MM application.

The uptake of nutrients by crop is a product of nutrient content and grain and dry matter yield. The increased uptake is due to increased root growth which increased growth parameters, yield parameters and thereby total biomass of the

crop in STCR based fertilizer dose which was higher than RDF. Further addition of HA and MM increased the uptake of these macronutrients mainly due to balanced nutrition of the crop and increased efficiency of macronutrients with the application of micronutrients. Increased uptake of NPK by HA was in conformity with the findings of Ananthi and Mallika (2014) [2] in green gram, Khaled and Hassan (2011) [8] in corn and Singaravel *et al.* (1998) [16] in sesame.

The total uptake of iron and zinc (1425.35 and 108.26 g ha⁻¹, respectively) by grain + haulm was highest in T₁₂ and manganese uptake (300.91 g ha⁻¹) in T₁₀ and copper and boron (58.60 and 181.85 g ha⁻¹, respectively) in T₁₁. The higher uptake might be attributed to foliar application of micronutrients through MM alone or in combination with humic acid which improved the root growth and thereby overall growth of the plants and absorption of micronutrients applied on foliage.

Table 5: Soil pH, EC and OC content of soil as influenced by STCR based fertilizer dose with foliar HA and MM application

Treatment	pH	EC (dS m ⁻¹)	Organic carbon (g kg ⁻¹)
T ₁ - Absolute control	6.88	0.13	5.90
T ₂ - RDF + FYM	6.76	0.14	6.27
T ₃ - STCR	6.82	0.13	5.95
T ₄ - STCR (no P)	6.87	0.13	5.92
T ₅ - STCR (50% RDP) + FYM	6.82	0.13	6.10
T ₆ - T ₅ + HA 500 ppm	6.76	0.15	6.13
T ₇ - T ₅ + HA 1000 ppm	6.89	0.13	6.43
T ₈ - T ₅ + MM1	6.80	0.13	6.27
T ₉ - T ₅ + MM2	6.88	0.14	6.30
T ₁₀ - T ₅ + HA 500 ppm + MM1	6.85	0.14	6.40
T ₁₁ - T ₅ + HA 1000 ppm + MM1	6.80	0.14	6.37
T ₁₂ - T ₅ + HA 500 ppm + MM2	6.81	0.14	6.40
T ₁₃ - T ₅ + HA 1000 ppm + MM2	6.80	0.15	6.37
S.Em±	0.05	0.01	0.25
CD (P=0.05)	NS	NS	NS

Table 6: Available N, P₂O₅ and K₂O content of soil after harvest of cowpea as influenced by STCR based fertilizer dose with foliar HA and MM application

Treatment	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)	Ca (cmol (p ⁺) k ⁻¹)	Mg (cmol (p ⁺) kg ⁻¹)	S (mg kg ⁻¹)
T ₁ - Absolute control	175.69	74.62	155.89	4.90	1.27	10.17
T ₂ - RDF + FYM	227.19	86.76	177.89	4.83	1.17	11.45
T ₃ - STCR	213.25	85.23	189.09	4.40	1.13	10.97
T ₄ - STCR (no P)	225.78	78.78	219.30	4.60	1.13	10.85
T ₅ - STCR (50% RDP) + FYM	229.50	79.45	235.34	4.93	1.17	10.90
T ₆ - T ₅ + HA 500 ppm	232.05	79.52	211.18	4.30	1.53	10.92
T ₇ - T ₅ + HA 1000 ppm	244.63	79.11	221.83	5.03	1.30	11.05
T ₈ - T ₅ + MM1	229.50	79.64	227.27	4.67	1.40	11.52

T ₉ - T ₅ + MM2	223.25	81.41	218.85	4.70	1.40	11.65
T ₁₀ - T ₅ + HA 500 ppm + MM1	225.75	79.56	223.96	4.60	1.20	11.58
T ₁₁ - T ₅ + HA 1000 ppm + MM1	257.13	78.75	218.06	4.90	1.17	11.56
T ₁₂ - T ₅ + HA 500 ppm + MM2	250.85	82.64	217.51	4.90	1.17	11.58
T ₁₃ - T ₅ + HA 1000 ppm + MM2	231.88	80.48	214.77	4.40	1.33	11.55
S.Em±	8.96	1.91	9.95	0.20	0.09	0.38
CD (P=0.05)	26.15	5.57	29.05	NS	NS	NS

Table 7: DTPA extractable iron, manganese, zinc, copper and hot water soluble boron content of soil after harvest of cowpea as influenced by STCR based fertilizer dose with foliar HA and MM application

Treatment	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	B (mg kg ⁻¹)
T ₁ - Absolute control	9.16	10.60	1.03	0.44	0.31
T ₂ - RDF + FYM	10.42	10.71	1.10	0.51	0.33
T ₃ - STCR	10.61	11.11	1.04	0.53	0.33
T ₄ - STCR (no P)	10.44	10.92	1.15	0.50	0.34
T ₅ - STCR (50% RDP) + FYM	10.17	10.78	1.13	0.50	0.34
T ₆ - T ₅ + HA 500 ppm	10.77	10.91	1.08	0.48	0.35
T ₇ - T ₅ + HA 1000 ppm	10.96	10.57	1.18	0.51	0.34
T ₈ - T ₅ + MM1	11.60	11.09	1.15	0.50	0.32
T ₉ - T ₅ + MM2	11.92	11.23	1.25	0.52	0.33
T ₁₀ - T ₅ + HA 500 ppm + MM1	11.55	11.02	1.21	0.53	0.33
T ₁₁ - T ₅ + HA 1000 ppm + MM1	11.41	11.15	1.15	0.53	0.34
T ₁₂ - T ₅ + HA 500 ppm + MM2	11.19	11.07	1.10	0.54	0.35
T ₁₃ - T ₅ + HA 1000 ppm + MM2	11.07	11.24	1.19	0.53	0.34
S.Em±	0.43	0.44	0.08	0.02	0.01
CD (P=0.05)	1.26	NS	NS	0.05	NS

The data presented in Table 5 revealed that the effect of different treatments on soil pH, electrical conductivity and soil organic carbon content in post harvest soil did not differ significantly due to treatments effect. However, the lowest pH was noticed (6.76) in T₂ and T₆ treatment and highest was recorded in T₇ (6.89). While the lowest EC value of 0.13 dS m⁻¹ was recorded in T₁, T₃, T₄, T₅, T₇ and T₈. With regard to SOC the maximum (6.43 g kg⁻¹) and minimum (5.90 g kg⁻¹) value was noticed in T₇ and control, respectively.

Effect of STCR based fertilizer dose with foliar application of HA and MM on available nutrient status in soil

Available N content in soil after harvest of the crop was found to be significantly higher in T₁₁ (257.13 kg ha⁻¹) when compared with T₁ (175.69 kg ha⁻¹), T₂ (227.19 kg ha⁻¹), T₄ (225.78 kg ha⁻¹), T₉ (223.25 kg ha⁻¹), T₁₀ (225.75 kg ha⁻¹) and on par with rest of the treatments. Available phosphorous content in soil varied significantly. Highest available Phosphorous content was observed in T₂ with 86.76 kg ha⁻¹ which was significantly higher than T₁ (74.62 kg ha⁻¹), T₄ (78.78 kg ha⁻¹), T₅ (79.45 kg ha⁻¹), T₆ (79.52 kg ha⁻¹), T₇ (79.11 kg ha⁻¹), T₈ (79.64 kg ha⁻¹), T₁₀ (79.56 kg ha⁻¹) and T₁₁ (78.75 kg ha⁻¹). However, T₃ (85.23 kg ha⁻¹), T₉ (81.41 kg ha⁻¹), T₁₂ (82.64 kg ha⁻¹) and T₁₃ (80.48 kg ha⁻¹) were on par with T₂. Available potassium content in soil at harvest ranged from 155.89 kg ha⁻¹ to 235.34 kg ha⁻¹ due to treatment difference. Potassium content in control was 155.89 kg ha⁻¹ which increased significantly to 235.34 kg ha⁻¹ due to application of STCR recommended fertilizers with FYM, followed by 227.27 kg ha⁻¹ with the application STCR based fertilizer dose with foliar application of MM1 at 30 and 45 DAS and these treatments were found to be significantly higher than T₁ (155.89 kg ha⁻¹), T₂ (177.89 kg ha⁻¹), T₃ (189.09 kg ha⁻¹). (Table 6)

Exchangeable calcium content in soil was not significant but higher value was observed in T₇ (5.03 cmol (p⁺) kg⁻¹) due to application of STCR based fertilizer dose with 1000 ppm HA as a foliar spray followed by T₅ (4.93 cmol (p⁺) kg⁻¹). Due to

different treatments effect the exchangeable magnesium content in soil varied from 1.13 to 1.53 cmol (p⁺) kg⁻¹. Higher exchangeable magnesium status was observed in T₆ with 1.53 cmol kg⁻¹ and was on par with T₇ (1.30 cmol (p⁺) kg⁻¹), T₈ (1.40 cmol (p⁺) kg⁻¹), T₉ (1.40 cmol (p⁺) kg⁻¹) and T₁₃ (1.33 cmol (p⁺) kg⁻¹). Application of humic acid and micronutrient mixture along with STCR recommended fertilizers had no significant effect on sulphur content in soil at harvest of crop. Significantly higher sulphur content of 11.65 mg kg⁻¹ was recorded in T₉ (STCR + MM2) and was on par with all other treatments except T₁ (10.17 mg kg⁻¹). (Table 6)

Available NPK status increased from 175.69, 74.62 and 155.89 kg ha⁻¹, respectively in control to 229.50, 79.45 and 235.34 kg ha⁻¹, respectively in STCR (50% RDP) + FYM. This may be due to the balanced supply of nutrients might have improved the N fixation by the crop which resulted in higher root growth which added root litter to the soil and thus increased the nutrient status in post-harvest soil. The treatment that received STCR based fertilizer dose have resulted in build-up of N and K nutrients in soil than that have received RDF dose and control. The build-up of N and K might be attributed to higher dose of N (50 kg ha⁻¹) and K (43.5 kg ha⁻¹) supplied through STCR treatments than that supplied with RDF (25: 50: 25 kg ha⁻¹). While the P content was higher in case of RDF than STCR treatments (50% of RDP) as a result P build was observed in treatment receiving RDF + FYM.

Increase in the NPK content in soil after harvest of the crop was evidenced by Sabeetha *et al.* (2011) [14] in green gram; Arjumend *et al.* (2015) [3] in wheat; Mahmoud *et al.* (2011) [9] in soybean, Sarwar *et al.* (2012) [15] and El-Galad (2013) [6] in Fababean.

Micronutrients (DTPA extractable Fe, Mn, Zn, Cu and Hot water soluble B) content of soil

The data presented in Table 7 is pertained to DTPA extractable Fe, Mn, Zn, Cu and hot water soluble B status of soil at harvest of crop as influenced by application of STCR

recommended fertilizers with humic acid and multi-micronutrient mixture.

The DTPA extractable Fe content in soil after harvest of the crop ranged from 9.16 mg kg⁻¹ to 11.92 mg kg⁻¹. Significantly higher value of 11.92 mg kg⁻¹ was observed in T₉ as compared with T₁ (9.16 mg kg⁻¹), T₂ (10.42 mg kg⁻¹), T₃ (10.61 mg kg⁻¹), T₄ (10.44 mg kg⁻¹) and T₅ (10.17 mg kg⁻¹). The manganese content did not vary significantly among the treatments. However, higher manganese content was observed in the treatment with STCR based fertilizer dose (50% RDP) with HA 1000 ppm and MM2 (T₁₃) (11.24 mg kg⁻¹), followed by T₉ (11.23 mg kg⁻¹). The lowest was in T₁ (10.60 mg kg⁻¹), T₂ (10.71 mg kg⁻¹) and T₅ (10.78 mg kg⁻¹). DTPA extractable Zn content in soil did not differ significantly due to treatments. But higher zinc content in soil was recorded in T₉ (1.25 mg kg⁻¹) due to STCR based fertilizer dose with foliar application of MM2, followed by T₁₀ (1.21 mg kg⁻¹) and the lowest value of 1.03 mg kg⁻¹ was observed in control. The treatments had a significant effect on copper status in soil. Higher copper content was recorded in T₁₂ with 0.54 mg kg⁻¹ which was significantly higher than control (0.44 mg kg⁻¹) and T₆ (0.48 mg kg⁻¹) and on par with rest of the treatments. Boron content in the soil did not varied significantly due to treatments. However higher B content of 0.35 mg kg⁻¹ was observed in T₆ and T₁₂ and the minimum boron content was recorded in control (0.31 mg kg⁻¹).

Higher available micronutrients (Fe, Mn, Zn, Cu and B) content was recorded at harvest due to application of STCR based fertilizer dose along with MM with or without HA. This can be attributed to two time foliar application of MM might have contributed to the available pool and the MM has supplied the required amount of nutrients to the crops and this reduced the uptake of nutrients from the soil and also increased root growth by balanced nutrition, added FYM and fallen leaves have added the nutrients to the soil after harvest of the crops contributed to the increased status of these nutrients in post-harvest soil. Quddus *et al.* (2011)^[13] in mung bean, Kannan *et al.* (2014)^[7] and Manivannan *et al.* (2003)^[11] in black gram also evidenced the increase in micronutrient concentration in soil due to foliar application of MM.

Conclusion

Application of STCR fertilizer dose with foliar application of humic acid and multi-micronutrient mixture increased the total uptake of nutrients from soil by higher biomass production and higher nutrient content. While application of STCR fertilizer dose to soil improved the soil nutrient status when compared to control and RDF. Application of humic acid and MM improved the nutrient uptake efficiency of the crop.

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