Plant Archives Volume 20 No. 2, 2020 pp. 5297-5302 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

AVAILABLE PLANT NUTRIENT STATUS IN SOIL UNDER MAIZE CULTIVATION AS INFLUENCED BY APPLICATION OF FLY ASH, VERMICOMPOST, FARM-YARD MANURE AND INORGANIC FERTILIZERS

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Abstract

An experiment was carried out in the field to study the effect of recommended dose fertilizers (RDF), fly ash (FA), vermicompost (VC) and farm yard manure (FYM) at their different doses, alone or in combination, on nutrient availability in soil under maize (*Zea mays* L.) cultivation during *kharif* season. FYM application in combination with inorganic fertilizers at their recommended doses (T_2, 100% RDF + 100% FYM) exhibited maximum positive influence on available N, P, K, Ca, Mg and S content in soil, followed by T_4 (20% FA + 80% VC + 80% RDF) and T_1 (100 % RDF + 100 % VC). However, VC with inorganic fertilizers (T_1, 100% RDF + 100% VC) exerts more influence on soil organic carbon content than FYM. Among FA treatments, lower concentration (T_4, 20 % FA + 80 % RDF + 80 % VC) exhibited better performance in increasing available nutrients in soil.

Key words : Fly ash, Vermicompost, Farm-yard manure, Fertilizers, Soil nutrient status.

Introduction

Maize (*Zea mays* L.) is a heavy feeder of nutrients, so its productivity is largely dependent on nutrient management (Singh *et al.*, 2003). In addition to inorganic fertilizers, it is a common practice to use eco-friendly and non-toxic products like vermicompost (VC) and farm yard manure (FYM) which not only supply macronutrients and micronutrients but also improve soil health from physical, chemical and biological points of view (Reddy and Reddy, 2003). VC contains considerable amount of nutrients with huge amount of beneficial microbial population, cytokinins, auxins, and gibberellins like biological active growth promoting substances (Pawar and Patil 2007, Jack *et al.*, 2011).

Fly ash (FA) is produced by combusting coal in thermal power station (Kaur *et al.*, 2019). Its disposal poses a threat to the environment due to its nature of fineness. Although FA is considered as a waste material, it is being utilized for beneficial economic applications *viz.*, cement industries, construction of roads, agriculture etc. FA contributes a larger role to modify soil pH and it contains many nutrients, especially the secondary (Ca, Mg & S) and the micronutrients (Fe, Mn, Zn & Cu). Therefore, it may be used as nutrient source to plants and to improve the physicochemical properties of soils, although it may also contain toxic substances (Lee *et al.*, 2006, Tiwari *et al.*, 2008). The presence of these toxic elements is restricted in such a low level of their availability that they do not exert any harmful role on the soil and crop quality. Therefore, it becomes a practice to use FA as a useful soil amendment to enhance the productivity of crops and fertility of soils by improving the physicochemical and biological properties of soil (Panda and Biswal, 2018; Singh and Sukul, 2019). Limited information are available on the effect of FA in combination with other soil amendments on the fertility status of soil, especially under Punjab agro-climatic conditions. Therefore, in the present study, attempts are made to examine the effect of FA alone and in combination with organic amendments (VC) and inorganic fertilizers on the fertility status of soil under maize cultivation, taking primary (N, P and K) and secondary

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(Ca, Mg and S) nutrients into consideration.

Materials and Methods

A field experiment was conducted at the experimental farm of School of Agriculture, Lovely Professional University during Kharif season 2017-2018, in Randomized Block Design with three replications. Average value of temperature (highest and lowest) and rainfall during the field experimental period of July, August, September, and October in 2017 have been 17.3 – 35.4 ^{0}C and 27 – 197 mm, respectively.

Recommended dose of fertilizers (RDF) for N, P and K were used as 180, 60 and 40 kg/ha, respectively. FYM, VC and FA were applied to the field @16, 5 and 20 t/ha. These treatments include control (T_0, no RDF and manures), T_1 (100 % RDF + 100 % VC), T_2 (100 % RDF + 100 % FYM), T_3 (100 % FA), T_4 (20 % FA + 80 % RDF + 80 % VC), T_5 (40 % FA + 60 % RDF + 60 % VC), T_6 (60 % FA + 40 % RDF + 40 % VC), T_7 (80 % FA + 20 % RDF + 20 % VC). The FA, VC, FYM and full dose of diammonium phosphate and muriate of potash were added during the last preparation of field and urea was applied as basal and two split doses.

Maize seeds (Kawari 50) were sown by dibbling method, keeping plant to plant and row to row distance as 20 cm and 60 cm, respectively. Soil samples were taken before application of any soil amendment and after soil treatments at different time intervals (30, 60, 90 DAS and at harvest). The soil samples were air dried, ground and screened through a 2 mm sieve. Physico-chemical properties of the VC, FYM, and FA are summarized in Table 1.

Organic carbon was estimated employing wet-oxidation method (Black, 1965). Available nitrogen was analyzed by alkaline permanganate method (Subbiah and Asija, 1965). Ammonium acetate method (Muhr *et al.*, 1965) was employed to estimate available potassium and available phosphorus was analyzed by Olsen method (Olsen, 1954). Ca and Mg were determined using Versenate method (Chapman and Pratt, 1961). Available Sulphur was analyzed by turbidimetric method (Chesnin and Yien,1950).

Statistical analysis

Duncan Multiple Range Test (DMRT) was applied to identify the most efficient treatment. Anova was done to test the significance of difference for each parameter. Calculation was done at 5 % significance level.

Results and Discussion

Organic Carbon

(Table 2) represents the effect of various treatments containing organic & inorganic fertilizers and FA, alone or in combinations, on soil organic carbon (OC) content. At 30 DAS, all treatments, except 80% (T_7) and 100% (T_3) FA, showed significant enhancement of organic carbon content over control (0.4%). This is due to higher OC content in vermicompost and FYM, and low carbon content in FA (0.71%, 0.62%, 0.20%, respectively; Table 1). In all treatments a decreasing trend in soil OC content was observed during 60 DAS which might be due to mineralization of carbon by microbial activity for improved physico-chemical soil environment, followed by a gradual increase at 90 DAS and after harvesting. This second phase of soil OC content increase might be explained by further natural incorporation of dried leaves from the plants to the soil. Interestingly, control treatment showed OC content as 0.4% at 30 DAS which is far below the original initial soil OC content (0.63%), measured before application of any treatment. This explains the influence of tillage operation, irrigation and other cultural practices adopted during 30 days on carbon mineralization by encouraging microbial activities. Considering all treatments including control, the mean organic carbon was found to be in the range of 0.40 – 0.73%, 0.18 – 0.37%, 0.31 – 0.49% and 0.40 – 0.77 % at 30 DAS, 60 DAS, 90 DAS, and after harvesting, respectively. Maximum OC was obtained in T_1 (0.73%) followed by T_4 (0.69%), T_5 (0.66%), T_2 (0.64%), T_6 (0.62%), T_7 (0.40%), T_3 (0.41%) and T_0 (0.40%) at 30 DAS. However, at 60 DAS the increasing trend in organic carbon was found in the order of T_1>T_4>T_5>T_2>T_3>T_6>T_7>T_0 and the trend at 90 DAS was found to be in order of T_1>T_4>T_5>T_2>T_6>T_3>T_7>T_0. After harvesting, trend was in the order of T_1>T_4>T_3>T_5>T_6>T_7>T_3>T_0. Among all treatments, T_1 treatment showed highest increase in soil OC content. Per cent increase in OC in T_1 treatment was 82.5%, 105.56%, 58.06% and 92.5% at 30, 60, 90 DAS and after harvesting, respectively. VC are organic materials with low C: N ratios formed by interactions between micro-oganism and earthworms in a mesophilic process (Ramasamy *et al.*, 2011). In the present study, increase in OC content in soil also confirms carbon sequestration by organic manures and FA (Montes-Hermandez *et al.*, 2009;). However, OC content decreased with increasing doses of FA. Our results conform earlier findings (Roy and Joy, 2011; Das *et al.*, 2013).

Available Nitrogen

Soil available nitrogen as influenced by treatments ranged between 121.12 – 149.51 mg/kg, 118.23 – 145.60 mg/kg, 114.77 – 140.28 mg/kg and 113.09 – 138.32 mg/

Table 1: Physiochemical properties of VC, FYM, and FA.

Properties	VC	FYM	FA
Organic carbon (%)	0.71	0.62	0.20
Nitrogen (%)	1.12	0.52	0.067
Phosphorous (%)	0.23	0.21	0.097
Potassium (%)	0.73	0.53	0.184
Calcium (%)	0.24	0.20	0.21
Magnesium (%)	0.56	0.53	0.42
Sulphur (%)	0.19	0.16	0.024

kg at 30, 60, 90 DAS and after harvesting, respectively (Table 2). The maximum available N in soil (149.51 mg/kg) was recorded in treatment of T_2 (100% RDF + 100% FYM), while the minimum under T0 (control) 121.12 mg/kg at 30 DAS. The treatment T_2 was found significantly superior to T_5 (40% FA + 60% RDF + 60% VC), T_4 (20% FA + 80% RDF + 80% VC), T_1 (100 RDF + 100% VC), T_6 (60% FA + 40% RDF + 40% VC), T_7 (80% FA + 20% RDF + 20% VC), T_3 (100% FA) and T_0 (Control). Same trend was found in the 60 DAS, 90 DAS and after harvesting. Percent increase in available nitrogen was calculated for all treatments over control. It was found that the per cent increase in available nitrogen in T2 treatment over T_0 was 23.44%, 23.15%, 22.23% and 22.31% at 30, 60, 90 and after harvesting, respectively. The increase in soil available nitrogen status in the treatments was associated with the addition of inorganic fertilizer and organic manures which acted as nitrogen sources. T_3 (100% FA) showed little effect on enhancing available nitrogen content as FA contains negligible amount of nitrogen (Table 1). However, its improved performance over control was mainly due to the improved soil physical conditions which delivered a congenial soil atmosphere for improved microbial activity leading to improved nitrogen mineralization. Increased availability of nitrogen with application of FA, FYM and vermicompost was also earlier reported (Jala and Goel, 2010; Das *et al.*, 2013, Kaur and Sukul, 2019). Available nitrogen content was found to decrease gradually, perhaps due to plants uptake or leaching loss.

Available Phosphorous

The available phosphorous content in the soil significantly decreased in all treatments from 30 DAS to harvesting stage where FA at different levels with organic and inorganic fertilizers were applied (Table 2). This may be due to plants uptake. Interestingly, control exhibited higher amount of available phosphorus at 30 DAS (8.53 mg/kg) than its initial value (7.23 mg/kg), monitored before application of any treatments to soil. This explains the influence of tillage operation, irrigation and other cultural practices adopted during 30 days on phosphorus mineralization by encouraging microbial activities. Thus, the accumulation of available phosphorus occurred in soil. Considering all treatments including control, mean available phosphorous at 30 DAS was found to be in the range of 8.53 – 14.01 mg/kg, which decreased in the range of 7.77 – 12.25 at 60 DAS, 6.43 – 10.78 at 90 DAS and 5.57 – 9.60 at after harvesting. Highest available phosphorous was obtained in T_2 (100% RDF + 100% FYM, 14.01 mg/kg) followed by T_5 (13.06 mg/kg), T_4 (12.56 mg/kg), T_1 (11.39 mg/kg), T_6 (10.65 mg/kg), T_7 (10.0 mg/kg), T_3 (9.36 mg/kg) and T_0 (8.53 mg/kg) at 30 DAS. However, at 60 DAS the trend was changed to the order of T_2>T_5>T_4>T_7>T_1>T_6>T_3>T_0 and at 90 DAS, T_2>T_5>T_4>T_6>T_1>T_7>T_3>T_0 and after harvesting, T_2>T_5>T_4>T_6>T_1>T_7>T_1>T_3>T_0. Organic manures, particularly VC, are good substitute for commercial fertilizer, as they contain good amount of N, P and K. An increase in soil pH and thus, increase in the availability of Si, P, and some other mineralogical components in Korean paddy field soil was reported earlier (Lee *et al.*, 2006). In our experiment a slight increase in pH was observed, which might restrict the formation insoluble phosphate salts of Fe and Al, rendering more availability of phosphorus. The change in soil phosphorus content with application of inorganic fertilizers, FYM, VC, FA was observed in various research studies (Jabeen and Sinha, 2012; Manyuchi *et al.*, 2013).

Available Potassium

Soil available potassium as influenced by various treatments ranged between 130.81 – 158.0, 127.70 – 153.87, 123.77 – 151.01 and 121.36 – 149.28 mg/kg at 30, 60, 90 DAS and after harvesting, respectively (Table 2). Initial soil available potassium content, before application of any nutrient supplements and FA, was 128.66 mg/kg. The maximum available K in soil (158.0 mg/kg) was recorded in T_2 (100% RDF + 100% FYM), while the minimum under T0 (control) 130.81 mg/kg at 30 DAS. In respect of treatments performance on available K, T_2>T_5>T_4>T_1>T_6>T_7>T_3>T_0 was found as a likely trend at 30, 60, 90 DAS and after harvesting. Per cent increase in available potassium in T_2 was 20.79%, 20.79%, 22.01% and 23.01% at 30, 60, 90 DAS and after harvesting, respectively. The increase availability of potassium with application of FA, FYM, VC and fertilizer were mainly because of their reasonable available K content. Improvement in available K content in soil through application of FA, manures and fertilizers was also observed earlier (Sarkar *et al.*, 2013; Das *et al.*, 2013; Nasab *et al.*, 2015). However, in a separate experimental set-up no alteration in available K status in soil was also observed in spite of FA incorporation (Sharma and Kalra,

Table 2: Effect of FA, organic manures and inorganic fertilizers on soil available nutrients.

Treatment	30 DAS	60 DAS	90 DAS	At harvest
Organic carbon (%) [Initial value before application of any treatments: 0.63%]				
T_0	$0.40^{e} \pm 0.003$	$0.18^{f} \pm 0.01$	$0.31^{f} \pm 0.005$	$0.40^{h} \pm 0.005$
T_1	$0.73^{a} \pm 0.008$	$0.37^{a} \pm 0.008$	$0.49^{a} \pm 0.005$	$0.77^{a} \pm 0.003$
T_2	$0.64^{d} \pm 0.006$	$0.31^{c} \pm 0.003$	$0.45^{bc} \pm 0.003$	$0.62^{c} \pm 0.006$
T_3	$0.41^{e} \pm 0.006$	$0.27^{d} \pm 0.008$	$0.39^{e} \pm 0.01$	$0.47^{g} \pm 0.008$
T_4	$0.69^{b} \pm 0.008$	$0.35^{ab} \pm 0.003$	$0.47^{ab} \pm 0.008$	$0.70^{b} \pm 0.003$
T_5	$0.66^{c} \pm 0.013$	$0.34^{b} \pm 0.005$	$0.45^{c} \pm 0.005$	$0.59^{d} \pm 0.005$
T_6	$0.62^{d} \pm 0.005$	$0.26^{d} \pm 0.003$	$0.42^{d} \pm 0.003$	$0.55^{e} \pm 0.005$
T_7	$0.41^{e} \pm 0.006$	$0.22^{e} \pm 0.008$	$0.37^{e} \pm 0.006$	$0.50^{f} \pm 0.008$
Available N (mg/kg) [Initial value before application of any treatments: 117.65 mg/kg]				
T_0	$121.12^{h} \pm 0.36$	$118.23^{g} \pm 0.16$	$114.77^{g} \pm 0.43$	$113.09^{h} \pm 0.29$
T_1	$141.14^{d} \pm 0.43$	$135.73^{c} \pm 0.41$	$132.01^{d} \pm 0.17$	$128.03^{d} \pm 0.63$
T_2	$149.51^{a} \pm 0.41$	$145.60^{a} \pm 0.24$	$140.28^{a} \pm 0.35$	$138.32^{a} \pm 0.37$
T_3	$126.56^{g} \pm 0.67$	$121.57^{f} \pm 0.23$	$115.48^{g} \pm 0.39$	$114.50^{g} \pm 0.29$
T_4	$144.07^{c} \pm 0.60$	$140.63^{b} \pm 0.37$	$133.86^{c} \pm 0.36$	$132.22^{c} \pm 0.30$
T_5	$146.78^{b} \pm 0.67$	$141.58^{b} \pm 0.23$	$138.83^{b} \pm 0.67$	$136.90^{b} \pm 0.43$
T_6	$135.28^{e} \pm 0.97$	$129.45^{d} \pm 0.35$	$123.76^{e} \pm 0.42$	$121.94^{e} \pm 0.50$
T_7	$129.39^{f} \pm 0.86$	$126.86^{e} \pm 0.96$	$119.40^{f} \pm 0.30$	$117.41^{f} \pm 0.35$
Available P (mg/kg) [Initial value before application of any treatments: 7.23 mg/kg]				
T_0	$8.53^{f} \pm 0.23$	$7.77^{d} \pm 0.28$	$6.43^{e} \pm 0.26$	$5.57^{e} \pm 0.24$
T_1	$11.39^{c} \pm 0.29$	$9.97^{b} \pm 0.24$	$8.13^{d} \pm 0.18$	$6.78^{d} \pm 0.18$
T_2	$14.01^{a} \pm 0.40$	$12.25^{a} \pm 0.29$	$10.78^{a} \pm 0.36$	$9.60^{a} \pm 0.20$
T_3	$9.36^{ef} \pm 0.32$	$8.26^{cd} \pm 0.30$	$6.78^{e} \pm 0.30$	$6.03^{e} \pm 0.24$
T_4	$12.53^{b} \pm 0.26$	$11.23^{a} \pm 0.41$	$9.06^{c} \pm 0.35$	$7.89^{c} \pm 0.21$
T_5	$13.06^{b} \pm 0.30$	$11.76^{a} \pm 0.30$	$9.94^{b} \pm 0.20$	$8.57^{b} \pm 0.18$
T_6	$10.65^{cd} \pm 0.29$	$9.95^{c} \pm 0.30$	$8.32^{cd} \pm 0.22$	$7.30^{cd} \pm 0.19$
T_7	$10.0^{de} \pm 0.28$	$8.87^{c} \pm 0.41$	$7.68^{d} \pm 0.24$	$6.80^{d} \pm 0.20$
Available K (mg/kg) [Initial value before application of any treatments: 128.66 mg/kg]				
T_0	$130.81^{h} \pm 0.39$	$127.70^{g} \pm 0.46$	$123.77^{h} \pm 0.52$	$121.36^{g} \pm 0.41$
T_1	$145.54^{d} \pm 0.38$	$141.64^{d} \pm 0.23$	$139.12^{d} \pm 0.42$	$137.85^{d} \pm 0.55$
T_2	$158.0^{a} \pm 0.45$	$153.87^{a} \pm 0.66$	$151.01^{a} \pm 0.91$	$149.28^{a} \pm 0.65$
T_3	$134.32^{g} \pm 0.42$	$130.60^{f} \pm 0.83$	$127.40^{g} \pm 0.32$	$125.73^{f} \pm 0.38$
T_4	$150.75^{c} \pm 0.37$	$146.53^{c} \pm 0.79$	$141.83^{c} \pm 0.37$	$139.82^{c} \pm 0.45$
T_5	$154.34^{b} \pm 0.35$	$150.33^{b} \pm 0.66$	$146.80^{b} \pm 0.26$	$144.77^{b} \pm 0.36$
T_6	$142.15^{e} \pm 0.35$	$138.06^{e} \pm 0.79$	$133.89^{e} \pm 0.15$	$132.38^{e} \pm 0.16$
T_7	$137.89^{f} \pm 0.62$	$131.77^{f} \pm 0.24$	$129.00^{f} \pm 0.63$	$126.71^{f} \pm 0.38$

The mean followed by different letters are significantly different at $p < 0.05$, according to DMRT (Duncan's Multiple Range Test) for separation of means. Values are mean ± SE.

2006). Reasonable increase in the uptake of major and secondary nutrients such as N, P, K, Ca, and Mg by rice under VC treatment than FYM was noticed, justifying the superiority of VC over FYM (Jadhav *et al.*, 1997).

Available Calcium and Magnesium in soil

Available calcium and magnesium contents in soil under different treatments are presented in (Table 3). All treatments showed a significant increase in soil available Ca and Mg contents as compared to the control plot. Interestingly, at 30 DAS all treatments including control showed more available Ca and Mg contents than its initial value (2.28 & 5.69 me/100g, respectively); and after wards a gradual declining trend was observed. Maximum Ca and Mg were obtained in T_2 followed by T_5, T_4, T_1, T_6, T_7, T_3 and T_0 at all periodic intervals. In the present study, initially soil pH remained slightly alkaline and with course of time pH value decreased (Singh and Sukul, 2019). Status of Ca and Mg in soil were at par with the trend of soil pH, which were found more initially and then gradually decreased. Earlier findings (Chandraka *et al.*, 2015) revealed positive significant effects of VC, FYM and FA in resulting high pH and Ca accumulation in surface soils. It was also observed that application of FA in combination with other organic sources (FYM and VC) and RDF enhanced the availability of P, K, Ca, Mg, Zn and Cu (Mittra *et al.*, 2005). Considerable amount of oxides of Ca and Mg is generally present in FA (Aggarwal *et al.*, 2009; Kishor *et al.*, 2010; Kumar and Jha, 2014), that might also be a contributor of Ca and Mg to soils. Capacity of VC to increase Ca content of soil (about 54-75%) was established earlier (Azarmi *et al.*, 2008), confirming our findings.

Available Sulphur

Maximum available sulphur in soil (9.56 mg/kg) was recorded in treatment of T_2 (100% RDF + 100% FYM) while, the minimum 6.04 mg/kg was found under T0 (control) at 30 DAS (Table 3). The treatment T_2 (9.56 mg/kg) was found significantly superior to T_5 (9.02 mg/kg), T_4 (8.33 mg/kg), T_1 (8.24 mg/kg), T_6 (7.77 mg/kg), T_7 (7.23 mg/kg), T_3 (6.88 mg/kg) and T_0 (6.04 mg/kg). Same trend was found at 60, 90 DAS and after harvesting.

Table 3: Effect of FA, organic manures and inorganic fertilizers on available calcium, magnesium and sulphur in soil.

Treatment	30 DAS	60 DAS	90 DAS	After harvesting
Ca (me/100g) [Initial value before application of any treatments: 2.28 me/100g]				
T_0	$2.69^{d} \pm 0.12$	$2.25^{e} \pm 0.10$	$1.88^{e} \pm 0.06$	$1.58^{e} \pm 0.08$
T_1	$3.52^{bc} \pm 0.15$	$3.08^{bcd} \pm 0.10$	$2.51^{cd} \pm 0.10$	$2.08^{bcd} \pm 0.05$
T_2	$4.30^{a} \pm 0.09$	$3.87^{a} \pm 0.12$	$3.32^{a} \pm 0.12$	$2.72^{a} \pm 0.09$
T_3	$3.11^{c} \pm 0.12$	$2.70^{cde} \pm 0.10$	$2.23^{d} \pm 0.06$	$1.87^{d} \pm 0.08$
T_4	$3.69^{b} \pm 0.12$	$3.14^{bc} \pm 0.12$	$2.57^{c} \pm 0.09$	$2.16^{bc} \pm 0.07$
T_5	$4.08^{a} \pm 0.11$	$3.45^{ab} \pm 0.20$	$2.93^{b} \pm 0.11$	$2.30^{b} \pm 0.07$
T_6	$3.31^{bc} \pm 0.13$	$2.89^{cd} \pm 0.13$	$2.30^{cd} \pm 0.09$	$2.13^{bc} \pm 0.06$
T_7	$3.12^{c} \pm 0.12$	$2.62^{de} \pm 0.18$	$2.32^{cd} \pm 0.10$	$1.98^{cd} \pm 0.08$
Mg (me/100g) Initial value before application of any treatments: 5.69 me/100g]				
T_0	$5.66^{f} \pm 0.16$	$5.10^{f} \pm 0.10$	$4.43^{f} \pm 0.08$	$3.85^{f} \pm 0.07$
T_1	$6.90^{cd} \pm 0.13$	$6.28^{c} \pm 0.11$	$5.50^{d} \pm 0.11$	$4.88^{cd} \pm 0.10$
T_2	$8.08^{a} \pm 0.12$	$7.49^{a} \pm 0.08$	$6.77^{a} \pm 0.13$	$6.04^{a} \pm 0.15$
T_3	$6.11^{e} \pm 0.10$	$5.54^{e} \pm 0.10$	$4.92^{e} \pm 0.14$	$4.24^{ef} \pm 0.07$
T_4	$7.07^{bc} \pm 0.18$	$6.45^{bc} \pm 0.17$	$5.93^{c} \pm 0.09$	$5.07^{c} \pm 0.18$
T_5	$7.51^{b} \pm 0.15$	$6.84^{b} \pm 0.16$	$6.31^{b} \pm 0.13$	$5.53^{b} \pm 0.13$
T_6	$6.71^{cd} \pm 0.15$	$6.11^{cd} \pm 0.10$	$5.54^{d} \pm 0.13$	$4.92^{cd} \pm 0.13$
T_7	$6.30^{de} \pm 0.15$	$5.75^{de} \pm 0.16$	$5.11^{e} \pm 0.10$	$4.54^{de} \pm 0.13$
Available S (mg/kg) [Initial value before application of any treatments: 5.43 mg/kg]				
T_0	$6.04^{f} \pm 0.23$	$5.47^{d} \pm 0.39$	$4.55^{d} \pm 0.15$	$4.08^{d} \pm 0.15$
T_1	$8.24^{bc} \pm 0.24$	$7.64^{ab} \pm 0.33$	$6.43^{b} \pm 0.27$	$5.09^{bc} \pm 0.20$
T_2	$9.56^{a} \pm 0.23$	$8.55^{a} \pm 0.64$	$7.35^{a} \pm 0.24$	$6.06^{a} \pm 0.26$
T_3	$6.88^{ef} \pm 0.20$	$5.93^{cd} \pm 0.52$	$5.0^{cd} \pm 0.22$	$4.59^{cd} \pm 0.13$
T_4	$8.33^{bc} \pm 0.31$	$6.87^{bc} \pm 0.36$	$5.61^{c} \pm 0.27$	$4.81^{bc} \pm 0.14$
T_5	$9.02^{ab} \pm 0.39$	$7.82^{ab} \pm 0.26$	$6.51^{b} \pm 0.27$	$5.28^{b} \pm 0.18$
T_6	$7.77^{cd} \pm 0.29$	$6.66^{bcd} \pm 0.40$	$5.41^{c} \pm 0.17$	$4.76^{bc} \pm 0.22$
T_7	$7.23^{de} \pm 0.29$	$6.45^{bcd} \pm 0.29$	$5.15^{cd} \pm 0.20$	$4.54^{cd} \pm 0.19$

The mean followed by different letters are significantly different at $p < 0.05$, according to DMRT (Duncan's Multiple Range Test) for separation of means. Values are mean ± SE.

Per cent increase in available nitrogen in T_2 treatment was 58.28, 56.31, 61.54 and 48.53 at 30, 60, 90 DAS and after harvesting, respectively. The initial increase in available sulphur might be explained by mineralization of sulphur during the decomposition of organic matter, which was followed by its decrease due to continuous removal of sulphur by crops. The results agreed with earlier reports (Tiwari *et al.,* 2008; Thakur *et al.,* 2011).

Conclusion

All treatments of soil amendments showed significant positive influence over control treatment in respect of increasing availability of soil nutrients, which might be exhibiting positive influence on crop yield. However, T_2 (100% RDF + 100% FYM) treatment showed the best result as compared to others. Among FA treatments, lower concentration (20%) exhibited better performance in increasing available nutrients in soil.

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