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Nutrient content and post harvest soil fertility as influenced by methods of planting and nutrient management techniques in cotton based cropping system

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Abstract : Imbalanced use of fertilizer can degrade the soil quality and productivity so the present investigation was carried out to assess the effect of different nutrient management practices on soil properties and available micronutrients using Soil Test Crop Response (STCR) based targeted yield equations under raised bed and flat bed planting system at Research Farm, Department of Soil Science, CCS, HAU, Hisar. The experiment was planned in a randomized block design with three replication and five treatments *viz.* T_1 -control, T_2- FYM @ 15 t/ha, T_3- FYM @ 15 t/ha + biofertilizer + cow urine based formulation, T_4-STCR with TY 5.5/2.8 t/ha and T_5 -STCR with TY 6.0/3.2 t/ha. The results of the experiment revealed that the application of FYM alone or with cow urine based formulation and biofertilizer had increased the available N, P and K from 91.28 to 113.70 kg/ha, 8.00 to 14.53 kg/ha and 145.53 to 175.57 kg/ha in surface soil (0-15cm) under raised bed planting system. The corresponding values of available N, P and K in flat bed planting system ranged from 84.60 to 111.20 kg/ha; 7.57 to 12.20 kg/ha and 141.27 to 170.77 kg/ha. DTPA extractable Zn, Fe and Mn increased with increase in organic carbon content of the soil while Cu content decreased. In raised bed planting system, maximum Zn (1.92 and 1.86 mg/kg) was observed in FYM treatments (T_2- T_3) followed by chemical treatments (1.67 and 1.69 mg/kg) (T_4–T_5) and minimum in control (1.49 mg/kg) (T_1). Similarly, Fe and Mn concentration were also found highest in organic (T_2 and T_3) treatments and minimum in control (T1). The availability of macronutrients and micronutrients in soil were found higher under raised bed planting, which was significantly superior to conventional flat-bed planting method as raised bed system of planting improves the porosity of the soil and thus, resulted in higher seed germination and uniform crop growth besides improving the post-harvest fertility of the soils even after growing the nutrient exhaustive crop of cotton. The high positive and linear correlation was observed of organic carbon with available N, P and K having R2 values 0.531, 0.389 and 0.68 and 0.526, 0.423 and 0.714, respectively which further showed the improvement the high relation of organic carbon in increasing the nutrient availability to the crop.

Keywords: Biofertilizer, correlation, FYM, STCR, targeted yield equation

Cotton wheat is a well established crop production system of north western plains of the Indian sub-continent and this rotation occupies prestigious place in the agricultural growth of India. These crops contribute largely to improve the economic conditions of the huge population engaged in farming, processing, trade and textile industry. Cotton (*Gossypium* spp) is an important commercial cash crop grown under diverse agro climatic conditions and is called as white gold, contributing 85 per cent of raw materials to textile industries. It plays a vital role in the country's economic growth by providing substantial employment and making significant contributions to export earnings. Among the cotton growing countries, India ranks first in area (13.01M/ha) of cotton on global scale and it is the second largest producer of cotton in the world after china. Haryana state having area of 0.74 M ha with production 1.82 M bales, the cotton production of Haryana state is 5.69 per cent of all India production (Anonymous, 2021, Goyal and Singh, 2018). In India, transgenic *Bt* cotton are being cultivated in about 11.4 M ha with an adoption rate of about 93 per cent, and this represents approximately 36 per cent of the global cotton area (James 2017).

Supply of nutrients is the major limiting factor in cotton production and most of soil in rainfed areas is not only thirsty but also hungry. It is well established fact that sufficient quantities of nutrients are needed at proper time for achieving targeted yield. The nutrient management in cotton is a complex phenomenon due to simultaneous production of vegetative and reproductive structures during the active growth phase. Cotton plant, being a heavy feeder, require adequate supply of nutrients to optimize the seed cotton yield, quality and net profit in cotton production (Aladakatti *et al.*, 2011).

The effective fertilizer recommendation should consider crop needs and nutrients already available in the soil. Among different methods and approaches for predicting the fertilizer requirements of crop, the fertilizer recommendation based on targeted yield (Ramamoorthy *et al.*, 1967) is unique one, which provides the balanced nutrition to crop and helps to maintain soil fertility condition. The soil test crop response (STCR) for targeted yield is an unique approach in indicating both soil test-based fertilizer dose and the level of yield that can be achieved with good management practices. In order to sustain the yield and reduce the cost of fertilizers and in turn cost of cultivation, the STCR approach is very important (Saxena *et al.*, 2008 and Chatterjee *et al.*, 2010).

The organic manures play an important role in crop production (Usman *et al.*, 2013). It acts on the soil physical properties, thus promotes formation of soil crumbs and makes the soil friable and thereby facilitates the proper movement of air and water as well as absorption of nutrients (Kumar *et al.*, 2021). It also adds plant nutrients to the soil during organic matter decomposition which act on the insoluble nutrients reserve in the soil and make them available biologically as it provides food for the beneficial soil microorganisms.

Method of sowing also will increase in availability of nutrients in the soils. Each sowing method has its own associated merits and demerits under different conditions; therefore, studies are required to determine the suitability of different sowing methods on site specific basis under different nutrient management practices. Bed planting enhances the seedling emergence and eliminates the formation of crust on the soil surface (Ahmad *et al.*, 2009). Iftikhar *et al.* (2010) reported that cultivation of cotton on beds gave better yield than flat sowing method. Ridge sowing of cotton has been found to improve the soil physical properties such as increased soil moisture content and decreased root penetration resistance and also enhances the emergence and seed cotton yield (Gursoy *et al.*, 2011). The FIRB (furrow irrigated raised bed) system gives 5 to 10 per cent higher yield over conventional sowing methods and brings considerable savings in irrigation water and facilitates manual weeding (Kumar *et al.*, 2001).

Therefore, the present investigation was carried out to study the effect of planting methods on various chemical properties of soil in different nutrient management practices under cotton crop.

MATERIALS AND METHODS

Study site and experimental treatments

The soil samples were collected from an experimental site located at 29o16‘ N latitude and 75o7‘E longitude in north western part of India and south west part of Haryana. The experiment was carried out at Research Farm, Department of Soil Science, CCS Haryana Agricultural University, Hisar. Climatic conditions of the region are semi arid with a mean annual precipitation of 443 mm and mean annual temperature of 24.8°C. The summer month are extremely hot with maximum temperature of Hisar reaching to 47°C and winters are markedly cold with minimum temperature goes to 1°C. Around, 80 per cent of rainfall is received during the months from July to September and the remaining rainfall is received during December to February.

The experiment was started in 2020 under cotton wheat cropping system with the objective to sustain yield and maintain soil fertility by nutrient management practices adopted on the basis of inductive cum targeted yield concept of STCR studies. The experiment, having five treatments with two planting system *i.e.* flat bed planting system and raised bed planting system, consists of one absolute control plot (T_1), one with FYM @15 t/ha FYM (T_2), one with FYM @15 t/ha+biofertilizer + jeevamrut (T_3) and other two with targeted yield of STCR (T_4 & T_5) were included in the treatments to see the reponses of fertilizers and FYM *w.r.t* control. In STCR treatments (T_4 and T_5), fertilizer doses were calculated based on fertilizer adjustment equations for specific yield targets (Ramamoorthy *et al.*,1967) and site specific nutrient management as given below:

IPNS based fertilizer adjustment equations for Bt cotton

$$FN = 13.76\,T -- 1.95\,SN - 0.13\,FYM\,(N)$$

$$F(P2O5) = 4.47\,T - 4.78\,SP - 0.12\,FYM\,(P_2O_5)$$

$$F(K2O) = 7.64\,T - 0.77SK - 0.10\,FYM\,(K_2O)$$

Where FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O (kg/ha) rates, SN, SP and SK are the soil test values (kg/ha) for KMNO4-N, Olsen's P and Ammonium acetate, FYM (N), FYM (P_2O_5) and FYM (K_2O) are the N, P_2O_5 and K_2O in FYM (kg/ha) and T is the targeted yield (Mg/ha).

Crop management

During cropping seasons of *kharif* 2020 and *rabi* 2020-21, *Bt* cotton (var RCH 773) and wheat (WH 1105) was grown in sequence with three replications following randomized block design. The net unit plot size in the experiment was 100 m2 (12.5×8.0 m). The available N, P and K of the field at the start of the experiment in 2019-2020 were 112 kg N, 12 kg P and 220 kg K/ha at 0-15 cm soil and 85kg N, 8 kg P and 200 kg K/ha at 15-30 cm depth.

Soil sampling and analysis

Soil samples were collected from a depth of 0-15 and 15-30 cm after harvest of *Bt* cotton with the help of soil auger. The soil samples were air dried ground in wooden pestle and mortar and passed through 2.0 mm sieve for chemical properties.

Air dried soil samples were analyzed for pH and EC using potentiometric and conductivity method, respectively. For determination of EC and pH of soil, soil: water suspension of 1:2 was prepared by taking 20 g oven dried soil in 100 ml beaker with 40 ml of distilled water. The soil suspension was stirred intermittently for about 30 minutes and then allowed to stand until clear supernatant is obtained. Meanwhile, the conductivity meter was calibrated with 0.01 M KCl solution and pH meter was calibrated with buffer solution of pH value 7.0 and 9.2. First, the EC of supernatant of each sample was measured using conductivity meter. After measuring EC, the sample is thoroughly mixed with glass rod for measuring pH of the soil solution using pH meter.

The available nitrogen in soil sample was determined by alkaline permanganate method as described by Subbiah and Asija (1956). A known weight of soil was mixed with excess of alkaline $KMnO^4$ and distilled. Ammonia gas released by distillation was absorbed in a known volume of standard sulphuric acid excess of which is titrated with standard alkali using methyl red as an indicator. Available phosphorous was determined by extracting the soil sample with 0.5M $NaHCO^3$, pH 8.5 in the presence of Darco G60 and measuring the P content in soil by using a spectrophotometer at 660 nm. Available potassium in soil was determined by ammonium acetate method using flame photometer as described by Jackson 1973.Micronutrient (Zn, Cu, Fe and Mn) in soil was determined by DTPA extractable method using atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

Statistical analysis

The data of each treatment related to soil and plant samples were analyzed in a randomized block design. The least square difference (LSD) was used to compare the effect of the treatment at p<0.05 using OPSTAT software (Sheoran *et al.*, 1998). Significance (P<0.05) of the treatment means were estimated by employing Duncan's multiple range test at 5 per cent level of significance.

RESULTS AND DISCUSSION

Soil pH

The pH of soil in different treatments ranged from (7.76-7.97 and 7.72- 8.06) for the surface soil and (7.78-8.03 and 7.74-8.06) for sub-surface soil, in raised bed and flat bed system, respectively (Table 1). It was observed that the pH of the soil decreased significantly in the treatments where FYM either alone orintegrated with cow urine based formulation and biofertilizer was applied (T2 and T3). In treatments T2-T3 and T4-T5 the pH values was at par with each other under both raised bed and flat bed system at both depths of the soil. The pH of sub-surface soil was found higher as compared to surface soil. However, the effect of different nutrient practices on soil pH was found non-significant at sub-surface in both raised and flat-bed planting system.

The decrease in soil pH in FYM treatment might be due to release of organic acids *i.e.* aliphatic and aromatic hydroxy acids and carbon dioxide (CO^2) released into the soil during decomposition of FYM which could have resulted in complexation of free and exchangeable aluminum ions (Walker *et al.*, 2004; Swarup and Wanjari 2000; Hati *et al.*, 2008). The treatments where only NP fertilizers were applied also

Table 1. Effect of nutrients management practices on soil pH at varying depths under different planting system

Treatment	Raised bed system		Flat bed system	
Sample depth	**0-15**	**15-30**	**0-15**	**15-30**
T_1 (Control)	7.97a	8.03a	8.06a	8.06a
T_2 (FYM)	7.77b	7.78a	7.80b	7.80a
T_3 (FYM+biofertilizer +cow urine based formulation)	7.76b	7.78a	7.72b	7.74a
T_4 (STCR 2.8)	7.94a	7.95a	7.95a	7.96a
T_5 (STCR 3.2)	7.93a	7.93a	7.95a	7.95a
SE (m) ±	0.042	0.067	0.042	0.072
LSD (pd+ 0.05)	0.138	N/A	0.14	N/A

Values followed by similar letters in a column indicate non-significant difference (p<0.05) according to Duncan Multiple Range test (DMRT) for separation of means; (mean ± SE, n=3)

Table 2. Effect of nutrients management practices on soil electrical conductivity; (EC dSm-1) (1:2) at varying depths under different planting system

Treatment	Raised bed system		Flat bed system	
Sample depth	**0-15**	**15-30**	**0-15**	**15-30**
T_1 (Control)	0.39c	0.35a	0.43c	0.39a
T_2 (FYM)	0.51ab	0.43a	0.51ab	0.46a
T_3 (FYM + biofertilizer + cow urine based formulation)	0.54a	0.44a	0.53a	0.49a
T_4 (STCR 2.8)	0.45bc	0.39a	0.46bc	0.41a
T_5 (STCR 3.2)	0.46abc	0.37a	0.48abc	0.43a
SE(m) ±	0.022	0.021	0.02	0.022
LSD (pd"0.05)	0.073	N/A	0.067	N/A

Values followed by similar letters in a column indicate non-significant difference (p<0.05) according to Duncan Multiple Range test (DMRT) for separation of means; (mean ±SE, n=3) showed the decrease in pH value over control which might be due to nitrification of ammonium (NH4+) to nitrate (NO3-) with the subsequent release of H+ ions in the soil that might have lowered the soil pH. Among the planting system, low pH was found under raised bed plating system over flatbed system (Gaurav *et al.*, 2018).

Soil electrical conductivity; EC

The electrical conductivity as a measure of soluble salts or salinity varied in different treatments of nutrient management of organic and inorganic both at surface (0-15cm) and sub–surface (15-30cm). The EC varied from 0.39-0.54 dS/m and 0.43-0.53dS/mfor the surface soil and 0.35-0.43dS/mand 0.39-0.49dS/mfor sub-surface soil, in raised bed and flat bed system, respectively (Table 2). The lowest value of electrical conductivity of soil was found to be in control (T_1). With the addition of organic sources of nutrients, significant increase in EC was observed as compared to control treatment in the surface soil. However, EC was lowered in sub-surface soil and found non-significant among different nutrient management treatments of organic and inorganic. Among the different treatments of STCR, the electrical conductivity did not vary significantly among fertilizer treatments (T_4-T_5) and also among FYM treatments (T_2-T_3). The EC was also found non-significant at sub-surface soils for both raised and flat bed planting system.

The higher soil electrical conductivity was observed in the application of FYM alone treatment or with combination of cow urine based formulation and biofertilizer as compared to chemical and control treatments which is due to addition of soluble salts through FYM (Antil and Singh, 2007; Escobar and Hue, 2008; Goyal and Jhorar 2007). This may be attributed to the mixed problem of soil salinization and water logging arouse in the study area due to introduction of canal irrigation water in the region (Goyal *et al.*, 2008) due to which the amounts of dissolved salts in the manures are generally found high. The increase in soil electrical conductivity with organic matter was also reported by Chang *et al.*, 2007 and Roy and Kashem, 2014. Soil EC decreased with increased in soil depth. Among the crop establishment methods, lower EC was found under raised bed plating system as compared by flatbed system (Gaurav *et al.*, 2018). Soil electrical conductivity was higher in chemical treatments than control due to addition of soluble salts through fertilizers (Escobar and Hue, 2008; Kumar *et al.*, 2020).

Available macronutrients (NPK)

Available nitrogen

The effect of nutrient management practices on available macronutrients content in soils at surface and subsurface soils is given in Table 3 for raised bed system and in Table 4 for flat bed system. The fertilizer doses in T_4 to T_5 treatment of STCR were calculated by using

Table 3. Effect of different nutrient management practices on soil available nitrogen, phosphorous, potassium (kg/ha) at varying depths in raised bed planting

Treatment	Available Nitrogen		Available Phosphorous		Available Potassium	
Sample depth	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
T_1 (Control)	91.28d	68.00c	8.00d	3.90d	145.53d	83.57d
T_2 (FYM)	108.90b	81.87a	13.80ab	8.70b	167.23b	98.67ab
T_3 (FYM+biofertilizer +cow urine based formulation)	113.70a	82.43a	14.53a	9.03a	175.57a	100.53a
T_4 (STCR 2.8)	102.70c	74.07b	10.43cd	6.87c	155.10c	94.07c
T_5 (STCR 3.2)	104.28c	76.43b	11.40bc	7.00c	163.30bc	96.63bc
SE (m)	1.27	1.07	0.86	0.08	2.54	0.79
LSD (p<0.05)	4.21	3.56	2.83	0.266	8.40	2.62

Values followed by similar letters in a column indicate non-significant difference (p<0.05) according to Duncan Multiple Range test (DMRT) for separation of means; (mean ±SE, n=3)

Table 4. Effect of different nutrient management practices on soil available nitrogen, phosphorous, potassium (kg/ha) at varying depths in flat bed planting

Treatment	Available Nitrogen		Available Phosphorous		Available Potassium	
Sample depth	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
T_1 (Control)	84.60c	63.46d	7.57c	3.70e	141.27c	81.50d
T_2 (FYM)	107.80a	78.60ab	12.07a	8.41b	165.07a	97.63ab
T_3 (FYM+biofertilizer +cow urine based formulation)	111.20a	80.00a	12.20a	8.93a	170.77a	98.87a
T_4 (STCR 2.8)	98.80b	73.50c	9.93b	5.96d	151.23b	93.33c
T_5 (STCR 3.2)	101.50b	76.23b	10.60b	6.90c	155.23b	95.33bc
SE(m)	1.78	0.84	0.35	0.11	2.73	0.79
LSD (p<0.05)	5.91	2.78	1.17	0.38	9.05	2.62

Values followed by similar letters in a column indicate non-significant difference (p<0.05) according to Duncan Multiple Range test (DMRT) for separation of means; (mean ±SE, n=3)

Table 5. Effect of nutrients management practices on micronutrients (Zn, Cu, Fe and Mn) (mg/kg) in soil at varying depths under different planting system

Treatment	Zn		Fe		Cu		Mn	
Sample depth	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
Raised bed system								
T_1 (control)	1.49d	0.65d	5.64e	3.39e	1.07a	0.81a	4.98d	3.88b
T_2 (FYM)	1.86b	0.79b	6.73b	4.02b	0.89d	0.75a	6.26b	4.48a
T_3 (FYM+biofertilizer +cow urine based formulation)	1.92a	0.85a	6.90a	4.24a	0.91cd	0.75a	6.45a	4.51a
T_4 (STCR 2.8)	1.67c	0.72c	5.98d	3.69d	0.98bc	0.80a	5.42c	4.25ab
T_5 (STCR 3.2)	1.69c	0.75c	6.19c	3.81c	0.99b	0.80a	5.35c	4.27ab
SE(m)	0.009	0.013	0.029	0.026	0.021	0.018	0.056	0.118
LSD (p<0.05)	0.029	0.043	0.095	0.086	0.068	N/A	0.186	0.391
Flat bed system								
T_1 (control)	1.50d	0.63d	5.64e	3.35e	1.05a	0.80a	4.93d	3.79b
T_2 (FYM)	1.83b	0.77b	6.63b	3.95b	0.82c	0.74a	6.23b	4.46a
T_3 (FYM+biofertilizer +cow urine based formulation)	1.91a	0.83a	6.78a	4.16a	0.83bc	0.72a	6.41a	4.53a
T_4 (STCR 2.8)	1.62c	0.71c	5.99d	3.63d	0.92abc	0.78a	5.38c	4.24ab
T_5 (STCR 3.2)	1.64c	0.70c	6.18c	3.79c	0.96ab	0.78a	5.31c	4.23ab
SE(m)	0.01	0.011	0.038	0.035	0.038	0.021	0.051	0.133
LSD (p<0.05)	0.033	0.037	0.126	0.116	0.127	N/A	0.169	0.44

Values followed by similar letters in a column indicate non-significant difference (p<0.05) according to Duncan Multiple Range test (DMRT) for separation of means; (mean ±SE, n=3)

target yield equations of cotton. The soil samples pertaining to available N, P and K clearly revealed that the soil available nitrogen (N) content was found significantly higher in FYMand FYM + Bio fertilizer + cow urine based formulation as compared to fertilizer treatment of STCR and control in both raised bed and flat bed planting system. However, it was found to be non-significant among each other (T_2 & T_3 treatments and T_4 and T_5 treatments) in both surface and sub surface soil. Availability of N further decreased with increase in depth from 0-15 to 15-30 cm ranging from 91.28 to 68.00 kg/ha in T_1 treatment, 108.90 to 81.87 kg/ha in T_2 and 113.70 to 82.43 kg/ha in T_3 treatments and for STCR treatments it ranged from 102.70 to 74.07 kg/ha in T_4 and 104.28 to 76.43 kg/ha in T_5 for raised bed system. However, available N in flat bed decreased slightly ranging from 84.60 to 63.46 kg/ha in T1 treatment; 107.80 to 78.60 kg/ha in T_2 and 111.20 to 80.00 kg/ha in T_3 treatments and for STCR treatments 98.80 to

73.50 kg/ha in T_4 and 101.50 to 76.23 kg/ha in T_5.

The increase in available macronutrients with addition of FYM either alone (T_2) or in combination with cow urine based formulation and biofertilizer (T_3) was observed for surface as well as sub-surface soil. This might be due to the addition of organic matter through FYM which not only improves the biological and chemical processes but during its decomposition it out-turn in further dissolution of nutrient ions thus resulting in more availability of nutrients for crop. Organic matter also complexes the nutrients ions present in the soil and make it available to the plants easily at different stages of crop growth period. Moreover, FYM may increase the activity of soil microbes which convert the organically bound nutrients into more readily available inorganic form (Kumar *et al.*, 2021). The available macronutrients had higher value in surface soil than sub surface soil (Kumar *et al.*, 2020; Kumar *et al.*, 2012).

Available phosphorous

The soil available phosphorous was increased in organic treatments over control after application of FYM @15 t/ha. Higher available P has been observed in raised bed planting system as compare to the flat bed system and it ranged from 8.00 to 14.53 kg/ha and 7.57 to 12.20 kg/ha, respectively in surface soils of raised bed and flat bed system (Table 3 and Table 4). The corresponding values of available P at subsurface depth varied from 3.90 to 9.03 and 3.70 to 8.93 kg/ha, respectively for raised bed and flat bed planting system. The increased availability of P with organics could be ascribed to their solubilizing effect on native soil P and then consequent contribution of labile pool mineralization of organic P due to microbial action and enhanced mobility of P (Kumar *et al.*, 2020). Organic materials like FYM/ vermicompost form protective cover on sesquioxides and this facilitates reduction in the phosphate fixation capacity of soil (Tolanur and Badanur, 2003). The available phosphorous content of soil increased with increase in soil organic carbon content of soil.

Available potassium

The effect of various treatment showed that the soil available K was higher in raised bed method as compared to conventional flat bed system. In flatbed planting system, lowest available K was found in control T_1 (141.27 kg/ha and 81.50 kg/ha), which was significantly lower than T_2 (165.07 kg/ha and 97.63 kg/ha), T_3 (170.77 kg/ha and 98.87 kg/ha), T_4 (151.23 kg/ha and 93.33 kg/ha) and T_5 (155.23 kg/ha and 95.33 kg/ha) at surface and subsurface soil (Table 4). The available K of the soil was found to be *at par* among the chemical treatments (T_4 and T_5) and organic treatments (T_2 and T_3). The soil potassium content decreases as the soil depth increase from 0-15 to 15-30 cm. The buildup of available potassium in organic treatments (T_2 and T_3) was due to application of FYM while decrease in available potassium in control (T_1) and chemical (T_4 and T_5) is due to mining of available potassium by crop without any application of potassium fertilizers. Thakare and Wake (2015) also observed that increasing levels of the organic manures significantly increased the nutrients availability in soil over control as the application of organic manure might have caused reduction in K fixation. Similar findings were recorded by Patil and Varade (2006).

Gaurav *et al.* (2018) reported the higher availability of macronutrients in soil under raised bed planting, which was significantly superior to conventional flat bed sowing method. This might be due to fact that raised bed planting lowered down the weed population and minimized the loss of nutrients by weeds, which resulted in increase in the availability of nutrient in soil. Similar results were also reported by Jayashree and Rao (2002), Dhimmer (2003) and Singh and Kler (2005). Also, the raised bed planting system provides natural drainage of the soil thus preventing the sudden change in soil moisture due to which more build up of microbes occurs that may help in releasing the nutrients

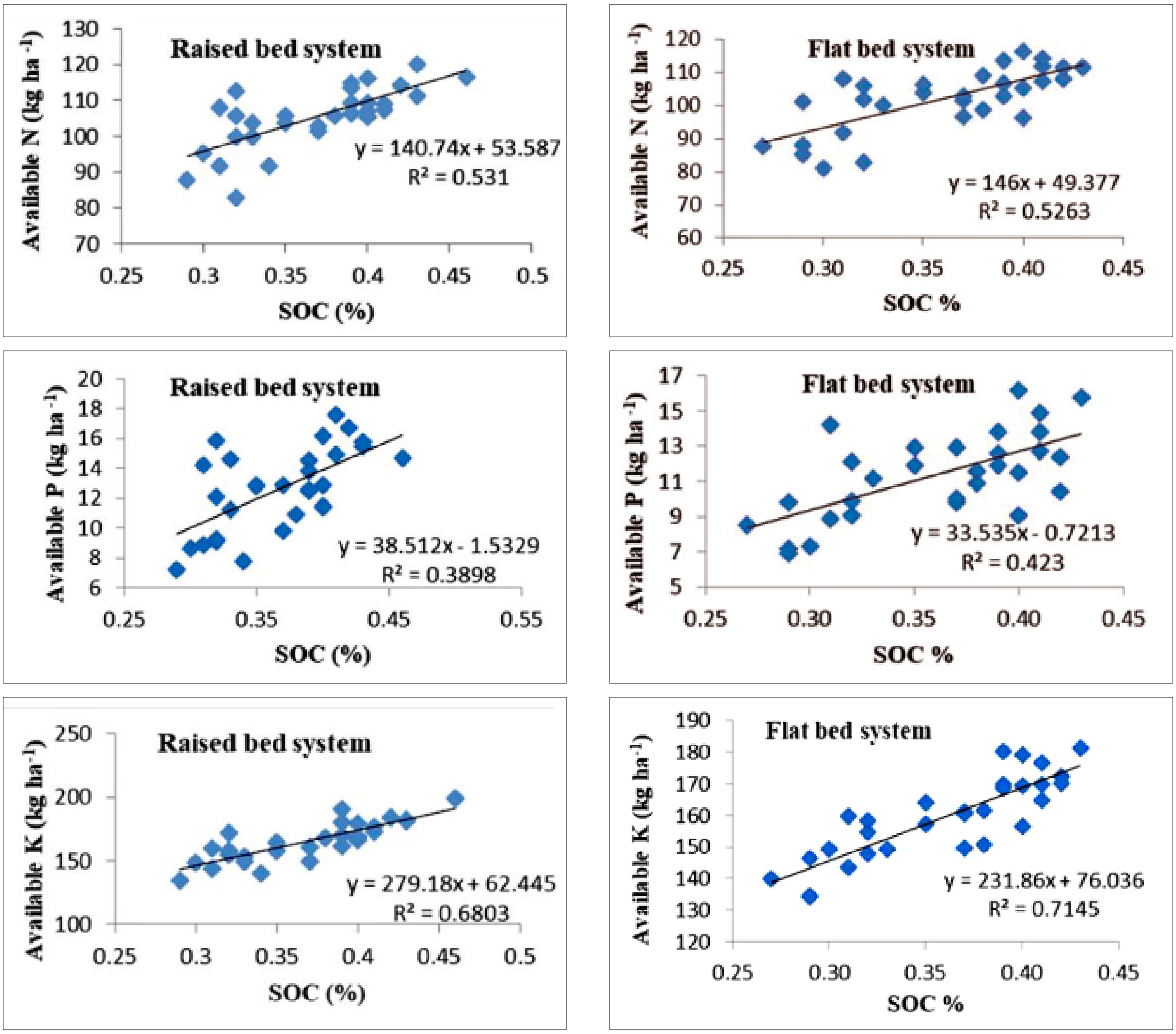

Fig. 1. Relationship of available N, P and K (kg/ha) with SOC (%) in different planting system

slowly from its recalcitrant form to its available form during the period of time.

The high positive and linear correlation was observed of organic carbon with available N, P and K having R2 values 0.531, 0.389 and 0.68 and 0.526, 0.423 and 0.714, respectively for raised bed and flatbed planting system (Fig 1). This high correlation of SOC with macronutrients (N, P and K) further showed that organic matter acts as a store house of available N, P and K and contribute significantly the availability of nutrients from the soil native pool.

Available micronutrients (Zn, Cu, Fe and Mn) in soil

The data pertaining to micro nutrient levels as affected by different nutrient management practices for raised bed and flat bed planting system is presented in Table 5. The micronutrient *viz.* Zn, Fe and Mn in the soil were found to increase significantly over the control in the organic treatments (T_2 and T_3) under both the planting system. This might be due to dissolution of nutrients from the exchange/bound site in to the soluble form while the concentration of Cu was found to decrease significantly with increasing application of inorganic (T_4 and T_5)

and organic sources of nutrients (T_2 and T_3) under both the planting system at surface soil because Cu could be bound with organic matter and become unavailable to crops. However, it was found non significant in subsurface soils both in raised bed and flatbed system. The concentrations of Zn, Fe, Cu and Mn as essential micronutrients are available in soil for crop growth and their availability affects the transfer from soil to crop and thus affects to a great extent on the crop yield and its quality. Organic treatment (T_2- T_3) showed highest values of Zn (1.92-1.83 mg/kg), Fe (6.90-6.63 mg/kg) and Mn (6.45-6.23 mg/kg) followed by fertilizer treatments (T_4 -T_5) and least in control (T_1). The available Fe varies from 6.90 – 5.64 mg/kg and 4.24– 3.39 mg/kg and 6.78 – 5.64 mg/kg and 4.16 – 3.35 mg/kg in raised bed and flat bed system, respectively at surface and sub surface soil. The micronutrient content also decreased with increase in soil depth from 0-15 to 15-30 cm. In the raised bed system micronutrient concentration is more as compare to the flat bed system. Kumar *et al.* (2020) in their long term study of organic and inorganic of STCR showed the decreasing trends of Cu in plots receiving organic matter singly or in integration with fertilizers. However, the decrease was more pronounced on FYM alone treatments of STCR. The available micronutrient content decreases with increasing soil depth in all treatment plots. Sharma *et al.*, (2015) recorded an increase in DTPA extractable micronutrient in FYM @ 20 t/ha treatments with 5.2, 9.2, 4.9 and 46.8 mg/kg of Zn, Fe, Cu and Mn. Mohrana *et al.* (2017) studied the availability of micronutrients using STCR-basedtargeted yield equations under pearl millet-wheat cropping system. They observed that the availability of micronutrients (Zn, Fe, Mn and Cu) increased with the application of FYM at surface soil as compared to sub surface soil. Pandey *et al.* (2018) observed reduction in available Zn content with increasing levels of N, P and K may be due to more dry matter yield which accured to more removal of Zn from soil. Incorporation of organic materials significantly increased the available Zn of the soil. The available Zn was higher under raised bed system compared to the flat bed system. This may be due to the fact that raised bed planting lowered down the weed population and minimized the loss of nutrients by weeds, which resulted in increase in the availability of nutrient in soil (Gaurav *et al.*, 2018).

CONCLUSIONS

The present study demonstrated that the use of FYM and NPK fertilizer using STCR-basedtargeted yield approach increased available micronutrients and soil properties. Though with addition of FYM, EC increases slightly and pH decreases slightly, however, the effect of different nutrient management practices using STCR approach was found non significant. Available N, P and K increased significantly with increase in organic carbon content of the soil which may be due to balanced nutrition in the FYM that may have helped in build up or maintenance of these nutrients over the time. In sub surface soil, available N, P and K content decreases as compared to surface soils. With increase in organic carbon content of the soil, DTPA extractable Zn, Fe and Mn increased while the Cu content decreased because Cu could be bound with organic matter and become unavailable to crops. Availability of macronutrients and micronutrients in soil was higher under raised bed planting, which was significantly superior to conventional flat bed sowing method.

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