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Effect of integrated plant nutrient system on passive and active pools of organic carbon in soybean-chickpea sequence

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Abstract: A field experiment was conducted at Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) during *kharif* season of 2012-13 to evaluate the long term impact of Integrated Plant Nutrient Supply (IPNS) on passive and active pools of soil organic carbon in relation to soybean-chickpea cropping sequence. The experiment was laid in randomised block design (RBD) with eight treatments comprising absolute control, 100% recommended dose of fertilizer (RDF) along with farm yard manure (FYM) @ 5 Mg ha^{-1}, 50 % RDF + 50 % P through phosphocompost, 75 % RDF + 25 % N through cotton stalk and 100 % RDF supplemented through organics only. The results revealed that, the application of 100% RDF + FYM @ 5 Mg ha^{-1} (100% RDF to *rabi*) led to highest organic carbon fraction *viz*. Fulvic Acid (FA-C) (0.35 %), Humic Acid (HA-C) (0.28%), organic matter (9.77 g kg^{-1}). The active pools of carbon *vz.* SMB-C (264.3 mg kg^{-1}), SMB-N (39.66 mg kg^{-1}), WS-C (45.66 mg kg^{-1}) and WS-CHO (862.3 mg kg^{-1}) were also influenced significantly with the application of 100 % RDF + FYM @ 5 Mg ha^{-1} (100 % RDF to *rabi*). The grain (27.93 q ha^{-1}) and stover (32.33 q ha^{-1}) yield of soybean was maximum with the application of 100 % RDF + FYM @5 Mg ha^{-1} (100 % RDF to *rabi*). The different fractions of organic carbon were significantly correlated themselves as well as with the yield of soybean. The HA-C (r^2 = 0.86) and FA-C (r^2= 0.84) were significantly correlated with SMB-C and SMB-N. There also exists a significant and positive correlation among different organic carbon fractions with soybean yield, the correlation coefficient was observed to r^2=0.558**, r^2=0.479** and r^2=0.413*, respectively for HA-C, organic carbon and FA-C. The application of 100 % RDF + FYM @ 5 Mg ha^{-1} (100 % RDF to *rabi*) recorded highest FA-C: HA-C ratio (1.25) and it was least in control (1.10).

Key words: *FA-C, HA-C, SMB-C, SMB-N, WS-C, WS-CHO, phosphocompost, Passive pools, Active pools.*

Introduction

The long term sustainability and overall productivity of cropping system is directly related to the maintenance of soil organic matter through recycling plant nutrients and improving physical, chemical and biological properties of soil. Although, the content of organic matter in Indian soils is relatively low ranging from 0.1 to 1 per cent and majority less than 0.5 per cent, its influence on soil fertility and physical conditions is of great significance (Anonymous 2001). The soil microbial biomass carbon (SMB-C) is an important component of the soil organic matter and comprises 1 to 3 per cent of the total soil organic carbon (Jenkinson and Ladd 1981). Soil organic matter is the key component that regulates the available nutrient status and reflects the overall state of soil fertility and quality. Arresting the fall in organic matter is effective to fight soil degradation and ensure sustenance of soil quality and agricultural productivity.

Humic substances are considered as the most important constituent of soils. Humic and fulvic substances enhance plant growth directly through physiological and nutritional effects. Some of these substances function as natural plant hormones (auxins and gibberellins) and are capable of improving seed germination, root initiation, uptake of plant nutrients and can serve as sources of N, P and S. Indirectly, they may affect plant growth through modifications of physical, chemical and biological properties of the soil, *e.g*. enhanced soil water holding capacity, cation exchange capacity (CEC), and improved tilth and aeration through good soil structure (Stevenson 1994). Soybean (*Glycine max* L.) is an important pulse and oilseed crop grown extensively on large scale in India. The area under soybean in India is 103.34 million ha and production is 119.39 lakh tonnes whereas, in Maharashtra, the area under soybean is 30.61 million ha and production is 38.46 lakh tonnes (Anonymous 2011). Deterioration of soil health is considered as main cause for decline in soybean productivity (Reddy *et al*. 2005), keeping this in view the present investigation was conducted to study the effect of integrated plant nutrient system (IPNS) on passive and active pools of organic carbon and yield soybean.

Material and Methods

The long term experiment was initiated during 2010-11 at research farm, Integrated Farming System Research, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS). The effect of IPNS on soil organic carbon pools in relation to soybean-chickpea based cropping sequence was studied during 2012-13. The experimental soil was clayey, slightly alkaline in reaction with pH (7.8), organic carbon (4.8 g kg^{-1}), low in available N (158 kg ha^{-1}), medium in available P (9.5 kg ha^{-1}) and with high in available K (320 kg ha^{-1}), whereas, marginal in DTPA-Zn (0.61 mg kg^{-1}). The experiment was laid out in randomized block design with eight treatments replicated three times as given below.

Soybean-chickpea sequence with different set of treatments *viz*.; T1-Absolute control; T2-100% RDF; T3-100% recommended dose of fertilizer (RDF) + farm yard manure (FYM) @ 5 Mg ha^{-1} (75%RDF); T4-100% RDF + FYM @ 5 Mg ha^{-1} (100% RDF); T5-50% RDF+50% P through phosphocompost (75% RDF + *in situ* soybean straw); T6-50% RDF+50% P through phosphocompost (100% RDF + *in situ* soybean straw), T7-75% RDF+25% N through cotton stalk (50% RDF+50% P through phosphocompost) and T8-100% RD of N through FYM and remaining P was added through phosphocompost (*in situ* soybean straw + remaining N and P was applied through phosphocompost). The phosphocompost were prepared from wheat straw which contained 1.23% N, 1.94% P and 0.78% K. The *rabi* treatments are indicated in parenthesis.

FYM and other organics were incorporated as per treatment at the time of field preparation and mixed thoroughly. Recommended dose of fertilizers were applied at 30:75:30 kg ha^{-1} N, P_2O_5 and K_2O for soybean. All recommended agronomic and cultural practices were followed for soybean in a sequence. The soil samples at 50 % flowering stage were collected following the standard procedure. The samples were air dried in shade, ground with Willey mill, passed through appropriate sieve size and analyzed for important soil properties given below.

Data generated was subjected to statistical analysis in RBD as per Panse and Sukhatme (1967).

Results and Discussion

Passive pools

Among the soil organic matter fraction, the content of FA-C fractions was found higher than HA-C fraction (Table 1). The FA-C fraction ranged from 0.23 to 0.35 per cent in the various treatments. The highest value of FA-C fraction was noted in the treatment where, 100% RDF + FYM @ 5 Mg ha^{-1} was applied to soybean during *kharif* season along with 100% and 75% RDF to the chickpea. The FA-C content was mostly affected due to the addition of FYM, because of readily decomposed FYM is an intermediate product consisting of humic substances and organic matter. As the conversion process continues, the solubility of humic substances increased which resulted increase in fulvic acid fraction. These findings are corroborated with the findings of Manna (2002) who reported that improvement in FA-C was higher with the application of NPK + FYM.

Table 1. Effect of various treatments on passive pools of organic carbon at 50 per cent flowering stage of soybean

	Treatments	OM (g kg^{-1})	Passive pool (%)		FA-C: HA-C ratio
			FA-C	HA-C	
T1	Control	7.64	0.23	0.21	1.10
T2	100 % RDF	9.36	0.28	0.23	1.22
T3	100 % RDF + FYM 5 Mg ha^{-1}	9.77	0.34	0.28	1.21
T4	100 % RDF + FYM 5 Mg ha^{-1}	9.77	0.35	0.28	1.25
T5	50 % RDF + 50% P through Phosphocompost	9.37	0.28	0.24	1.17
T6	50 % RDF + 50% P through Phosphocompost	9.41	0.28	0.25	1.12
T7	75 % RDF +2 5% N through cotton stalk	8.68	0.29	0.26	1.12
T8	100% RDF through FYM + remaining P through Phosphocompost	9.65	0.33	0.28	1.18
	SE (m±)	0.76	0.0051	0.0048	-
	CD at 5 %	1.64	0.016	0.014	-

OM: Organic matter, FA-C: Fulvic acid carbon, HA-C: Humic acid carbon

The HA-C fraction ranged from 0.21 to 0.28 per cent. The significantly highest HA-C fraction was recorded with the application of 100 % RDF + FYM @ 5 Mg ha^{-1} (0.28%), followed by 100 % recommended dose of N through FYM + remaining P through phosphocompost (0.28%). Both these treatments were found statistically at par with each other. Considerably lower value of HA-C was registered under 100 % RDF (0.23%) and control (0.21%). To build up carbon stock in the soil, sufficient amounts of carbon is to be added to the soil through crop residues and/or other organic amendments. The applications of FYM, phosphocompost and crop residues contributed to organic matter in the soil. This resulted in the build up of passive pools of organic carbon. Bandyopadhay *et al.* (2010); Ghosh *et al*. (2010 and 2012) and Pathak *et al.* (2011) reported that one of the known and easy ways for carbon enrichment in soils is incorporation of crop residues or organic amendments.

However, increasing amount of theirs addition with a view to achieve higher carbon sequestration met with mixed success. Application of 5-10 Mg of FYM-crop residues for decades together could bring about an increase in C content in soils to the extent of only 10-15 per cent (Mandal 2011). These results are in line with the findings of Ravankar (2003), Pothare (2001) and Thakare (2004).

Active pools

Soil organic carbon dynamic is of paramount importance for improving soil quality and sustaining crop productivity under intensive cropping .The active pools of soil organic carbon chiefly consist of soil microbial biomass carbon (SMB-C), soil microbial biomass nitrogen (SMB-N), water soluble carbon (WS-C) and water soluble carbohydrates (WS-CHO).

Soil microbial biomass carbon (SMB-C)

The application of 100% RDF + FYM @ 5 Mg ha^{-1} (with 100 % RDF to chickpea) recorded significantly higher SMB-C (264.3 mg kg^{-1}) followed by 100% RDF + FYM @ 5 Mg ha^{-1} with 75% RDF to chickpea (255.06 mg kg^{-1}) (Table 2). The application of 100% recommended dose of N through FYM + remaining P through phosphocompost was also found promising in improving soil microbial biomass carbon (251.6 mg kg^{-1}) over 100% RDF (207.6 mg kg^{-1}).

The lowest SMB-C was found in control treatment. The addition of FYM in combination with chemical fertilizer almost doubled the biomass carbon as compared to control treatment, the supply of additional minerlizable and readily hydrolizable carbon due to organic sources resulted in higher microbial activity and which in turn higher microbial biomass carbon (Verma and Mathur 2009; Sarode and More 2010; Basak 2012).

Table 2. Effect of various treatments on active carbon pool at 50 per cent flowering of soybean

	Treatments	Active carbon pool (mg kg^{-1})			
		SMB-C	SMB-N	WS-C	WS-CHO
T1	Control	186.2	24.00	21.33	604.8
T2	100 % RDF	207.6	29.33	34.00	707.8
T3	100 % RDF + FYM 5 Mg ha^{-1}	255.0	39.00	40.33	820.2
T4	100 % RDF + FYM 5 Mg ha^{-1}	264.3	39.66	45.66	862.3
T5	50 % RDF + 50% P through Phosphocompost	239.7	36.00	36.33	705.5
T6	50 % RDF + 50% P through Phosphocompost	234.1	35.00	37.00	646.0
T7	75 % RDF +25% N through cotton stalk	227.5	37.00	36.00	676.1
T8	100% RDF through FYM + remaining P through Phosphocompost	251.6	38.00	38.00	780.7
	SE (m±)	4.70	2.55	3.41	42.9
	CD at 5 %	14.26	7.74	10.36	130.3

SMB-C: Soil microbial biomass carbon, SMB-N: Soil microbial biomass carbon, WS-C: Water soluble carbon, WS-CHO: Water soluble carbohydrates

The other management practices involving 50% RDF along with 50% P through phosphocompost in which 75% RDF (T5) and 100% RDF (T6) in combination with *in situ* soybean straw also recorded higher biomass carbon than control and 100% RDF treatments. This revealed that, the judicious use of chemical fertilizers along with organics proliferate microbial activity and their subsequent impact on microbial biomass carbon. Since, the soil microbial biomass carbon is an important component of the soil organic matter and comprises 1 to 3 per cent of the total soil organic carbon (Jenkinson and Ladd 1981).

Soil microbial biomass nitrogen (SMB-N)

Soil microbial biomass nitrogen (SMB-N) was influenced significantly by various treatments at 50% flowering stage. Significantly higher SMB-N (39.66 mg kg^{-1}) was recorded with the application of 100% RDF + FYM @ 5 Mg ha^{-1} (with 100 % to chickpea). The application of 100% RDF + FYM @ 5 Mg ha^{-1} (with 75 % RDF to chickpea) was also found equally beneficial in improving SMB-N (39 mg kg^{-1}) indicating aggregative effect of organics and inorganics in the sequence. However, 100% recommended N through FYM and remaining P through phosphocompost recorded numerically similar SMBN (38 mg kg^{-1}). High soil organic carbon, more root decomposition and additional supply of N through FYM to micro-organism may be reason for improving microbial biomass. Similarly, the combination of organics along with inorganic fertilization indicating synergistic effect on soil microbial biomass may be the reason for improving SMB-N. This is in close relation with earlier findings of Varma and Mathur (2009), Saini *et al*. (2005), in soybean-maize sequence.

Water soluble carbon and carbohydrates (WS-C and WS-CHO)

The WS-C and WS -CHO act as source of energy for soil microorganisms and help in dynamics of plant nutrient in short time. It was observed that, the application of 100% RDF + FYM @ 5 Mg ha^{-1} (with 100 % RDF to chickpea) influenced significantly the WS-C to 45.66 mg kg^{-1}, whereas, the application of 100% RDF + FYM @ 5 Mg ha^{-1} (with 75% RDF to chickpea) was also beneficial in improving WS-C (40.33 mg kg^{-1}). The application of 100% recommended dose of N through FYM and remaining P through phosphocompost recorded WS-C to the extent of 38 mg/kg indicating effect of organics in improving overall soil physical and biological conditions of soil as compared to sole inorganic (100% RDF) application and control treatment.

The results pertaining WS-CHO revealed that, the application of 100% RDF + FYM @ 5 Mg ha^{-1} (with 100 % RDF to chickpea) significantly improved the WS-CHO (862.3 mg kg^{-1}) followed by application of 100% RDF + FYM @ 5 Mg ha^{-1} with 75 % RDF to chickpea (820.2 mg kg^{-1}). The application of 100% N through FYM and remaining P through phosphocompost were found promising over RDF through chemical fertilizers. The application of 75% RDF + 25 % N through cotton stalk considerably lowered the value of WS-CHO (676.1 mg kg^{-1}) only next to control (604.8 mg kg^{-1}). The possible reason behind this, may be the wide C:N ratio of cotton stalk which takes long time to decompose and thereby breakdown of complex organic substances like lignin, cellulose, hemicelluloses and proteins are slower down and inhibits the conversion of these complex organic substances into simpler ones.

Yield of soybean

The significantly higher grain yield of soybean (27.93 q ha^{-1}) was recorded (Table 3) in treatment receiving 100% RDF + FYM @ 5 Mg ha^{-1} (with 100% RDF to chickpea) followed by (27.60 q ha^{-1})100% RDF + FYM @ 5 Mg ha^{-1} with 75% RDF to chickpea.

Table 3 Effect of various treatments on yield soybean

Treatments		Yield (q ha^{-1})	
		Grain	Straw
T1	Control	18.37	19.77
T2	100 % RDF	25.60	29.37
T3	100 % RDF + FYM 5 Mg ha^{-1}	27.60	32.17
T4	100 % RDF + FYM 5 Mg ha^{-1}	27.93	32.33
T5	50 % RDF + 50% P through Phosphocompost	24.80	28.57
T6	50 % RDF + 50% P through Phosphocompost	24.90	28.67
T7	75 % RDF +2 5% N through cotton stalk	22.00	25.73
T8	100% RDF through FYM + remaining P through Phosphocompost	21.17	24.83
SE (m) ±		1.17	1.35
CD at 5 %		3.07	3.55

These findings indicate that integrated use of optimal dose of fertilizer and organic manure treatment is superior to sub-optimal dose. Thus, the balanced use of fertilizer either alone or in combination with organic manure is necessary for sustaining soil fertility and productivity of crops (Tiwari *et al.* 2002). These findings are similar with Muneshwar Singh (2008).

Correlation study

The correlation studies among active and passive pools of organic carbon and yield revealed that all the active pools of organic carbon were positively and significantly correlated (Table 4) with passive pools of organic carbon. The highest correlation was observed among soil microbial biomass carbon and humic acid fraction (r^2 = 0.864**) followed by FA-C (r^2 = 0.849**). There exists a strong and positive correlation among SMB-C, WS-C and WS-CHO with humic and fulvic acid. The grain yield of soybean was also significantly correlated with all the passive pools of organic carbon, the correlation coefficient was found in the order, HA-C (r^2 = 0.558**) > FA-C (r^2 = 0.413*). The depletion of soil organic matter results in poor water holding capacity, poor aggregation, acceleration in soil erosion, poor retention of applied nutrients, reduced soil biological and enzyme activities, and decline in the productivity. The improvement in active pool of soil organic carbon as a result of improved organic carbon status is clearly demonstrated by significant and positive correlation among themselves. The SMB-C was correlated significantly with organic carbon (r^2 = 0.672**) followed by SMB-N (r^2 = 0.546**), WS-C (r^2 = 0.495**) and WS-CHO (r^2 = 0.435**). The significant and positive correlation was observed among passive pools and organic carbon. The grain yield was significantly correlated with organic carbon fraction. This might be due to fact that organic carbon is the key factor which governs almost all the soil properties.

Table 4. Correlation between different organic carbon fractions and yield of soybean

Fractions	SMBC	SMBN	WS-C	WS-CHO	Grain
OC	0.546**	0.672**	0.495**	0.435*	0.479**
HA	0.864**	0.749**	0.617**	0.622**	0.558**
FA	0.849**	0.737**	0.574**	0.679**	0.413*

SMB-C: Soil microbial biomass carbon, SMB-N: Soil microbial biomass carbon, WS-C: Water soluble carbon, WS-CHO: Water soluble carbohydrates, OC: Organic carbon, HA: Humic acid, FA: Fulvic acid
*Significant at 5% ** Significant at 1%

Conclusion

From the present study, it can be concluded that, application of 100 % RDF + FYM to soybean during *kharif* and 100% and 75% RDF to the chickpea was equally beneficial for improvement in active pools (SMB-C ,SMB-N,WS-C,WS-CHO) and passive pools (FA-C and HA-C) of carbon. The improvement in the FA-C: HA-C ratio was also noted with the application of 100% RDF + FYM. The yield of soybean was increased with the application of 100 % RDF + FYM to soybean during *kharif* and 100% and 75% RDF to the chickpea. The positive and significant correlation was observed among active and passive pools of carbon.

References

Anonymous (2001). Organic pools and dynamics in relation to land use tillage and agronomical practices for maintenance of soil fertility. *Report of National Agricultural Technology Project*, RRPS-**19**, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola pp.2.

Anonymous (2011a). Directorate of Economics and Statistics, Corporation.

Bandyopadhyay P.K., Saha, S, Mani, P.K. and Mandal, B. (2010). Effect organic inputs on aggregate associated organic carbon concentration under long term rice wheat cropping system. *Geoderma* **154**, 379-386.

Ghosh, S., Wilson, B.R., Ghosal, S.K., Senapati, N and Mandal, B. (2012). Organic amendments influence soil quality and carbon sequestration in the Indo-Gangetic plains of India. *Agriculture, Ecosystem and Environment* **156,** 134-141.

Ghosh, S., Wilson, B.R., Mandal, B., Ghosal, S.K. and Grown (2010). Changes in soil organic carbon pools in three long term fertility experiments with different cropping systems and inorganic and organic soil amendments in the eastern belt of India. *Australian Journal of Soil Research* **48,** 413-420.

Mandal, B. (2011). Soil organic carbon research in India- A way forward. *Journal of the Indian Society of Soil Science* **59** (Supplement): S9-S22.

Pathak, H., Byjesh, K., Chakraborti, B. and Agarwal, P.K. (2011). Potential and cost of carbon sequestration in Indian Agriculture: Estimates from long term fertility experiments. *Field Crop Research* **120**, 102-111.

Piper, C.S. (1966). Soil and Plant Analysis, Hans publisher, Bombay, pp 240.

Ravankar, H.N., Rathod, P.K., Sarap, P.A, Pothare, S.V., Jadhao, S.. and Rathod D.R. (2003). Dynamics of major nutrients in Vertisols under long term fertilization to sorghum-wheat sequence. *Agric. Sci. Digest* **23**, 73-79.

Reddy, K.S., Kumar, N., Sharma, A.K., Acharya, C.L. and Dalal, R.C. (2005). Biophysical and sociological impact of farmyard manure and its potential role in meeting crop nutrient needs: A farmers survey in Madhya Pradesh, India. *Australian Journal of Experimental Agriculture* **45**, 357-367.

Saini, V.K., Bhandari, S.C., Sharma, S.K. and Trafdar, J.C. (2005). Assessment of microbial biomass under integrated nutrient management in soybean-winter maize cropping sequence. *Journal of the Indian Society of Soil Science* **53**, 346-351.

Sarode, P.B. and More, S. D. (2010). Long term effects of integrated nutrient management on active pool of soil organic carbon and nutrients. *Abst. State level seminar on soil resource management for sustainable soil health and food security*. January 2-3, 2010. Akola chapter of ISSS, Dept. SSAC, Dr. PDKV, Akola. pp 7.

Stevenson, F. J., (1994). Humus Chemistry, John Wiley, New York, USA.

Tiwari, A., Dwivedi, A.K. and Dixit, P.R., (2002). Long term influence of organic and inorganic fertilization on soil fertility and productivity in Vertisol. *Journal of the Indian Society of Soil Science* **50**, 472-475.

Verma, G. and Mathur, A.K. (2009). Effect of integrated nutrient management on active pools of soil organic matter under maize wheat system of *Typic Haplustepts*. *Journal of the Indian Society of Soil Science* **53**, 317-322.

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