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Effect of organic sources of nutrients on performance of soybean (*Glycine max*)

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ABSTRACT

A field experiment was conducted at the Research Farm of ICAR-Indian Institute of Soil Science, Bhopal, India to study the effect of different combinations of organic inputs on performance of soybean [*Glycine max* (L.) Merr.]. Soybean (cv. JS 335) was grown in a randomized block design with seven treatments and four replications. The treatments studied were organic manure (OM) (T_1); biodynamic preparation (BD) (T_2); OM+*panchagavya* (OM+PG) (T_3); OM+BD (T_4); OM+PG+BD (T_5); control (T_6); and recommended dose of fertilizers (RDF) (T_7). The results of the study revealed that, the treatments with organic manures either alone or in combination with *panchagavya* and/or biodynamic application improved the performance of soybean crop. The yield of soybean was found comparable and even better (higher 5–13%) with those obtained under RDF, which enhanced nutrient removal by soybean crop by 5–13% with organic combinations. Similarly, the application of organic manures significantly improved the available nutrient status of soil and showed 19–22% and 28–33% higher available N and P, respectively than RDF. Soil enzyme activities, viz. dehydrogenase and alkaline phosphatase increased by 62–72% and 27–35%, respectively under the treatments receiving organic source of nutrients over RDF.

Key words: Alkaline phosphatase, Biodynamics, Dehydrogenase, Nutrient uptake, Panchagavya, Soybean

Agriculture sector is vital for food and nutritional security of the nation. The sector remains the principal source of livelihood for more than 58% of the population through its contribution (14.2%) to the national GDP i.e. gross domestic product. Compared to other countries, India faces a greater challenge, since with only 2.3% share in world's total land area; it has to ensure food security of its population which is about 17.5% of the world population. This leads to excessive pressure on global soil resource and fragmentation of land holdings. The chemical fertilizers are the most important for realizing potential yield of crops but their continuous application caused deficiency of several micronutrients in soil and also leads to environmental pollution (Kumar 2008). Similarly, the prolonged application of chemical fertilizers alone leads to deterioration of soil productivity and fertility. Reduced agricultural productivity, escalating production costs, heavy reliance on non-renewable resources, reduced microbial diversity, water contamination and chemical residues in food grains and health risk to the population are the main reason to think for substituting the nutrient requirement of the crops through different inputs. Organic sources of nutrients offer a unique combination of environmentally-sound practices with low external inputs while contributing to food availability and quality (Aher *et al.* 2012, Aher *et al.* 2018a).

The soybean [*Glycine max* (L.) Merr.] is a legume with nitrogen fixing ability through the symbiotic bacteria called *Rhizobia* within the nodules of their root systems. The microbiology of the soil is interrelated with the organic carbon content of the soil. Application of organic manures has direct effect on the crop yield and properties of soil. Keeping this in view, a field experiment was conducted to evaluate locally available organic manures as source of nutrients on the growth, yield and nutrient uptake of soybean and properties of a vertisol.

MATERIALS AND METHODS

Treatments and agronomic practices: A field experiment was conducted at the Research Farm of ICAR- Indian Institute of Soil Science (23°18' 28" N and 77° 24' 21" E), Bhopal, India during 2011–12 and 2012–13. The soil of the experimental site was clayey in texture (*Typic Haplusterts*) with 25.2, 18.0 and 56.8% of sand, silt and clay, respectively. Initially, the soil (0–15 cm depth) was medium in soil

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organic carbon (0.53%), low in available N (68.8 mg/kg), medium in available P (12.8 mg/kg) and high in available K (237 mg/kg). The soil was normal in reaction (*p*H 7.76 and EC 0.48 dS/m) having DTPA extractable micronutrients in optimum range (Fe, Mn, Zn and Cu; 5.52, 9.44, 0.74 and 1.32 mg/kg respectively). The experiment was conducted in randomized block design with four replications. The experiment consisted of T_1-Organic manure on nitrogen equivalent basis, T_2- Biodynamic Preparation (BD 500 (Cow Horn Manure) as soil application @75 g/ha + BD 501(Cow Horn Silica) as foliar application @2.5 g/ha), T_3- Organic Manure on nitrogen equivalent basis + foliar spray of 3% Panchagavya, T_4- Organic Manure on nitrogen equivalent basis + Biodynamic Preparation (BD 500 (Cow Horn Manure) as soil application @75 g/ha + BD 501 (Cow Horn Silica) as foliar application @2.5 g/ha), T_5- Organic Manure on nitrogen equivalent basis + Biodynamic Preparation (BD 500 (Cow horn manure) as soil application @75 g/ha + BD 501 (Cow Horn Silica) as foliar application @2.5 g/ha) + foliar spray of 3% Panchagavya, T_6-Control and T_7- Recommended dose of chemical fertilizers N:P:K @30-26.2-16.6 kg/ha through urea, single super phosphate and murate of potash, respectively. Cattle dung manure (CDM) was used as organic manure and was applied on the N equivalent basis with due adjustment of moisture in all the treatments involving application of organic manure.

Panchagavya: The *panchagavya* was prepared by mixing of cow dung, cow urine, milk, curd and ghee in 5:3:2:2:1 proportion in 3 L of water and incubated for 10 days in a wide mouth plastic container. In addition to five products, jaggery (500 g), ripened banana fruit (12 nos.) and water of tender coconut (3 L) were also added to improve the fermentation process. The contents were stirred daily clockwise and anticlockwise during morning and evening. The prepared *panchagavya* were filtered with cloth and used for foliar spray (3%).

Biodynamics: The biodynamic preparation BD 500 (Cow Horn Manure) and BD 501 (Cow Horn Silica) were commercially procured from Kurinji Organic Food (I) Pvt. Ltd.,Theni - 625203, Tamil Nadu, India.

Nutrient composition of organics and biodynamics: The mean nutrient content of the organic inputs was cattle dung manure- 0.86% N, 0.44% P and 1.07% K; *panchagavya*- 0.78% N, 0.19% P and 0.35% K; Cow horn manure (BD 500)- 2.12% N, 0.81% P and 0.82% K whereas in cow horn silica (BD 501) no nutritional element was detected.

Application of organic manures and inorganic fertilizers: Cattle dung manure and cow horn manure (BD 500) was supplied as basal application before last plough. Doses of fertilizers in recommended dose of chemical fertilizer treatment were given as basal application at the time of sowing. The *panchagavya* (3%) and cow horn silica (BD 501) were sprayed at 30 and 45 days after sowing.

Crop culture, weed and pest control: Disease and pest free seeds of the JS-335 variety of soybean were used for sowing with 45 cm × 5 cm spacing. The seed was treated with phosphate solubilizing micro-organisms (PSB) and *Rhizobium* having 10^9 viable cell/g (Manufactured by Biofertilizer Unit of Jawaharlal Nehru Krishi VishwaVidyalaya (JNKVV), Jabalpur) @20 g/kg seed. The sowing was carried out with seed drill with 75 kg/ha seed rate. Neem Oil *(Azadiractin* 3%; Make:Pest Control (I) Pvt. Ltd) and Hostathion (Trizophos 40 EC; Make: Bayer Crop Science Ltd.; @0.75 L/ha) was used to control the pests in organic and chemical fertilizer treatments, respectively. Pheromone Traps were also used in organic plots in order to control the crop specific pest *Helicoverpa armigera* and *Spodoptera litura* of soybean. Two hand weedings were carried out at 25 and 45 days after sowing and kept the plots weed free. No weedicide was used in either treatment. The crop was harvested at physiological maturity stage.

Meteorological observations: During the crop growth period, an average 16.2°C minimum and 28.9°C maximum temperature was observed. The average maximum and minimum relative humidity were recorded as 50.1 and 88.0%, respectively. The crop received 645.6 mm and 842.1 mm total rainfall in 2011 and 2012, respectively.

Agronomic observations and computation: The yield and yield attributing parameters such as number of pods per plant, number of seeds per pod, seed yield, straw yield, total biomass and test weight of 100 seeds were recorded. Five randomly selected plants were used to record the number of pods per plant and number of seeds per pod whereas the total biomass and seed yield (kg/ha) was calculated on the basis of total weight of harvested dry matter and seed of soybean from the experimental plot. Harvest index is the ratio of grain yield to above ground biomass yield i.e.

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

Soil sampling, processing and analysis: The soil samples were collected at the harvest of soybean crop from 0–15 cm depth at three randomly selected spots in each replication and composite samples were prepared. The soil was gently ground, well mixed and sieved through 2 mm mesh and utilized for laboratory analysis for chemical and biological properties. The field moist soil samples were collected for microbiological study and stored at 4°C until further analysis. Soil chemical parameters were determined by following standard methods outlined by Jackson (1973). The soil *p*H and EC were determined (1:2 soil:water suspension) on potentiometer. The available N, P, and K and soil organic C was estimated from soil samples. The soil microbial enzyme activities, viz. alkaline phosphatase (Tabatabai and Bremner 1969) and soil dehydrogenase activity (Casida *et al.* 1964) were measured by following the standard methods.

Plant analysis and nutrient uptake: The plant and grain samples collected at harvest of soybean crop were cleaned with double distilled water and tipped with butter paper and air dried first. Then samples were dried in oven at 65°C till constant weight was reached. These samples were powdered in grinder and used for determining concentration of macro and micronutrients. Macro and micro nutrient uptake was calculated by multiplying the nutrient concentration of soybean (seed and straw) with their respective yield. The total nutrient uptake was obtained by summation of the nutrient uptake of seed and straw.

Statistical analysis: The data obtained during the investigation was pooled, statistically analyzed and the differences among the treatment means were tested for their significance (P<0.05) as per the methods outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield attributes, yield, biomass and harvest index: The pooled data of 2011–12 and 2012–13 revealed that, the pods per plant, seeds per pod and seed index of soybean found significantly varied among the seven different treatments (Table 1). The seed per pod in soybean varied from 21.0–26.6 with significantly higher under the treatments receiving the organic sources of nutrients. The seeds per pod in soybean was ranged from 2.6 in control (T_6) to 3.0 in T_5 (OM+PG+BD) followed by T_1, T_3 and T_4 with 2.9 pods/plant (Table 1). All the treatments, involving organic soil amendments were found statistically superior over T_7 (RDF), T_2 (BD) and T_6 (control) but were statistically at par with each other. The test weight of 100 seeds of soybean varied from 10.088–10.386 g with highest observed in treatment T_3 (OM+PG) followed by T_5 (OM+PG+BD). The soybean seed yield was found low during both the years across the treatments due to extraordinary rains in the months of July and August that caused many problems such as incidence of insect pest, disease as well as poor pod formation. However, the organic treatments recorded 28–45% increment in seed yield and 24–37% rise in total biomass over control (T_6). Similarly, the treatment T_5 (OM+PG+BD) and T_3 (OM+PG) were also proved superior over T_7 (RDF) with an increment of 9% and 13% in seed yield and 11% and 10% in total biomass, respectively. The performance of soybean measured in terms of pods per plant, seeds per pod, test weight (100 seeds), seed yield, straw yield and total biomass were significantly influenced by nutrient management except harvest index. The effect of application of sole biodynamic preparations (T_2) did not reflect in performance of soybean as the treatment was at par with control.

In general, application of organics improved the agronomic performance of soybean and increased crop yield. The improved crop performance under the application of organic manures might be due to the cumulative effects on soil available nutrients, enhanced organic carbon, higher microbial population, increased enzyme activities and also due to the residual effect (Aher *et al.* 2018). The positive effects of organic manure application on performance of soybean and other crops in black soils are well documented (Aher *et al.* 2015). The combined application of *panchagavya* and organic manures significantly enhanced the crop performance due to presence of naturally occurring beneficial and effective microorganisms, plant growth promoters and nutrients in *panchagavya* (Xu 2000, Somasundaram and Singaram 2006).

Nutrient uptake: The N uptake by soybean crop was increased by 32–50% under the treatments receiving different organic combinations (OM, OM+PG, OM+BD and OM+PG+BD) over control (Table 2). The increment in case of P and K uptake was found between 45 and 63%; and 30 and 45% under organic treatments, respectively over control. Further, the application of organic manure along with *panchagavya*, increased the N, P and K uptake in soybean crop by 14%, 20% and 12%, respectively over RDF (T_7). Similarly, the micronutrients uptake by soybean crop was significantly influenced by different organic treatment combinations. The treatment receiving organic manure alone or in combination with *Panchangavya* and/or biodynamic significantly improved the micronutrient uptake of soybean crop as compared to the treatments receiving recommended dose of chemical fertilizers. These treatments registered an increment of 13–29% in Fe, 21-36% in Zn, 14–29% in Cu and 19–37% in Mn uptake by soybean crop over treatment RDF (T_7) (Table 2). The application of manures known to increase the micronutrients uptakes especially zinc has already been reported (Yashona *et al.* 2018). The extent of crop removal of N, P, K and micronutrients was the highest in treatment receiving cattle dung manure in soybean

Table 1 Yield and yield attributes of soybean under organic and inorganic sources of nutrients (Pooled of 2011 and 2012)

Treatment	Pods/ Plant	Seeds/ Pod	100 Seed wt (g)	Seed Yield (kg/ ha)	Straw Yield (kg/ ha)	Total Bio-mass (kg/ha)	Harvest Index
T1	24.4	2.9	10.30	441	916	1357	0.33
T2	21.5	2.7	10.09	352	778	1130	0.31
T3	26.0	2.9	10.39	497	998	1495	0.33
T4	24.2	2.9	10.28	441	913	1354	0.33
T5	26.6	3.0	10.38	480	1017	1497	0.32
T6	21.0	2.6	10.10	344	747	1091	0.32
T7	23.7	2.8	10.27	440	915	1355	0.32
CD (P=0.05)	0.74	0.12	0.05	22.8	54.3	57.6	NS

Table 2 Effect of organic sources of nutrients on nutrient uptake by soybean crop (Pooled of 2011 and 2012)

Treatment	N	P	K	Fe	Zn	Cu	Mn
	--------(kg/ha)-------			--------(g/ha)-------			
T1	63.5	4.78	31.3	81.9	30.7	13.9	59.5
T2	49.8	3.40	25.0	52.0	17.7	8.0	33.8
T3	72.0	5.36	34.7	91.5	34.3	15.6	68.6
T4	63.2	4.81	31.3	81.7	30.6	13.8	61.7
T5	72.0	5.33	35.0	93.7	34.4	15.6	68.6
T6	48.0	3.29	24.1	49.4	17.0	7.6	31.9
T7	63.2	4.43	31.3	72.3	25.3	12.1	49.9
CD (P=0.05)	2.65	0.21	1.46	7.58	3.16	0.88	5.32

Table 3 Effect of organic sources of nutrients on soil properties in 0–15 cm soil depth (Pooled of 2011 and 2012)

Treatment	*p*H	Organic Carbon (g/kg)	N	P	K
			---------(mg/kg)----------		
T1	7.84	7.62	113.8	17.1	259.1
T2	8.01	6.29	92.3	9.2	255.1
T3	7.94	7.82	114.5	16.8	259.7
T4	7.92	7.66	115.1	16.4	256.4
T5	7.92	7.73	116.5	17.1	257.6
T6	8.02	6.34	91.4	9.1	252.5
T7	7.96	6.74	95.3	12.8	263.1
CD (P=0.05)	NS	0.25	7.79	3.36	NS

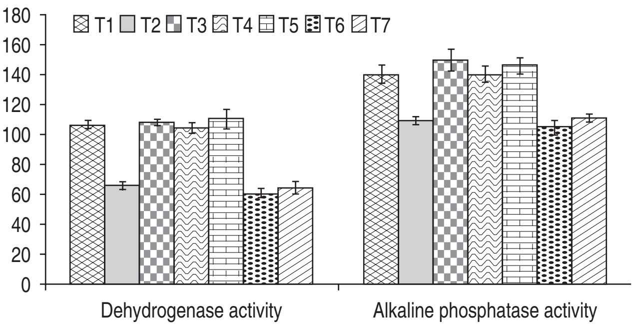

Fig 1 Effect of organic sources of nutrients on soil enzyme activity (Pooled of 2011 and 2012; DHA (µg TPF/g/day); Alk-PO_4 (µg PNP/g/hr); CD (0.05): DHA- 8.18; Alk-PO_4-16.35; Error bars indicate Standard Error of Mean-SEm).

in combination with *panchagavya* and/or biodynamic application than the control (T_6), BD (T_2) and RDF (T_6) might be due to higher availability of available nutrients in adequate quantity throughout the crop growth period as evidenced from soil available nutrient status (Table 3). The significant increase in the nutrient uptake upon application of FYM/CDM (Ramesh *et al.* 2008, Mandale *et al.* 2018), and organic manure along with *panchagavya* by different crops in different soils of India are well documented.

Soil pH: The *p*H of the soil was found neutral to slightly alkaline in nature across all the treatments. The application of organic nutrients and chemical fertilizers had no marked difference on soil *p*H during the study (Table 3).

Soil organic carbon (SOC): The treatments receiving organic manures either alone or in combinations (T_5, T_3, T_4 and T_1) recorded 13–16% increase in SOC over the treatment receiving recommended dose of chemical fertilizers (T_7). The observed increase in SOC might be due to the continuous buildup of carbon in soil as present experiment relies on external carbon inputs i.e. cattle dung manure. Besides the regular applications of different organic manures, the root biomass and left over stubbles have also contributed to the increment in carbon pools. Lakaria *et al.* (2012) also reported 105 and 71% higher SOC in long term organic farming practice over absolute control and recommended dose of NPK fertilizers, respectively under soybean-wheat cropping system.

Soil available N, P and K: The available N and P at soybean harvest were found significantly higher in treatments receiving organic manure alone or in combinations (T_1, T_3, T_4 and T_5) than T_2, T_6 and T_7 (Table 3). The different organic treatments registered 19–22% and 28–33% increment in soil available N and P over RDF, respectively. The increment in total soil N under organic farming practices has already been reported by many researchers (Tadesse *et al.* 2013, Aher *et al.* 2015). The significant increase in available N content of soil was due to the increased mineralization of organic N by active microorganisms and the regular dynamics of biomass carbon (Nardi *et al.* 2004). The long term application of organic manures and relatively slow release of N from applied organic manures induces a residual effect on soil nutrient status and succeeding crop which results in to improved nutrient status of soil and higher crop yield ensuring long- term sustainability of the system (Bodruzzaman *et al.* 2010). The higher soluble P in the organic systems is mainly attributed to the release of inorganic P from added organics, inhibition of P adsorption by organic molecules released from the organics (Haynes and Mokolobate 2001). The available K in soil was found statistically at par among over all the treatments. The beneficial effect of organic application on available K was not found significant due to high available K status of the experimental soils.

Soil enzyme activities: The soil enzyme activities, viz. dehydrogenase (DHA) and alkaline phosphatase (Alk-PO_4) were significantly influenced by the application of organic nutrients (Fig 1). The DHA activity in organic treatments (T_5, T_3, T_1 and T_4) was significantly higher than rest of the treatments. Like DHA enzyme activity, Alk-PO_4 activity in soil also followed similar trends across the treatments. The DHA and Alk-PO_4 enzyme activities showed 62–72% and 27–35% increment under organic treatments as compared the treatment involving application of chemical fertilizers, respectively. The increment might be attributed to the higher organic carbon content as the application of organic manures is known to increase the microbial enzyme activities in soil as reported by Aher *et al.* (2018b).

The study revealed that, the application of organic sources of nutrients significantly increased the productivity of soybean, enhanced nutrient uptake and improved soil nutrient status and accelerate soil enzyme activities. For soybean, to achieve maximum performance with sustenance of soil health, application of cattle dung manure (CDM) on N equivalent basis along with foliar application of *panchagavya* @3% is recommended.

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