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## Impact of Long Term Fertilization on Soil Properties and Soybean Productivity in a Vertisol

Jalendra Bairwa\*, B. S. Dwivedi, A. K. Dwivedi, R. K. Thakur and N. Patidar

Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India 482004

\*Corresponding author

### ABSTRACT

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The present investigation was conducted during 2018-19 under All India Coordinated Research Project on “Long Term Fertilizer Experiment” at the Research Farm Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), which was commenced since 1972, to assess the effect of continuous application of different fertilizer with or without organic manure on soil fertility and soybean productivity. There was ten treatments i.e. T<sub>1</sub> (50% NPK), T<sub>2</sub> (100% NPK), T<sub>3</sub> (150% NPK), T<sub>4</sub> (100% NPK + Hand weeding), T<sub>5</sub> (100% NPK + Zn), T<sub>6</sub> (100% NP), T<sub>7</sub> (100% N), T<sub>8</sub> (100% NPK + 5 t FYM ha<sup>-1</sup>), T<sub>9</sub> (100% NPK-S) and T<sub>10</sub> (Control), which replicated four times in a randomized block design. The findings of the present investigation revealed that the application of recommended dose of N, P and K (20:80:20 kg ha<sup>-1</sup>) with organic manure (@ 5 FYM ha<sup>-1</sup>) enhanced soybean crop yields over control plot. Further, the integrated use of FYM with 100% NPK substantially improved the organic carbon content by 2.9 g kg<sup>-1</sup> as well as available N and P in soil over its initial values, thereby indicating significant contribution towards sustaining the soil health. Thus, the balance use of fertilizers continuously either alone or in combination with organic manure is necessary for sustaining soil fertility and soybean productivity.

### Introduction

Soybean [*Glycine max* (L.) Merri.] an important protein as well as oil seed crop belonging to leguminosae family that is for its nutritional value, called and considered as “Protein hope of future”. Generally, soybean contains 40-45% protein while content of seed oil contributes to about 18-20% (Ibrahim and Kandil, 2007). Soybean is one of the major global crops that also have a unique

role in sustainable agriculture due to its ability to fix atmospheric nitrogen through symbiotic interactions with rhizobia in the soil (Keyser and Li, 1992). The area of soybean in the world is about 129.30 m ha and yield of soybean in the world is about 370.50 m t in 2018. In India, soybean is grown in about 10.96 M ha under diverse agro-climatic and soil conditions with average production and productivity of 13.45 million tonnes and 1.22 t ha<sup>-1</sup>, respectively (Directorate of Economics

and Statistics, 2018). While in Madhya Pradesh it is cultivated in an area of 54.01 Lakh ha with productivity of 1.23 t ha<sup>-1</sup> and contributes about 60% production from around 55% of soybean grown area of the country (Ministry of Agriculture GOI, 2016). The low productivity in the state and country calls for optimizing it through efficient nutrient management. The lack of integrated nutrient management approach coupled with unbalanced nutrition not only limits the productivity, but also leads to deterioration in soil quality (Sharma *et al.*, 2016). Long term fertilizer experiments can be used for precise monitoring of changes in soil fertility and productivity. This helps in solving the complex problems related to soil fertility management. There is an apprehension that the use of chemical fertilizers over the years may impair soil fertility. In continuous cropping, use of imbalance nutrients (N or NP alone) through inorganic fertilizers without organic manure cannot sustain the desired level of crop production (Thakur *et al.*, 2009). Integration of inorganic fertilizers with organic manures will not only sustain crop production but also be effective in improving soil health and enhancing the nutrient use efficiency (Thakur *et al.*, 2011). An adequate information is lacking on the effect of continuous cropping and fertilization on soil properties and crop productivity in a Vertisol, hence the present study was undertaken.

## Materials and Methods

The Long Term Fertilizer Experiment initiated at the Research farm of the Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur since 1972. This experiment was focused to study changes in number of nodules, nitrogen fixation and yield of soybean by the continuous application of different dose of fertilizer and manure. In this regard, an investigation was

carried out during Kharif season 2018-19. It is situated at 23°10'N latitude and 79°57' E longitude at 393 meters above the mean sea level. The temperature during this period varies from 25 to 35°C and the relative humidity ranges between 70 to 80 per cent. The average annual rainfall varies from 1200 to 1500 mm. The soil of the experimental field is medium black (56.82% clay) belonging to Kheri series of fine montmorillonitic hyperthermic family of *Typic Haplustert* and had pH of 7.6, electrical conductivity 0.18 dS m<sup>-1</sup> (1: 2.5 soil: water ratio) and organic carbon 5.7 g kg<sup>-1</sup>. The soil available N, P, K and S were 193, 7.6, 370 and 15.6 kg ha<sup>-1</sup>, respectively. Also, at the start of the experiment, the concentrations of soil available Zn, Fe, Mn and Cu, in the surface soil were 0.33, 2.47, 16.10 and 0.11 mg kg<sup>-1</sup> soil, respectively. The experiment included 10 treatments viz., T<sub>1</sub> - 50% NPK, T<sub>2</sub> - 100% NPK, T<sub>3</sub> - 150% NPK, T<sub>4</sub> - 100% NPK + Hand weeding, T<sub>5</sub> - 100% NPK + Zn, T<sub>6</sub> - 100% NP, T<sub>7</sub> - 100% N, T<sub>8</sub> - 100% NPK + 15 t FYM ha<sup>-1</sup>, T<sub>9</sub> - 100% NPK – S (Sulphur free) and T<sub>10</sub> - Control, each replicated four times in a randomized block design. The gross plot size being 17 x 10.8 m with 1 m spacing between the plots and 2m spacing between the replications.

The recommended N, P and K dose for soybean, based on initial soil test, was 20 kg N, 80 kg P<sub>2</sub>O<sub>5</sub> and 20 kg K<sub>2</sub>O ha<sup>-1</sup>. The sources of N, P and K used were urea, single super phosphate and muriate of potash. In sulphur free treatment, diammonium phosphate (DAP) was used instead of SSP as source of P. Zinc application @ of 20 kg ZnSO<sub>4</sub> ha<sup>-1</sup> in alternate years to wheat crop was followed till 1987. Due to high build-up of Zn, its addition is discontinued till date. The application of FYM @ 5 t ha<sup>-1</sup> year<sup>-1</sup> was applied only to soybean crop during *kharif* season. 100% NPK + HW treatment weeding is done manually, whereas in other

treatments chemical weed control (herbicide) was followed.

For the present investigation soil samples were drawn from surface 0-20 cm soil depths in the 46th cropping year (2018-19) and were analysed for different parameters by following standard procedures for soil pH was determined in a 1:2.5 soil water suspension by glass electrode pH meter (Piper, 1950). Electrical conductivity was determined by using conductivity meter (Piper, 1950), organic carbon (Walkley and Black 1934), available N (Subbiah and Asija 1956), available P (Olsen *et al.*, 1954) and available K ((Muhr *et al.*, 1965). Determination of Calcium Carbonate was done by Rapid titration method as described by Puri (1930). For the calculation of soybean grain and straw yields in each plot 5 x 4 m<sup>2</sup> was harvested. After complete air drying, the bundles were weighed and data recorded. The produce was threshed and a grain and straw yields of soybean were recorded. The grain and straw of soybean was taken to determine nutritional consistence. For the determination of nitrogen content in soybean crop micro kjeldahl method (AOAC, 1965), for phosphorus content of the plant extract was determined using Vanado Molybdo phosphoric yellow colour method (Bhargava & Raghupathi, 1984) and potassium was determined with the help of flame photometer (Bhargava & Raghupathi, 1984). On the basis on nutrient content the nutrient uptake of soybean was calculated in kg ha<sup>-1</sup> in relation to (dry matter production) yield ha<sup>-1</sup>. All observations recorded on soybean yield, nutrients uptake and soil properties were analysed statistically.

## **Results and Discussion**

### **Basic Soil Properties (pH, EC, Organic carbon and Calcium carbonate)**

There were no significant differences could be noticed with soil reaction (pH) due to

different treatment of fertilizers and manure (Table 1). The soil pH did not significantly show any visible trend in all the treatment after harvest of the crop. The highest pH value 7.59 was recorded in control and lowest value 7.45 in 100% N alone and 100% NPK + FYM treatment. This could be due to the high buffering capacity of the soil and presence of appreciable content of free calcium carbonate (Divya *et al.*, 2016). Similarly soil EC value was also found to be no changed over initial which ranged between 0.14 and 0.18 dSm<sup>-1</sup>. It was found that imposition of various doses of fertilizers and manure did not affect significantly to electrical conductivity of soil in a Vertisol (Thakur *et al.*, 2009). The continuous use of inorganic fertilizers over a long period of time had no marked influence on EC of the soil and conjoint use of FYM and fertilizer might cause meager change which could be due to addition of organic manure which increased the buffering capacity of the soil reported by Dwivedi and Dwivedi (2015).

The organic carbon content significantly increased with increasing levels of fertilizer application (Table 1). The lowest value was noted in control (4.70 g kg<sup>-1</sup>) which was increased to 6.21, 7.22 and 8.03 g kg<sup>-1</sup> due to application of recommended dose of 50% NPK, 100% NPK, and 150% NPK respectively. However, the highest value (8.61 g kg<sup>-1</sup>) was recorded with 100% NPK+FYM treatment. The super optimal dose showed a significantly higher content of organic carbon over sub optimal dose optimal dose. The value of OC was found to be slightly changed at harvest of crop. The OC value was increased to 6.22, 7.24 and 8.03 g kg<sup>-1</sup> due to application of 50% NPK, 100% NPK, and 150% NPK dose of fertilizers respectively. The lowest value was recorded in control (4.68 g kg<sup>-1</sup>) and the highest value (8.63 g kg<sup>-1</sup>) was recorded with 100% NPK+FYM treatment. continuous application

of FYM alone or in combination with inorganic fertilizer results in higher organic carbon content as compared to inorganic fertilizer application after harvest of soybean was reported by (Patel *et al.*, 2018 and Mundhe *et al.*, 2018).

The data on calcium carbonate content in soils are presented in Table 1, indicated the highest value was recorded in 150% NPK (50.9 g kg<sup>-1</sup>) and the lowest value was recorded in control (39.3 g kg<sup>-1</sup>). With the increase in doses of application of fertilizers the value of calcium carbonate was increased as 50% NPK, 100% NPK and 150% NPK (43.7, 46.0 and 50.9 g kg<sup>-1</sup>) respectively. Higher value of CaCO<sub>3</sub> in soil after harvest of soybean and wheat crops was recorded in the treatments of balanced application of nutrients and lower values in imbalanced nutrient application treatments. It may be due to long term application of SSP which also contains calcium (Nagwanshi *et al.*, 2018).

### **Available Nitrogen**

The data pertaining to soil available N was significantly highest in optimal dose of fertilizer with FYM (351 kg ha<sup>-1</sup>) and the lowest available N content was found in control plot. These results are in line with findings of Khamparia *et al.*, (2018) who observed that available nitrogen content in soil increased significantly with the use of recommended dose of fertilizer in combination with manure. Further, by increasing the application rate of nutrients, the amount of available nutrients also increased significantly (T<sub>8</sub> and T<sub>3</sub>).

However, application of phosphorus along with nitrogen (100% NP) improved the available nitrogen status of the soil in comparison to the application of nitrogen alone (100% N), and further the application of potassium with 100% NP (100% NPK) had

also improved N content (295 kg ha<sup>-1</sup>) in soil. Sharma *et al.*, (2015) also reported an increase in available nitrogen contents due to graded application of NPK. Control plot showed reduction in the available nitrogen status due to removal of nutrients with continuous cropping without fertilization (Raghuwanshi *et al.*, 2016). Shirale *et al.*, (2014) reported that the higher gain of available N was found only in FYM treated plots as compared to 100 % NPK treatment.

### **Available Phosphorous**

The data on available P was presented in Table 1 found that imbalanced use of fertilizers reduced the available P content in the soil. A significant reduction in available P content observed under nitrogen alone (100% N) and unfertilized treatments occurred due to removal of P by the crops in the absence of P supplementation through external source. Use of 100% NP over 100% N significantly increased the available P status of soil. Similar trend on available P was reported by Khamparia *et al.*, (2018). Further, the application of 100% NPK over 100% NP had no significant effect on available P status. A marked build-up of available P status of soil was observed under 100% NPK + FYM and 150% NPK treatments (Thakur *et al.*, 2009).

### **Available Potassium**

The data of available K indicated a declining trend (238 to 333 kg ha<sup>-1</sup>) from its initial level (370 kg ha<sup>-1</sup>) which indicates considerable mining of available soil K after 46 years of soybean – wheat intensive cropping (Table 1).

The maximum decline was observed in case of control followed by 100% N alone; the magnitude of decline decreased with increasing levels of NPK application. Among the inorganic fertilizers, continuous

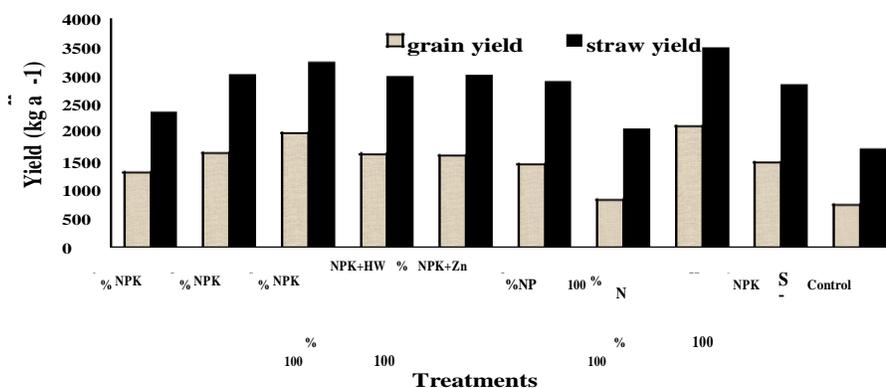
application of N or NP had depressive effect on available K content of the soil which may be due to nutrient imbalance in the soil. Continuous omission of K in crop nutrition caused mining of its native pools that caused reduction in the crop yields (Thakur *et al.*, 2011 and Sawarkar *et al.*, 2013). However, the highest available K status of soil found

associated with 100% NPK+FYM followed by 150% NPK treatments. The application of organic manure may have caused reduction in K fixation and consequentially increased K content due to interaction of organic matter with clay besides the direct addition to the available K pools of soil (Sawarkar *et al.*, 2015).

**Table.1** Effect of long term application of fertilizers and manure on basic properties of soil

Treatments	Soil	Soil EC	Soil OC	CaCO <sub>3</sub>	Available Nutrients (kg ha <sup>-1</sup> )		
	pH	(dSm <sup>-1</sup> )	(g kg <sup>-1</sup> )		N	P	K
50 % NPK	7.50	0.15	6.2	43.7	227	23.0	252
100 % NPK	7.53	0.16	7.2	46.0	295	34.1	293
150 % NPK	7.57	0.18	8.0	50.9	332	38.0	314
100 % NPK+HW	7.54	0.16	7.2	46.4	295	32.3	288
100 % NPK+Zn	7.55	0.17	7.2	44.4	294	32.5	284
100 % NP	7.53	0.15	6.6	44.6	265	28.8	240
100%N	7.45	0.14	5.0	43.9	217	11.6	239
100 % NPK+FYM	7.45	0.17	8.6	43.9	351	39.0	333
100 % NPK(-S)	7.56	0.15	7.1	42.3	277	31.7	278
Control	7.59	0.14	4.7	39.3	191	9.0	238
<b>S Em±</b>	<b>0.08</b>	<b>0.01</b>	<b>0.14</b>	<b>0.73</b>	<b>11.96</b>	<b>0.99</b>	<b>11.04</b>
<b>CD (p=0.05)</b>	<b>NS</b>	<b>NS</b>	<b>0.42</b>	<b>2.13</b>	<b>34.77</b>	<b>2.86</b>	<b>32.03</b>

**Fig.1** Impact of different treatment on grain and straw yield of soybean

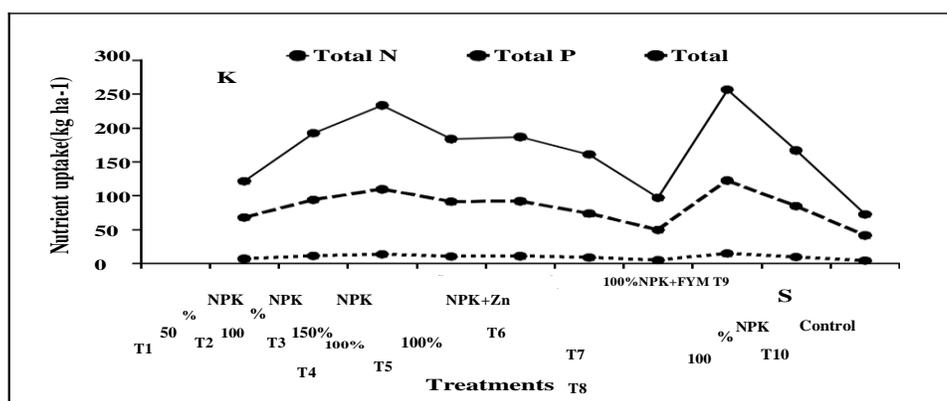


**Figure 1 : Impact of different treatment on grain and straw yield of soybean**

**Table.2** Effect of long term application of fertilizers and manure on nutrient uptake by soybean

Treatments	Grain	Nitrogen Straw	Nutrients uptake (kg ha <sup>-1</sup> )							
			Phosphorous				Potassium			
			Total	Grain	Straw	Total	Grain	Straw	Total	
50 % NPK	67.9	53.5	121.4	3.57	3.48	7.05	17.28	50.61	67.89	
100 % NPK	100.9	91.4	192.3	6.00	5.34	11.34	23.62	70.29	93.91	
150 % NPK	125.3	108.0	233.3	7.72	5.98	13.69	31.81	77.80	109.61	
100 % NPK+HW	95.3	88.4	183.7	5.58	4.92	10.50	22.64	68.70	91.33	
100 % NPK + Zn	96.7	89.9	186.6	5.79	5.27	11.07	22.56	69.41	91.97	
100 % NP	82.4	78.6	161.0	4.49	4.49	8.98	17.68	56.05	73.73	
100%N	46.2	50.9	97.0	2.16	2.82	4.98	10.07	39.58	49.64	
100 % NPK+FYM	135.8	120.7	256.5	8.39	6.54	14.93	34.59	87.79	122.38	
100 % NPK(-S)	86.0	80.8	166.9	4.91	4.69	9.60	20.50	64.31	84.81	
Control	37.5	35.1	72.6	1.85	2.43	4.28	8.84	32.78	41.62	
<b>S Em±</b>	<b>4.71</b>	<b>4.65</b>	<b>5.68</b>	<b>0.32</b>	<b>0.32</b>	<b>0.44</b>	<b>1.06</b>	<b>3.99</b>	<b>4.36</b>	
<b>CD (p=0.05)</b>	<b>13.66</b>	<b>13.507</b>	<b>16.49</b>	<b>0.925</b>	<b>0.93</b>	<b>1.28</b>	<b>3.07</b>	<b>11.59</b>	<b>12.67</b>	
	<b>0</b>		<b>2</b>		<b>3</b>					

**Fig.2** Impact of different treatment on nutrient uptake



**Soybean grain and Straw yield**

Soybean seed yield indicated that the lowest seed yield was recorded in control (737 kg ha-

1) followed by 100% N (825 kg ha<sup>-1</sup>). But when P fertilizer (100% NP) was included in fertilizer schedule resulted in seed yield of (1443 kg ha<sup>-1</sup>) while there was a further

improvement noted in seed yield when K nutrient was included (100% NPK) which accounted for about 1637 kg ha<sup>-1</sup> over imbalanced NP application (Figure 1). On the contrary, there was a significantly decline in productivity of yield (1480 kg ha<sup>-1</sup>) when sulphur nutrient was excluded (100% NPK-S) dose which had resulted in comparatively lower seed over balanced fertilizer addition (1637 kg ha<sup>-1</sup>). It has also been observed that successive addition of fertilizer progressively increased the seed yield of crop (Dwivedi and Dwivedi, 2015). In this regard, proportionately significant lower yield was associated with 50% NPK as compare to balance application of 100% NPK. However, the significant higher yield was obtained with 150% application of NPK. The maximum seed yield was noticed with integrated application of 100% NPK along with FYM (2106 kg ha<sup>-1</sup>) over balance application of 100 % NPK in soybean. Application of recommended optimal dose (100% NPK) resulted in productivity of seed yield for 1637 kg ha<sup>-1</sup> but exclusion of sulphur (i.e. 100% NPK-S) dose had resulted in lower seed yield (1480 kg ha<sup>-1</sup>) amounted to decline yield of soybean. Similar results have also been observed by Sawarkar *et al.*, (2010), Dwivedi *et al.*, (2016) and Gupta *et al.*, (2019).

### **Nutrient Uptake by Soybean**

The data portioning to nutrient uptake by soybean was presented in table 2 and illustrated in Figure 2 and revealed that the nutrient uptake differs significantly with different treatment combinations. In seed, maximum uptake of N, P and K was recorded under treatment receiving 100 % NPK + 5 t FYM ha<sup>-1</sup> was 135.80 kg ha<sup>-1</sup>, 8.39 kg ha<sup>-1</sup> and 34.59 kg ha<sup>-1</sup> respectively. Applied FYM with 100% NPK helped to increase the N uptake by soybean seed as compared to the application of 100% NPK (100.91 kg ha<sup>-1</sup>) while, further addition of P (100% NP) was

significantly raised the uptake. Similar findings were reported by Raghuwanshi *et al.*, (2016). All the treatments were found significantly higher K uptake by soybean seed over control except 100% N alone. In straw the highest phosphorus uptake (6.54 kg ha<sup>-1</sup>) was recorded with treatment receiving 100% NPK + 5 t FYM ha<sup>-1</sup> followed by 150% NPK (5.98 kg ha<sup>-1</sup>). The successive addition of fertilizer had resulted in higher content and uptake by seed and straw of soybean. This could be due to successive addition of P through fertilizer which had resulted in proportionately, higher availability in the soil for its subsequent uptake and utilization by plants. Hence, the lowest content of P coincided with control and 100% N alone plots. Similar result was reported by Sharma and Vikas (2007). There was a progressive increase in K content and uptake with successive additions of NPK fertilizer over sub optimal, imbalance or without fertilizer addition, which could obviously be a result of successive addition of K through higher fertilizer doses (Dwivedi *et al.*, 2007).

It was concluded that maximum number of nodules was recorded with optimal + FYM followed by super optimal dose (150% NPK) and minimum in control. Nodulation (both nodule number and oven dry weight) increased in all the treatments expect 100% N dose where it decreased significantly over control. It was found maximum in 100% NPK dose +FYM followed by 150% NPK dose. The N<sub>2</sub> fixation of soybean was significantly increased with increase fertilizer application rate. Maximum nitrogen fixation and seed yield of soybean was found in treatment receiving 100% NPK + FYM (197 kg ha<sup>-1</sup>, 2106 kg ha<sup>-1</sup>) and minimum in control (66 kg ha<sup>-1</sup>, 737 kg ha<sup>-1</sup>) respectively.

It is concluded that under continuous cropping with soybean and wheat in sequence over fourty six years, conjoint use of organic

manure along with 100% NPK not only sustained the higher yield of both soybean and wheat, but also improved the soil fertility. The findings indicated that balance use of fertilizers alone or in combination with organic manure resulted in significant build-up of organic carbon and available N, P and S. A declining trend of available K from its initial status was noticed as a result of continuous cropping, which indicated considerable soil mining of available K. Incorporation of fertilizers and manure in swell-shrink soils improved the bulk density and hydraulic conductivity. Further, nutrient balance of soil implied build-up of phosphorous under soybean-wheat cropping sequence, which needs refinement of P level recommendations.

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