Impact of long term application of fertilizer and FYM on nutrient uptake by soybean crop and properties of a black soil

Abstract

Long Term Fertilizer Experiment (LTFE) play an important role in understanding the complex interactions involving plant, soil, climate, management practices and their effect on soil productivity over a long period of time. The present investigation is part ongoing All India Coordinated Research Project on Long Term Fertilizer Experiment with Soybean-Wheat Cropping Sequence, which was initiated since 1972. The experiment was carried out in a randomized block design consisting of eight treatments, viz. 50% NPK, 100% NPK, 150% NPK, 100% NP, 100% N, 100% NPK+5 t ha^{-1} FYM (100% NPK+FYM), 100% NPK (-S) and Control. The significant nutrient content with nutrient uptake by soybean was seen in 100% NPK+FYM treatment over control plot. It was also observed that nutrient content with nutrient uptake increased significantly with consecutive doses of fertilizers. On the other hand, 100% N alone in the control group had the lowest value. However, adding fertilizer P in addition to N (100% NP) increased nutrient content and nutrient uptake by soybean crop. The highest OC content was recorded with 100% NPK dose+FYM followed by 150% NPK treatment combination which could apparently due to the synergistic contribution of integration of fertilizer and FYM application. Similarly, the available N,P, K and S content in soil were found highest with 100% NPK + FYM followed by 150% NPK fertilizer dose. However, lowest content was noted in control where crop was grown without fertilizers. Available sulphur was significantly higher over control in all the treatment receiving single super phosphate.

Key Words: Soil properties, Nutrient content, Nutrient uptake, soybean

Introduction

Soybean (*Glycine max* L.) is one of the leading oil and protein containing crops of the world. Long term fertilizer experiments give the valuable information on effect of continuous application of different levels of fertilizer nutrients alone with and without organic manure under intensive cropping on soil fertility and crop productivity. These experiments can be used for precise monitoring of changes in soil fertility and could be of paramount help in solving the complex problems related to the soil fertility management (Nagwanshi *et al.* 2018 and Tiwari *et al.* 2023).It has been discovered that a long-term organic amendment significantly affects soil parameters including pH, accessible phosphorus, inorganic nitrogen, organic carbon, and other organic matter (Thakur *et al.* 2007 and Ge *et al.* 2018). Crop production requires balanced fertilization; however, applying manure in combination with other fertilizers may minimize the requirement for artificial fertilizers. According to studies by Dwivedi *et al.* (2012), Dwivedi *et al.* (2015) and Raghuwanshi *et al.* (2016), applying chemical fertilizers in addition to FYM may increase the yield and yield contributing characteristics like grain yield, straw yield, nutrient content, and nutrient uptake. The soil available N, P, K and S also found higher under the sole application of balanced fertilization and its combined application with FYM. The long term fertilizer application with or without organic manure influences the soil nutrient status (Khandagle *et al.* 2019). Bender *et al.* (2015) observed that modern soybean nutrient uptake compared to cultivars planted in the country. The maximum N content in grain and straw was observed with the application of super optimal dose and the lowest content in grain and straw was recorded in control treatment (Tiwari *et al.* 2019 and Diwvedi *et al.*2018). In view of this, the present investigation was undertaken to study the Impact of long term application of fertilizer and FYM on nutrient uptake by soybean crop and properties of a black soil.

Materials and methods

Location Description

The present investigation is a part of an ongoing All India Coordinated Research Project on Long-Term Fertilizer Experiments with the soybean–wheat cropping system, which was initiated during 1972 at the Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, and Madhya Pradesh, India. The experimental site (23°10" N latitude and 79°57" E longitude) has a semi-arid and subtropical climate with a characteristic feature of dry summer and cold winter. During winter, i.e., from November to February, the temperature ranges from 4 to 33 °C and the relative humidity varies from 70 to 90%. Dry and warm weather usually prevail during the months of March to June. The temperature in the month of May attains a value as high as 46 °C. The monsoon season extends from mid-June to mid-September. The temperature during this period varies from 25 to 35 °C, and the relative humidity ranges from 70 to 80%. The total annual rainfall varies from 1000 to 1500 mm with the mean value of around 1350 mm. The length of growing period ranges from 150 to 180 days.

Experimental details

The experiment was designed and conducted with 8 treatments having four replications arranged in the randomized block design. Two blocks were separated with a gap of 2.0 m, whereas individual plots (17.0 m × 10.8 m) were separated with a permanent bund. The 100% optimal NPK doses based on initial (1972) soil test values were 20:80:20 and 120:80:40 kg ha^{-1} for soybean and wheat, respectively. The treatment details and quantity of nutrients added are given in Table 1.

Table 1: Details of treatment and nutrient rates (kg ha^{-1}) in soybean and wheat

Treatments	Soybean			Wheat		
	N	P	K	N	P	K
50 % NPK	10	17.6	8.3	60	17.6	16.6
100 % NPK	20	35.2	16.6	120	35.2	33.2
150% NPK	30	52.8	24.9	180	52.8	49.8
100 %NP	20	35.2	NA	120	35.2	NA
100 % N	20	NA	NA	120	NA	NA
100 % NPK+FYM*	46.5	41.8	42.7	120	35.2	33.2
100 % NPK (-S)#	20	35.2	16.6	120	35.2	33.2
Control	NA	NA	NA	NA	NA	NA

*FYM (contains 0.53% N, 0.30% P_2O_5 & 0.63% K_2O) was applied 5 t ha^{-1} to soybean every year 15–20 days before sowing;

DAP was used instead of SSP as source of P.

The sources of N, P and K used were urea, single superphosphate and muriate of potash. In sulphur-free treatment, diammonium phosphate (DAP) was used instead of SSP as source of phosphorus. Farmyard manure @ 5 t ha^{-1} $year^{-1}$ was applied only to soybean crop during *kharif* season. During rainy season, all the nutrients, viz. N, P and K were applied as basal before last harrowing, whereas in wheat half of the nitrogen was applied at the time of sowing and the remaining half was applied in two splits first half at 21–25 days (after first irrigation) and the rest at 51-55 days after sowing.

Soil sampling and analysis

Initial soil samples (0-15 cm depth) were taken from 8 different locations in the study area and analyzed for pH, EC, organic carbon, available N, P and K by following standard procedures. Soil pH and EC were determined by preparing 1:2.5 soil water suspension and measured by glass electrode pH meter and digital electrical conductivity meter (Jackson, 1973). Organic carbon content in soil was determined using potassium dichromate rapid titration method (Walkley and Black, 1934) and soil available N was determined by Subbiah and Asija (1956). Available phosphorus was extracted with 0.5 M $NaHCO_3$ (pH 8.5) and colour developed by ascorbic acid (Olsen *et al.,* 1954) and available potassium was extracted with neutral normal ammonium acetate and estimated using flame photometer (Jackson, 1973). Available sulphur was determined by Chesnin and Yien (1950). All soybean plants were harvested at crop maturity and grain yield was obtained. Formula: Nutrient absorption (kg ha^{-1}) = Nutrient content (%) x Yield (kg ha^{-1}).

Table 2. Initial properties of the experimental soil (1972).

S.NO.	Soil properties	value
1.	pH (1:2.5)	7.6
2.	Electrical conductivity (1:2.5)	0.18 dSm^{-1}
3.	Organic. carbon	5.7 g kg^{-1}
4.	Calcium carbonate	46.0 g kg^{-1}
5.	Available nitrogen	193 kg ha^{-1}
6.	Available phosphorus	7.60 kg ha^{-1}
7.	Available potassium	370 kg ha^{-1}
8	Available sulphur	15.6 kg ha^{-1}

Statistical analysis

The data generated on soil analysis, grain and straw yields and their P uptake were statistically analyzed to draw suitable inference as per standard method described by Panse and Sukhatme (1970).

Results and discussion

Impact of treatments on properties of a black soil

Soil pH

The data presented in table 3, ranged between 7.46 (100% N) to 7.60 (150% NPK) in various treatments. There was not any significant effect of continuous use of fertilizer and manure on soil pH. *This could be due to the high buffering capacity of the soil and presence of appreciable content of free calcium carbonate (Nagwanshi et al., 2018).*

Soil Electrical conductivity

The EC values in soil as influenced by the long term application of fertilizer and FYM presented in table 3. It ranged between 0.14 (control) to 0.19 dSm-1 (150% NPK) in various treatments and it was noticed that the continuous application of different doses of fertilizers and manure did not result in any significant effect on soil EC (*Suman et al., 2017*). This could also be due to the inherent high buffering capacity of soil reported by (Dwivedi and Dwivedi, 2015).

Organic carbon in soil

The organic carbon significantly increased with increase in the doses of fertilizers. The lowest value was noticed in control (4.23 g kg^{-1}) which was increased to 5.75, 7.48 and 8.34 g kg^{-1} due to use of 50% NPK, 100% NPK and 150% NPK of RDF, respectively. The highest content 8.96 g kg^{-1} was observed in 100% NPK+FYM treatment (Table 3). Further, 100% NPK+FYM dose showed a significantly higher content of organic carbon over optimal and sub optimal dose. This could be ascribed to the organic manure (5 t FYM ha^{-1}) application combination with fertilizers that increased total N and soil organic matter contents compared with sole fertilizer treatments. Increasing levels of fertilizer application helped in increasing the organic carbon content, which may be ascribed to an increase in productivity and incorporation of larger residual biomass through root, leaves, stable, and rhizodeposition (Parihar *et al.* 2010; Pathariya *et al.*, 2022). Further, it may also be attributed to the addition of FYM which stimulated the growth and activity of microorganisms and better root biomass (Dwivedi and Rawat. 2013; Meshram *et al.*, 2018). Soil organic matter is vital for enhancing soil fertility and sustaining crop productivity.

Content of available N in soil

The data on Table 3 indicated that the highest available N content (315 kg ha^{-1}) was recorded in 100% NPK+FYM could be resulted due to better biological activities in the presence of FYM (Sunam *et al*., 2018 and Dwivedi *et al.* 2019). Whereas the lowest value was noticed as 183 kg ha^{-1} in control. However, due to addition of fertilizer dose (suboptimal, optimal and super optimal) N content was correspondingly improved indicating an impact of fertilizer application on enrichment of available nitrogen in soil. Available nitrogen in soil was significantly higher in all the treatments over control except 100%N and 50%NPK treatments reported by (Birwa *et al*., 2021).

Content of available P in soil

The result showed that the available P content incresed successively and significantly from 9.38 kg ha^{-1} (control) to 21.60, 32.86 and 38.55 kg ha^{-1} in 50%NPK, 100%NPK and 150%NPK treatments, respectively (Table 3).

The content of available P was higher in 100% NPK (32.86 kg ha^{-1}) than 100% NPK-S (30.93 kg ha^{-1}). Because continuous use of balanced fertilizer is conducive for maintaining the soil available P. In black soil, the applied phosphorus gets fixed (80-85%) and only a small part (15–20%) of it becomes available to the plants (Dubey *et al.* 2016 and Dwivedi *et al.* 2019). However, the build-up of available P in 100% NPK+ FYM was higher 39.42 kg ha^{-1} in comparison to 32.86 kg ha^{-1}in 100% NPK treatments indicating the beneficial effect of FYM on mineralization of P to a greater extent in soil observed by (Misha *et al.* 2010 and Bagde *et al*., 2023). Further, 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 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 Bairwa *et al.*, (2020).

Content of available K in soil

The perusal of data indicated a declining trend (228 to 328 kg ha^{-1}) from its initial level (370 kg ha^{-1}) of available K status which indicates considerable soil mining of available K after forty five years of intensive cropping (Table 3). The decline was observed maximum in case of control followed by 100% N alone. The magnitude of decline decreased with increasing levels of NPK applications. 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 soil. Continuous omission of K in crop nutrition caused mining of its native pools that caused reduction in the crop yields (Pathariya *et al.* 2022).The available K content was significantly higher in 100%NPK-S, 100%NPK, 150%NPK and 100%NPK+FYM treatments. The highest value of available K (328 kg ha^{-1}) was recorded in 100% NPK+FYM followed by 150% NPK (305 kg ha^{-1}) whereas; the lowest value (228 kg ha^{-1}) was observed in control. Available K content in soil was significantly higher in 150%NPK and 100%NPK+FYM over 50%NPK treatments. Similar results have also been reported by Patidar *et al.* (2021) and Inwati *et al.* (2022).

Content of available sulphur in soil

The maximum build up of available sulphur was observed in 100% NPK+FYM (37.03 kg ha^{-1}) followed by 150% NPK (35.20 kg ha^{-1}).The magnitude of buildup correspond to proportion to level of applied fertilizer (Birla *et al.*, 2015). The highest value was found associated with FYM addition that provide the favorable condition for better nutrient use efficiency Singh *et al.* (2012).However, the minimum content of available sulphur was observed in control (10.90 kg ha^{-1}). The content of available sulphur was found higher in 100% NPK (31.05 kg ha^{-1}) as compared to 100% NPK-S (11.10 kg ha^{-1}). It was also found that the available sulphur content was higher in 50% NPK (22.10 kg ha^{-1}) than 100% N (11.20 kg ha^{-1}). Available sulphur was significantly higher over control in all the treatment receiving single super phosphate, respectively (Birla *et al.*, 2015 and Suman *et al*. (2017).

Table: 3 Effect of long term application of fertilizer and FYM on available Nutrients Status

Treatments	pH	EC(dsm^{-1})	OC(g kg^{-1})	Available Nutrients ($kgha^{-1}$)			
				N	P	K	S
50 % NPK	7.50	0.14	5.75	201	21.60	254	22.10
100 % NPK	7.55	0.17	7.48	278	32.86	280	31.05
150% NPK	7.60	0.19	8.34	302	38.55	305	35.20
100 % NP	7.54	0.17	6.68	248	31.39	230	29.30
100 % N	7.46	0.15	5.68	219	9.88	227	11.20
100%NPK+FYM	7.54	0.18	8.96	315	39.42	328	37.03
100 % NPK-S	7.56	0.17	7.25	263	30.93	270	11.10
Control	7.55	0.14	4.23	183	9.38	228	10.90
CD (p=0.05)	**NS**	**NS**	**1.05**	**40.10**	**3.97**	**39.24**	**4.00**

Impact of treatments on nutrient content and uptake in soybean

Nutrient content in grain

The data of Table 4 indicate that the highest N content (6.69%) was recorded in 100% NPK+FYM whereas the lowest value was noticed as 3.80% in control. Nitrogen content in grain was significantly higher in all the treatments over control except 50%NPK treatments. Whereas, P content in grain raised successively from 0.23% (control) to 0.25%, 0.33% and 0.35% in 50%NPK, 100%NPK and 150%NPK treatments respectively. Phosphorus content in grain was higher in 100% NPK+FYM (0.36%) than 150% NPK (0.35%). P content in grain was significantly higher in all the treatments over control except 50%NPK and 100%N treatments.The highest K content (1.68%) was recorded in 100% NPK+FYM whereas the lowest value was noticed as 1.18% in control. Potassium content in grain was significantly higher in all the treatments over control except 50%NPK, 100%NP and 100%N treatments. The S content in grain increased successively from 0.18% (control) to 0.22%, 0.30% and 0.32% in 50%NPK, 100%NPK and 150%NPK treatments, respectively. Sulphur content of grain was higher in 100% NPK+FYM (0.33%) than 150% NPK (0.32%). S content in grain was significantly higher in all the treatments over control except 50%NPK, 100%N and 100%NPK-S treatments reported by Raghuwanshi *et al.* (2016) and Solanki *et al.* (2018).

Nutrient content in stover

The data of Table 4 indicate that the highest N content (2.81%) in stover was resulted by 100% NPK+FYM whereas the lowest value was noticed as 1.51% in control. Nitrogen content in stover was significantly higher in all the treatments over control except 50%NPK treatment. As regard the P content in stover raised successively from 0.11% (control) to 0.12%, 0.15% and 0.16% in 50%NPK, 100%NPK and 150%NPK treatments, respectively. Phosphorus content in stover was higher in 100% NPK+FYM (0.17%) than 150% NPK (0.16%). P content in stover was significantly higher in all the treatments over control except 50%NPK and 100%N treatments. Further, the highest K content (2.56%) was observed in 100% NPK+FYM whereas the lowest value was obtained (1.89%) in control. Potassium content in stover was significantly higher in all the treatments over control except 50%NPK, 100%N and 100%NP treatments. The S content in stover raised successively from 0.14% (control) to 0.16%, 0.21% and 0.22% in 50%NPK, 100%NPK and 150%NPK treatments, respectively. Sulphur content of stover was higher in 100% NPK+FYM (0.23%) than 150% NPK (0.22%). S content in stover was significantly higher in all the treatments over control except 50%NPK, 100%N and 100%NPK-S treatments. reported by Nagawanshi *et al*. (2018) and Tiwari *et al.* (2019).

Table 4. Effect of treatments on nutrient content of soybean grain and stover

Treatments	Nutrients (%)							
	Nitrogen		Phosphorus		Potassium		Sulphur	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
50 % NPK	4.36	1.73	0.25	0.12	1.28	2.12	0.22	0.16
100 % NPK	5.51	2.48	0.33	0.15	1.42	2.37	0.30	0.21
150% NPK	6.38	2.65	0.35	0.16	1.64	2.48	0.32	0.22
100 % NP	5.41	2.17	0.28	0.14	1.26	1.92	0.27	0.18
100 % N	5.18	1.90	0.24	0.12	1.20	1.90	0.19	0.15
100%NPK+FYM	6.69	2.81	0.36	0.17	1.68	2.56	0.33	0.23
100 % NPK-S	5.40	2.20	0.29	0.15	1.39	2.30	0.19	0.15
Control	3.80	1.51	0.23	0.11	1.18	1.89	0.18	0.14
S Em±	**0.217**	**0.089**	**0.011**	**0.005**	**0.049**	**0.120**	**0.015**	**0.008**
CD (p=0.05)	**0.629**	**0.259**	**0.032**	**0.013**	**0.141**	**0.349**	**0.044**	**0.024**

Nutrient uptake by soybean grain and stover

Nutrient uptake by grain

The effect of fertilizer and FYM addition on nutrient uptake by crop revealed that the wide variation has been obtained which clearly reflect the influence of varying fertilizer levels on crop growth and yield. In this regard, uptake of N, P, K and S by grain (Table 5.) synchronized with the biomass yield produced and the highest uptake was found in 100 % NPK + FYM treatment followed by 150 % NPK and 100 % NPK. The beneficial effect of FYM can be due to steady supply of all nutrients including the micronutrients and improvements in physical condition. The similar beneficial effects of FYM along with NPK have been reported by Sharma *et al.* (2006), Tiwari *et al.* (2012) and Dwivedi *et al.* (2012). They observed that the continuous use of chemical fertilizers either singly or in combination with FYM had a marked effect on nutrient uptake by soybean. The uptake of N, P, K and S by soybean grain were found 48.88, 2.23, 11.34 and 1.75 kg ha^{-1}, respectively in 100 % N alone treatment, increased to 86.89, 4.55, 20.53 and 4.43 kg ha^{-1} due to inclusion of P i.e. 100 % NP. However, inclusion of K with 100 % NP *i.e.* 100 % NPK resulted in slight increase as 104.98, 6.32, 26.93 and 5.75 kg ha^{-1}, and minimum uptake of N, P, K and S in grain were observed in control plot, respectively.Total nutrient uptake in soybean was significantly higher in all the treatments over control except 100%N treatment reported by Gupta *et al.* (2019) and Khandagle *et al*. (2020).

Nutrient uptake by stover

The finding exhibited that successively increasing addition of fertilizer proportionately increased the uptake of nutrient by the crop. In this regard, uptake of N, P, K and S by stover (Table 5) synchronized with the biomass yield produced and the highest uptake was found in 100 % NPK + FYM treatment followed by 150 % NPK and 100 % NPK. Similar findings were also reported by Dwivedi *et al.* (2016) and Suman *et al.* (2017). who found maximum uptake with the treatment of integrated use of organic manure and recommended fertilizer dose as compared to control plot.The uptake of N, P, K and S in soybean stover which was 39.75, 3.36, 40.12 and 3.13 kg ha^{-1}, respectively in 100 % N alone treatment, increased to 56.23, 4.63, 49.98 and 4.67 kg ha^{-1} due to inclusion of P i.e. 100 % NP. However, inclusion of K with 100 % NP *i.e.* 100 % NPK resulted in slight increase 74.38, 5.79, 70.82 and 6.34 kg ha^{-1}, and minimum uptake of N, P, K and S in straw were found in control plot, respectively . Total nutrient uptake in soybean was significantly higher in all the treatments over control except 100 % N treatment reported by Gupta *et al.* (2019) Tiwari *et al.* (2019).

Table 5: Effect of treatment on nutrient uptake (kg ha^{-1}) by soybean

Treatments	Nitrogen			Phosphorus			Potassium			Sulphur		
	Grain	**Stover**	**Total**	**Grain**	**Stover**	**Total**	**Grain**	**Stover**	**Total**	**Grain**	**Stover**	**Total**
50% NPK	64.30	43.42	107.72	3.74	3.74	7.48	18.97	53.11	72.07	3.23	3.96	7.20
100%NPK	104.98	74.38	179.36	6.32	5.79	12.11	26.93	70.82	97.75	5.75	6.34	12.08
150%NPK	139.70	92.57	232.27	7.75	7.30	15.04	35.84	86.90	122.74	6.95	7.80	14.76
100%NP	86.89	56.23	143.12	4.55	4.63	9.18	20.53	49.98	70.51	4.43	4.67	9.09
100%N	48.88	39.75	88.64	2.23	3.36	5.60	11.34	40.12	51.46	1.75	3.13	4.88
100%NPK+FYM	152.86	101.31	254.17	8.28	7.84	16.11	38.50	92.96	131.45	7.51	8.41	15.92
100%NPK-S	87.23	66.20	153.43	4.64	5.32	9.96	22.49	68.94	91.43	2.97	4.44	7.41
Control	34.98	30.17	65.15	2.08	2.75	4.83	10.94	38.26	49.19	1.63	2.82	4.45
S Em±	**5.253**	**3.167**	**7.528**	**0.317**	**0.483**	**0.642**	**1.598**	**4.134**	**4.935**	**0.246**	**0.309**	**0.440**
CD (p=0.05)	**15.244**	**9.189**	**21.847**	**0.921**	**1.403**	**1.864**	**4.639**	**11.998**	**14.322**	**0.727**	**0.898**	**1.278**

. **Conclusions**

Thus, it could be concluded that the long-term application of balanced and integrated use of nutrient (100% NPK, 150% NPK and 100% NPK+FYM) to soybean significantly improved the soil properties, nutrient content, and nutrients uptake. It has been observed that nutrient composition in plant and soil was increased proportionately with successive addition of fertilizer doses. Hence, lowest content was noted in control and 100 % N alone while, increasing trend was observed with higher fertilizer addition from suboptimal to optimal and super optimal dose. However, in general higher content and uptake of nutrients was found in grain as compared to straw. Thus, conjoint and judicious use of organics and mineral fertilizers found promising in long run.

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