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Soil Properties and Soybean Yield as Influenced by Long Term Fertilizer and Organic Manure Application in a Vertisol under Soybean-Wheat Cropping Sequence

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ABSTRACT

Background: Long term fertilizer experiment was initiated during 1972 under All India Coordinated Research project with soybean – wheat cropping system at the Research Farm of Department of Soil Science, JNKVV, Jabalpur, Madhya Pradesh, India. The present study was taken during 2017 and 2018 in soybean crop.

Methods: The present investigation was conducted with eight treatments *i.e.* 50% NPK, 100% NPK, 150% NPK, 100% N alone, 100% NP, 100% NPK + farmyard manure (FYM) @ 5 t ha^{-1} yr^{-1}, 100% NPK (-S) and unfertilized plot (control), replicated four times in a randomized block design

Result: A significant increase in soil organic carbon was recorded with 100% NPK + FYM @ 5 t ha^{-1} over control plot. The availability of N, P, K, S, soil microbial biomass carbon (SMBC) and soil (SMBN) increased significantly with the integrated application of fertilizers and FYM over imbalance application fertilizer or control. Further, the conjoint use of fertilizers and FYM was also significantly superior to other treatments in terms of activities of soil enzymes like dehydrogenase, acid phosphatase, alkaline phosphatase and β-glucosidase.

Key words: Soil microbial biomass carbonnitrogen, Enzymatic activities, Soybean.

INTRODUCTION

Soybean (*Glycine max* L.)- wheat (*Triticum aestivum* L.) is one of the most prevalent cropping systems followed in a substantial area of Madhya Pradesh. Long-term fertilizer experiments (LTFE) provide valuable information on the effect of continuous application of different levels of fertilizer nutrients alone and in combination with organic manure under intensive cropping on soil fertility and crop productivity. These experiments are of paramount help in monitoring soil fertility changes and solving the complex problems related to soil fertility management (Pathariya *et al*., 2022). Soil microorganisms are important to the agro-ecosystems. Fertilization usually favors the accumulation of bacterial residues and increases soil microbial biomass. In the long-term, repeated fertilization may result in shifts in the functionality and quality of soils by directly or indirectly changing the soil's physical chemical and biological properties as it changes available nutrient level and fertility. In recent years, components like soil microbial biomass carbon, microbial community structures and functions and enzyme activities have been used to describe soil quality under different agricultural practices (Khandagle *et al.,* 2020). As information is lacking on the long-term effect of fertilization and manuring on soil biological and enzymatic activity in a Vertisol under soybean-wheat cropping system, hence, the investigators hypothesized that the long-term fertilization and manuring under an intensive cropping system may influence the soil chemical, biological and enzymatic activities and ultimately the crop productivity.

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MATERIALS AND METHODS

Experimental site, climate and soil characteristics

The long term field experiment under the aegis of ICAR All India Coordinated Research Project has been from the inception of 1972 with soybean-wheat crop rotation grown at Research Fram, Department of Soil Science, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in Kymore Plateau and Satpura Agro climatic region of Madhya Pradesh. The experimental soil is medium black belonging to Kheri series of fine montmorillonitic hyperthermic family of Typic Haplustert (Vertisol). The experimental data was collected after 46-year crop cycle (1972-2018).

Experimental details

The experiment has been in continuance since 1972 with 10 different treatments; however the present experiment was designed and conducted with eight treatments having four replications arranged in the randomized block design. The selected treatments involve 50% NPK; 100% NPK; 150% NPK; 100% NP; 100% N; 100% NPK+FYM; 100% NPK (-S) and Unfertilized plot *i.e*. Control. The 100% optimal NPK doses based on initial (1972) soil test values were 120:80:40 and 20:80:20 ($N:P_2O_5:K_2O$) kg ha^{-1} for wheat and soybean, respectively. The amounts of nutrients applied in different treatments are given in Table 1. The sources of N, P and K were urea, single super phosphate and muriate of potash, while in sulphur-free treatment DAP was used instead of SSP as source of P. The farm yard manure was applied @ 5 ton ha^{-1} $year^{-1}$ to soybean crop only. Soil analysis in present investigations, surface soil samples (0-15 cm depth) were collected after harvest of soybean crop during 2017-18 and 2018-19 Table 2.

Soil biochemical properties

The fresh soil samples collected for estimating SMBC (Jenkinson and Powlson, 1976), SMBN (Jenkinson and Ladd, 1981), dehydrogenase activity (DHA) following TTC method (Burns, 1978), phosphatase (Tabatabai and

Table 1: Treatment details and nutrient application rates (kg ha^{-1}) in soybean and wheat crops.

Treatments	Nutrients doses (kg ha^{-1})							
	Soybean				Wheat			
	N	P	K	S	N	P	K	S
50% NPK	10	17.6	8.3	10.2	60	17.6	16.6	10.2
100% NPK	20	35.2	16.6	20.4	120	35.2	33.2	20.4
150% NPK	30	52.8	24.9	30.6	180	52.8	49.8	30.6
100% NP	20	35.2	0	20.4	120	35.2	0	20.4
100% N	20	0	0	0	120	0	0	0
100% NPK+ FYM*	110	54	95.1	56.6	120	35.2	33.2	20.4
100% NPK (–S)#	20	35.2	16.6	0	120	35.2	33.2	0
Control	0	0	0	0	0	0	0	0

*FYM was applied 5 t ha^{-1} to soybean every year 15-20 days before sowing;
#Di-ammonium phosphate (DAP) was used instead of SSP as source of P.

Table 2: Initial properties of the soil (1972) at LTFE experimental site, Jabalpur, India.

Soil properties	Value	Method
Soil pH (1: 2.5)	7.60	Jackson (1973)
Electrical conductivity (1: 2.5)	0.18 dS m^{-1}	Jackson (1973)
Organic carbon	5.7 g kg^{-1}	Walkley and Black (1934)
Alkaline permanganate extractable N	193 kg ha^{-1}	Subbiah and Asija (1956)
Sodium bicarbonate extractable P	7.60 kg ha^{-1}	Watanabe and Olsen (1965)
Ammonium acetate extractable K	370 kg ha^{-1}	Muhr *et al.* (1965)
$CaCl_2$ extractable S	7.80 mg kg^{-1}	Williams and Steinbergs (1959)
Total nitrogen	845 kg ha^{-1}	Piper, (1966)

Table 3: Effect of continuous application of fertilizers and FYM on soil pH, EC and organic carbon contents.

Treatments	Soil pH			EC (dSm^{-1})			OC (g kg^{-1})		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
50% NPK	7.51	7.53	7.52	0.16	0.18	0.17	6.21	6.24	6.22
100% NPK	7.58	7.57	7.57	0.18	0.19	0.18	7.20	7.24	7.22
150% NPK	7.62	7.63	7.62	0.19	0.20	0.19	8.01	8.03	8.02
100% NP	7.56	7.55	7.55	0.17	0.18	0.18	6.57	6.50	6.53
100% N	7.46	7.48	7.47	0.15	0.16	0.15	5.02	5.05	5.03
100% NPK+ FYM	7.50	7.52	7.51	0.17	0.18	0.18	8.60	8.64	8.62
100% NPK (-S)	7.56	7.60	7.58	0.18	0.19	0.18	7.11	7.14	7.12
Control	7.50	7.50	7.50	0.16	0.17	0.16	4.73	4.72	4.72
CD (p=0.05)	NS	NS	NS	NS	NS	NS	0.72	0.74	0.58
Initial value (1972)		7.6			0.18			5.7	

Bermner, 1969) and β-glucosidase (Eivazi and Tabatabai, 1988). The data generated were subjected to statistical analysis (Panse and Sukhatme,1970).

RESULTS AND DISCUSSION

Soil pH and EC

There were no significant differences noticed with soil reaction (pH) due to different treatment of fertilizers and manure (Table 3) even after a 46-years continuous use of inorganic fertilizers and organic manure in a Vertisol. The highest pH value 7.62 was recorded in 150% NPK treatment and lowest value 7.47 in 100% N alone treatments. This could be due to the high buffering capacity of the soil and presence of appreciable content of free calcium carbonate (4.60%). Similarly soil EC value was also found to be no changed over initial which ranged between 0.15 and 0.19 dSm^{-1}. It was found that imposition of various doses of fertilizers and manure did not affect significantly to electrical conductivity of soil in a Vertisol (Sawarkar *et al*., 2013).The continuous use of inorganic fertilizers over a long period of time had no marked influence on EC of the soil.

Soil organic carbon

The mean value of organic carbon (OC) contents ranged between 4.72 to 8.62 g kg^{-1} (Table 3). Soil organic carbon content increased significantly and attained a maximum value of 8.62 g kg^{-1} in the plots that received 100% NPK along with FYM over the initial value of 5.70 g kg^{-1} (1972). In the 100% NPK + FYM treatments, soil organic carbon values increased 82.6% over control plot and 51.2% over its initial values (1972). 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. It was also observed that soil OC levels in Vertisol increased considerably due to long-term fertilization and manuring for 46 years.

Available nutrients (NPKS)

Continuous application of fertilizers and FYM for 46 years under the soybean-wheat cropping system led to a significant increase in available N, P and S content in soil (Table 4). The highest value of available nutrients (N, P, K and S) was found under conjoint application of recommended fertilizers and organic manure (100% NPK+ 5 t FYM ha^{-1}) and the availability of N, P and S increased over their initial content (1972). The increase in available N observed under NPK+FYM may be due to the direct addition of organic matter through FYM, helping multiplication of soil microbes and ultimately enhancing the conversion of organically-bound N to mineral form (Suman *et al.,* 2017). However, due to addition of N fertilizer doses suboptimal, optimal and super optimal, N content was correspondingly improved indicating an impact of fertilizer application on

Table 4: Effect of continuous application of fertilizers and FYM on soil available nutrients (kg ha^{-1}).

Treatments	Available nutrients (kg ha^{-1})											
	Nitrogen			Phosphorous			Potassium			Sulphur		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
50% NPK	220	228	224	21.10	21.60	21.35	253	256	255	22.15	22.00	22.07
100% NPK	282	286	284	32.16	32.53	32.35	290	295	293	31.65	31.25	31.45
150% NPK	310	315	313	35.37	36.14	35.76	316	318	317	35.85	35.00	35.43
100% NP	253	258	256	27.32	28.08	27.70	235	237	236	29.85	29.90	29.87
100% N	216	221	218	10.02	10.11	10.07	233	236	234	11.10	11.15	11.12
100% NPK+ FYM	321	325	323	35.63	36.90	36.27	335	337	336	37.75	37.80	37.78
100% NPK(-S)	262	269	265	29.78	30.25	30.01	272	277	275	10.50	10.60	10.55
Control	184	187	185	9.88	9.94	9.91	232	236	234	10.65	10.40	10.52
CD (p=0.05)	25.2	24.2	16.9	3.16	2.45	1.80	30.8	23.0	16.5	2.78	2.13	1.29
Initial Value (1972)	193	7.6	370	15.6								

enrichment of N pool. The difference in N contents of soil among the sources is attributed to variable nutrient use efficiency, differential N conservation and fixation by the bio-inoculants and the variable biochemical activities within the soil (Sawarkar *et al.,* 2013).

Availability of P increased to the extent of 51.2 percent under 100% NPK compared with 50% NPK and was higher by 24.9 percent under 150% NPK compared with 100% NPK. The maximum build-up of soil P was observed under NPK+ FYM. 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. The results from this long-term experiment indicate (Table 4) that the application of recommended dose of fertilizer with FYM resulted in an increase in the available P status of soil 377.24% over its initial value (1972), due to the beneficial effects of organic matter on available P in soils. The increase in available P due to FYM may be due to the inactivation of iron and aluminium and hydroxyl aluminium ions, which reduced fixation of P. The concentration of P in available pool further increased due to the P addition from FYM. The FYM also being a direct source of nutrients, might have also solubilized the insoluble phosphate in the soil through release of various organic acids (Thakur *et al*., 2011) However, continuous cropping without the addition of K and imbalanced fertilization (N and NP) reduced the availability of K compared with initial soil K status, obviously continuous mining of native K pools that also caused a reduction in crop yields under these treatments. The decline was observed maximum in the case of control followed by100% 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 the 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 (Sawarkar *et al*. 2013and Pathariya *et al*., 2022).

The availability of sulphur was increased with the addition of S (Pathariya *et al*., 2022) found that regular supply of P through single superphosphate since 1972 increased available S content in the soil. The data indicated the available increased with of addition of Sover without S additions and control plots, which could be due to higher transformation of added fertilizer S to available S retention in soil. The addition of FYM along with optimal dose resulted in maximum build-up of available S this could be due to the release of organic acids during the decomposition of organic matter ultimately causing resolution of applied as well as native Sin to available S compounds thereby it increases the activity and concentration of available S in soil (Birla *et al*., 2015).

Soil microbial biomass carbon (SMBC)

The highest value of Soil Microbial Biomass Carbon Table 5 (SMBC) 340 µg C g^{-1} soil was recorded with 100% NPK + FYM treatments, while, the lowest content 169 µg C g^{-1} soil was found in control plot. The SMBC increased with successive addition of fertilizers *i.e*. 50% NPK (234 µg C g^{-1} soil), 100% NPK (295 µg C g^{-1} soil) and 150% NPK (305 µg C g^{-1} soil) treatments. The highest SMBC in the integrated nutrient management treatments was due to additional mineralizable and readily hydrolysable carbon from.

Soil microbial biomass nitrogen (SMBN)

The datapresented in the Table 5 revealed that the soil microbial biomass nitrogen was significantly influenced by the different nutrient management options. The highest value of SMBN 42.2 µg g^{-1} of soil was noted in conjoint use of balance dose of NPK with farmyard manure (100% NPK+ 5 t FYM ha^{-1}), while, the lowest value (22.4 µg g^{-1} of soil) was observed in control plot. However, the SMBN decreased under imbalance use of nutrients *i.e*. 100% NP and 100%N alone treatments as compared to balanced application of NPK (100% NPK) which hindicated necessity of balanced fertilizer application for enhancing soil microbial activity. It was further observed that combined use of 100% NPK + 5 t FYM ha^{-1} increased SMBN as compared with 100% NPK

Table 5: Effect of continuous application of fertilizers and FYM on soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN) and C: N ratio.

Treatments	SMBC (µ gg^{-1} soil)			SMBN (µ gg^{-1} soil)			C:N ratio		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
50% NPK	233	234	234	27.9	28.4	28.2	8.4 : 1	8.2 : 1	8.3 : 1
100% NPK	294	295	295	34.8	36.2	35.5	8.4 : 1	8.1 : 1	8.3 : 1
150% NPK	304	305	305	36.8	37.1	37.0	8.3 : 1	8.2 : 1	8.3 : 1
100% NP	248	250	249	28.4	30.1	29.3	8.7 : 1	8.3 : 1	8.5 : 1
100% N	219	221	220	23.3	25.6	24.5	9.4 : 1	8.6 : 1	9.0 : 1
100% NPK+ FYM	339	342	340	41.2	43.2	42.2	8.2 : 1	7.9 : 1	8.1 : 1
100% NPK(-S)	283	285	284	31.0	31.9	31.5	9.1 : 1	8.9 : 1	9.0 : 1
Control	168	170	169	20.5	22.2	21.4	8.2 : 1	7.7 : 1	7.9 : 1
CD (p=0.05)	27.0	26.0	20.6	4.40	3.57	2.91	-	-	-

treatments indicating beneficial effect of organics in augmenting microbial activity. High soil organic carbon, greater root proliferation and additional supply of N by FYM to microorganisms might be responsible for increasing the level of SMBN (Jalendra *et al*., (2021). Addition of inorganic fertilizer along with organic manure would help to increase the plant biomass yield, an increases the carbon input to soil is a main factor for higher soil organic matter (SOM). Also addition of FYM with inorganic fertilizer produces the cationic bridges with the functional groups leads to reduce the SOM solubilization or oxidation. These SOM provide a better soil environment for proliferation of soil microbial population which would increase the SMBC and SMBN. Even though, increasing levels of inorganic fertilizer alone (i.e. 50% NPK, 100% NPK and 150% NPK) also given the higher plant biomass that could increased the soil organic carbon contents as well as SMBN. But when compared the manure with inorganic fertilizer, these inorganic fertilizers treatments (50 % NPK, 100 % NPK and 150 % NPK) decreased the SOM and other microbial biomass like SMBC and SMBN.

C: N ratio

The pooled mean of two consecutive years the microbial C: N ratio, as. Microbial C: N ratio of soil ranged from 7.9:1 to 9.0: 1 (Table 5). The highest value C: N ratio (9.0: 1) was recorded in 100% NPK (-S) and 100% N alone treatments, while, the lowest values was found in 100% NPK+FYM treatments (8.1:1) and control plot (7.9: 1). This may be ascribed to the direct addition of organic matter through FYM and increase in root biomass which helped in the growth and development of soil microorganisms causing a beneficial effect on SMBC, SMBN and C: N ratio. Application of FYM to soybean during Kharif season significantly increased SMBC, SMBN and C: N ratio over control which might be due to a steady source of organic carbon to support the microbial community (Bhattacharyya *et al.,* 2008).

Dehydrogenase activity in soil

The DHA increased with graded levels of fertilizers from 50 to 150% NPK (Table 6). Application of FYM with 100% NPK recorded significantly higher DHA (13.0 µg TPF g^{-1} $24hr^{-1}$) compared with other treatments. The increase in DHA was to the extent of 23.81 percent under INM over 100% NPK treatments. The results are in agreement with the findings of Jalendra *et al*., (2021) and Tiwari *et al.,* (2019) that reported a 4-5 folds' increase in DHA due to FYM application along with NPK. The addition of FYM coupled with fertilization exerted a stimulating influence on the preponderance of bacteria. It was significantly higher under 100% NPK (10.5 µg TPF g^{-1} 24 h^{-1}) compared with control (8.4 µg TPF g^{-1} 24 h^{-1}), suggesting the importance of balanced fertilization. Jalendra *et al*., (2021) showed that easily decomposable components of crop residues may have a strong effect on DHA and the metabolism of soil microorganisms. Further, it was observed that continuous application of imbalanced fertilization (100% N alone and 100% NP) decreased the DHA by 12.90% and

Table 6: Effect of continuous application of fertilizers and FYM on Dehydrogenase (DHA), Acid phosphatase, Alkaline phosphatase and β-glucosidase activities of soil.

Treatments	DHA (µg TPF g^{-1} soil 24 hr^{-1})			Acid phosphatase (µg PNP g^{-1} soil hr^{-1})			Alkaline phosphatase (µg PNP g^{-1} soil hr^{-1})			β- glucosidase activity (µg PNP g^{-1} hr^{-1})		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
50% NPK	8.6	9.0	8.8	8.0	11.0	9.5	17.6	18.5	18.1	31.4	32.4	31.9
100% NPK	10.0	11.1	10.5	9.3	12.1	10.7	22.4	23.2	22.8	36.4	37.7	37.1
150% NPK	10.8	12.0	11.4	10.0	12.0	11.0	25.6	26.4	26.0	39.4	41.3	40.3
100% NP	9.9	10.7	10.3	8.7	9.7	9.2	19.7	20.7	20.2	32.2	32.8	32.5
100% N	8.3	10.4	9.3	7.5	9.4	8.4	16.9	17.7	17.3	31.0	32.0	31.5
100% NPK+ FYM	11.3	14.6	13.0	10.6	11.6	11.1	28.8	29.6	29.2	46.3	47.4	46.9
100% NPK(-S)	9.2	11.0	10.1	8.8	13.0	10.9	20.7	22.5	21.6	35.2	36.4	35.8
Control	7.9	8.9	8.4	6.7	8.9	7.8	15.3	16.8	16.0	27.2	28.4	27.8
CD (p=0.05)	1.55	1.94	0.90	1.75	2.11	1.15	2.70	2.04	1.59	3.12	3.14	1.97

TPF= Triphenylformazan; PNP= P-nitrophenol.

Table 7: Effect of long term application of fertilizer and manure on soybean yield.

Treatments	Grain yield (kg ha^{-1})			Straw(kg ha^{-1})		
	2017	2018	Pooled	2017	2018	Pooled
50% NPK	1481	1300	1391	2520	2356	2438
100% NPK	1908	1637	1773	3091	3019	3055
150% NPK	2196	1987	2092	3335	3237	3286
100% NP	1628	1443	1536	2604	2894	2749
100% N	950	825	888	2108	2262	2185
100% NPK+ FYM	2276	2106	2191	3624	3482	3553
100% NPK(-S)	1605	1480	1543	2704	2844	2774
Control	920	737	829	2013	1887	1950
CD (*p*=0.05)	180	215	130	305	453	265

1.94% over 100% NPK treatments. The decrease was most spectacular in 100% N alone where DHA was significantly lower than the 100% NP plots, which could be due to increased redox potential of soil owing to accumulation of nitrate and other anions due to continuous application of N alone (Verma *et al.,* 2022).

Acid and alkaline phosphatase activity

The two years pooled data pertaining to acid phosphatase activity in soil are depicted in Table 6 which showed the 100% NPK, 150% NPK and 100% NPK (-S) was comparable with 100% NPK + FYM and these treatments are superior to 50% NPK and 100% NP treatments, while 100% N alone and control plot showed the lowest value of acid phosphatase activity, it could be due to the absence of P in these treatments. The highest value for acid phosphatase activity was found in 100% NPK + FYM (11.1 µg p-nitrophenol g^{-1} h^{-1}) and the lowest value in control (7.8 µg p-nitrophenol g^{-1} h^{-1}). With regard to alkaline phosphatase activity in soil (Table 6), 100% NPK+FYM treatment showed significantly highest value (29.2 µg p-nitrophenol g^{-1} h^{-1}) compared with 100% NPK (22.8 µg p-nitrophenol g^{-1} h^{-1}), whereas control plot showed the lowest value (16.0 µg p-nitrophenol g^{-1} h^{-1}). Activity of phosphatases is important in studying the P cycle because this can provide a route for P mineralization and plant uptake. However, activities of these enzymes were not persistent and sometimes appeared contrasting. The acid phosphatase activity was much lower than alkaline phosphatase activity, irrespective of the treatments, which may be due to the alkaline reaction of the soil. Earlier studies also proved that phosphatase activity was strongly âinfluenced by soil pH Tiwari *et al.,* (2019) .

β-glucosidase activity in soil

The pooled data of β-glucosidase activities in soils (Table 6) ranged from 27.8 to 46.9 µg β-glucosidase g^{-1} hr^{-1}.The value of β glucosidase increased significantly with graded doses of NPK and lack of P or K recorded lower values of β Glucosidase activity. The percent increase in enzyme activity ranged from 13.31 to 68.71 due to different treatments over control.The highest value 46.9 µg p nitrophenol g^{-1} hr^{-1}of β-glucosidase activity was recorded in 100% NPK+FYM treatment and lowest value was noted in control plot (27.8 µg β-glucosidase g^{-1} h^{-1}). The activity of β-glucosidase increases with organic matter content and this is why it is considered a very sensitive biological indicator of the effect of soil management practices. The application of FYM significantly increased β-glucosidase activities, in bulk soil and all particle-size fractions as compared to those in mineral fertilizer and control Liang *et al.,* (2014).

Crop productivity

Grain and straw yield of soybean increased significantly due to different treatments over control (Table 7). The grain yield ranged from 829 to 2191 kg/ha and straw yield increased from 1950 to 3553 kg/ha. The percent increase in grain yield due to different treatments ranged from 7.12 to 164.3 over control. Similarly, percent increase in straw yield increased from 12.06 to 82.21 over control. Graded doses of NPK (50 to 150%) increased grain yield significantly over each other, while in straw yield, 100% NPK and 150% NPK was on at par. Lack of potassium caused reduction grain yield by 15.43% compared to 100 % NPK and straw yield reduction by 11.14%. Similarly, lack of P and K caused reduction in grain yield by 99.63% and straw yield reduction by 39.82%. Lack of sulphur caused reduction in grain and straw yield by 14.91 and 10.13% compared to 100% NPK. A small intervention of adding FYM 5 t/ha over 100% NPK caused 23.58 and 16.31% increase in grain and straw yield, respectively over 100% NPK. Further it is observed that lack of K or S or PK results in lower yield and therefore it is advocated to promote balanced fertilization. These findings were also supported by Dwivedi *et al.,* (2015), Dwivedi *et al*., (2019) and Pathariya *et al.,* (2022).

CONCLUSION

It could be concluded that the long-term application of balanced and integrated use of nutrients (100% NPK, 150% NPK and 100% NPK+ 5 t FYM ha^{-1} treatments) to soybean and wheat significantly improved the soil chemical and biological properties as well as crop productivity. The microbial biomass (C and N) and soil enzyme activities were controlled by the long-term manure and fertilizer treatments, as the same were highest under 100% NPK+ 5 t FYM ha^{-1} treatment. On the other hand, imbalanced use of nutrients (100% NP and 100% N alone treatments) produced a deleterious effect on the chemical and biological properties of soil.

Conflict of interest: None.

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