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Long-term Effects of Fertilizers and Manure on Productivity of Soybean (*Glycene max* L.) - Safflower (*Carthamus tinctorius*) Cropping System and Soil Health under *Vertisols* in Central Platue of India

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ABSTRACT

Background: The declining trends in yields of different crops and cropping systems have been reported to be mainly due to over-exploitation and mis-management of soil, imbalanced use of fertilizers Therefore, the present investigation was undertaken to examine the effects of long-term application of varying levels of fertilizers and manures on productivity and dynamics of soil health under soybean- safflower cropping system.

Methods: The present study was carried out at research farm of AICRP on long term fertilizer experiment, Vasantroa Naik Marathwada Krishi Vidyapeeth, Parbhani in medium deep black soil. The experiment was conducted with eleven treatments in a randomized block design with four replications. This study was made to evaluate the effect of long-term effects of fertilizers and manures on productivity of soybean (*Glycene max* L.)-safflower (*Carthamus tinctorius)* cropping system and soil health under Vertisols in central plateau of India during 2019-20, 2020-21 and 2021-22.

Result: The pooled data of three years concluded that, soybean and safflower yields were highest in treatment 100% NPK+5 t FYM ha^{-1} and gave maximum and significantly more population of bacteria, fungi and actinomycetes and soil microbial biomass C. Fertilizer treatments with 100% NPK and 150% NPK were comparable and significantly better than application of 50% NPK, 100% N, 100% NP and 100% NPK(-S) in various studied soil biological properties. Integrated use of 100% NPK with FYM sustained higher yields and soil biological properties under soybean-safflower cropping system in *Vertisol* at Vasantrao Naik Marathwada Krishi Vidyappeth, Parbhani (Maharashtra).

Key words: Long-term fertilizer experiment, Soil biological properties, Soybean-safflower, Yields.

INTRODUCTION

Soybean (*Glycene max* L.)-Safflower (*Carthamus tinctorius*) is the important oil seed crops in Maharshtra. Soybean occupies 49.10 lakh/ha area, 4.167 lakh/ha production and 317 kg/ha productivity (Anonymous, 2023). Similarly, safflower occupies 510 lakh/ha area, 0.111 lakh/ha production and 218 kg/ha productivity in Maharashtra. The production of soybean and safflower has increased remarkably with the development of high-yielding and fertilizer responsive crop varieties (Ladha *et al*., 2003; Manna *et al.,* 2005). The stagnation and declining trends in yields in different crops and cropping systems have been reported to be mainly due to over-exploitation and mismanagement of soils, imbalanced use of fertilizers (Yadav *et al.,* 2000; Neetu *et al*., 2025). Microorganisms present in soil play a key role in organic matter decomposition, nitrogen fixation, mobilization and solubalization of plant nutrients and also contribute to the efficiency of applied fertilizers (Poll *et al*., 2003). Soil biological properties respond rapidly and are influenced by the application of fertilizers, manures, irrigation, pest control measures, etc. Enzyme activities in soil showed positive correlations with microbial respiration, microbial biomass and soil management practices that alter microbial communities in soil are also expected to bring change in soil enzyme levels (Drjber *et al.,* 2000; Nannipieri *et al*., 1990; Aon *et al*., 2001; Masto *et al*., 2007; Trasar-Cepeda *et al*., 2008). However, Some researchers have noted beneficial effects of application of manure on the

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biochemical activity in soil due to associated effects on microorganisms (Jenkinson 1990; Kandeler *et al.,* 1999), whereas, others reported harmful effects, which depend on quality of manure (Schipper and Sparling, 2000). Similarly, fertilizers have been reported to inhibit enzyme synthesis in soil (Olander and Vitousek, 2000) due to presence of readily available inorganic nutrients, while others indicated an increase in soil enzyme activities due to accelerated plant growth and secretion of enzymes by roots. Thus, it appears important to understand the dynamics and status of soil biological and biochemical properties for cycling of nutrients and assessment of soil health under different ecological settings, soil and crop management practices. Long-term experiments are valuable for providing information on the effects of continuous use of nutrient management options in crop production on the productivity and quality of soil. Soil biological and biochemical properties are considered reliable indicators of soil quality as these are highly sensitive to alteration of land management practices (Gil-Sotres *et al*., 2005). Some long-term effects of integrated use of fertilizers and manure on yields and soil biological properties have been studied in different cropping systems under varying climatic conditions in India, this information is lacking behind under *Vertisols* in soybean-safflower cropping in central pleatue of India. Therefore, the present investigation was undertaken to diagnose the effects of long-term application of varying levels of fertilizers and manure on productivity and dynamics of soil microbial biomass and enzyme activities under soybean- safflower cropping system in *Vertisols* at Parbhani, Central India.

MATERIALS AND METHODS

The long-term fertilizer experiment was initiated in 2006 at research farm of AICRP on Long Term Fertilizer Experiments, Department of Soil Science, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, India with a Soybean (*Glycene max* L.) - Safflower (*Carthamus tinctorius*) cropping sequence. The soil of the experimental field comes under *Vertisols* with montmorillonitic, hyperthermic family of Typic Haplustert clayey in texture. The soybean cultivar MAUS-162 and safflower PBNS-12 were sown in 2019-20, 2020-21 and 2021-22 by adopting recommended crop management practice for both the crops in *Kharif* and *Rabi* seasons, respectively. The nutrients were applied through fertilizers (urea, single super phosphate, muriate of potash and diammonium phosphate). Zinc was applied through $ZnSO_4$. $5H_2O$ and FYM was applied every year before 15 days of sowing in *Kharif* season. The recommended dose of fertilizer (RDF) applied to soybean and safflower was 30:60:30 and 60:40:00 kg N, P_2O_5 and K_2O ha^{-1}, respectively. The mean annual rainfall is about 850 mm, received between June and September. The treatment combinations being used for soybean and safflower crops were 50% NPK (T_1), 100% NPK (T_2), 150% NPK (T_3), 100% NPK+Hand weeding (T_4), 100% NPK+Zn (T_5), 100% NP (T_6), 100% N (T_7), 100% NPK+FYM (T_8), 100% NPK-S (T_9), FYM @ 10 ha^{-1} (T_{10}) and Control (T_{11}). The Experiment was laid out in a randomized block design in a plot of 13.5 m $\times$ 10 m size with four replications. Soil samples were collected from individual plots after the harvesting of soybean and safflower during three years of experimentations at 0-15 cm soil layer. The population of bacteria, fungi and actinomycetes in soil was determined by serial dilution pour plate method using Nutrient agar medium for bacteria, Ken Knight and Munaier's medium for actinomycetes and Martin's Rose-Bengal streptomycin agar medium for fungi (Wollum, 1982). Microbial biomass carbon estimated by fumigation-extraction procedure as described by Jenkinson and Powlson (1976), soil organic carbon estimated by using oxidation and reduction procedure as given by Walkley and Black (1934), Soil de-hydrogenase by Tabatabai (1994) and acid and alkaline enzyme activities by Tabatabai and Bremner (1969). All the estimated soil biological properties were calculated based on oven dry weight of soil. The data on different parameters were analyzed statistically by adopting Fisher's method of ANOVA suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Grain yields of soybean and safflower

After the 17th years of crop cycle, the impact of fertilizers and manure on mean grain yields of soybean and safflower crops were monitored in soybean- safflower cropping system under *Vertisols*. Pooled data on grain yields of soybean and safflower tabulated in (Table 1) showed significantly highest in treatment 100% NPK+5 t FYM ha"1and produced higher mean grain yields of 9.37 per cent of soybean and 11.22 per cent of safflower over treatment 100% NPK, respectively and found significantly superior to all other treatments. Results indicated that the application of 100% N alone had increased the grain yield by 18.81 per cent of soybean and 24.01 per cent of safflower respectively, over control. Treatment 100% NP enhanced the grain yield of soybean and safflower by 107.59 per cent and 99.73 per cent respectively over the treatment 100% N. Further, the deficiency of S noticed itself through yield reduction of 3.15 per cent and 2.85 per cent in grain yields of soybean and safflower, respectively over treatment 100% NPK. Increase in yield might be due to beneficial effects of FYM on nutrient availability. Shirale *et al.* (2014) and Arbad *et al.* (2011) have also reported similar results. Further, Meshram *et al.* (2016) showed that the yield by NPK with FYM application could be attributed to enhanced population of phosphate solubilizing microorganisms. Treatment 100% NPK+Zn produced highest soybean and safflower mean grain yield increased by 3.98% and 5.70% over treatment 100% NPK, respectively. The significant positive response of Zn application with 100% NPK could be attributed to the development of Zn deficiency in soil due to continuous soybean-safflower crops over the last 17th

years, as reported by Narendra *et al*. (2024); Meshram *et.al*. (2016). Treatments 100% NPK+HW and 100% NPK+Zn were statistically comparable with each other in grain yields of soybean and safflower.

Microbial population

Treatment 100% NPK+5 t FYM ha^{-1} recorded (Table 2) highest population of bacteria (57.75 cfu$\times10^{6}$ g^{-1}) and actinomycetes (49.79 cfu$\times10^{5}$ g^{-1}) after harvest of crops, respectively. However, fungal population was observed significantly highest in treatment FYM @ 10 t ha^{-1} (13.62 cfu$\times$10-4). Treatments 50% NPK, 100% N, 100% NP and 100% NPK-S recorded significantly lower population of bacteria, fungi and actinomycetes in soil than treatment 100% NPK. Khandare *et al.* (2020) and Tejada *et al*. (2009) reported depletion in native pools of plant nutrients in soil under these treatments, which caused reduction in plant biomass production (carbon substrate) and addition in soil (Suresh *et al.,*1999). Treatment 150% NPK was comparable to treatment 100% NPK in soil microbial population and suggested that supply of inorganic nutrients higher than at optimum level without manure cannot support microbial population in soil (Selvi *et al*., 2004; and Ingle *et al*., 2014). The treatments of 100% NPK+Hand weeding, 100% NPK+Zn were statistically comparable with 100% NPK in recording mean counts of bacteria, fungi and actinomycetes after soybean and safflower; however, these treatments gave significantly lower counts than 100% NPK+5t FYM ha^{-1} indicating that manure has greater positive effect on microbial population in soil. The lowest microbial population was observed in control and 100% N treatment due to unavailability of organic sources.

Microbial biomass C and organic C in soil

It is evident from (Table 2) significantly maximum microbial biomass C and soil organic carbon were observed in

Table 1: Long-term effects of fertilizers and manure on Grain yield (kg ha^{-1}) of soybean and safflower.

Treatments	Soybean				Safflower			
	2019-20	2020-21	2021-22	Pooled mean	2019-20	2020-21	2021-22	Pooled mean
50% NPK	1118	1172	920	1070	1111	430	991	844
100% NPK	1730	1335	1065	1376	1331	563	1257	1051
150% NPK	1869	1413	1118	1467	1518	624	1305	1149
100% NPK+HW	1743	1373	1021	1379	1373	591	1223	1062
100% NPK+Zinc	1814	1396	1093	1434	1453	597	1283	1111
100% NP	1536	1297	957	1264	1248	502	1160	970
100% N	125	493	461	360	550	131	543	408
100% NPK+FYM @ 5 t ha^{-1}	1963	1427	1124	1505	1534	631	1342	1169
100% NPK -Sulphur	1739	1277	993	1336	1320	554	1188	1021
FYM @ 10 t ha^{-1}	1505	1271	826	1201	1252	434	856	847
Control	210	361	339	303	518	74	395	329
SE ±	59.79	101.40	40.85	120.50	59.10	30.38	103.55	55.22
CD at 5%	172.66	292.82	117.96	355.50	170.67	87.73	299.04	162.91

Table 2: Long-term effects of fertilizers and manure on population (cfuXg^{-1} soil) of bacteria, fungi and actinomycetes in soil after safflower (pooled mean).

Treatments	Bacteria (cfu × 107)	Fungi (cfu × 104)	Actinomycetes (cfu × 106)	SMBC (µg/g soil)	Soil organic carbon (g kg^{-1})
50% NPK	32.67	7.23	32.45	240.45	6.29
100% NPK	34.50	8.33	32.95	249.70	6.55
150% NPK	36.59	10.25	40.87	339.50	6.71
100% NPK+HW	40.84	8.93	34.12	290.45	6.62
100% NPK+Zinc	37.17	9.51	38.62	321.48	6.60
100% NP	33.50	7.81	31.87	208.75	5.77
100% N	31.50	7.56	29.20	205.17	5.72
100% NPK+FYM @ 5 t ha^{-1}	57.75	10.70	49.79	361.62	6.99
100% NPK -Sulphur	33.67	8.55	34.54	215.29	6.29
FYM @ 10 t ha^{-1}	55.17	13.62	47.95	297.82	6.77
Control	31.00	6.44	26.62	206.49	5.50
SE ±	0.41	0.20	0.33	0.68	0.02
CD at 5%	1.20	0.59	0.97	2.01	0.06

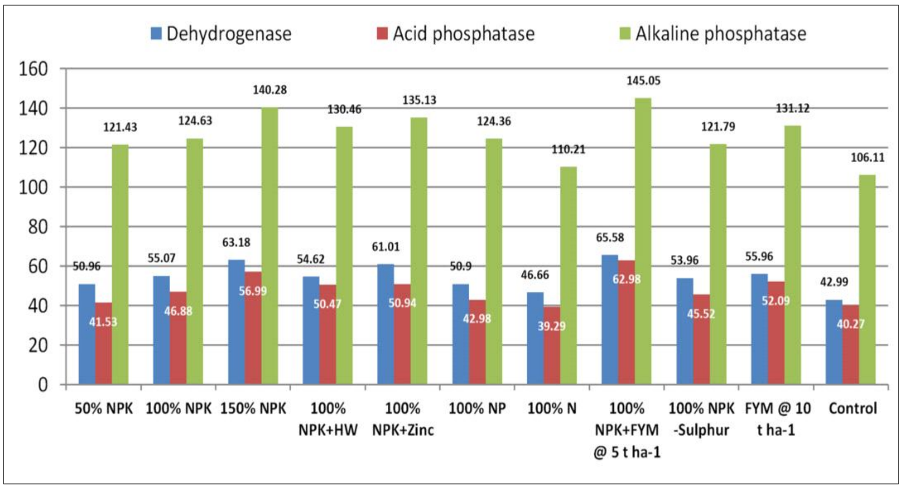

Fig 1: Long-term effects of fertilizers and manure on dehydrogenase (ug TPF g^{-1} soil 24 hr^{-1}) and phosphatase enzyme activities (µg PNP g^{-1} h^{-1}) in soil after safflower (pooled mean).

treatment 100% NPK+5 t FYM ha^{-1} (361.62 µg g^{-1}soil, 6.99 g kg^{-1}) and significantly at par with 150% NPK (339.50 µg g^{-1} soil 6.71 g kg^{-1}), this may be attributed to FYM as a food material for stimulating microbial growth, resulting in higher microbial biomass C and soil organic carbon. Patil and Puranik (2001) reported the beneficial effects of integrated use of fertilizers with FYM. However, application of FYM ensured the balanced supply of nutrients and carbon, which in-turn might have supported the higher population of microorganisms in soil (Basak *et al.,* 2012; Lal 2021). Treatment 100%NPK and 150% NPK were comparable in microbial biomass C and organic C and lowest was observed in treatment 50% NPK. Similarly, continuous use of 100% N, 100% NP and 100% NPK (-S) resulted in significantly lower soil microbial biomass C and organic C than 100% NPK possibly due inadequate and imbalanced supply of nutrients for microbial utilization in soil.

Enzyme activity

The enzyme activities were monitored for good biological health indicator of soil and represent the overall metabolic status and have been widely used as an index of microbial activity. Treatment 100% NPK+5t FYM ha^{-1} gave significantly maximum dehydrogenase (145.05 ug TPF g^{-1} soil 24 hr^{-1}), acid (62.98 µg PNP g^{-1} h^{-1}) and alkaline phosphatase enzyme (65.58 µg PNP g^{-1} h^{-1}) activity in soil and was found significantly superior to all other treatments (Fig 1). A relatively more pronounced effect of FYM on soil enzyme activities in comparison to fertilizers has also been reported earlier and these results are in conformity with the findings of Bhattacharyya *et al*. (2008), who reported a four times increase in dehydrogenase activity in soil due to application of FYM in combination with NPK. Imbalanced and inadequate application of fertilizers in treatments 50% NPK, 100% NP and 100% N resulted significant decrease in dehydrogenase, acid and alkaline phosphatase enzyme activities. Simillarly, dehydrogenase, acid and alkaline phosphatase enzyme activities were significantly low in treatment 100% N as compared to all other treatments, which can be attributed to the presence of nitrate and nitrite that serve as alternative electron acceptors reported by Kukreja *et al.* (1991). The significantly lower enzyme activity in soil was observed in 100% NPK-S treatment in comparison to 100% NPK Treatments of 100% NPK and 150% NPK were at par and gave significantly higher acid phosphatase activity, by 41.9% and 50.5% and alkaline phosphatase activity, by 38.5% and 51.3%, increased over 50% NPK treatment for soybean and safflower, respectively.

CONCLUSION

The present study revealed that treatment 100% NPK+ FYM @5 t ha”1 gave higher yield of soybean-safflower cropping system in *Vertisols*. This treatment also recorded significantly maximum population of microorganisms, microbial biomass carbon, organic carbon and activities of various enzymes in soil, which play a vital role in nutrient cycling. It can thus be concluded that integrated use of fertilizers with FYM enhanced soil properties and sustaining productivity of soybean and safflower cropping system in *Vertisols*.

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Disclaimers

The conclusions were drawn from Long Term Fertilizer experiment and expressed in this research article are solely those of authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All procedures for determination of Soil available nutrients, microbial population and enzyme activities of these experiments were formulated and approved by the Committee, Annual Research Council of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of manuscript.

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