*Int.J.Curr.Microbiol.App.Sci* (2023) *12*(03): 119-131

*International Journal of Current Microbiology and Applied Sciences*
***ISSN: 2319-7706*** **Volume 12 Number 3 (2023)**
Journal homepage: http://www.ijcmas.com

**Original Research Article** https://doi.org/10.20546/ijcmas.2023.1203.016

# Effect of Long Fertilization and Manuring on Yield, Nutrient Uptake and Soil Microbial Properties in Soybean- Safflower Cropping Sequence under Vertisol

**Priyanka S. Nakhate, Ramprasad N. Khandare, Pravin H. Vaidya and Ravi H. Wanjari**

*Department of Soil Science and Agricultural Chemistry,*
*AICRP on Long Term Fertilizer Experiments, Vasantrao Naik Marathwada Krishi Vidyapeeth,*
*Parbhani-431402, M.S., India*

**Corresponding author*

## A B S T R A C T

**Keywords**

Soybean Safflower Grain Yield, Nutrient Uptake and Microbial properties

**Article Info**

***Received:***
06 February 2023
***Accepted:***
27 February 2023
***Available Online:***
10 March 2023

A long-term fertilizer experiment under soybean-safflower cropping sequence was used to investigate the effect of organic and inorganic fertilizer applications on yield, uptake and microbial properties in soil. Application of 100% NPK +FYM @5 t ha$^{-1}$ significantly highest grain yield of soybean (14.27q ha-1) and safflower (6.31q ha-1) followed by 150% NPK of soybean (14.13q ha-1) and safflower (6.24 q ha-1) and these treatments are found to be significantly superior than all treatments of long term fertilization. The microbial and enzyme activities are improved by application 00% NPK + FYM @ 5 t ha$^{-1}$ and only FYM @ 10 ha$^{-1}$ in soybean -safflower cropping sequence under Vertisol. Nutrient uptake of Nitrogen (113.02 kg ha$^{-1}$), Phosphorous (23.91 kg ha $^{-1}$) and Potassium (50.75 kg ha $^{-1}$) by soybean and Nitrogen (56.50 kg ha $^{-1}$), Phosphorous (23.50kg ha $^{-1}$) and Potassium (75.62 kg ha $^{-1}$) by safflower were recorded significantly maximum in 100% NPK +FYM @5 t ha$^{-1}$ at harvest of both the crops. The balance application of chemical fertilizers improves physico chemical and biological properties soil than imbalance use of chemical fertilizers. The grain yield of soybean and safflower, nutrient uptake and soil biological properties were lowest in absolute control and only application of 100 % nitrogen in soybean safflower cropping sequence under Vertisol.

## Introduction

Soybean [*Glycine max* (L.) Merill] is an important oil seed and plays vital role in human diet. It contains high quality of proteins (40%) and edible oil (20%) containing major essential amino acids (Raghuvanshi and Bisht, 2010). Soybean grains content high-quality protein source for livestock feed rations (Mary *et al.*, 2013). It is the world's most important oil seed crop contributes about 25% of the global edible oil, about two-thirds of the world's protein concentrate for livestock feeding (Agarwal *et al.*, 2013). Soybean improve the soil health and fertility by fixing nitrogen through biological nitrogen fixation in soil which is carried out by symbiotic nitrogen fixing bacteria residing in the root nodule of soybeans (Javaid and Mahmood, 2010). Soybean also has the capacity to ameliorate the nutritional situation, enhance productivity of other crops and also protects the environment from allelopathy tendencies of agricultural chemicals (FAO, 1998; Shala and Stacey, 2001).

It is generally known that long-term fertilizer experiments provide important data on the effects of continuous application of various fertilizer nutrient levels alone, in combination with or without organic manure, during intensive cropping sequence (Thakur *et al.,* 2011). However, oldest oilseed crop grown in India is safflower (*Carthamus tinctorius* L.), which is primarily grown for cooking oil and colours. Additionally, safflower is a versatile agricultural species that is used to make margarine, salad dressing, cosmetics, and medications (Balasubramanian and Palaniappan, 2005). Safflower seeds have an oil content of 28–34% that is flavourless and colourless, similar in nutritional value to sunflower oil, and high in linoleic acid (78%), which is particularly effective at lowering blood cholesterol levels (Kadu and Ismail, 2008). It is preferred to use safflower oil since it contains more polyunsaturated fatty acids (78% linoleic acid), which lowers blood cholesterol levels (Belgin, 2007). Adopting effective integrated and balanced nutrient management techniques for boosting the safflower productivity significantly in Vertisol.

The long-term field experiment is being seen as the best practicable approximation to a test of farming techniques' sustainability. The long-term fertilizer studies carried out in India over the past few years have clearly shown that they might be used to assess and evaluate the impact of continuous cropping and fertilizer use on soil quality and, consequently, the sustenance of the system. (Wagnet and Hutson, 1997).

Long-term fertilization is an experiment where no aspect of the variables being studied has changed since the beginning, such as the treatments, input rates, or crop rotation. Long-term fertilizer studies that have not altered any aspect of the variables being researched since the start of treatments, input rates, or crop rotation assessing how society views land usage and sustainable food production is a significant asset. (Static form: 1844 to 1960) (Ashcroft *et al.,* 1990; Macdonald, 2020).

## Materials and Methods

The present investigation entitled was carried out during *kharif* and *rabi* season of 2020-21. The experiment was carried out at the research farm of AICRP on Long Term Fertilizer Experiment, Department of Soil Science and Agriculture Chemistry, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani which is located within the Godawari catchment area in India between $17^0$, 35 to $26^0$, 40 N latitude and $74^0$, 40 to $76^{0,}$ 15 E longitude with an altitude of 347 M from above mean see level (MSL). The present experiment was framed in Randomized Block Design with twelve treatments and four replications in soybean-safflower cropping system Under Vertisol.

The 100% N, P and K was applied to both crops at the rate of 30:60:30 kg $ha^{-1}$ for soybean and 60:40:00 kg $ha^{-1}$ for safflower respectively. The fertilizers used were urea, single super phosphate and muriate of potash. FYM was applied before 15 days of sowing only for *kharif* crop and NPK applied through straight fertilizers urea, single super phosphate and muriate of potash as per treatments, whereas in treatment ($T_9$) diammonium phosphate was used in place of single super phosphate to avoid sulphur application. In $T_4$ treatment only two hand weeding were taken for weed control, without use of any weedicide.

The nitrogen content in dry matter and grain was determined by Micro Kjeldhals methods (AOAC, 1993). The phosphorous in dry matter and grain was spectrophotometrically by vanado molybdate phosphoric acid yellow colour method (Jackson, 1973). Potassium content in plant and seed was determined from the diluted diacid extract on flame photometer (Jackson, 1973)

## Nutrient uptake and yield

The soybean and safflower were harvested from area of 13.5 X 10 m of each plot at during the year 2020-2021, respectively. The harvested produce was sun dried for 4-5 days and weighed for recording biological yield. The grains were separated from the produce with mechanical thresher, cleaned, sun dried to approximately 12.0% moisture and weighed for recording grain yield. Total N, P and K concentrations and uptake in grain samples of soybean and safflower were determined after finely grinding as described by Page (1982).

## Microbial Properties

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 Muners medium for actinomycetes and martins Rose- Bengal streptomycin agar medium for fungi (Wollum, 1982). The acid and alkaline phosphatase enzyme activities were determined as per method given by (Tabatbai and Bermner, 1969) by using *p*- nitrophenyl phosphate tetrahydrate solution at pH 6.5 for acid phosphatase and pH 11.00 for alkaline phosphatase enzymes.

## Statistical analysis

Critical difference (CD) was used to compare the treatment effects at $p < 0.05$. The stastical analysis was done with the help of method described by (Panse and Sukhatme, 1985)

## Results and Discussion

## Grain yield of soybean-safflower

The data from the table 1 representing the grain of soybean and safflower in the soybean-safflower cropping sequence and grain of soybean and safflower was differed significantly due to different inorganic fertilizers and manuring treatments of long-term fertilization and varied from 3.61 q $ha^{-1}$ to 14.27 q $ha^{-1}$ and 10.20 q $ha^{-1}$ to 30.02 q $ha^{-1}$grain yields of soybean and safflower, respectively after harvest of both the crops.

The grain yield of soybean and safflower was significantly recorded maximum in 100% NPK+FYM@ 5 t $ha^{-1}$ (14.27 q $ha^{-1}$, 6.31q $ha^{-1}$) followed by 150% NPK (14.13 q $ha^{-1}$, 6.24q $ha^{-1}$) and 100% NPK +Zn (13.96 q $ha^{-1}$, 5.97q $ha^{-1}$q $ha^{-1}$), respectively as well as lowest grain yield of soybean and safflower was recorded by application absolute control (3.61 q $ha^{-1}$, 0.74 q $ha^{-1}$) followed by only nitrogen (4.93 q $ha^{-1}$, 1.31 q $ha^{-1}$). Data clearly indicated that higher grain and straw yield of soybean and safflower was recorded with integrated application of NPK+ FYM and 150%. NPK. While lowest recorded at imbalanced nutrient supply treated with absolute control. This may be due continuous supply of imbalanced fertilizers. The application of 100% NPK +FYM@ 5 t $ha^{-1}$ significantly superior in soybean and safflower grain yield over 50% NPK, 100% NPK, 150 % NPK, 100% NPK + Hand weeding, 100% NPK +Zn, 100% NP, 100% N, 100% NPK+ FYM@ 5 t $ha^{-1}$, 100% NPK-Sulphur, only FTM@ 10 t $ha^{-1}$, absolute control and fallow treatment respectively at harvest in soybean-safflower cropping sequence under Vertisol. Our findings are similar with results of Nandapure *et al.,* (2011) and Arbad *et al.,* (2014) stated that application 100% NPK+ 10 t $ha^{-1}$ significantly increased the yield of sorghum and wheat followed by application of 150% NPK. However, Khandare *et al.,* (2020); Jadhao *et al.,* (2019) observed that applying of 100% NPK + FYM@ 5 t $ha^{-1}$ significantly higher the yield of soybean in grain (4.61 t $ha^{-1}$) and as well as grain (3.55 t $ha^{-1}$) yield of safflower due to long term effects of chemical fertilizers applied in combination with FYM in soybean- safflower cropping sequence.

## Nutrient uptake in soybean and safflower

## Nitrogen Uptake

The nitrogen uptake (Table 2) was differed significantly due to inorganic fertilizers and manuring on treatments of long-term fertilization and it was ranged from 24.60kg ha$^{-1}$ to 113.02 kg ha$^{-1}$in soybean and 11.21 kg ha$^{-1}$ to 56.90 kg ha $^{-1}$for safflower, respectively under long term fertilizers experiment in soybean safflower cropping sequence.

The nitrogen uptake for soybean and safflower crop was significantly recorded maximum in 100% NPK+FYM@ 5 t ha$^{-1}$ (113.02 kg ha$^{-1}$and 56.90 kg ha$^{-1}$) followed by 150% NPK (110.29 kg ha$^{-1}$ 54.97 kg ha$^{-1}$) and application of 100% NPK+ Zn (104.60 kg ha$^{-1}$ 49.50 kg ha$^{-1}$) in soybean and safflower, respectively. The lowest nitrogen uptake was recorded by absolute control (24.60 kg ha$^{-1}$ and 11.21 kg ha$^{-1}$) and followed only 100% N (33.87 kg ha$^{-1}$ and 14.60 kg ha$^{-1}$) and application of 50% NPK (74.95 kg ha$^{-1}$ and 29.34 kg ha$^{-1}$), respectively in soybean and safflower at harvesting stage. Reddy *et al.,* (2017) and Meshram *et al.,* (2016). This could be attributed due to application of zinc sulphate combined with 100% NPK as compared to all the treatments resulted in a significant build-up of accessible zinc. When 100% NPK + FYM @ FYM Mg ha$^{-1}$ was applied, soybean N absorption increased significantly compared to other treatments.

## Phosphorous uptake

Significant variations are observed in phosphorous uptake (Table 2) due to inorganic fertilizers and manuring on treatments of long-term fertilization and it was ranged from 4.67 kg ha$^{-1}$ to 23.91 kg ha$^{-1}$ in soybean and 3.79 kg ha$^{-1}$ to 23.50 kg ha$^{-1}$ for safflower, respectively under long term fertilizers experiment in soybean safflower cropping sequence.

The phosphorous uptake for soybean and safflower crop was significantly recorded maximum in 100% NPK+FYM @ 5 t ha$^{-1}$ (23.91 kg ha$^{-1}$ and 23.50 kg ha$^{-1}$) followed by 150% NPK (22.94 kg ha$^{-1}$and 21.89 kg ha$^{-1}$) and application of 100% NPK+ Zn (20.58 kg ha$^{-1}$18.51 kg ha$^{-1}$) in soybean and safflower, respectively. The lowest nitrogen uptake was recorded by absolute control (4.67 kg ha$^{-1}$ and 11.21 kg ha$^{-1}$) and followed only 100% N (5.43 kg ha$^{-1}$ and 14.60 kg ha$^{-1}$) and application of 50% NPK (10.13 kg ha$^{-1}$ and 13.15 kg ha$^{-1}$), respectively in soybean and safflower at harvesting stage. Reddy *et al.,* (2017) and Meshram *et al.,* (2016).

This could be attributed due to application of zinc sulphate combined with 100% NPK as compared to all the treatments resulted in a significant build-up of accessible zinc. When 100% NPK + FYM @ FYM Mg ha$^{-1}$ was applied, soybean N absorption increased significantly compared to other treatments. Ravankar *et al.,* (2001) noted the increased uptake of phosphorous by sorghum and wheat crops was observed at 100% NPK + 10 t FYM ha$^{-1}$. Reddy *et al.,* (2017) reported that the using of 100% NPK + FYM resulted in greater phosphorous uptake (23.82 Kg ha$^{-1}$). The highest phosphorous uptake by grain was reported in the 100% NPK + FYM (19.00 Kg ha$^{-1}$). The phosphorous uptake by straw was the increased (5.21 Kg ha$^{-1}$) under 150% NPK treatment.

## Potassium uptake

The inorganic fertilizers and manuring treatments of long-term fertilization gave significant variations among the treatments and it was ranged from 12.02 kg ha$^{-1}$ to 50.79 kg ha$^{-1}$ in soybean and 17.60 kg ha$^{-1}$ to 75.62 kg ha$^{-1}$ for safflower, respectively under long term fertilizers experiment in soybean safflower cropping sequence.

The potassium uptake (Table 2) for soybean and safflower crop was significantly recorded maximum in 100% NPK+FYM @ 5 t ha$^{-1}$ (50.79 kg ha$^{-1}$ and 75.62 kg ha$^{-1}$) followed by 150% NPK (48.64 kg ha$^{-1}$ and 72.17 kg ha$^{-1}$) and application of 100% NPK+ Zn (46.29 kg ha$^{-1}$ 67.82 kg ha$^{-1}$) in soybean and safflower, respectively. The lowest nitrogen uptake was recorded by absolute control (12.02 kg ha$^{-1}$ and 17.60 kg ha$^{-1}$) and followed only 100% N (14.17 kg ha$^{-1}$ and 20.91 kg ha$^{-1}$) and application of 50% NPK (33.83 kg ha$^{-1}$ and 42.99 kg ha$^{-1}$), respectively in soybean and safflower at harvesting stage. Reddy *et al.,* (2017) and Meshram *et al.,* (2016). This could be attributed due to application of zinc sulphate combined with 100% NPK as compared to all the treatments resulted in a significant build-up of accessible zinc. When 100% NPK + FYM @ FYM Mg $ha^{-1}$ was applied, soybean N absorption increased significantly compared to other treatments. Similar, results were also reported by Singh *et al.,* (2019) and observed the treatment of the 100% recommended fertilizer dose led to significantly increased potassium uptake by soybean crop by different treatments of organic and inorganic in long term fertilization. Similar, results were reported by Khandare *et al.,* (2020); Lakshmi *et al.,* (2015); Kakraliya *et al.,* (2017), noted the prime effect, where organics on decomposition release organic acids that solubilize native forms of K, i.e. fixed and non-exchangeable forms of K, and charge the soil solution with K+ ions at later stages of crop growth, may be the cause of the increased K uptake under concurrent use of organic and inorganic materials. The results are inconformity with the findings of Kumawat *et al.,* (2009) reported that applying organic manure along with inorganic fertilizers enhances nutrient uptake. This may also be due to improved rhizosphere's nutrient environment and the plant system's use of the nutrients, which enhances the translocation of nutrients to reproductive structures like pods, seeds, and other plant parts.

## Bacterial population

The bacterial population (Table 3) ranged from 29.25 CFU × $10^{-7}$ $g^{-1}$ soil to 59.25 CFU × $10^{-7}$ $g^{-1}$ soil and it was recorded significantly maximum by application of 100% NPK +FYM@ 5 t $ha^{-1}$ (59.25 CFU × $10^{-7}$ $g^{-1}$ soil) followed by only FYM @ 10 t $ha^{-1}$ (57.00 CFU × $10^{-7}$ $g^{-1}$ soil) and 100 % NPK+ Hand weeding (41.00 CFU ×$10^{-7}$ $g^{-1}$soil) at harvest, respectively. The lowest population of bacteria was recorded by fallow treatment (29.25 CFU × $10^{-7}$ $g^{-1}$ soil) followed by absolute control (31.00 CFU × $10^{-7}$ $g^{-1}$ soil) and application of 100 % N (31.50 CFU × $10^{-7}$ $g^{-1}$ soil), respectively in soybean-safflower cropping sequence. This could be attributed to the FYM, which provided a significant amount of readily available carbon, leading to a more diversified and dynamic microbial system than in soil that had received inorganic fertilizer. Additionally, the majority of soil microorganisms are chemoheterotrophs, which means they need an organic food source and gain energy by oxidizing organic materials. This may be the reason the microbial population is improving in integrated nutrition management. These results are conformity with the results of Suresh *et al.,* (1999) studied that a prolonged farming may have reduced the microbial population by depleting the local source of nutrients. Our results are confirmed with the findings of Meshram *et al.,* (2016) they reported that organic manure combined with NPK fertilizer has a stimulating effect on the prevalence of the soil microbial community. Similar findings reported by Patil and Varade (1998) and Selvi *et al.,* (2004). Recently, Arbad and Ismail (2011)

## Fungal population

The fungal population (Table 3) ranged from 6.55 CFU ×$10^{-3}$ $g^{-1}$ soil to 14.53 CFU× $10^{-3}$ $g^{-1}$ soil and it was observed significantly maximum in application of only FYM @ 10 t $ha^{-1}$ (14.53 CFU × $10^{-3}$$g^{-1}$ soil) followed by 100 % NPK+ FYM@ 5 t $ha^{-1}$ (11.30 CFU ×$10^{-3}$$g^{-1}$ soil), respectively. However, lowest population of fungi was noticed in by absolute control (6.55 CFU× $10^{-3}$ $g^{-1}$ soil) followed by fallow treatment (6.83 CFU× $10^{-3}$ $g^{-1}$ soil) and 100 % N only (7.00 CFU×$10^{-3}$ $g^{-1}$ soil) at harvesting in soybean-safflower cropping sequence.

The fungal population was maximum in only FYM @10 t $ha^{-1}$ because of increased numbers of fungi in manuring treatments may be caused by the availability of food from organic sources that decomposes quickly (FYM). Due to nutritional response and microbial oxidation of the ammonia salt present in inorganic fertilizers, which results in the generation of nitric acid, the application of inorganic fertilizers also improves the fungal population relative to control Malewar *et al.,* (1999); Chesti and Ali, 2012; Chauhan *et al.,* (2011); Meshram *et al.,* (2016). Similar findings reported by Sharma *et al.,* (2000) reported that FYM-treated plots had the highest number of them in the soil.

**Table.1** Treatment details

| Treatment No. | Treatments | Fertilizer source |
|---|---|---|
| $T_1$ | 50% NPK | N-Urea, P-SSP, K-MOP |
| $T_2$ | 100% NPK | N-Urea, P-SSP, K-MOP |
| $T_3$ | 150% NPK | N-Urea, P-SSP, K-MOP |
| $T_4$ | 100% NPK+HW | N-Urea, P-SSP, K-MOP |
| $T_5$ | 100% NPK+Zinc | N-Urea, P-SSP, K-MOP, Zn -$ZnSO_4$ |
| $T_6$ | 100% NP | N-Urea, P-SSP |
| $T_7$ | 100% N | N-Urea |
| $T_8$ | 100% NPK+FYM @5t/ha. | N-Urea, P-SSP, K-MOP |
| $T_9$ | 100% NPK-Sulphur | N-Urea, P-DAP, K-MOP |
| $T_{10}$ | Only FYM @10t/ha. | -- |
| $T_{11}$ | Absolute Control | -- |
| $T_{12}$ | Fallow | -- |

**Table.2** Long term effect of fertilization and manuring on grain yield of soybean and safflower at soybean-safflower cropping sequence.

| Treatments | Soybean (q $ha^{-1}$) | Safflower (q $ha^{-1}$) |
|---|---|---|
| $T_1$- 50% NPK | 11.72 | 4.30 |
| $T_2$-100% NPK | 13.37 | 5.63 |
| $T_3$-150% NPK | 14.13 | 6.24 |
| $T_4$-100% NPK + Hand weeding | 13.73 | 5.91 |
| $T_5$- 100%NPK +Zn | 13 .96 | 5.97 |
| $T_6$- 100% NP | 12 .97 | 5.02 |
| $T_7$- 100%N | 4.93 | 1.31 |
| $T_8$-100% NPK + FYM @ 5 t $ha^{-1}$ | 14.27 | 6.31 |
| $T_9$- 100% NPK –Sulphur | 12 .77 | 5.54 |
| $T_{10}$- Only FYM @ 10 t $ha^{-1}$ | 12.71 | 4.34 |
| $T_{11}$- Absolute Control | 3 .61 | 0.74 |
| **SE±** | 1.01 | 0.30 |
| **CDat 5%** | 2.93 | 0.88 |

**Table.3** Long term effect of fertilization and manuring on uptake of N, P and K by soybean and safflower at harvest in soybean-safflower cropping sequence.

| Treatments | Nitrogen uptake (kg ha$^{-1}$) | | Phosphorous uptake (kg ha$^{-1}$) | | Potassium uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | Soybean | Safflower | Soybean | Safflower | Soybean | Safflower |
| $T_1$- 50% NPK | 74.95 | 29.34 | 13.15 | 10.13 | 33.83 | 42.99 |
| $T_2$-100% NPK | 93.50 | 46.37 | 17.10 | 15.30 | 41.10 | 62.27 |
| $T_{3}$-150% NPK | 110.29 | 54.97 | 22.94 | 21.89 | 48.64 | 72.17 |
| $T_4$-100% NPK + Hand weeding | 98.95 | 46.84 | 18.40 | 15.95 | 43.55 | 63.65 |
| $T_5$- 100%NPK +Zn | 104.60 | 49.50 | 20.58 | 18.51 | 46.29 | 67.82 |
| $T_6$- 100% NP | 90.01 | 37.23 | 17.74 | 13.85 | 39.56 | 50.83 |
| $T_7$- 100%N | 33.87 | 14.60 | 5.43 | 4.36 | 14.77 | 20.91 |
| $T_8$-100% NPK + FYM @5 t ha$^{-1}$ | 113.02 | 56.90 | 23.91 | 23.50 | 50.79 | 75.62 |
| $T_9$- 100% NPK –Sulphur | 89.70 | 45.49 | 18.50 | 16.60 | 39.65 | 64.12 |
| $T_{10}$- Only FYM @ 10 t ha$^{-1}$ | 92.05 | 39.77 | 18.96 | 13.92 | 40.90 | 50.72 |
| $T_{11}$- Absolute Control | 24.60 | 11.21 | 4.67 | 3.79 | 12.02 | 17.60 |
| **SE±** | 4.81 | 3.71 | 0.79 | 1.42 | 1.79 | 4.87 |
| **CD at 5%** | 13.90 | 10.71 | 2.27 | 4.10 | 5.17 | 14.07 |

**Table.4** Long term effect of fertilization and manuring on soil bacterial, fungal and actinomycetes population at harvest in soybean-safflower cropping sequence.

| Treatments | Bacteria (CFU×10$^{-7}$ g$^{-1}$ soil ) | Fungi ( CFU × 10$^{-3}$ g$^{-1}$ soil ) | Actinomycetes ( CFU × 10$^{-4}$ g$^{-1}$ soil ) |
|---|---|---|---|
| $T_1$- 50% NPK | 33.00 | 7.98 | 32.75 |
| $T_2$-100% NPK | 34.50 | 8.03 | 33.25 |
| $T_{3}$-150% NPK | 36.25 | 10.45 | 41.50 |
| $T_4$-100% NPK + Hand weeding | 41.00 | 9.20 | 35.25 |
| $T_5$- 100%NPK +Zn | 37.25 | 9.65 | 38.75 |
| $T_6$- 100% NP | 33.50 | 8.00 | 31.75 |
| $T_7$- 100%N | 31.50 | 7.00 | 29.50 |
| $T_8$-100% NPK + FYM @5 t ha$^{-1}$ | 59.25 | 11.30 | 50.75 |
| $T_9$- 100% NPK –Sulphur | 33.75 | 9.08 | 33.50 |
| $T_{10}$- Only FYM @ 10 t ha$^{-1}$ | 57.00 | 14.53 | 48.50 |
| $T_{11}$- Absolute Control | 31.00 | 6.55 | 26.75 |
| $T_{12}$- Fallow | 29.25 | 6.83 | 28.00 |
| **SE±** | 1.23 | 0.41 | 1.03 |
| **CD at 5%** | 3.54 | 1.17 | 2.96 |

**Table.5** Long term effect of fertilization and manuring on acid phosphate, dehydrogenase enzyme activity and alkaline phosphatise at harvest in soybean-safflower cropping sequence.

| Treatments | Acid phosphatise(ug P-NP $g^{-1}$ soil $hr^{-1}$) | Alkaline phosphatase (ug P-NP $g^{-1}$ soil $hr^{-1}$) | Dehydrogenase enzyme activity (ug TPF $g^{-1}$ soil 24 $hr^{-1}$) |
|---|---|---|---|
| $T_1$- 50% NPK | 41.94 | 121.02 | 50.93 |
| $T_2$-100% NPK | 46.31 | 124.89 | 50.94 |
| $T_3$.150% NPK | 57.12 | 138.88 | 64.39 |
| $T_4$-100% NPK + Hand weeding | 50.09 | 125.56 | 54.67 |
| $T_5$- 100%NPK +Zn | 50.71 | 134.50 | 62.04 |
| $T_6$- 100% NP | 42.56 | 123.51 | 52.91 |
| $T_7$- 100%N | 40.57 | 109.84 | 49.21 |
| $T_8$-100% NPK + FYM @5 t $ha^{-1}$ | 63.07 | 144.88 | 67.21 |
| $T_9$- 100% NPK –Sulphur | 45.13 | 121.23 | 56.03 |
| $T_{10}$- Only FYM @ 10 t $ha^{-1}$ | 52.42 | 135.58 | 62.86 |
| $T_{11}$- Absolute Control | 37.74 | 105.84 | 43.91 |
| $T_{12}$- Fallow | 37.53 | 98.15 | 46.12 |
| **SE±** | 1.51 | 2.82 | 1.85 |
| **CD at 5%** | 4.36 | 8.12 | 5.34 |

## Actinomycetes population

Actinomycetes population (Table 3) ranged from 26.75 CFU $\times 10^{-4}$ $g^{-1}$ soil to 50.75 CFU$\times$ $10^{-4}$ $g^{-1}$soil and found to be significantly maximum by application 100 % NPK+ FYM @ 5 t $ha^{-1}$ (50.75 CFU $\times$ $10^{-4}g^{-1}$soil) followed by only FYM@ 10 t $ha^{-1}$ (48.50 CFU$\times$ $10^{-4}g^{-1}$soil$g^{-1}$soil) respectively. The lowest population of actinomycetes was found in absolute control (26.75 CFU$\times 10^{-4}g^{-1}$soil) followed by fallow treatment (28.00 CFU $\times 10^{-4}g^{-1}$soil) and only 100% N (29.50 CFU $\times 10^{-4}$ $g^{-1}$soil), respectively during the year 2020-2021 in soybean-safflower cropping sequence. The actinomycetes population differed significantly due to different treatments of inorganic fertilizers and manuring due to long term fertilization under Vertisol at harvest in soybean-safflower cropping sequence because of an increase in the number of actinomycetes in soil. Selvi *et al.*, (2004) found that continuous application of NPK + FYM had a higher actinomycetes activity than the control and other treatments in inceptisol. Arbad and Ismail (2011); Shashidhar *et al.*, (2009) observed that 100% NPK + FYM and FYM @ 10 Mg $ha^{-1}$ had the greatest populations of actinomycetes and were noticeably superior to the other treatments and absolute control in long term fertilizer experiment in Vertisol

## Acid phosphatase

The data from the table 4 showed the enzyme activity in soil after harvest of soybean-safflower cropping sequence. The acid phosphate activity was different significantly due to different inorganic fertilizers and manuring treatments of long term fertilization and it was ranged from the 37.53ug P-NP $g^{-1}$ soil $hr^{-1}$ to 63.07ug P-NP $g^{-1}$ soil $hr^{-1}$ in soil respectively under long term fertilizer experiment in Vertisol. The acid phosphate was significantly recorded maximum in 100% NPK+ FYM@ 5 t $ha^{-1}$ (63.07ug P-NP $g^{-1}$ soil $hr^{-1}$) followed by 150%

NPK(57.12ug P-NP $g^{-1}$ soil $hr^{-1}$) and application of only FYM@ 10 t $ha^{-1}$ (52.42ug P-NP $g^{-1}$ soil $hr^{-1}$) in soil, respectively. The lowest acid phosphate was recorded by fallow treatment (37.53 ug P-NP $g^{-1}$ soil $hr^{-1}$) and followed by absolute control (37.74ug P-NP $g^{-1}$ soil $hr^{-1}$) and only 100% N (40.57 ug P-NP $g^{-1}$ soil $hr^{-1}$), respectively at the harvest of safflower. It was found due to effects of inorganic and manuring treatments. Srilatha *et al.,* (2013) they reported the highest acid phosphatase activity was found in the 150% NPK-treated plot (90.3 and 120.6 g PNP released $g^{-1}$ soil $h^{-1}$), was on par with the application of 100%NPK along with FYM @10 t $ha^{-1}$ (85.1 and 110.5 g PNP released $g^{-1}$ soil $h^{-1}$) and lowest in control. Meshram *et al.,* (2016) showed that in the soybean-safflower cropping systems 100% NPK with FYM significantly increased acid phosphatase activity (160.65 g PNP $g^{-1}$ soil 24 $hr^{-1}$).

## Alkaline phosphatase

The alkaline phosphatise (Table 4) was differed significantly due to different inorganic fertilizers and manuring treatments of long term fertilization and it was ranged from the 98.15 ug P-NP $g^{-1}$ soil $hr^{-1}$ to 144.88 ug P-NP $g^{-1}$ soil $hr^{-1}$ in soil respectively under long term fertilizer experiment in Vertisol. The alkaline phosphatase was significantly recorded maximum in 100% NPK+FYM@ 5 t $ha^{-1}$ (144.88 ug P-NP $g^{-1}$ soil $hr^{-1}$) followed by 150% NPK (138.88 ug P-NP $g^{-1}$ soil $hr^{-1}$) and application of only FYM@ 10 t $ha^{-1}$ (135.58 ug P-NP $g^{-1}$ soil $hr^{-1}$) in soil, respectively. The lowest alkaline phosphatase was recorded by fallow (98.15 ug P-NP $g^{-1}$ soil $hr^{-1}$) and followed by absolute control (105.84 ug P-NP $g^{-1}$ soil $hr^{-1}$) and only 100% N (109.84 ug P-NP $g^{-1}$ soil $hr^{-1}$), respectively at the harvest of safflower.

The alkaline phosphatase build up into soil might be due to the addition of organic manures caused a significantly larger build up of alkaline phosphate phosphatase activity over NPK fertilizer alone. Kumar *et al.,* (2005) and Aher *et al.,* (2015) reported the faster decomposition of organic materials in the presence of mineral N and P, which drive the manufacture of the enzyme, may be the cause of the rise in alkaline phosphatase activity by releasing more organically bound Phosphorous.

## Dehydrogenase enzyme activity

The dehydrogenase enzyme activity (Table 4) was differed significantly due to inorganic fertilizers and manuring on treatments of long term fertilization and it was ranged from 43.91ug TPF $g^{-1}$ soil 24 $hr^{-1}$ to 67.21ug TPF $g^{-1}$ soil 24 $hr^{-1}$ in soil respectively under long term fertilizer experiment in Vertisol. The dehydrogenase enzyme activity was significantly recorded maximum in 100% NPK+FYM @ 5 t $ha^{-1}$ (67.21 ug TPF $g^{-1}$ soil 24 $hr^{-1}$) followed by 150% NPK (64.39 ug TPF $g^{-1}$ soil 24 $hr^{-1}$) and application of only FYM @ 10 t $ha^{-1}$ (67.86 ug TPF $g^{-1}$ soil 24 $hr^{-1}$) in soil, respectively. The lowest dehydrogenase enzyme activity was recorded by absolute control (43.91 ug TPF $g^{-1}$ soil 24 $hr^{-1}$) and followed fallow treatment (46.12ug TPF $g^{-1}$ soil 24 $hr^{-1}$) and only 100% N (49.21 ug TPF $g^{-1}$ soil 24 $hr^{-1}$) respectively, at the harvest of safflower. It could be attributed due to application of organic manure alone or in combination with NPK fertilizers significantly increased dehydrogenase activity due to as compared to NPK fertilizer applied alone Lakshmi *et al.,* (2014) and Chu *et al.,* (2017) and Romero *et al.,* (2010).

The presence of higher carbon substrates, which are the only sources of carbon and energy for heterotrophs, is thought to be the cause of the increase in dehydrogenase enzyme activity Saha *et al.,* (2008) and Bhattacharya *et al.,* (2008) who showed that the application of FYM along with NPK increased the dehydrogenase enzyme activity in soil by four times (Burns, 1982).

Dehydrogenase activity is thought to represent the whole spectrum of oxidative activity of soil microflora and may be an excellent predictor of microbial activity Nannipieeri *et al.,* (1990). Goyal *et al.,* (1992) reported that dehydrogenase activity is susceptible to the inhibitory effects of high nitrogen fertilizer concentrations. (Casida *et al.,* 1964 and Marinari *et al.,* 2000) observed the mineral nitrogen fertilization had no impact on dehydrogenase activity and in sandy loam under maize, mineral N fertilizer had less of an impact than organic manuring.

The grain yield of soybean and safflower are recorded significantly by 100% NPK+ FYM @ 10 t $ha^{-1}$ as well as nutrient Uptake of plant such as N, P, K content in soybean and safflower plant increased with the application of inorganic fertilizer in conjunction with organic manure i.e. 100% NPK+ FYM @ 10 t $ha^{-1}$ in plant. These suggest that continuous use of balance fertilizer and in combination with organic manure and improve the nutrient uptake in soybean-safflower cropping sequence and soil biological properties of Vertisol.

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**How to cite this article:**

Priyanka S. Nakhate, Ramprasad N. Khandare, Pravin H. Vaidya and Ravi H. Wanjari. 2023. Effect of Long Fertilization and Manuring on Yield, Nutrient Uptake and Soil Microbial Properties in Soybean-Safflower Cropping Sequence under Vertisol. *Int.J.Curr.Microbiol.App.Sci.* 12(03): 119-131.
**doi:** https://doi.org/10.20546/ijcmas.2023.1203.016