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Impact of Integrated Nutrient Management on Growth and Properties of Soil in Sunflower (*Helianthus annuus* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted on sandy loam soil at Udai Pratap (Autonomous) College, Varanasi with sunflower, variety PSH-50 as test crop during *Zaid* season (2020-2021) to study the impact of integrated use of inorganic fertilizers, FYM and bio-fertilizers on performance of sunflower (*Helianthus annuus* L.) and soil properties. The experiment was laid out in a randomized block design (RBD) with four replications. The treatments were T_1 (control), T_2 (50% RDF), T_3 (100% RDF), T_4 (125% RDF), T_5 (50% RDF + 15 tons FYM ha^{-1} + PSB + *Azotobacter*), T_6 (75% RDF +15 tons FYM ha^{-1} + PSB + *Azotobacter*) and T_7 (100% RDF +15 tons FYM ha^{-1} + PSB + *Azotobacter*). It is evident from the results that maximum plant height, number of leaves, capitulum diameter, test weight and oil content were obtained with treatment T_6 (75% RDF +15 tons FYM ha^{-1} + PSB + *Azotobacter*). It was also found that nutrient availability (NPKS) and nutrient uptake (NPKS) was also superior in treatment T_6 (75% RDF +15 tons FYM ha^{-1} + PSB + *Azotobacter*).

Keywords: Inorganic fertilizers; FYM; PSB; RDF; bio-fertilizers; soil fertility; capitulum diameter; NPK; animal manure; crop nutrition.

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a most important oilseed crop for its premier oil and manifold uses of both industrial and pharmaceutical importance. In India during *Kharif* 2020-21 sunflower crop has occupied 1.185 lakh hectares (2.928 lakh acres) as against 0.975 lakh ha (2.409 lakh acres) during the same period in 2019-20. Karnataka 0.995 lakh ha (2.459 lakh acres), Maharashtra 0.150 lakh ha (0.371 lakh acres) and Andhra Pradesh 0.019 lakh ha (0.047 lakh acres) are major sunflower growing states in India during *Kharif* 2020-21. Manure has always been considered as a beneficial input to the soil for crop production. In a broad sense, manure management relates to the appropriate use of animal manure according to each farm's capabilities and goals while improving soil quality, crop nutrition, and farm profits. Phosphorous solubilizing bacteria (PSB) are a group of beneficial bacteria capable of hydrolyzing organic and inorganic phosphorous from insoluble compounds. When PSB used with phosphate, it can save about 50% of the crop requirement of phosphatic fertilizer. *Azotobacter* fix nitrogen aerobically, elaborate plant hormones, solubilize phosphates and also suppress phytopathogens or reduce their deleterious effect. Application of wild type *Azotobacter* spp. results in better yield of oil seeds like mustard and sunflower and several other crops. The integrated use of inorganic fertilizers, farmyard manure (FYM), and bio-fertilizers has garnered significant attention in modern agricultural practices due to its potential impact on crop performance and soil health [1]. Sunflower (*Helianthus annuus* L.), a vital oilseed crop, stands to benefit from this integrated approach, presenting a sustainable solution for optimizing yield and maintaining soil fertility. Inorganic fertilizers contribute essential nutrients that are readily available to the sunflower crop, promoting robust growth and enhanced productivity. Concurrently, farmyard manure enriches the soil with organic matter, fostering microbial activity and improving overall soil structure. Bio-fertilizers, containing beneficial microorganisms, play a pivotal role in fostering nutrient uptake and augmenting plant growth, further bolstering sunflower performance. This integrated approach not only maximizes crop yield but also positively influences soil properties. The symbiotic relationship among inorganic fertilizers, FYM, and bio-fertilizers creates a balanced nutrient environment, reducing the environmental impact associated with excessive fertilizer use. The study of this tripartite interaction provides insights into sustainable agricultural practices, emphasizing the importance of a holistic approach for optimizing sunflower cultivation and preserving soil quality.

2. MATERIALS AND METHODS

A field experiment was conducted in *zaid* season (2021) at the agricultural farm of Udai Pratap Autonomous College, which was sandy loam in texture, slightly saline and non-alkaline in reaction. The initial physicochemical properties of experimental soil were bulk density 1.42 g cm^{-3}, particle density 2.65 g cm^{-3}, pH (1:2.5) 7.40, EC 0.33 dSm^{-1}, organic carbon 0.37%, available nitrogen 239.45 kg ha^{-1}, available phosphorus 7.42 kg ha^{-1}, available potassium 221.36 kg ha^{-1} and available sulphur 9.50 kg ha^{-1}. The treatments were T_1- (control), T_2- (50% RDF), T_3- (100% RDF), T_4- (125% RDF), T_5- (50% RDF +

15 tons FYM ha^{-1} + PSB + *Azotobacter*), T_6- (75% RDF +15 tons FYM ha^{-1} + PSB + *Azotobacter*) and T_7- (100% RDF +15 tons FYM ha^{-1} + PSB + *Azotobacter*). The treatments were applied in a randomized block design (RBD) with three replications. Recommended doses of NPK @ 60, 90 and 60 kg ha^{-1}, respectively were applied to sunflower plots. Half dose of nitrogen, full dose of phosphorous and potash were applied as per treatment at time of showing. Rest half dose of nitrogen was applied in two split doses as top dressing first at button stage and second at flowering stage. Seed treatment was done with PSB + *Azotobacter* @ 200 g/10 kg with a 10% solution of Jaggery as a sticker before sowing. FYM was also applied as basal dose as per treatment before 30 days of sowing. Sunflower seeds were sown at the rate of 5 kg ha^{-1}. Sowing was done in line with a spacing of 60 × 30 cm. Soil samples from 0-15 cm depth were collected in a plastic bag from individual plots at 45 DAS and at harvesting of the crop. The soil sample of each plot was air-dried, processed to pass through a 2 mm round hole sieve and analyzed for oxidizable organic carbon (1*N* $K_2Cr_2O_7$), available N (0.32% alkaline $KMnO_4$ oxidizable), P (0.5 M $NaHCO_3$ extractable), K (1 *N* neutral ammonium acetate extractable) and S (0.15% $CaCl_2$) following the methods described by Walkley and Black (1934), Subbiah and Asija (1956), Olsen’s et al. (1995), Hanway and Heidel (1952) and Williams and Steinbergs (1959), respectively. Soil pH was determined in 2:1 soil: water suspension with the help of glass electrode in digital pH meter and electrical conductivity of soil was measured in the supernatant liquid of soil water suspension (1:2) by Conductivity Bridge. Bulk density in undisturbed samples collected with metal cores of 4.2 cm diameter and 5.8 cm height was measured. Five plants were marked randomly in each replicated plot and plant height was measured from the base of the plant to the tip of the uppermost latest leaf for calculating mean plant height at 30 DAS, 60 DAS and at harvesting. The number of leaves of the same selected plants was counted and the average was obtained per plant. The capitulum diameter was recorded in each plot and designated as the mean diameter per plant. After harvesting and threshing, the test weight of the seeds was recorded. The data collected from the field and laboratory was analyzed statistically using the standard procedure of randomized block design. Critical difference (C.D.) and standard error of the mean (SEM) were calculated to determine the significance among treatment means.

3. RESULTS AND DISCUSSION

3.1 Plant Height

It is evident from the result that plant height of sunflower significantly increased with application of NPK, FYM and bio-fertilizers (PSB and *Azotobacter*) in comparison to control at all the growth stages (Table 1). Plant height of sunflower also increased with advancement of the crop age. Effect of different treatment on plant height could be arranged in the order of $T_6>T_7>T_5>T_3>T_4>T_2>T_1$.At all growth stages of plant, the maximum plant height i.e., 61.04cm, 201.83cm and 205.29cm at 30 DAS, 60 DAS and at maturity stage, respectively were recorded under T_6 (i.e., 75% NPK, FYM 15 tons ha^{-1}, and bio-fertilizers) and minimum plant height was observed in T_1 (control). Application of NPK, FYM and bio-fertilizers (PSB and *Azotobacter*) increased the plant height might be due to rapid cell division and cell elongation in the meristematic region. It was also observed that increasing rate of NPK significantly increased plant height due to sufficient supply of nutrients throughout growing periods of crop. It was also recorded that conjoint use of inorganic fertilizers and organic manures significantly increased plant height; similar results are observed by Patra et al. [2].

3.2 Number of Leaves

It is evident from results that the number of leaves increased continuously with crop age up to harvest under all treatments (Table 1). Data showed that the effect of different doses of inorganic fertilizers, FYM, and Bio-fertilizers (PSB and *Azotobacter*) addition on sunflower was statistically significant in the order of $T_6>T_7>T_5>T_3>T_4>T_2>T_1$. The addition of 75% NPK, FYM 15 tons ha^{-1}, and bio-fertilizers (PSB and *Azotobacter*) in T_6 showed a significant increase in plant leaves of sunflower crop over other treatments. Results indicated that conjoint use of organic and inorganic forms of fertilizers significantly increase the number of leaves that might be attributed by continuous supply of sufficient plant nutrients during experimentation. Similar results are also reported by Rasool et al. [3] and Gupta et al*.* [4].

3.3 Capitulum Diameter

The data revealed that the effect of various treatments on capitulum diameter of sunflower was found in order of $T_6>T_7>T_5>T_3>T_4>T_2>T_1$

with the highest size observed in T_6 and lowest size in T_1 with the values of 18.56 cm and 12.82 cm respectively (Table 1). Results indicated that application of FYM and bio-fertilizers along with chemical fertilizers leads to the formation of large sized capitula compared to chemical fertilizers alone. Similar results were reported by Patra et al*.* [2].

3.4 Test Weight and Oil Content

Thousand grain weight was varied significantly by the application of organic manures and inorganic fertilizer levels the mean test weight of seeds was 50.53 gm. Application of 75% NPK, FYM (15 tons ha^{-1}), and bio-fertilizers (PSB and *Azotobacter*) in T_6 recorded highest seed weight (55.70) followed by T_7 and T_5 which were higher than T_1.

The highest percentage (42.44%) of seed oil belonged to T_6 with application of 75% NPK, FYM 15 tons ha^{-1}, and bio-fertilizers (PSB and *Azotobacter*) and the least content of oil percentage was recorded in treatment T_1 (control). Increasing nutrients consumption in this experiment did not only increase the oil percentage of seeds but it also reduced consumption of chemical fertilizers (Table 1). In the experiment of Yousef and Youdi, [5] with increasing chemical fertilizer to a certain extent, the percentage of oil increased but then decreased. With the increase in nitrogen consumption, the formation of nitrogen-containing protein precursor's increases and protein formation increases in providing photosynthetic materials, resulting in a decrease in the amount of materials needed to convert to oil.

3.5 Nutrients Uptake

Application of NPK either alone or in combination with FYM and bio-fertilizers recorded significantly higher total uptake of N, P, K, and S over that of control. Application of 75% NPK, FYM 15 tons ha^{-1} and bio-fertilizers recorded significantly higher N, P, K and S uptake in comparison to other treatments (Table 1). The increase in uptake of nutrients in bio-fertilizer treated plot may be due to extra amount of nutrients supplied in bio-fertilizer treated plots. Bio-fertilizers helped in providing conductive physical environment facility and better atmospheric nitrogen fixation through *Azotobacter*. The effect of various treatments on N, P, K and S uptake could be arranged in order of $T_6>T_7>T_5>T_3>T_4>T_2>T_1$. The uptake of N varied from 25.34 to 32.71 Kg ha^{-1}, P from 125.04 to 142.09 Kg ha^{-1}, K from 32.05 to 38.17 and S from 16.76 to 27.40 Kg ha^{-1}. The substantial improvement in nutrient uptake indicates the requirement of integration of nutrient as supply sources for sunflower crop and also for overall improvement in soil physico - chemical properties and biological environment. The conjunctive use of organic and inorganic source of fertilizer significantly increased both the concentration and uptake of N,P, K and S**.** The application of organic manure alone or along with bio-fertilizer inoculation significantly improved the N, P, K and S uptake.

3.6 Soil pH

As evident from results the application of FYM with chemical fertilizers decreased the soil pH as compared to chemical fertilizers alone. Effect of different treatments on soil pH could be arranged in order of $T_1>T_2>T_4>T_3>T_5>T_7>T_6$ and the values varied from 7.27 to 7.45, 7.24 to 7.37, 7.04 to 7.32, 6.92 to 7.31, 6.77 to 7.21, 6.69 to 6.91 and 6.62 to 6.73 under respective treatments (Table 2). The pH of soil water suspension increased with day after sowing and highest values were recorded at harvesting of crop might be attributed due to decrease in organic matter with time. Organic matter (FYM) treated plots recorded low pH as compared to chemical fertilizer alone may be due to release of organic acid during decomposition of added organic manure and removal off during irrigation of crop. The soil pH was increased with chemical application than organic manures similar results reported by Argal et al. [6].

3.7 Electrical Conductivity

The electrical conductivity under different treatments decreased with advancement of crop age. The EC of soil water suspension of sunflower plots increased continuously with day after sowing under all treatments. The effect of different treatments on EC of soil could be arranged in order $T_1>T_2>T_4>T_3>T_5>T_7>T_6$ and the values varied from 0.31 to 0.33, 0.30 to 0.31, 0.29 to 0.30, 0.29 to 0.30, 0.28 to 0.28, 0.27 to 0.28 and 0.26 to 0.27 dSm^{-1} under respective treatments (Table 2). Application of 75% NPK, FYM 15 tons ha^{-1} and bio-fertilizers in T_6 recorded significantly lower EC as compared to other treatments at all growth stages. Lower EC of FYM treated plots might be due to release of organic acid during decomposition of FYM which reduce the salt content by exchange phenomena. Increasing levels of NPK decreases the EC of soil might be due to formation of various acids during reactions of fertilizers which removed the salt from exchange sites [6].

3.8 Organic Carbon

In general, organic carbon content of soil gradually decreases with age of crop. In field experiment the combined application of 75% NPK, FYM 15 tons ha^{-1} and bio-fertilizers in T_6 contains the maximum organic carbon content at all growth stages. The effect of various treatments based on organic carbon content in the soil could be arranged in order $T_6>T_7>T_5>T_3>T_4>T_2>T_1$ and the values were 0.50, 0.48, 0.47, 0.45, 0.45, 0.43 and 0.42% at 45 DAS; 0.46, 0.44, 0.43, 0.43, 0.41, 0.39, and 0.38% at the end of the experiment (Table 2). The increase in the organic carbon content in treatment T_6 (75% NPK, FYM 15 tons ha^{-1} and bio-fertilizers) may be attributed due to the direct incorporation of organic materials, and bio-fertilizers (PSB and *Azotobacter*). Application of chemical fertilizers alone or in combination with organic manures increased the organic carbon content significantly over control. Improvement in organic carbon status in treatments receiving FYM and bio-fertilizers may be due to their stimulating effect on growth and activity of micro-organisms. The effect was further enhanced by addition of fertilizers that improved the root and shoot growth and highest production of root biomass that might have increased organic carbon content. Root development of the crop which brought about improvement in water stable aggregates under organic matter applied plots observation was also noted by Shrivastava and Gupta [7].

3.9 Available Nitrogen

The data showed that available nitrogen content of experimental soil decreased continuously with advancement in growth stage up to harvesting. The effect of various treatments of Inorganic fertilizers, FYM and bio-fertilizers (PSB and *Azotobacter*) on available nitrogen was found in the order of $T_6>T_7>T_5>T_3>T_4>T_2>T_1$ with the values varied between 294.87 to 273.53, 290.95 to 268.90, 284.70 to 263.67, 279.53 to 259.79, 273.91 to 254.95, 266.50 to 248.93 and 258.00 to 243.39 kg ha^{-1} under respective treatments. The available nitrogen content differed significantly due to addition of various levels of organic and inorganic fertilizers. Significantly higher available nitrogen content was recorded in plot T_6 (75% NPK, FYM 15 tons ha^{-1} and bio-fertilizers) which was treated with chemical fertilizers, organic manures and bio-fertilizers (Table 2). Application of fertilizers either alone or in combination with organism was significantly increased the available nitrogen content over control. The lowest value of available nitrogen in control may be due to mining of nutrients with cropping without fertilization. Increase in available nitrogen with organic manures is attributed to its direct addition through FYM. Similar findings have also been reported by Kumar et al. [8]

3.10 Available Phosphorous

Available phosphorous content of soil significantly Increased with addition of chemical fertilizers along with organic manures and bio-fertilizers (PSB and *Azotobacter*). The effect of different treatments on available phosphorous content of soil of sunflower plot was found in order $T_6>T_7>T_5>T_3>T_4>T_2>T_1$ with values varied from 28.53 to 17.75, 27.80 to 16.64, 25.81 to 15.75, 24.55 to 14.85, 21.64 to 12.74, 19.64 to 10.71 and 17.68 to 7.85 kg ha^{-1} under respective treatments (Table 2). Incorporation of FYM along with inorganic fertilizers have increased the availability of phosphorous to crop. Increase in available phosphorous content with the integrated use of fertilizers with organic manures and bio-fertilizers was ascribed to release of organic acids during decomposition which help in releasing native phosphorous through solubilizing action of these acids. Also, organic matter forms a coating on sesquioxide’s and make them inactive and thus decrease the phosphate fixing capacity of soil due to which increase the availability of phosphorous to plants. Similar results were also observed by Kumar et al. [8]

3.11 Available Potassium

As evident from results, potassium content of soil gradually decreased with age of crop. The data revealed that application of either fertilizer alone or in combination with organic matter recorded an increase in available potassium content of soil over control (Table 2). Increase in available potassium due to addition of FYM may be ascribed to the reduction of potassium fixation and release of potassium due to interaction of organic matter with clay, besides the direct potassium addition to soil. [9]. In case of chemical fertilizer alone, the available potassium significantly increases with increasing level of

NPK might be due to higher amount of unused potassium. It was also observed that increasing level of fertilizer and FYM increased the available potassium content of soil and treatments arranged in the order of $T_6>T_7>T_5>T_3>T_4>T_2>T_1$ with values varied from 291.14 to 275.41, 287.73 to 265.08, 276.32 to 257.96, 269.50 to 248.48, 261.50 to 238.49, 255.23 to 232.01 and 245.33 to 224.66 kg ha^{-1} under respective treatments [10].

3.12 Available Sulphur

Increasing levels of chemical fertilizers were associated with improvement in sulphur availability in soil. Available sulphur content in soil continuously decreased with advancement in crop growth stage under all treatments. The effect of different treatments of NPK, FYM and bio-fertilizers on available sulphur content of soil was found in order $T_6>T_7>T_5>T_3>T_4>T_2>T_1$ and the values of available sulphur varied from 25.64 to 21.20, 24.51 to 19.74, 22.38 to 18.77, 20.59 to 17.71, 18.67 to 14.73, 16.69 to 10.69 and 12.59 to 9.48 kg ha^{-1} under respective treatments (Table 2). The data revealed that application of FYM recorded an increase in available sulphur content of soil over chemical fertilizer alone. Addition of 75% NPK, FYM 15 tons ha^{-1} and bio-fertilizers in T_6 have shown a remarkable significant increase in available sulphur content of experimental soil. The increase in available sulphur content of soil in treated plot over control could be due to no addition of sulphur in control and removal by crops because sulphur is known to be an integral part of soil organic matter. Addition of FYM contributed to increase in amount of sulphur to the soil at 50% substitution rate which resulted in increased content of sulphur in soil. Increase in sulphur with the application of fertilizers might be due to addition of SSP contained about 12%, similar results were reported by Singh et al. [11].

4. CONCLUSION

It is concluded from the present study that the application of 75% RDF +15 tons FYM ha^{-1} + PSB + *Azotobacter* not only produce the higher yield of sunflower but also improved the soil fertility as compared to application of 100% or 125% chemical fertilizers alone. Thus, optimum mineral nutrition in conjunction with FYM, PSB and *Azotobacter* can play a vital role to reducing 25% chemical fertilizer and exploiting high yield potential of sunflower through the favorable effect of nutrient supply and soil properties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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