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RESEARCH ARTICLE

IMPACT OF BIO-INOCULANTS AND DIFFERENT LEVELS OF NPK FERTILIZERS APPLICATION ON SOIL NUTRIENT STATUS AND YIELD OF CHRYSANTHEMUM IN PROTECTED CONDITION

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Abstract: Alternatives to fertilizers are required due to the rising expense of fertilizers with lower nutrient usage efficiency. The availability of macro and micronutrients is influenced by the various chemical changes that soil microorganisms contribute to. This study evaluated the effectiveness of various microbial strains for enhancing plant nutrient availability in soil. The present investigation was conducted during 2021–2022 at the College of Agriculture, Shivamogga, Karnataka, to assess the effect of bio-inoculants and graded potassium levels on soil chemical properties, nutrient availability, and yield in chrysanthemum (Chrysanthemum morifolium Ramat.). The experiment was laid out in a Randomized Complete Block Design (RCBD) with ten treatments and three replications, using the variety 'Kolar Local.' Bio-inoculants including *Bacillus mucilaginosus* (KSB), *Aspergillus awamori* (KSF), *Azotobacter chroococcum*, *Pseudomonas striata* (PSB), and *Glomus fasciculatum* (VAM) were incorporated along with FYM and chemical fertilizers. Soil analysis post-harvest revealed that treatment T7 (100% N & P_2O_5 + 75% K_2O + KSB + KSF) recorded optimum soil pH (6.80), EC (0.36 dS/m), and significantly higher available nitrogen (292.13 kg/ha), phosphorus (85.67 kg/ha), and potassium (205.68 kg/ha). Flower yield (2.68 t/560 m²) and sucker yield (21,315.5 suckers/560 m²) were also highest in T7, showing 34.67% and 78.94% increases, respectively. The enhanced nutrient availability and yield were attributed to improved microbial activity, nutrient solubilization, and hormone production. This study confirms that integrated nutrient management using bio-fertilizers with reduced chemical fertilizers is a sustainable approach to enhance soil fertility, flower yield, and quality in chrysanthemum cultivation.

Keywords: Soil chemical properties, microbial inoculants, KSB, KSF

INTRODUCTION

Flowers are closely connected to human life, symbolizing nature's beauty and used widely in religious and social events. They represent emotions like love, grace, and spirituality. The horticulture industry also plays a vital role in the economy through domestic sales and exports. Among ornamental flowers, chrysanthemum stands out for its vibrant colors and beauty. Chrysanthemum (*Chrysanthemum morifolium* Ramat.), from the Asteraceae family (2n = 36), is one of the oldest cultivated flowers. Native to Asia and Europe, it was praised by Confucius in 550 BC as "yellow glory." Known as the "Queen of the East," it is commercially grown in countries like Japan, China, and India.

In India, it's called *Guldaudi*, *Chandramallika*, *Samanti*, or *Sevanti*, and is widely cultivated in Maharashtra, Tamil Nadu, Rajasthan, Karnataka, and Madhya Pradesh. It also holds significance as the floral emblem of Japan's imperial family. They are used for garlands, decorations, religious rituals, and as cut flowers. They also serve as sources of essential oils and natural pesticides. With a wide range of colors and the ability to bloom year-round,

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chrysanthemums rank second in the global cut flower trade.

The use of bio-fertilizers in chrysanthemum cultivation has gained significant importance due to their ability to enhance growth, yield, and flower quality while maintaining soil health. Bio-fertilizers such as Azotobacter, which fixes atmospheric nitrogen, and phosphate-solubilizing bacteria (PSB), which increase phosphorus availability, contribute to better root and flower development. Potassium-solubilizing bacteria (KSB) and fungi like *Aspergillus awamori* help in releasing potassium from soil minerals, thereby improving flower size, color, and shelf life. Additionally, vesicular-arbuscular mycorrhizae (VAM) enhance water and nutrient absorption, promoting overall plant vigor. The combined use of these bio-inoculants with reduced chemical fertilizers supports sustainable and eco-friendly chrysanthemum production. Research has shown that such integrated nutrient management not only improves soil fertility but also results in higher flower yield, better quality blooms, and extended post-harvest life.

MATERIALS AND METHODS

The present study was carried out at the College of Agriculture in Shivamogga, Karnataka, between 2021 and 2022. Plants were planted in ridges and furrows using rooted terminal cuttings of the chrysanthemum variety Kolar Local, with a plot size of 3.3 × 1 m and a spacing of 30 x 30 cm (33 plants per plot). Three replications were used in the Randomized Complete Block Design (RCBD) experiment. Ten treatments in all were used, including: T1 -100% RDF (control); T2 -100% NPK + KSB; T3 -100% NPK + KSF; T4 -100% NPK + KSB+ KSF; T5 -100% N & P+ 75% K+ KSB; T6 -100% N & P+ 75% K+ KSF; T7 -100% N & P+ 75% K+ KSB+KSF; T8 -100% N & P+ 125% K+ KSB; T9 -100% N & P+ 125% K+ KSF; T10 - 100% N & P+ 125% K+ KSB +KSF.

Five days before to planting, five different types of bio-inoculants, *Bacillus mucilaginosus*, *Aspergillus awamori*, *Azotobacter chroccacum*, *Pseudomonas striata*, and *Glomus fasciculatum*were applied in this study. Following the direct incorporation of the bio-inoculants into the soil along with farm yard manure (FYM). The recommended nutrient management for the crop includes the application of fertilizers at a dosage of 40:60:40 kg NPK per acre, supplemented with 8 tons of Farm Yard Manure (FYM) per acre, which is uniformly applied across all treatments. In addition to chemical fertilizers and FYM, bio-inoculants play a crucial role in enhancing nutrient availability and soil health. A combined dose of 5 kg/acre of bio-inoculants is applied, which includes Potassium Solubilizing Bacteria (KSB -*Bacillus mucilaginosus*) and Potassium Solubilizing Fungus (KSF – *Aspergillus awamori*). Furthermore, the application of FYM along with other beneficial microorganisms such as *Azotobacter chroococcum*, Vesicular Arbuscular Mycorrhiza (VAM – *Glomus fasciculatum*), and Phosphate Solubilizing Bacteria (PSB – Pseudomonas striata) at 5 kg/acre is common for all treatments, contributing to improved nutrient uptake and overall plant health. The data were then subjected to scientific analysis, and the findings were interpreted and discussed as follows.

Collection and preparation of soil samples

During harvesting stage, soil samples were taken at random from each treatment. In order to analyze pH, EC, organic carbon, accessible N, P, and K, the collected soil samples were well mixed, transported to the lab, dried in the shade, and sieved through a 2 mm sieve. For further investigation, the sieved samples were labeled appropriately and kept in plastic bags. Every precaution was taken in the estimations, including using double-distilled water as recommended by Jackson (1973), A.R. grade chemicals, and uncontaminated glassware.

Chemical analysis of soil

Soil pH: Using a 1:2.5 (soil: water) suspension, the potentiometry method assessed the hydrogen ion activity, which is expressed as pH, using a digital pH meter (Jackson, 1973).

Electrical conductivity: The digital electrical conductivity meter was used to measure the EC using the conductometry method and the clear supernatant that was extracted from the pH suspension (Jackson, 1973)

Organic carbon: The wet oxidation method developed by Walkley and Black was used to determine the amount of organic carbon in soil (Jackson, 1973).

Available nitrogen: As recommended by Subbiah and Asija (1956), it was calculated using the alkaline potassium permanganate method.

Available phosphorus: Bray's approach, as described by Bray and Kurtz (1945), was used to determine it.

Available potassium: A flame photometer was used to quantify it after neutral normal ammonium acetate was used as an extractant (Jackson, 1973).

Initial soil chemical properties of experimental site

The experiment was conducted in red sandy loam soil. The chemical composition of soil is analyzed and the results are furnished below. According to the potentiometry approach, the soil study showed that the pH of the soil was 5.80, indicating an acidic reaction. Using the conductometry method, the electrical conductivity was determined to be 0.36 dS/m, which is regarded as normal. Walkley and Black's wet oxidation method was used to measure the organic carbon content, which came out to be 0.55% and classified as medium. According to the alkaline potassium permanganate technique, the available nitrogen concentration was 225.55 kg/ha, falling into the poor group. According to Bray's technique, the accessible phosphorus (P_2O_5) level was 60 kg/ha, which is regarded as high. Meanwhile, the available potassium (K_2O) content was 120.66 kg/ha, falling in the medium range, determined using the flame photometric method with NH_4OAc extractant.

RESULTS AND DISCUSSION

Chemical properties and available nutrients in soil

Significant differences exist between the treatments in terms of the amount of available nitrogen, phosphorous, and potassium in the soil, according to the data on major soil nutrient content shown in Table 1.

1. Soil pH, EC (dS/m) and Organic carbon (g/kg)

The effect of bio-inoculants with graded levels of potassium on soil pH, EC and organic carbon content were found to be non-significant. However, the soil recorded neutral pH range (6.70-7.01), EC values (0.33-0.39 dS/m) and medium organic carbon status (6.24-6.27 g /kg) of soil due to different treatments effects.

2. Available Nitrogen (kg/ ha)

Significantly the highest available nitrogen in the soil (292.13 kg/ha) was recorded with the treatment T7 which received 100 per cent N and P_2O_5 + 75 per cent K_2O + KSB + KSF and it was statistically on par with T4 and T10 (290.84 and 286.78 kg/ha, respectively). However, lowest available nitrogen in soil (260.62 kg /ha) was registered in T1 (RDF).

3. Available Phosphorus (kg /ha)

Application of 100 per cent N and P_2O_5 + 75 per cent K_2O + KSB +KSF (T7) recorded significantly maximum available phosphorus (85.67 kg/ha) in the soil and it was statistically on par with T4 (84.87 kg /ha). However, minimum available phosphorus in the soil (65.04 kg /ha) was registered with RDF (T1).

4. Available Potassium (kg /ha)

Applying 100% N and P_2O_5 + 75% K_2O + KSB + KSF resulted in the significantly greatest amount of potassium accessible in the soil (205.68 kg/ha), which was statistically comparable to T4 (195.96 kg/ha). On the other hand, T1 that received RDF reported the lowest amount of potassium in the soil (156.95 kg/ha).

When compared to the other treatments, the one consisting of 100% N and P_2O_5 + 75% K_2O + KSB + KSF (T7) had the best pH (6.80) and electrical conductivity (0.36 dS /m). This could be because the inoculation of biofertilizers caused more organic acid to be released, which in turn caused the biofertilizers to break down organic matter. Consequently, buffering the pH of the soil and preventing further fluctuations.

Notably, when 100% N and P_2O_5 + 75% K_2O + KSB + KSF (T7) were applied to the soil, the highest levels of accessible nitrogen (292.13 kg/ha), phosphorus (85.67 kg/ha), and potassium (205.68 kg/ha) were seen in comparison to (T1) RDF. Research on how biofertilizers increase nutrient availability is also available (Mishra *et al*., 1999).

The adequate supply of nutrients made available to the plants by applied NPK fertilizers may be the likely cause of elevated NPK values following treatment application. The addition of chemical and biofertilizers may be the cause of the increase in nutrient availability. Furthermore, the organic acids and carbon dioxide generated during the decomposition process enhanced the availability of nutrients from both natural and applied fertilizers. fixed potassium through the release of enzymes and organic acids. All of these could have had a part in the soil's improved availability of these nutrients. According to Shaktawat and Shekhawat (2010), the usage of chemical fertilizers, organic manures, particularly FYM, and bacterial fertilizers that fix atmospheric nitrogen biologically were the causes of the soil's elevated nitrogen status. The organic acids generated by the increased microbial population in the soil as a result of applying KSB and KSF may be the cause of the buildup of accessible potassium in the soil. Conversely, the favorable interaction between RDF and biofertilizers may be the cause of the soil's increased potassium content, as it increases the amount of potassium available in the soil's nutrient pool (Laishram, 2013). Additionally, Godse *et al*. (2006) found that the application of both inorganic and biofertilizers enhanced the availability of N, P, and K in the soil.

Table1. Impact of Bio-inoculants and different levels of NPK fertilizers application on soil nutrient status of Chrysanthemum in protected condition

Treatments	pH	EC (dS/m)	Organic Carbon (%)	Available nitrogen (Kg/ha)	Available phosphorus (Kg/ha)	Available potassium (Kg/ha)
T_1	7.01	0.39	6.27	260.62	65.04	156.95
T_2	7.00	0.39	6.26	280.98	80.66	211.37
T_3	6.86	0.38	6.25	277.48	73.45	181.34
T_4	6.98	0.37	6.26	290.84	84.87	195.96

T_5	6.88	0.37	6.26	282.62	81.34	188.96
T_6	6.74	0.36	6.27	277.68	76.12	182.55
T_7	6.80	0.36	6.24	292.13	85.67	205.68
T_8	6.90	0.35	6.25	279.52	78.98	183.14
T_9	6.70	0.34	6.26	272.54	69.75	180.32
T_{10}	6.81	0.33	6.24	286.78	83.65	190.74
S. Em ±	**0.16**	**0.01**	**0.10**	**4.45**	**1.56**	**3.64**
C.D. @ 5%	**NS**	**NS**	**NS**	**13.34**	**4.59**	**10.66**

Flower and sucker yield and its attributing characters

Chrysanthemum flower output was significantly impacted by several treatments. Sucker yield was 21315.5 suckers/560m^2 and flower yield per polyhouse was 2.68 t/560m^2. The impact of bio-inoculants with varying concentrations of potassium of chrysanthemum on the percentage increase in flower output per 560m^2 is shown in Figure 1. T7 exhibits the largest increase in flower yield per 560m2, at 34.67%.

Increased flower yield due to the rapid and aggressive proliferation of microorganisms, especially in the rhizosphere. They create the perfect environment for nitrogen fixation and potassium solubilization more quickly by providing nitrogen through nitrogenous fertilizers and other nutrients, bacterial secretion, hormone production, and antibacterial and antifungal compounds. They promoted growth and ultimately increased marigold production (Kumar *et al*., 2009). The impact of bio-inoculants containing varying concentrations of potassium of chrysanthemum on the percentage increase in flower and sucker production per 560m^2 is shown in Figure 2. T7 exhibits the largest percentage increase in flower production (34.67%) and sucker yield (78.94%) per 560m^2.

Improved yield attribute performance and greater yield may be the result of KSB, KSF, Azotobacter, VAM, and PSB's possible contributions through nutrient and water intake, increased leaf number, and increased leaf area. Better plant growth, higher flower production per hectare, and more flowers per plant may have resulted from increased food buildup brought on by increased photosynthesis. Additionally, the presence of growth-promoting compounds such as auxin, gibberellins, and cytokinin caused by the usage of bio-fertilizers would have aided in the production and accumulation of sink, improving growth and ultimately increasing the number of blooms. better flower production per 560m2 and more flowers per plant as a result. The outcomes concur with previous research in marigold by Thumar*et al*. (2013) and Jadhav *et al*. (2014). Patanwar*et al*., 2014 in chrysanthemum, Sheergojri*et al*., 2013 in dahlia, Meshram *et al*., 2008 in chrysanthemum.

Table 2. Impact of Bio-inoculants and different levels of NPK fertilizers application on yield of Chrysanthemum in protected condition

Treatments	**Flower yield per 560m^2 (t)**	**Number of suckers per 560m^2**
T_1	1.99	21315.5
T_2	2.38	32534.1
T_3	2.26	26363.9
T_4	2.55	36460.7
T_5	2.45	34216.9
T_6	2.26	31412.3
T_7	2.68	38143.5
T_8	2.33	28607.6
T_9	2.18	24681.2
T_{10}	2.49	35338.5
S. Em ±	**0.08**	**1273.14**
C.D. @ 5%	**0.23**	**3782.69**

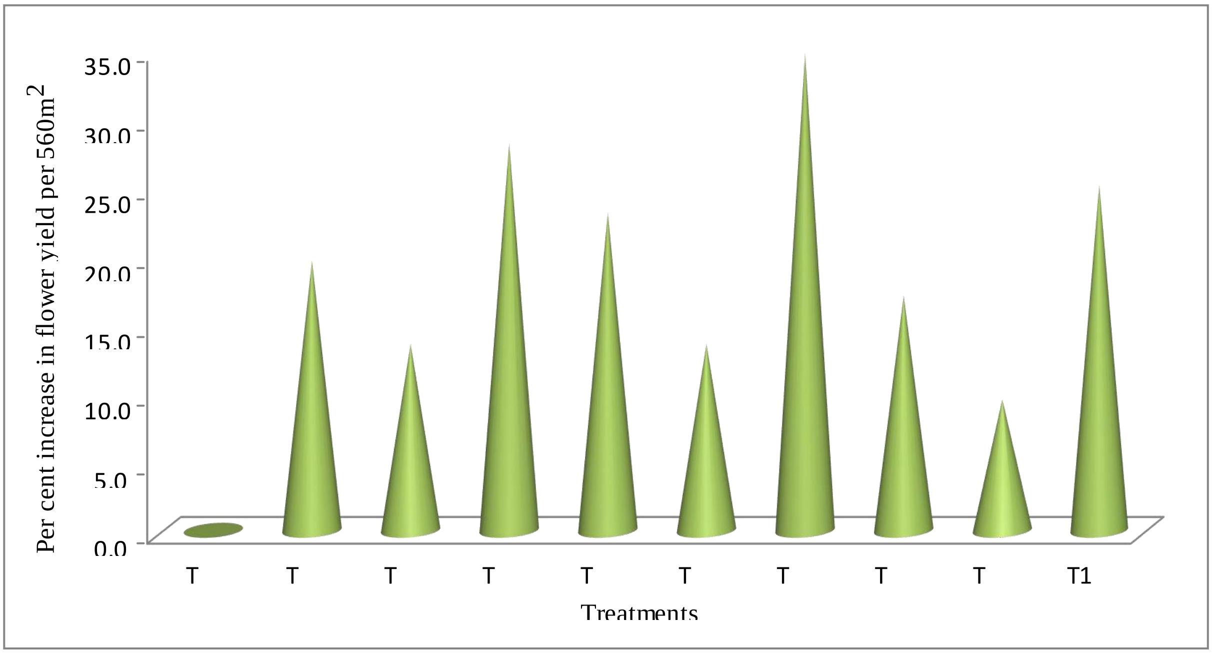

Fig. 1. Impact of Bio-inoculants and different levels of NPK fertilizers on Chrysanthemum for per cent increase in flower yield per polyhouse

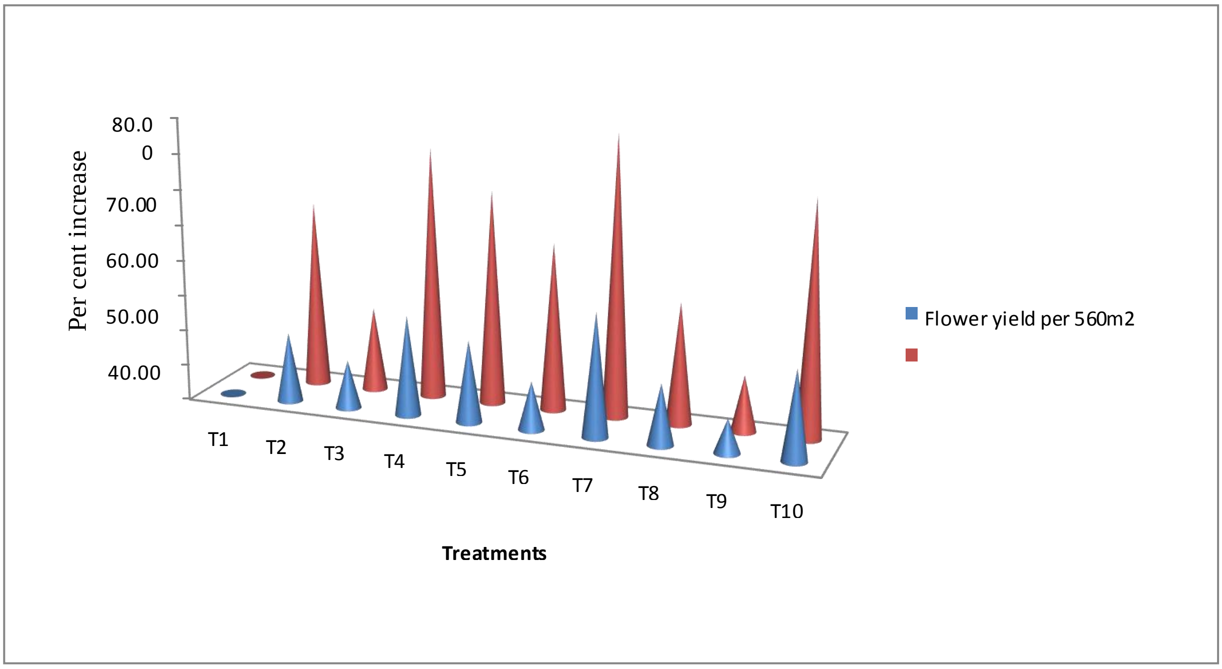

Fig. 2. Impact of Bio-inoculants and different levels of NPK fertilizers on Chrysanthemum for per cent increase in flower yield and sucker yield per polyhouse

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