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# Influence of Bio-Inoculants on Growth, Flowering, and Bulb Development of Tulip (Tulipa gesneriana L.) cv. "Purissima"

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## Abstract

The study "Influence of Bio-Inoculants on Growth, Flowering, and Bulb Development of Tulip (*Tulipa gesneriana* L.)" cv. "Purissima" was conducted during the 2023–2024 academic year at the Division of Floriculture and Landscape Architecture, SKUAST-K, Srinagar. The findings of the study revealed that the treatment combination ($T_7$) of PSB + KSB + VAM significantly outperformed the control across most parameters. This treatment led to earlier sprouting, improved vegetative growth (maximum plant height of 47.56 cm and leaf area of 152.06 $cm^2$), enhanced flowering characteristics (shortened days to anthesis, longer flower duration, and larger flower diameter), and superior bulb yield (maximum bulb weight of 24.60 g $bulb^{-1}$ and diameter of 3.55 cm). In addition, the bio-inoculants notably increased rhizospheric microbial populations, with $T_7$ (PSB + KSB + VAM) yielding the highest total bacterial counts ($78.50 \times 10^7$ CFU $g^{-1}$ soil), and individual treatments showing peak populations for phosphorus and potassium solubilizing bacteria and total fungi. These results underscore the potential of bio-inoculants as a sustainable tool for enhancing tulip production and minimizing chemical inputs.

## INTRODUCTION

Tulips (*Tulipa gesneriana* L.) are one of the most prominent bulbous flowering plants globally, cherished for their vibrant and diverse blooms. Tulips are often considered as one of Humanity's "canonical flowers", along with the rose, lily, orchid and peony. Only a select few of the various tulip species are grown for commercial purposes and used for hybridization. Important species include *Tulipa fosteriana*, *T. chrysantha*, *T. biflora*, *T. montana*, *T. persica*, *T. stellata*, *T. kaufmanniana, T. greigii*, *T. turkestanica*, *T. edulis*, *T. hoogiana* and *T. igens*. The tulips of today are hybrids, and hybridization has produced a number of new kinds. Few tulips are triploid or tetraploid, although the majority are diploid (2n = 24). When utilized in gardens, tulips inject vibrant splashes of colour into the landscape. Holland stands out as the primary producer of tulip flowers and bulbs, playing a pivotal role in the flowering industry in the Netherlands. In India, tulips are predominantly cultivated in the UT of Jammu and Kashmir. As a vital component of the floriculture industry, tulip cultivation has witnessed increasing demand for higher productivity and better quality. Traditionally, tulip production has relied on chemical fertilizers; however, such practices pose environmental and economic challenges. The rising emphasis on sustainable and eco-friendly agricultural practices have led to the exploration of bio-inoculants as an alternative to chemical fertilizers. Bio-inoculants, such as phosphate-solubilizing bacteria (PSB), potassium-solubilizing bacteria (KSB), and vesicular-arbuscular mycorrhizae (VAM), play a pivotal role in enhancing nutrient availability, improving soil health, and promoting plant growth. They not only improve phosphorus and potassium solubilization but also facilitate better root colonization and microbial synergy. The variety "*Purissima*" is renowned for whitish blooms and adaptability, making it a preferred choice among growers. However, limited research exists on optimizing its growth and flowering through bio-inoculant applications. This study aimed to evaluate the effect of PSB, KSB, and VAM, individually and in combination, on the growth, flowering, and bulb characteristics of *Purissima*. It also aimed to explore the potential of bio-inoculants in enhancing microbial populations in the rhizosphere, contributing to sustainable tulip cultivation.

## MATERIALS AND METHODS

The research was conducted at the at the Division of Floriculture and Landscape Architecture, SKUAST-K, Srinagar using a randomized block design (RCBD) with eight treatments (T0–T7). Each treatment was replicated thrice, and data was collected from three randomly selected plants per treatment during the year 2023 24. The treatments consisted of the following bio inoculant combinations: • T0: Control (Standard Control) • T1: PSB (Phosphate-solubilizing bacteria) • T2: KSB (Potassium-solubilizing bacteria) • T3: VAM (Vesicular-arbuscular mycorrhizae) • T4: PSB + KSB • T5: PSB + VAM • T6: KSB + VAM • T7: PSB + KSB + VAM. The soil was loamy, with a pH of 6.8, and was prepared by sterilizing and enriching it with organic compost. Standard tulip cultivation practices were followed, including planting bulbs at a density of 30 bulbs m-2.Bulbs were treated with bio inoculants using the dip method (30-minute dip before planting). Key parameters measured included: Days to sprouting, plant height, number of leaves, leaf area, days to flower opening, flower diameter, flower duration, number of daughter bulbs, weight, and diameter of bulbs, populations of PSB, KSB, total bacteria, and fungi in the rhizosphere. The collected data was subjected to ANOVA, and critical difference (CD) values were calculated at $p \leq 0.05$.

## RESULTS AND DISCUSSION

The application of bio-inoculants significantly influenced the growth parameters of tulips. The Treatment combination PSB + KSB + VAM recorded the earliest sprouting (80.33 days), indicating enhanced nutrient availability and rapid metabolic activity. The tallest plants were observed in the treatment combination PSB + KSB + VAM (47.56 cm), 9.8% taller than the control, attributed to improved nutrient uptake facilitated by bio-inoculants. This treatment also resulted in the highest leaf area (152.06 $cm^2$), reflecting better photosynthetic efficiency and vigour. Treatment combination PSB + KSB + VAM advanced flower opening to 124.33 days compared to 126.68 days in the control, suggesting accelerated physiological development. The same treatment combination (PSB + KSB + VAM) exhibited the largest flowers (7.74 cm) and longest flower duration (26.67 days), likely due to enhanced nutrient assimilation and hormonal activity. Bulb production parameters showed significant enhancement with Treatment combination PSB + KSB + VAM. Treatment combination PSB + KSB + VAM produced 1.67 bulbs/plant, with an average weight of 24.60 g, a 25% increase over the control and also resulted in the largest bulb diameter (3.55 cm), indicative of improved carbohydrate partitioning. Treatment PSB ($T_1$) recorded the highest rhizospheric populations of PSB (40.48 CFU $g^{-1}$ soil x $10^3$ ), (KSB)$T_2$ for KSB (29.78 CFU $g^{-1}$ soil x $10^2$), (PSB + KSB + VAM) $T_7$ for total bacterial population (78.50 CFU $g^{-1}$ soil x $10^7$) and (VAM)$T_3$ for total fungal population (46.62 CFU $g^{-1}$ soil x $10^4$) supporting a synergistic role of bio-inoculants in enhancing soil microbial activity and nutrient dynamics.

The early bulb sprouting can be attributed to the mobilization of reserve food material to the sink through increased activity by hydrolysing and oxidizing enzymes and organic acids including vitamins and amino acids. In addition to growth promoting substances produced by KSB, production of organic acids, such as vitamins and amino acids, as well as growth-promoting substances like gibberellic acid ($GA_3$) and indol-3-acetic acid (IAA), aid in sprouting and germination. VAM and PSB perform in a somewhat similar fashion. By expanding their network of hyphae, VAM increases the uptake of P and aids in the uptake of minor elements as, Zn, Cu, Fe, Mn, and other elements. By physically entangling soil particles and organic components, VAM fungal hyphae contribute significantly to soil aggregation by forming the skeleton of macroaggregates. These aggregates improve the storage of carbon and nutrients and provide an environment that is favourable for soil microorganism development and survival. PSB solubilize the insoluble forms of phosphate, such as tricalcium, iron and aluminium phosphates, into available forms thus reducing the time taken to sprout (9, 11). The enhancement in plant vegetative growth, manifested as increased plant height, could be ascribed to the ability of bioinoculant microorganisms to get involved in composite processes in nutrient assimilation in plants and facilitating the growth of the plants (10). Application of bio fertilizers was found to enhance plant height and scape length in rose and tulip species (6, 8). Similar positive effect of bioinoculants on plant vegetative growth were reported in Gladiolus (1). Microbes used as bioinoculants not only provide nutrients for plants but also aid in reducing a variety of biotic and abiotic stressors (3). The early initiation of floral buds due to the application of VAM, KSB and PSB can be attributed to easy uptake of nutrients and simultaneous transport of growth promoting substances like cytokinins to the auxiliary buds, resulting in removal of apical dominance (7). When compared to non-inoculated plants, the plants treated with bioinoculants showed early flower bud appearance. This could be because the vegetative primordial shifted to the reproductive primordial and the vegetative growth was completed earlier in tulip (4). The application of biofertilizers might increase bulb yield and number of bulblets per plant owing to the improvement in plant nitrogen availability, which could lead to an increase in the average number of bulbs and bulblets (5). The notable increase in the counted microbial population following treatment with the bioinoculants emphasizes the beneficial interaction of additional microbes with the incumbent populations. The fact that bioinoculants fixed, released, or solubilized specific compounds that served as nutrition for the occupant populations may be explained by this improvement. The main rhizosphere effect may be explained by the fact that microorganisms proliferate in the rhizosphere when roots secrete large amounts of readily degradable compounds in exchange of the nutrients solubilised by the bioinoculant populations (2).

Table 1
Different vegetative and floral traits of Tulip cv. Purisssima as influenced by Bio-inoculants.

| Treatment(T) | Days taken to sprouting(day) | Plant height(cm) | Leaf Area ($cm^2$) | Days to appearance of flower bud | Days to color break | Days to flower opening | Flower duration (day) | Flower diameter (cm) |
|---|---|---|---|---|---|---|---|---|
| $T_0$: Control | 82.68 | 42.40 | 148.71 | 112.35 | 121.35 | 126.68 | 23.20 | 5.83 |
| $T_1$: PSB | 82.38 | 43.58 | 149.48 | 112.05 | 121.05 | 126.38 | 23.76 | 6.10 |
| $T_2$: KSB | 82.10 | 43.11 | 149.56 | 111.77 | 120.77 | 126.10 | 24.18 | 6.29 |
| $T_3$: VAM | 81.33 | 44.47 | 150.44 | 111.00 | 120.00 | 125.33 | 24.67 | 6.54 |
| $T_4$: PSB + KSB | 81.75 | 45.62 | 149.45 | 111.42 | 120.42 | 125.75 | 24.88 | 6.80 |
| $T_5$: PSB + VAM | 81.37 | 46.78 | 151.82 | 111.04 | 120.04 | 125.37 | 25.33 | 7.28 |
| $T_6$: KSB + VAM | 80.84 | 46.31 | 151.75 | 110.51 | 119.51 | 124.84 | 25.70 | 7.48 |
| $T_7$: PSB + KSB + VAM | 80.33 | 47.56 | 152.06 | 110.00 | 119.00 | 124.33 | 26.67 | 7.74 |
| C.D ($p \leq 0.05$) | 0.047 | 0.661 | 0.270 | 0.148 | 0.150 | 0.069 | 0.243 | 0.216 |

Table 2
Different bulb traits of Tulip cv. Purisssima as influenced by Bio-inoculants.

| Treatment(T) | No. of daughter bulbs / plant | Weight of daughter bulbs/plant (g/bulb) | Avg. diameter of the daughter bulb(cm) |
|---|---|---|---|
| $T_0$: Control | 1.27 | 20.94 | 2.73 |
| $T_1$: PSB | 1.32 | 21.54 | 2.81 |
| $T_2$: KSB | 1.35 | 22.25 | 2.96 |
| $T_3$: VAM | 1.41 | 22.78 | 3.09 |
| $T_4$: PSB + KSB | 1.48 | 23.15 | 3.21 |
| $T_5$: PSB + VAM | 1.54 | 23.66 | 3.38 |
| $T_6$: KSB + VAM | 1.60 | 24.10 | 3.43 |
| $T_7$: PSB + KSB + VAM | 1.67 | 24.60 | 3.55 |
| C.D ($p \leq 0.05$) | 0.020 | 0.156 | 0.043 |

Table 3
Different rhizospheric microbial traits of Tulip cv. Purisssima as influenced by Bio-inoculants.

| Treatment(T) | PSB(CFU $g^{-1}$ soil x $10^3$) | KSB(CFU $g^1$ soil x $10^2$) | Total Bacteria (CFU $g^{-1}$soil x$10^7$) | Total Fungi (CFU g-1 soil x $10^4$) |
|---|---|---|---|---|
| $T_0$: Control | 21.33 | 17.53 | 66.85 | 37.33 |
| $T_1$: PSB | 40.48 | 21.30 | 68.31 | 40.18 |
| $T_2$: KSB | 34.66 | 29.78 | 72.49 | 41.92 |
| $T_3$: VAM | 31.50 | 19.66 | 69.55 | 46.62 |
| $T_4$: PSB + KSB | 38.11 | 26.46 | 76.11 | 39.66 |
| $T_5$: PSB + VAM | 37.49 | 23.42 | 70.74 | 43.53 |
| $T_6$: KSB + VAM | 33.74 | 27.34 | 74.67 | 43.84 |
| $T_7$: PSB + KSB + VAM | 38.27 | 25.31 | 78.50 | 42.78 |
| C.D ($p \leq 0.05$) | 0.985 | 0.948 | 0.696 | 0.539 |

## CONCLUSION

The combined application of PSB, KSB, and VAM ($T_7$) significantly improved the growth, flowering, and bulb characteristics of the tulip variety *Purissima.* Bio-inoculants not only enhanced plant productivity but also fostered sustainable cultivation by enriching the rhizosphere with beneficial microbial populations. Maximum rhizospheric phosphorus solubilising bacterial population (40.48 x $10^3$ CFU $g^{-1}$ soil) was recorded with treatment $T_1$ (PSB), whereas minimum rhizospheric phosphorus solubilising bacterial population (21.33 x $10^3$ CFU $g^{-1}$ soil) was recorded with $T_0$ (control). Maximum rhizospheric potassium solubilising bacterial population (29.78 x $10^2$ CFU $g^{-1}$ soil) was recorded with treatment $T_2$ (KSB), whereas minimum rhizospheric potassium solubilising bacterial population (17.53 x $10^2$ CFU $g^{-1}$ soil) was recorded with $T_0$ (control). Maximum rhizospheric population of total bacteria (78.50 x $10^7$ CFU $g^{-1}$ soil) was recorded with treatment $T_7$ (PSB + KSB + VAM), whereas minimum rhizospheric population of total bacteria (66.85 x $10^7$ CFU $g^{-1}$ soil) was recorded with $T_0$ (control). Maximum rhizospheric population of total fungi (46.62 x $10^4$ CFU $g^{-1}$ soil) was recorded with treatment $T_3$ (VAM), whereas minimum rhizospheric population of total fungi (37.33 x $10^4$ CFU $g^{-1}$ soil) was recorded with $T_0$ (control). These findings validate the potential of bio-inoculants as a sustainable alternative to chemical fertilizers in tulip production.

# Declarations


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Ethics, Consent to Participate, and Consent to Publish declarations: **Not applicable**.

Clinical trial number: **Not applicable.**

**No** competing Interests.

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# Figures

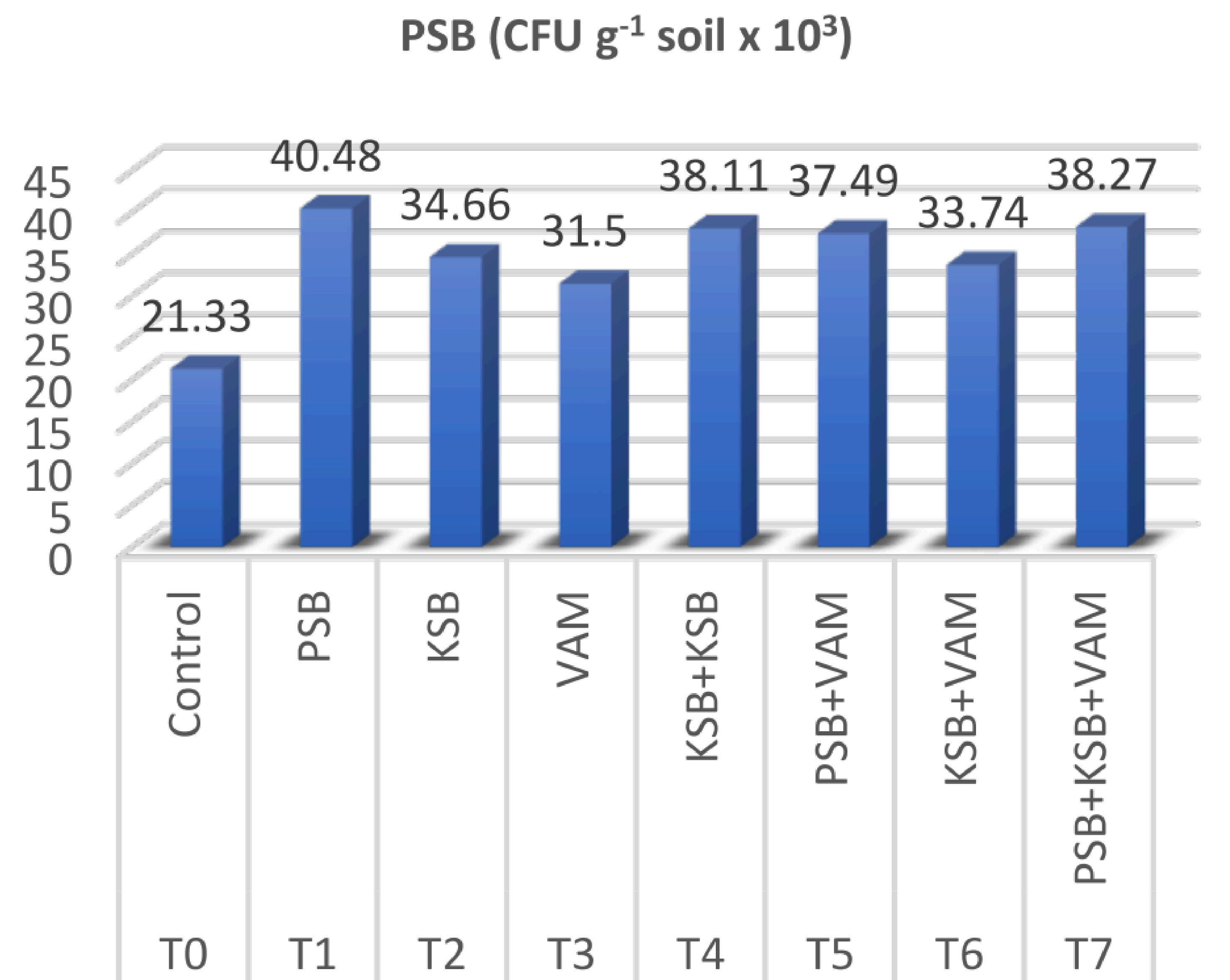


**Figure 1**

Rhizospheric PSB population of Tulip (*Tulipa gesneriana* L.) as influenced by bio inoculants

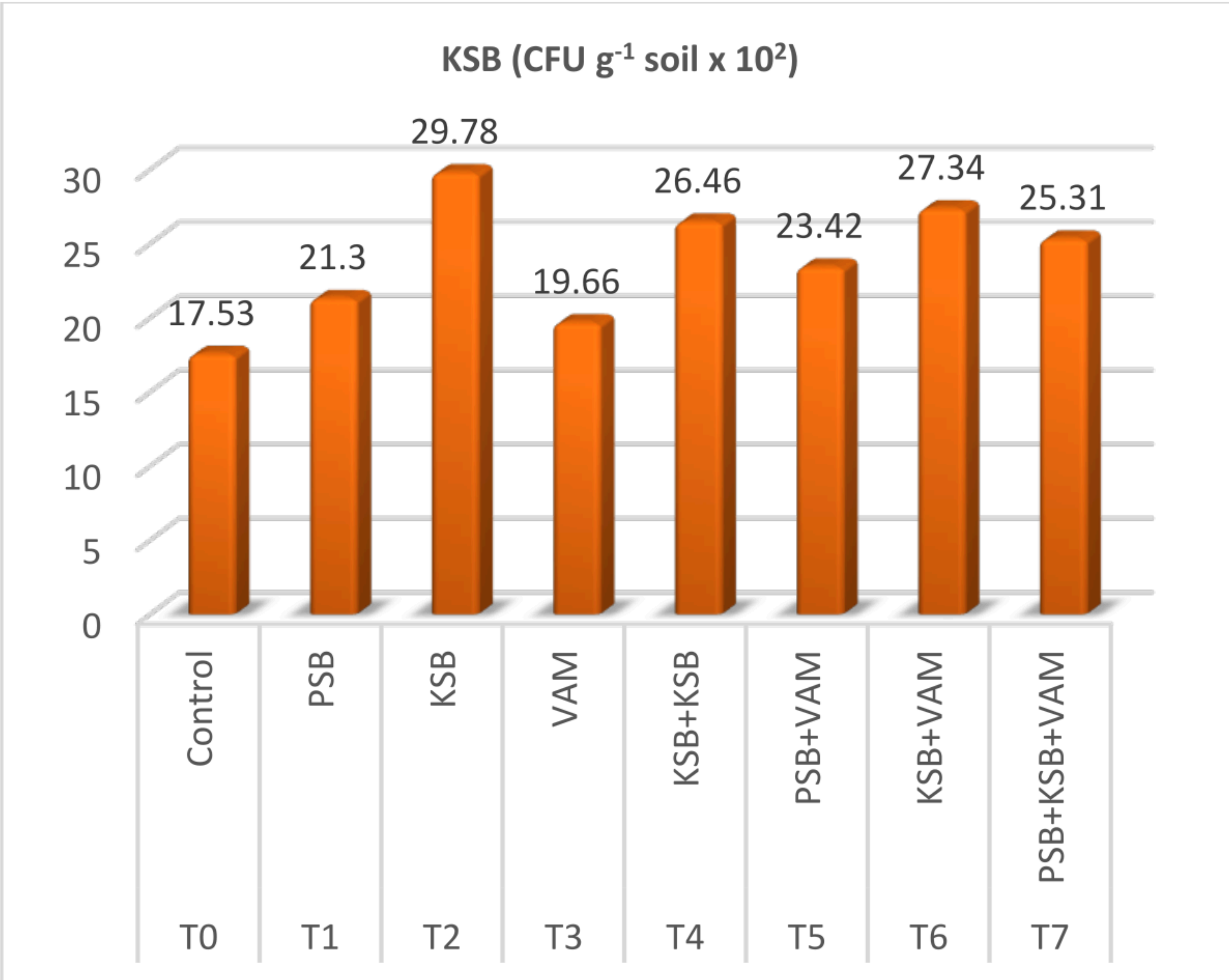


Figure 2

Rhizospheric KSB population of Tulip (*Tulipa gesneriana* L.) as influenced by bio inoculants.

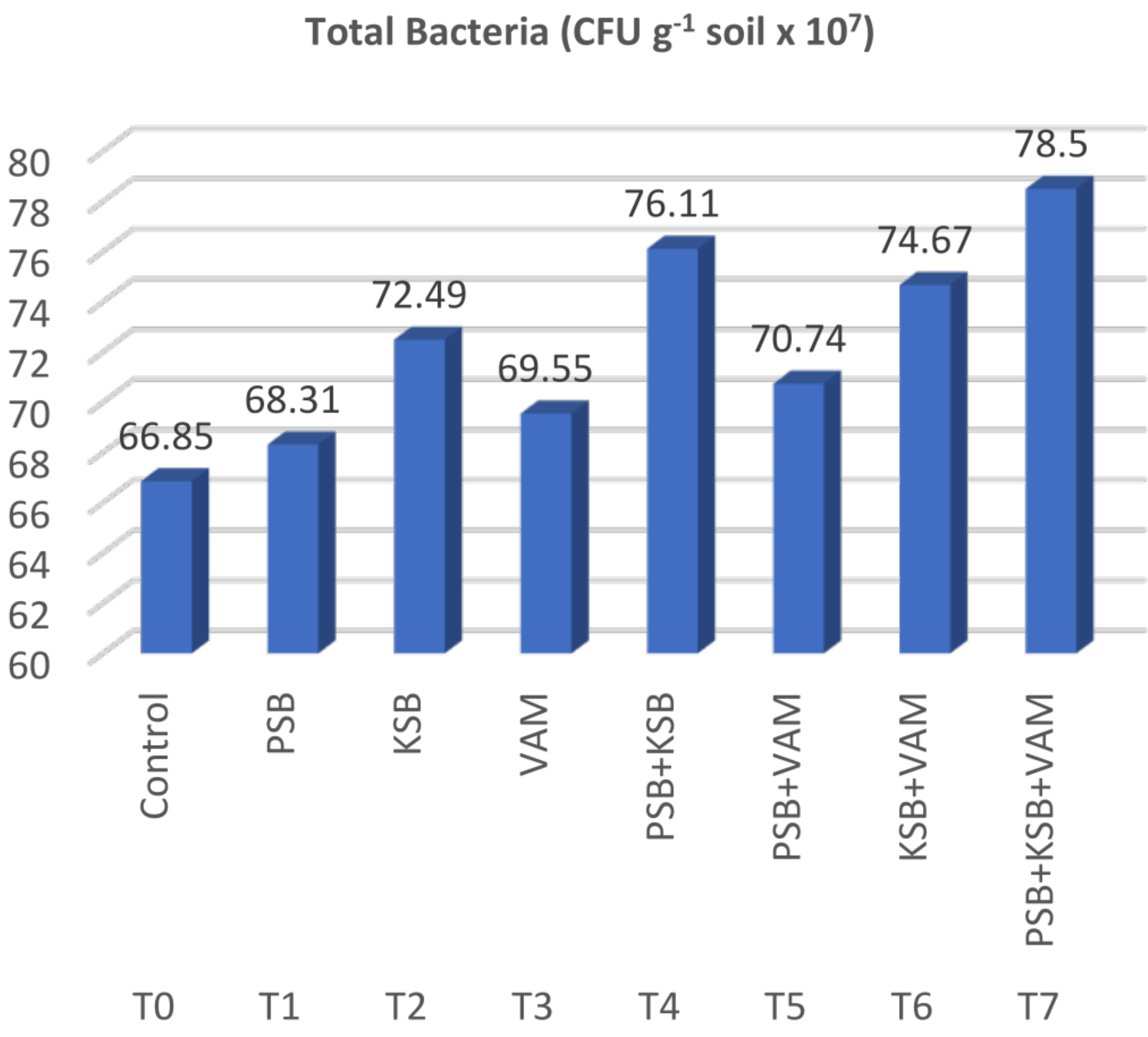


**Figure 3**

Rhizospheric population of total bacteria of Tulip (*Tulipa gesneriana* L.) as influenced by bio inoculants.

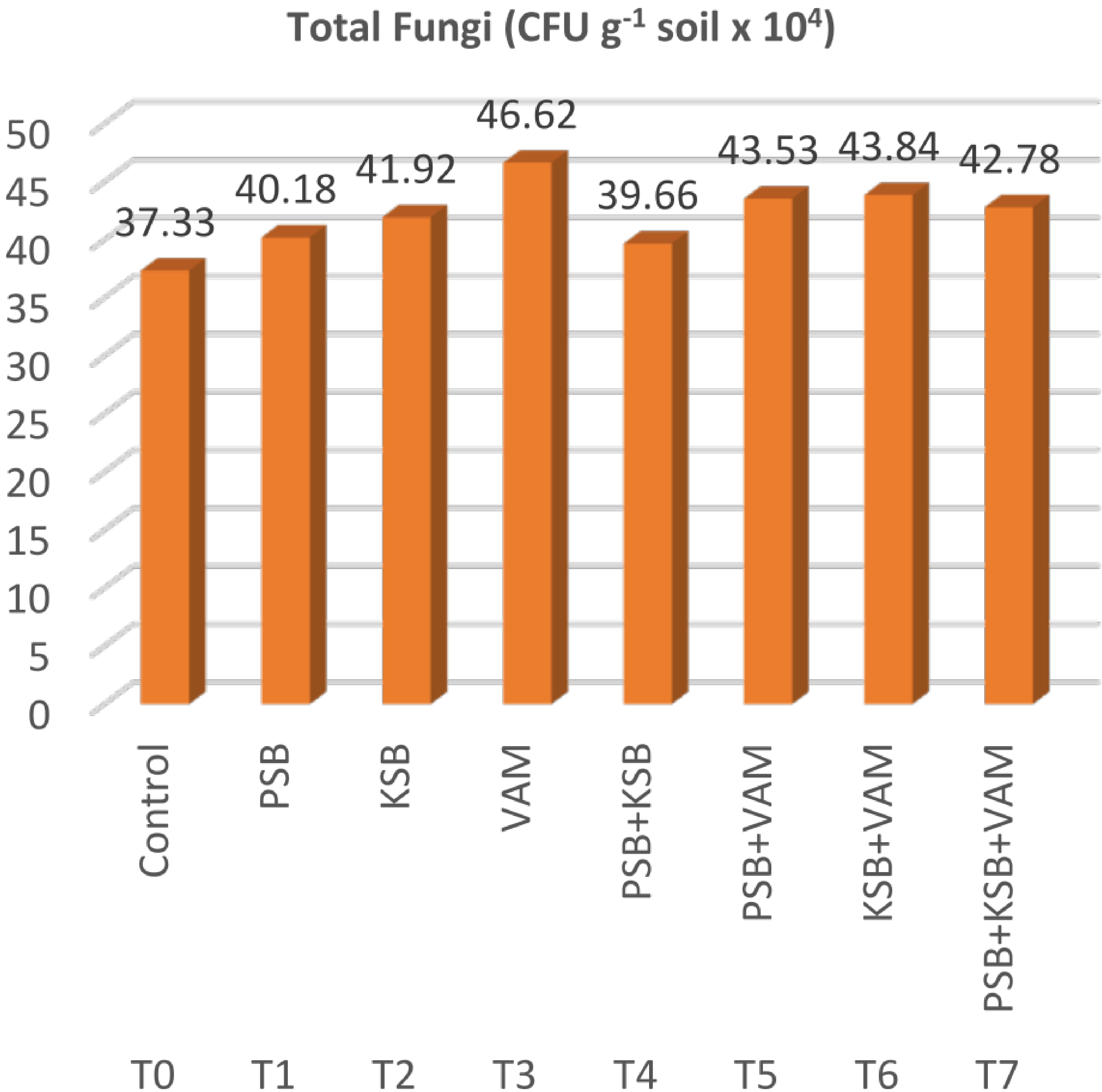


**Figure 4**

Rhizospheric population of total Fungi of Tulip (*Tulipa gesneriana* L.) as influenced by bio inoculants.