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## Introduction

Sun ower (Helianthus annuus L.) is one of the most important inoculation and levels of sulphur application are presented in table 2.

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and Agarwal [13] in soybean, Ghosh et al. [14] in mustard, Ravi et al. [15] in sa ower, and Gangadhara et al. [16] in sun ower.

## Discussion

A wide range of bacteria such as Rhizobium, Azospirillum, Azotobacter, Pseudomonas, Bacillus, and Enterobacter have been used as biofertilizer because of their positive e ects on growth and productivity of plants via several mechanisms including plant hormones production, $N_2$ xation, antagonism against phytopathogenic microorganisms and solubilization of nutrients [17-20].

e higher grain yield due to biofertilizers inoculation might be due to increase in plant height and total chlorophyll content and yield component (thalamus diameter, weight of thalamus, lled seeds capitulum$^{-1}$ and 100 seed weight, as well as seed and stalk yield, and oil content). e phosphate solubilizing bacteria is known produce vitamins and IAA and GA like growth substances [21].

Phosphorus (P) is an essential plant nutrient required for higher and sustained productivity of oil from sun ower. Its in uence on seed yield, oil yield, and oil quality has been well established [22-26], and application of phosphorus has become an essential part of sun ower fertilizer program. In general, phosphorus is added to soil as inorganic phosphates, because the free inorganic P in soil solution plays a central role in P-cycling and plant nutrition [27]. However, a large portion of soluble inorganic phosphate applied to soil as chemical fertilizer is immobilized rapidly a er application due to phosphate xation by aluminum, calcium, iron, magnesium, and soil colloids [28], and becomes unavailable to plants [29]. erefore, P is o en a limiting nutrient in agricultural soils. Micro-organisms are also involved in a range of process that a ect the transformation of soil P, and thus, an integral part of the soil P cycle [30]. In particular, P-solubilizing micro-organisms (bacteria or fungi) are able to solubilize unavailable soil P and increase the yield of crops [31]. Plant Growth-promoting Rhizobacteria (PGPR) and rhizosphere bacteria are free-living soil organisms that can bene t plant growth by di erent mechanisms [19]. P-solubilization ability of micro-organisms is considered to be one of the most important traits associated with plant P nutrition [30]. Several bacterial species, in association with plant rhizosphere, are capable of increasing availability of Phosphorus to plants, either by mineralization of organic phosphate, or by solubilization of inorganic phosphate by production of acids [28]. Phosphorus is commonly a limiting factor in sun ower growth and yield because P de ciencies reduce the accumulation of crop biomass [26]. is is attributable to (i) a reduction in the partitioning of assimilates to the formation of leaf area, or (ii) a decrease of the e ciency with which the intercepted radiation is used for the production of above-ground biomass [32]. Rodriguez et al. [33] reported that under P de ciencies sun ower showed a reduction in the rate of leaf expansion, and in photosynthetic rate per unit of leaf area. However, P application produced greater and more consistent e ects on crop performance as P fertilization allowed more e cient use of supplied N (soil+fertilizer). Loubser and Human [23] also noted that the response of seed and oil yield of sun ower was in agreement with the P absorption by the plants.

Inoculations of PSB which are known to produce growth hormones are likely to favour increased plant height. Inoculation with PSB+VAM+Azotobacter recorded higher chlorophyll content, which might be due to higher content of nitrogen and magnesium, which is core component of chlorophyll [21]. e high response of plant to the PSB+VAM+Azotobacter inoculation might be due to mobilization of available P by the native soil micro ora, or attributed due to increased PSB activity in the rhizosphere, following PSB+VAM+Azotobacter application, and consequently, by enhanced P solubilization. ese reasons might have contributed towards its enhanced P uptake by the crops, an increase in thalamus diameter, weight of thalamus, lled seeds capitulum$^{-1}$ and 100 seed weight, ultimately leads to higher seed yields. Stimulated photosynthetic activity and synthesis of protein due to sulphur application might have also contributed towards the improvement of better yield attributes.

Various nutrients and micronutrients are required for oilseed production, but the nutrient which plays a multiple role in providing nutrition to oilseed crops, particularly those belonging to cruciferae family is "Sulphur". Sulphur is the fourth most important nutrient a er nitrogen, phosphorus and zinc for Indian agriculture [34]. Its role in balanced fertilization and consequently in crop production is being increasingly realized. Considering similar sulphur and phosphorus requirements of crops, sulphur can rightly be called as the fourth major nutrient in Indian agriculture. Sulphur is best known for its role in the synthesis of proteins, oils, vitamins, and avoured compounds in plants. It is a constituent of three amino acids viz. Methionine (21% S), Cysteine (26% S) and Cystine (27% S), which are the building blocks of protein. About 90% of plant sulphur is present in these amino acids [35]. Sulphur is also involved in the formation of chlorophyll, glucosides production of crops of superior nutritional and market quality. Each unit of fertilizer sulphur generates 3-5 units of edible oil, a commodity needed by every family. Sulphur application also has marked e ect on soil properties, and is used as soil amendment to improve the availability of other nutrients in soil as gypsum and pyrite. Presently, S is being required as fourth major nutrient. S, which is mostly applied to oilseed and pulses, has been found to bene t more than one crop in a sequence due to its signi cant residual response [37]. S and P have synergistic and antagonistic e ect with each other on their varying levels of application, as well as level of availability in the soil [29,38].

Increase in oil content by sulphur application might be attributed to involvement of sulphur in the biosynthesis of oil. Sulphur is involved in the formation of glucosides and glucosinolates and sulphydril-linkage and activation of enzymes, which aid in biochemical reaction within the plant. e higher oil yield by sulphur application was obviously because of higher seed yield and oil content.

Based on the experiment, it can be concluded that inoculation of biofertilisers and sulphur have signi cant e ect on yield and yield attributes of sun ower. However, PSB+VAM+Azotobacter, as well as application of sulphur @40 kg$^{-1}$ ha may be considered as the best treatment for sun ower, with respect to height, total chlorophyll content, thalamus diameter, weight of thalamus, lled seeds capitulum$^{-1}$ and 100 seed weight, grain yield, stalk yield, biological yield, harvest index and oil content [39].

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