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Impact of microbial inoculants on growth and yield of tomato (*Solanum lycopersicon* L.) under temperate conditions

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Abstract
A field experiment was conducted to study the "Impact of Microbial Inoculants on Growth and Yield of Tomato (*Solanum lycopersicon* L.) under temperate conditions", during Kharif 2017 at Experimental Farm, Division of Basic Sciences & Humanities, Faculty of Agriculture and Regional Research Station, Wadura, Sopore, SKUAST-K, to evaluate the effect of various microbial inoculants on growth and yield parameters of tomato. The experiment was laid in Randomized complete Block Design (RCBD) with three replications which consisted of seven inoculants viz; *Azotobacter* sp., *Azospirillum* sp., Phosphorous Solubilizing Bacteria (PSB), Potassium Solubilizing Bacteria (KSB), Vesicular Arbuscular Mycorrhiza (VAM) and co-inoculation of VAM+ PSB and VAM+ KSB and control. Various growth and yield parameters viz., plant height, no. of leaves, root length, dry matter accumulation, average fruit weight, at various intervals responded significantly to all the microbial inoculants. The performance of microbial inoculants were evaluated individually and in combination with one other in contrast to control for screening the best microbial inoculants. The results depicted that among all the microbial inoculants, *Azotobacter* sp. followed by *Azospirillum* proved superior than rest of the inoculants in terms of improving various growth, quality and yield attributes viz. maximum plant height (45.9 cm), No. of leaves (248.2), dry matter accumulation (282.2g), average fruit weight (50.8g), root length (33.2cm) and yield (2.01 kg/plant) respectively. For number of fruits, *Azospirillum* sp. gave best results (40.83) followed by *Azotobacter* (40.7). Therefore, from the present investigation it can be concluded that among all the inoculants, *Azotobacter* sp. proved superior for increasing all the growth, yield and quality parameters of the tomato crop followed by *Azospirillum* sp.

Keywords: *Azotobacter*, *Azospirillum*, growth, KSB, PSB, tomato, VAM, yield

Introduction
Vegetables are a basic source of nutrition in our diet. They are a source of proteins, vitamins, minerals, dietary fibers, micronutrients, antioxidants and phytochemicals. Apart from nutrition characteristics, they also contain a wide range of potential phyto-chemicals like anti-carcinogenic principles and anti-oxidants (e.g. flavonoids, glucosinolates and isothyocynates). India is second largest producer of vegetables with production of 19697 metric tons of vegetables in 2016-17 on an area of 8.09 million hectares. (Horticultural Statistics at a glance 2017). The production of tomato in Jammu and Kashmir accounts for 93.48 million tonnes which accounts for 0.42% share in the country. (Horticulture Statistics Division). Still the production of vegetables is very low and needs improvement so that it can fulfill the nutritional requirement of the growing population. Our country is blessed with diverse agro-climatic condition with distinct seasons, making it possible to grow wide array of vegetables in a year.

Among vegetables tomato has a great significance. It is grown all over the world as a nutritive food. Tomato (*Solanum lycopersicon* L.) is one of the most popular and widely grown vegetable crop in the world. Tomato belonging to family Solanaceae, is native to Central and South America. It has originated in Latin America and has become one of the most widely grown vegetable. Tomato is rich source of minerals, vitamins and organic acid with its fruit providing 3-4% total sugar, 4-7% total solids, 15-30 mg/100g ascorbic acid, and 20-50 mg/100g fruit weight of lycopene. Also in 100g of edible part of fruit, it is composed of 93.1 g moisture, protein 1.9 g, fat 0.1 g, minerals 0.6 g, fiber 0.7 g, carbohydrates 3.6 g, sodium 45.8 mg, potassium 114 mg, copper 0.19 mg, sulphur 24 mg, chlorine 38 mg, vitamin A, thiamine 0.07 mg, riboflavin 0.1 mg, nicotinic acid 0.4 mg, vitamin C 31 mg, calcium 20 mg, magnesium 15 mg, oxalic acid 2 mg, phosphorus 36 mg, and iron 1.8 mg. Several epidemiological studies indicated beneficial effects of tomato consumption in the prevention of some major chronic diseases, such as cancer and cardiovascular diseases (Giovannucci, 1999) [10]. Tomato fruit is also a rich source of vitamin A, B and C and minerals like calcium, iron, and phosphorus besides they have been reported quite useful in controlling liver problems, indigestion, arthritis and urinary troubles Tomato also contains significant amounts of β carotene, niacin, riboflavin, thiamin, magnesium, iron, phosphorus, potassium and sodium (Ranieri *et al.*, 2004) [20]. Lycopene, one of the nature's most powerful antioxidants, is implicated in the prevention of various diseases including prostate cancer, coronary heart diseases and cataract is also present in it.

India has made a quantum jump in vegetable production starting from 28.36 MT (1969-1971) to 183.99 MT (2015-2016). However, the production remains far short of what is needed for nutritional security and economic stability of growers of India. Looking forward at the requirement of 225 million tons of vegetables by 2025, the production & productivity has to be increased so as to meet the dietary requirement of 300 q/capita /day. This increase in production is to be achieved vertically without disturbing the intricate environmental balance. Intensive farming practices even though warrant high yield and quality, but require the extensive use of chemical fertilizers, which are costly and have potential to create environmental problems. Therefore, more recently there has been a revival of interest in environment friendly, sustainable and organic agricultural practices.

Microbial inoculants are agricultural amendments that use beneficial endophytes (microbes) to promote plant health by various mechanisms *viz*., nitrogen fixation, phosphate solubilization, phytohormone production etc. They are considered cost effective, eco-friendly, cheaper and renewable sources of plant nutrients and play a vital role in maintaining long term soil fertility and sustainability. Moreover, they form an important component of organic farming practices. Therefore, the present study was endeavored to evaluate the effect of microbial inoculants on growth and yield of tomato plants.

Material & Methods

A field experiment was conducted to study the "Impact of Microbial Inoculants on Growth and Yield of Tomato (*Solanum lycopersicon* L.) under temperate conditions", during Kharif 2017 at Experimental Farm, Division of Basic Sciences & Humanities, Faculty of Agriculture and Regional Research Station, Wadura, Sopore, SKUAST-K, to evaluate the effect of various microbial inoculants on growth, yield and quality parameters of tomato. The experiment was laid in Randomized complete Block Design (RCBD) with three replications which consisted of seven treatments.

Experimental material

The materials used in the present investigation consisted of Shalimar II variety of tomato and different microbial inoculants, that were obtained from Division of Horticulture and Bio-fertilizer Laboratory (Basic Sciences), FoA/RSS, Wadura respectively. Roots of tomato seedlings were inoculated as per standard methods with inoculants as per the treatments except for VAM which was applied as top dressing. After inoculation, the seedlings were sown at a spacing of 60×45 cm on 15th May. All the cultural practices were followed as per the package of practices.

Observations Recorded

Various growth, and yield parameters viz., plant height, no. of leaves, root length, dry matter accumulation, average fruit weight, number of fruits were evaluated at various intervals. The performance of microbial inoculants Were evaluated individually and in combination with one other in contrast to control for screening the best microbial inoculants.

Statistical analysis

The results obtained from field observations were analyzed statistically as per Panse and Sukhatme (1985) [17] for Randomized Block Design. The significance was tested by referring to 'F' tables of Fisher and Yates (1963) [8]. The results from RBD were arranged in two way table according to the replication (blocks) and treatments; there will be 'rk' observation in total.

Results and Discussion

The results depicted that among all the microbial inoculants, *Azotobacter* sp. followed by *Azospirillum* proved superior than rest of the inoculants in terms of improving various growth, quality and yield attributes viz. maximum plant height (45.9 cm), No. of leaves (248.2), dry matter accumulation (282.2g), average fruit weight (50.8g), root length (33.2cm) and yield (2.01 kg/plant) respectively. For number of fruits and *Azospirillum* sp. gave best results (40.83) followed by *Azotobacter* (40.7).

Effect on growth parameters

In case of plant height, there was a significant variation in plant height due to different microbial inoculations. The plant height increased continuously in all the treatments of both with and without biofertilizer application. Among the treatments, *Azotobacter* sp was found to be significantly superior over all other treatments in respect of plant height. The maximum plant height (45.9 cm) after 75DAT was recorded with *Azotobacter* sp and the minimum was recorded under control plot having value 33.6 cm respectively (Table 1). The inoculations with *Azotobacter* isolate was highly effective in increasing the height of plants. The increase in plant height is an important parameter of plant vigour. The data indicated that plant height was significantly increased on application of *Azotobacter*. This could be attributed to increased uptake of N and P, more N fixation and thus increased vigorous growth of plant. The results are in conformity with those of Sharma and Thakur (2001) [22] who observed significant improvement in plant growth, number of fruits and fruit yield per plant in tomato on application of *Azotobacter*.

The interaction due to different biofertilizers for number of leaves was found significant. Among the treatments, *Azotobacter* sp. recorded higher number of leaves (248.2). Whereas, the lower number of leaves was recorded in Vesicular Arbuscular Mycorrhiza (VAM) (104.6). (Table 1). Mahato *et al.* (2009) [14] observed that application of *Azotobacter* increased the shoot length and more number of leaves per plant. This observation was also in line with that of Martinej *et al.* (1993) and Umar *et al.* (2009) [23] who clearly mentioned that application of *Azotobacter* resulted increase of shoot length and more number of leaves. The beneficial effect of *Azotobacter* on tomato plants might be due to nitrogen fixation as nitrogen enrichment helps in vegetative growth of plants (Azcon & Barea, 1975 and El-Shanshoury, 1979) [2, 3, 7].

Application of bio-fertilizer resulted in increase of shoot length and more number of leaves per plant. Similar observations were observed by Martinez *et al.* (1993) [15] in case of tomato.

Effect on yield and yield attributes

The highest dry matter accumulation (282.2 g) was found in *Azotobacter* inoculated plants, while the least dry matter was found in that of control plot (139.2 g). (Table 1). This increment in dry matter stimulates development of foliage, roots, branching, flowering and fruiting which is triggered by fixed nitrogen and plant growth regulator like substance produced. It also increases plant tolerance to lack of water under adverse condition (Zena and Peru, 1986) [24]. Similar results were put forth by Sandeep *et al.* (2011) which revealed that there is better growth response of *Azotobacter* inoculated plants as compared to non-inoculated control plants. Better crop growth response ultimately results in better dry matter accumulation.

The highest number of fruits were found in plants inoculated with *Azospirillum* (122.4), while the lowest number of fruits were recorded in control plot (86.8) (Table 1). This effective increase in number of fruits, could be attributed to higher metabolic activities because of optimum nitrogen supplies and phytohormones which were manifested in the form of enhanced growth (Govindan and Purushothaman, 1984) [11]. The results of present studies were also in confirmation with the results of Nirmala *et al.* (1999) [16], Parvatham *et al.* (1989) [18], Amrithalingam (1988) [1] and Balasubramani (1988) [5].

Higher fruit yield of tomato was obtained in *Azotobacter* inoculated plants (6.2 kg) while the least was found in that of control plot (2.9 kg) (Table 1). This increase of yield is associated with the efficient fixation of nitrogen as well as metabolic products of *Azotobacter* like gibberellins, indole acetic acid and cytokinin might have helped in inducing early flowering, fruit setting, fruit picking and also increased number of flowers and fruits per cluster (Bhadoria *et al.*, 2007) [4]. This view was corroborated with the observations of Jackson *et al.* (1964) [13] and Aeon & Barea (1975) [2, 3] who mentioned that favorable environment, as the roots provide through proper aeration for better bacterial activity resulting in more nitrogen fixation and higher growth attributes with seedling inoculation with *Azotobacter* as compared to soil inoculation with *Azotobacter*.

Further, increases in yield attributes with *Azotobacter* application might be due to increased nitrogen supply which might be responsible for vigorous growth and increased chlorophyll content, which in turn might have accelerated photosynthetic rate and thereby increased the supply of carbohydrate to plant. These findings are in agreement with Martinez *et al.* (1993) [15], Poopathi (1994) [19], Hamedunisa Begum (1998) [12], Chaurasia *et al.* (2001) [6], Sharma *et al.* (2001) [9], Gajbhjiye *et al.* (2003) [9] who have opined that application of *Azotobacter* enhanced secretion of plat growth promoting substances like IAA, gibberellins, cytokinins etc. in addition to fixation of atmospheric nitrogen leading to higher yields of tomato.

Table 1: Effect of microbial inoculants on various growth and yield parameters of tomato.

Treatments	Plant Height (cm)	No. of Leaves	Root length (cm)	Dry Matter Accumulation (g)	Average Fruit Weight (g)	Number of Fruits	Yield (kg)
Control	33.67	104.67	19.5	139.2	33.50	28.95	0.97
Azotobacter Sp.	45.93	248.27	33.2	282.2	50.80	40.72	2.01
Azospirillum Sp.	38.27	136.20	30.9	224.8	48.50	40.83	1.98
PSB	36.93	136.00	23.6	175.7	38.46	40.08	1.53
KSB	36.80	121.07	19.6	146.3	38.08	35.11	1.33
VAM	34.93	122.73	20.9	156.7	38.61	35.82	1.38
VAM+PSB	34.07	134.73	22.8	160.5	40.70	38.88	1.857
VAM+KSB	34.33	130.13	22.7	160.5	33.97	35.92	1.22
C.D (P=0.05)	7.81	15.77	0.52	12.79	4.63	3.41	0.14
SE(m)	2.57	5.20	0.18	4.21	1.52	1.17	0.05

Conclusion

The results depicted that among all the microbial inoculants, *Azotobacter* sp. followed by *Azospirillum* proved superior than rest of the inoculants in terms of improving various growth, quality and yield attributes viz. maximum plant height, No. of leaves, dry matter accumulation, average fruit weight, root length, and yield respectively. For number of fruits and *Azospirillum* sp. gave best results followed by *Azotobacter*. Therefore, from the present investigation it can be concluded that among all the inoculants, *Azotobacter* sp. proved superior for increasing all the growth and yield parameters of the tomato crop followed by *Azospirillum* sp. Thus, it indicates that the process of treatment by microbial inoculants may be better option for growers to achieve higher growth and yield attributes in tomato.

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