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EFFECT OF BIOFERTILIZERS AND THEIR CONSORTIA ON GROWTH AND YIELD OF LETTUCE (*LACTUCA SATIVA* L.) CV. RED REVOLUTION

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ABSTRACT

Lettuce (*Lactuca sativa* L.) is a popular salad vegetable belongs to family Compositae having chromosome number 2n = 18. This experiment was carried out at the Horticulture Research farm of the Department of Horticulture, Babasaheb Bhimrao Ambedkar University (A central University), Vidaya -Vihar Raebarely Road, Lucknow - 226 025 (U.P.), India during *Rabi* season of 2016-2018. Treatment combinations Control, BF1, BF2, BF1+BF2, BF1+VC, BF1+FYM BF2+VC, BF2+FYM, BF1+BF2+VC, BF1+BF2+FYM. BF1 (*Rhizobium radiobactor*) and BF2 (*Pantoea agglomerans*). *Pantoea agglomerans* was found to be the most effective in improving vegetative growth characters and final yield. Both independently and in combination with FYM and Vermi-compost, which were all statistically almost equivalent. However, further trials may be needed to substantiate the result in Lettuce (*Lactuca sativa* L.).

Key words : *Rhizobium radiobactor*, *Pantoea agglomerans*, Lettuce.

Introduction

Lettuce (*Lactuca sativa* L.) is a popular salad vegetable, belongs to family Compositae and has chromosome number 2n=18 (Rubatzky *et al*., 1997). It is an excellent source of different vitamins and minerals and facilitates digestion of food (Alahi *et al*., 2009). Lettuce is a cool season vegetable and the best temperature for cultivation is 18^0C to 25^0C with night temperatures 10^0C to 15^0C (Ryder, 1998). However, cultivation is possible even in the sub-tropical conditions (Bozkutr *et al*., 2009, Gulser *et al*., 2010).

Lettuce responds greatly to major essential elements like N, P and K in respect of its growth and yield (Islam *et al*., 2006) and source of the nutrients plays an important role in its production (Attiyeh *et al*., 2000). Since, it has the ability to accumulate proportionally larger quantities of nitrate (Jokinen *et al*., 2022; Tabaglio *et al*., 2020). Growing public concern about safety and quality of food and the high awareness towards health issues have motivated farmers to focus on organic food. Biological means of nutrient application such as microbial biofertilizers and compost have been seen as promising alternatives to chemical fertilizers (Seneviratne *et al*., 2011). The microorganisms they contain are also called plant growth promoting rhizobacteria (PGPR) and result in benefits to the plant hosts after inoculation, providing a sustainable approach to increase crop production. PGPRs affect plant growth and development, directly or indirectly, either by facilitating nutrient uptake by plants (N_2 fixation, P solubilization), inducing increases in root surface (hormone production), or reducing the harmful effect of pathogens (Arora *et al*., 2013) Organic farming is emerging as healthier alternative for improving crop production even under abiotic stress conditions such as soil salinity. Salinity affects growth of plants mainly by ion toxicity and osmotic effect, impacting the quality and yield of agricultural crops (Habib and Ashraf, 2016).

PGPR with abilities to solubilize phosphate and zinc (Zn) can be very useful in improving the nutrient value through biofortification (Ku *et al*., 2019). Similarly, *Enterobacter agglomerans*, now reclassified as *Pantoea agglomerans* also induced plant growth (Lindow *et al*., 1998). The present study was undertaken to ascertain the impact of Rhizobium and *Pantoea agglomerans* on the vegetative performance of lettuce for enhancing vegetative performance of lettuce resulting in higher leaf yield safe for human consumption.

Materials and Methods

The present experiment Performance of lettuce (*Lactuca sativa* L.) cultivar Red revolution under the influence of bio-fertilizer and their consortia was carried out at the Horticulture Research Farm-I of the Department of Horticulture, Babasaheb Bhimrao Ambedkar University (U.P.), India during *Rabi* season of 2016-2018. Geographically, Lucknow is situated of 123 meter above mean sea level (MSL) in the subtropical climate zone of central Uttar Pradesh at 26 55' North Latitude and 80 59' East longitudes. The soil of experimental field was sandy loam, slightly alkaline in nature with the soil pH 8.2 (Šimek and Cooper, 2002). The seed of cv. Red Revolution was obtained from Central Institute for Temperate Horticulture (CITH) Rangreth, Srinagar. Seeds were sown in second fortnight of September and transplanted in the experimental field after 25 days at four leaf stage at a spacing of 45x45 cm. The trial was laid out in Randomized Block Design (RBD) with 10 treatments replicated thrice. Treatment details Untreated Control (T_1), BF1-4% *Rhizobium radiobactor* (T_2), BF2-4% *Pantoea agglomerans* (T_3) and consortia BF1+BF2 4% *Rhizobium radiobactor* + 4% *Pantoea agglomerans*(T_4) , BF_1 + VC- *Rhizobium radiobactor* + Vermicompost(T_5), BF_1 + FYM-*Rhizobium radiobactor* + FYM (T_6), BF_2 + VC - *Pantoea agglomerans* + Vermicompost (T_7), BF_2 + FYM - *Pantoea agglomerans* + FYM(T_8), BF_1 + BF_2 + VC- *Rhizobium radiobactor* + *Pantoea agglomerans*+Vermicompost (T_9), BF_1 + BF_2 + FYM - *Rhizobium radiobactor* + *Pantoea agglomerans*+ FYM (T_{10}), Bio-fertilizers (*Rhizobium radiobactor* and *Pantoea agglomerans*) were obtained from the Department of Environmental Microbiology, School of Environmental Science, Babasaheb Bhimrao Ambedkar University (BBAU), Lucknow (U.P.), India. Seedlings were treated with 4% inoculum of bio-fertilizers *Rhizobium radiobactor* and *Pantoea agglomerans* independently and as consortia, for 30 minutes by dipping the roots of seedling in culture of PGPR's at the experimental site, before transplanting. Biofertilizer treatments were applied independently and in combination with FYM and vermicompost. The seedlings were transplanted in the experimental plots immediately after treatment. Observations were recorded for a number of leaf parameters *viz.*, leaf length(cm), leaf width (cm), along with plant height (cm), canopy of plant (north-south and east-west) (cm) at 15-day intervals. Yield per plant (g) was recorded at maturity. Data obtained were analysed statistically.

Number of leaves per plant

The numbers of leaves were recorded at fifteen days intervals at 30, 45 and 60 days from the transplanting till final harvesting. Four tagged plants were selected and fully open leaves were counted from each plant Average of four plants was computed to get mean number of leaves per plant.

Leaf length (cm)

The leaf length of the plants were recorded the with help of meter scale from collar zone of leaf at the soil surface to tip of the longest leaf the Leaf length at an interval of fifteen day at 30,45 and 60 days after transplanting. Four tagged Leaf length was recorded from each plot to obtain mean calculated average Leaf length

Leaf spread (cm)

The leaf spread of the plant was recorded the help of meter scale from collar zone of leaf at the maximum spread of the leaf the Leaf spread at an interval of fifteen day at 30, 45 and 60 days after transplanting. Four tagged Leaf spread was recorded from each plot to obtain mean calculated average Leaf spread

Plant height (cm)

The height of the plant were recorded with the help of meter scale from collar zone of plant at the soil surface to tip of the longest leaf of the plants height at an interval of fifteen day at 30, 45 and 60 days after transplanting. Four tagged plant height was recorded from each plot to obtain mean calculated average plant height.

Plant canopy spread (north-south) (cm)

In the canopy spread four tagged plants was selected measure the east - west direction of plant canopy. The meter scale was kept over the centre of the plant and the spread measure from north side of leaf tip to south side of leaf tip and calculated the average mean.

Plant canopy spread (east-west) (cm)

In the canopy spread four tagged plants was selected measure the east - west direction of plant canopy. The meter scale was kept over the centre of the plant and the spread measure from east side of leaf tip to west side of leaf tip and calculated the average mean.

Yield per plants (g)

There are four tagged plants were selected for weighing the plants. The plants were cut from the base of the stem and the plants were weighing with the help of balance. This procedure was followed in each plot and to obtain the average mean of the weight of the plants, the sum of four plants was divided by four.

Results and Discussion

Effect of Biofertilizers and their Consortia on leaf parameters

Application of *Pantoea agglomerans* was observed to have a statistically significant effect on the number of leaves, leaf length, leaf width in the present study. Maximum number of leaves (10.58, 15.58 and 24.00) was observed in the plants treated with *Pantoea agglomerans* at different days (30,45 and 60 DAT, respectively) a similar effect was observed for the leaf length (15.09, 21.08 and 32.18 cm) as well as leaf width (4.99, 9.75 and 22.31 cm) under study. This may be mainly due to both direct nutritional acquisition and production of phytohormones, and indirect inhibition of pathogens, inducing broad-spectrum resistance or alleviating abiotic stress (Lv, Luqiong *et al.*, 2022). The various roles of *Pantoea* may be attributed to the Plasmid-encoded loci, which have been found to play a role in various functions in plants such as abiotic stress resistance, iron uptake and nitrogen assimilation as well as metabolism and transport of carbohydrates, amino acids and organic acids. Further, *P. agglomerans* exhibited the ability to produce IAA (Megías *et al*., 2018) and can increase plant production by 10% to 50% of rice and other cereals. Thus, *P agglomerans* is an IAA-producing bacteria with a plant growth-promoting potential which is reflected in the improved performance of the Lettuce treated with *P agglomerans* (Sergeeva *et al.*, 2007). Rhizobia show an outstanding property of symbiotic nitrogen fixation for plant uptake. Apart from nitrogen fixation, rhizobia are also able to perform diverse plant growth promoting (PGP) activities such as solubilization of phosphate, Zn and potassium, production of phytohormones, exopolysaccharides (EPS), siderophore and biocontrol of phytopathogens (Karoney *et al*., 2020). Soil salinity is one of the major abiotic stresses negatively affecting plant growth and soil quality. Rhizobia are also known to show salt tolerance abilities and even reported for plant growth promotion in saline conditions (Peng *et al.*, 2021). Hence, apart from being important PGPR for legumes and non-legumes, salt-tolerant rhizobia can be used to increase crop productivity and quality in saline conditions, also leading to improvement of soil nutrient value. The main purpose of this study was to compare the impact of various treatments including chemical fertilizers,

Table 1 : Effect of Biofertilizers and their Consortia on leaf parameters.

Treatment details	Number of leaves			Leaf length (cm)			Leaf width(cm)		
	30DAT	**45DAT**	**60DAT**	**30DAT**	**45DAT**	**60DAT**	**30DAT**	**45DAT**	**60DAT**
T_1 Control (RDF)	7.17	13.42	18.66	9.48	15.39	22.06	4.99	9.75	22.31
T_2 (*Rhizobium radiobactor*)	10.17	15.17	22.05	14.56	19.21	27.98	9.23	19.35	29.55
T_3 (*Pantoea agglomerans*)	10.58	15.58	24	15.09	21.08	32.57	10.20	22.09	32.18
T_4 (*Rhizobium radiobactor* + *Pantoea agglomerans*)	7.92	14.5	20.17	14.63	20.39	28.95	10.18	21.19	29.21
T_5 (*Rhizobium radiobactor* + Vermicompost)	9.08	14.75	21.06	12.33	18.59	27.86	7.70	18.48	27.68
T_6 (*Rhizobium radiobactor* + FYM)	10.08	14.92	21.08	10.51	16.73	25.23	6.88	16.11	29.17
T_7 (*Pantoea agglomerans* + Vermicompost)	9.0	12.08	20.58	9.92	16.23	26.87	6.27	15.63	28.18
T_8 (*Pantoea agglomerans* + FYM)	7.75	14.5	20.92	9.68	17.19	25.76	5.70	15.74	27.22
T_9 (*Rhizobium radiobactor* + *Pantoeaagglomerans* + Vermicompost)	7.17	15	20.67	9.33	16.83	23.13	5.84	16.06	28.74
T_{10} (*Rhizobium radiobactor* + *Pantoea agglomerans* + FYM)	7.67	14.58	20.17	12.06	18.18	27.54	7.69	18.40	27.50
SE(m)±	0.55	0.31	0.27	0.54	0.98	0.45	0.47	0.37	0.38
CD at 5%	1.61	0.92	0.79	1.61	2.94	1.34	1.39	1.10	1.13

Table 2 : Effect of Biofertilizers and their Consortia on vegetative growth and yield parameters.

Treatment details	Plant height (cm)			Canopy of plant (North-South) (cm)			Canopy of plant (East-West) (cm)			Yield per plant (g)
	30DAT	45DAT	60DAT	30DAT	45DAT	60DAT	30DAT	45DAT	60DAT	
T_1 Control (RDF)	3.86	7.57	13.26	16.37	22.33	30.28	4.99	9.75	22.31	**562.31**
T_2 (*Rhizobium radiobactor*)	5.80	12.18	22.28	25.91	31.77	38.95	9.23	19.35	29.55	775.92
T_3 (*Pantoea agglomerans*)	6.17	12.58	26.19	26.05	32.10	42.18	10.20	22.09	32.18	910.74
T_4 (*Rhizobium radiobactor* + *Pantoea agglomerans*)	6.12	12.28	23.11	25.77	31.92	40.57	10.18	21.19	29.21	597.37
T_5 (*Rhizobium radiobactor* + Vermicompost)	5.22	11.14	19.78	22.65	30.125	39.11	7.70	18.48	27.68	884.16
T_6 (*Rhizobium radiobactor* + FYM)	4.57	10.05	19.91	19.91	26.82	40.93	6.88	16.11	29.17	732.68
T_7 (*Pantoea agglomerans* + Vermicompost)	4.17	9.48	21.03	18.82	26.33	36.79	6.27	15.63	28.18	822.52
T_8 (*Pantoea agglomerans* + FYM)	4.45	10.22	20.93	18.03	24.93	40.19	5.70	15.74	27.22	859.82
T_9 (*Rhizobium radiobactor* + *Pantoeaagglomerans* + Vermicompost)	4.28	10.28	19.71	18.26	26.21	38.38	5.84	16.06	28.74	860.94
T_{10} (*Rhizobium radiobactor* + *Pantoea agglomerans* + FYM)	5.39	11.16	20.47	20.87	30.41	37.37	7.69	18.40	27.50	741.01
SE(m)±	0.49	0.55	0.31	0.85	0.32	0.33	0.47	0.37	0.38	3.20
CD at 5%	1.04	1.58	0.92	2.54	0.95	0.99	1.39	1.10	1.13	9.58

organic fertilizers and mineral solubilizing salt-tolerant bacterial inoculants on growth, anti-oxidant properties, nutrient level and yield of lettuce grown in saline soil.

This was statistically at par with the treatment of *Rhizobium radiobactor* however, an important observation was that application of *Pantoea agglomerans* and *Rhizobium radiobactor* as a consortia on the lettuce plants didn't have any significant impact of leaf growth parameter over control. Lettuce is consumed primarily as a salad or in burgers etc. (Rubatzky *et al.*, 1997 and Dursun *et al.*, 2010). Thus, the leaf is most important part the plant. Hence the effect of biofertilizer application on the leaf growth parameters was studied. Equivalently, *Enterobacter agglomerans*, now reclassified as *Pantoea agglomerans* also induced plant growth (Lindow *et al.*, 1998). Since, *Pantoea agglomerans* is possessing an astonishing number of plant growth promotion genes, including those involved in nitrogen fixation, phosphate solubilization, 1-aminocyclopropane-1-carboxylic acid deaminase activity, indoleacetic acid and cytokinin biosynthesis and jasmonic acid metabolism. The extreme plant-growth-promoting properties of *Pantoea phytobeneficialis* MSR2 revealed by functional and genomic analysis (Nascimento, Francisco X. *et al.*, 2020)

Effect of Biofertilizers and their Consortia on vegetative growth parameters

Most people eat lettuce in salads or in burgers, among other things (Rubatzky *et al.*, 1997 and Dursun *et al.*, 2010). Thus, the leaf is the most crucial component of the plant. Therefore, the impact of using biofertilizer on the vegetative growth parameters was investigated. The increased growth and yield of *Pantoea* species may also be due to the physiological change in vegetables. Indeed, the results of several studies have indicated that exposure of plants to *Pantoea* can result in a superior metabolism capacity inside plant cells. For example, *Panotea agglomerans* has been reported to significantly improve the photosynthetic characteristics and accumulation and transformation of assimilation products in plants compared to the control (Feng *et al.*, 2006). Increasing evidence has shown that selected members of the *Pantoea agglomerans* species can have a great potential as plant growth–promoting bacteria (Paredes-Páliz *et al*., 2016a, b, 2017). The PGPR bacteria called as natural fertilizers offer a powerful and environmentally friendly alternative to the use of chemical fertilizers. *Enterobacter agglomerans*, now reclassified as *Pantoea agglomerans* or *Erwinia herbicola*, also induced plant growth (Lindow *et al*., 1998; Fuente-Ramirez and Caballero-Mellado, 2005; Sergeeva *et al*., 2007). Use of *Pantoea* sp. to promote rice growth, the results showed that management using *Pantoea* species mixed with fertiliser had significant effects on plant height, canopy width of crops (Rungrueng *et al*., 2022). In the current study, it was found that *Pantoea agglomerans* and *Rhizobium radiobactor* application significantly affected plant height, plant canopy (north-south) and plant canopy (east-west). Maximum plant heights of 6.17, 12.58 and 26.19 cm were seen in the *Pantoea agglomerans* treated plants on various days (30,45 and 60 DAT after transplanting) both the plant canopy (east-west) and plant canopy (north-south) under research (25.77, 32.10, and 42.18 cm) showed a similar effect. Similarly, *Enterobacter agglomerans*, now reclassified as *Pantoea agglomerans* also induced plant growth (Lindow *et al*., 1998). *Pantoea agglomerans* has been reported to have positive effects in some studies, where it has been found that *Pantoea agglomerans* promotes growth and disease protection as an endophyte (Feng *et al*., 2010; Xie *et al*., 2017). According to statistics, this was comparable to how *Rhizobium radiobactor* was treated. Even so, a note worthy finding was that applying *Pantoea agglomerans* and *Rhizobium radiobactor* to lettuce plants had no discernible effect on the vegetative growth parameter compared to control.

Effect of Biofertilizers and their Consortia on yield parameter

The majority of people consume lettuce in burgers, salads and other dishes. (Rubatzky *et al.*, 1997 and Dursun *et al.*, 2010). The leaf is the plant's most important part as a result. So, it was determined what effect applying biofertilizer would have on the yield parameters. The increased growth and yield of *Pantoea* species may also be due to the physiological change in plants. Indeed, the results of several studies have indicated that exposure of plants to *Pantoea* can result in a superior metabolism capacity inside plant cells. For example, *P. agglomerans* has been reported to significantly improve the photosynthetic characteristics and accumulation and transformation of assimilation products in plants compared to the control (Feng *et al.*, 2006). Application of *Pantoea agglomerans* and *Rhizobium radiobactor* considerably impacted yield per plant, according to the current study (gm) at harvest, *Pantoea agglomerans* treated plants had the highest yield per plant (910.74g). This was statistically equivalent to the management of *Rhizobium radiobactor*. The application of *Pantoea agglomerans* and *Rhizobium radiobactor* to lettuce plants, however, had no appreciable impact on the yield parameter compared to control, which was an interesting finding.

Conclusion

On the basis of present investigation, it can be concluded that the application of *Pantoea agglomerans* (T_3) is most effective in enhancing the leaf parameters like as number of leaves, leaf length and leaf width, vegetative parameters, plant height, plant canopy and yield per plant proved that was found to be most beneficial treatment for Lettuce. Thus, we can be recommended to growers for commercial cultivation of Lettuce (*Lactuca sativa* L.)

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