Biological Forum – An International Journal **14(3): 1252-1258(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Combined Effect of *Pseudomonas aeruginosa* MCCB 0035 with NPK on Growth and Yield Attributes of Cabbage (*Brassica oleracea* L. var. *capitata*)

Komal Singh[1], Ebenezer Jeyakumar[2], J.P. Singh[3] and Deepak Kumar Jaiswal[4*]
[1]M.Sc. Scholar, Department of Industrial Microbiology,
SHUATS, Prayagraj (Uttar Pradesh), India.
[2]Assistant Professor, Department of Industrial Microbiology,
SHUATS, Prayagraj (Uttar Pradesh), India.
[3]Assistant Professor, Department of Plant Pathology,
SMMTD College Jannayak Chandra Shekhar University Ballia (Uttar Pradesh), India.
[4]Specialist, Bioscience Division, Institute of Pesticide Formulation Technology, Gurugram (Haryana), India.

(Corresponding author: Deepak Kumar Jaiswal)*
(Received 09 July 2022, Accepted 14 August, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Cabbage (*Brassica oleracea* var. *capitata* L.) is an important nutritious short duration vegetable crop grown worldwide. Its qualitative and quantitative both characters are affected by integrated approaches of beneficial microbes as well as other combinations of NPK fertilizers. The study was conducted at Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS) Allahabad during year 2018-2019. The objective of this study was to find out the effect of microbial inoculants along with various combinations of fertilizers like Nitrogen, Potassium and Phosphorus. Various methodologies like solubilization assay, qualitative assay, harvest index, vigour index and different growth parameters of cabbage were measured to evaluate the synergistic properties of the fertilizers along with microbial population of *Pseudomonas aeruginosa* where *Pseudomonas aeruginosa* MCCB 0035 was found to be effective for phosphate solubilization efficiency (280.00%) followed by zinc solubilization efficiency (183.33%). Subsequently, similar results were also obtained for IAA production with observance of light pink color, *Pseudomonas aeruginosa* strain MCCB 0035 (population of 8.0 × 10^{-8} cfu/ml after 35 days). Whereas combination of *Pseudomonas aeruginosa* strain MCCB 0035 and NPK exhibited a germination percentage of 73.33% and vigor index of 56.66%. Conclusively in this field experiment, it was observed that NPK (full dose) + *P. aeruginosa* (Carrier based full dose) exhibited highest plant height (30.86cm), maximum number of leaf (23.33), maximum number of unfolded leaf (25.00), highest shoot length (30.00cm), maximum stem length (28.66cm), maximum number of lateral root/plant (60.33), maximum root weight (7.81g), maximum stem weight (22.08), maximum head weight (1583.33g), maximum head diameter (17.80 cm) and maximum harvest index (756.93g) among all the combinations tested. Hence NPK (full dose) + *P. aeruginosa* (carrier based full dose) can be recommended for the better growth of cabbage under natural field condition.

Keywords: Pseudomonas, Cabbage, NPK, combined effect.

INTRODUCTION

Cabbage (*Brassica oleracea* L. var. *capitata)*, belonging to family cruciferae is one of the most important cool season leafy vegetable growing all over the world. It is believed to have originated in Western Europe which was the first cole crop to be cultivated. Prior to cultivation and use as food, cabbage was mainly used for medicinal purposes. Cabbage contains a range of essential vitamins, minerals, small amount of protein and carbohydrates. It is an excellent source of Vitamin C (36.6 mg). In addition to containing some vitamins, cabbage supplies minerals like Potassium 170 mg, Calcium 40 mg, Phosphorus 26 mg and Magnesium 12 mg per 100 gram of the diet. In India, it is grown in an area of 4.01million ha producing 9.27 million tons with the productivity of 23.12mt/ha (Anonymous, 2020). Maximum cabbage producing states are West Bengal followed by Orissa, Madhya Pradesh, Bihar, Assam, Gujarat, Chhattisgarh, Haryana Jharkhand, and Uttar Pradesh. Among the various factors involved in cabbage production, nutrients play major role in enhancing the yield with its quality. Experimental evidences showed that cabbage responds positively to nitrogen application and moderately to phosphorus application. Importance of organic and inorganic fertilizer on the productivity and nutritional

quality of cabbage has been reported by several researchers. Recently soil management practices have changed dramatically, including an increased use of synthetic fertilizers and pesticides to increase the crop yield. The cultivation of crop requires balanced supply of plant nutrients whereas most of the farmers are applying only chemical fertilizer for fetching maximum yield. Inadequate soil management using only chemical fertilizers has caused a global problem of nutrition depletion in soil and has made the pH of the soil acidic that caused reduction in crop yield (Hungria *et al.,* 2005). As an attribute to the chemical fertilizers, plant growth promoting bacteria (PGPB) were used as first described by Kloepper and Schroth (1978) that can directly or indirectly enhance the plant growth. Direct mechanisms include production of plant hormones such as indole acetic acid (IAA), gibberellins and cytokines (Glick *et al.,* 1999) along with a symbiotic N_2 fixation as well as solubilization of phosphates. On the other hand, indirect mechanisms are the production of iron chelators, siderophores, as well as cyanides which act as antagonists to plant pathogens (Glick, 2012). All these traits of PGPB increase seedling emergence, vigor as well as yield (Kloepper *et al.,* 1989). There is an immediate need to replace the use of chemical fertilizers by alternative biological fertilizers. The use of microorganisms with the aim of improving soil fertility by maintaining biogeochemical cycles for nutrition management in the soil is necessary for agriculture. Hence the aim of study is to determine the influence of three different fertilization systems (NPK) on cabbage growth and yield in presence and absence of *Pseudomonas aeruginosa* for the recommendation of bio fertilizer application in cabbage.

MATERIAL AND METHODS

The present study was conducted in the Department of Industrial Microbiology (IM), Jacob Institute of Biotechnology and Bioengineering (JIBB), Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad during 2018-2019.

Phosphate solubilization assay: Sterilized NBRIP medium (National Botanical Research Institute's phosphate medium pH-7.0) was poured in sterilized petriplates and *P. aeruginosa* strain was spot inoculated at the center of NBRIP using sterile inoculating loop and incubated at 28±2° C. Further the colony diameter was observed for the visible halo zone around the colony after 2, 4, 6, 8 and 10 days intervals. Phosphate solubilization index and efficiency was calculated by the following formula:

$$\text{PSI} = \frac{\text{Colony diameter (cm)} + \text{Halo zone diameter (cm)}}{\text{Colony diameter (cm)}}$$

$$\text{PSE} = \frac{\text{Solubilization zone (cm)} - \text{Colony diameter (cm)}}{\text{Colony diameter (cm)}} \times 100$$

Zinc solubilization assay: Zinc solubilization was assayed by preparing 100ml Pikovskaya's agar medium containing 0.1% insoluble zinc compounds *viz.,* ZnO, ZnS and $ZnCO_3$. The sterilized Pikovskaya's agar media (pH-7.0) was poured in sterilized petriplates and the *P. aeruginosa* strain was spot inoculated at the center of the medium using sterile inoculating loop. Un-inoculated plate was used as control. Plates were incubated at 28±2°C for 24, 48 and 72 hours and observed for the diameters of visible clearing zone around the colony as discrossed center (Saravanan *et al.,* 2007).

$$\text{ZSI} = \frac{\text{Colony diameter (mm)} + \text{Halo zone diameter (mm)}}{\text{Colony diameter (mm)}}$$

$$\text{ZSE} = \frac{\text{Solubilization zone (cm)} - \text{Colony diameter (cm)}}{\text{Colony diameter (cm)}} \times 100$$

Potassium solubilization assay: The sterilized Aleksandrov media (pH-7.0) having mica powder (insoluble form of potassium) was poured in sterilized petriplates and the *P. aeruginosa* strain was spot inoculated at the center of the medium using sterile inoculating loop. Plates were incubated at 28±2ºC. Detection of potassium solubilization by culture was based upon the ability of solubilization zone formation (Parmar and Sindhu 2013).

$$\text{KSI} = \frac{\text{Colony diameter (cm)} + \text{Halo zone diameter (cm)}}{\text{Colony diameter (cm)}}$$

$$\text{KSE} = \frac{\text{Solubilization zone (cm)} - \text{Colony diameter (cm)}}{\text{Colony diameter (cm)}} \times 100$$

Qualitative assay for production of IAA: King's B broth (pH-7.2) was prepared with and without L-Tryptophan (0.5%) and sterilized, further it was grown in 50 ml conical flask containing 25 ml King's B broth (King *et al.,* 1954) with and without L-Tryptophan (0.5%) solution and incubated at 28±2°C for 24 hours on a shaker then the culture was centrifuged at 4000 rpm for 20 minutes. One ml of culture supernatant was dropped in a test tube and mixed with 2 ml Salkowski reagent A (2% of 0.5M $FeCl_3$ in 35% perchloric acid) and 4 drop of Orthophosphoric acid. After 25 minutes of incubation, light pink color observation indicated positive reaction for IAA production.

Seed treatment, sowing and measurement of growth attributes: Cabbage seeds (*Brassica oleracia* L.) were surface sterilized with 95% ethanol for 5 min and washed with sterilized water. Seeds were grown in three replications in a field containing sterilized soil and non-sterilized soil (control). The plots were watered regularly to maintain optimum moisture and other routine care was taken to protect the plants from pests and diseases. Three plants in each treatment were randomly selected and tagged with a label for recording various growth parameters (fresh weight of the head plant height, leaves per plant, root length, number of lateral roots, stem diameter, shoots length and leaf length) at 20, 40, 60, 80 and 100 days after sowing.

Vigor index: Seedling vigor index (SVI) was calculated by multiplying the germination percentage and seedling length in centimeter.

Harvest index: It is the net head weight to the gross head weight taken at marketable stage.

$$\text{Harvest index (\%)} = \frac{\text{Dry mass of harvested component (g)}}{\text{Total shoot dry mass (g)}} \times 100$$

RESULTS AND DISCUSSION

The observations recorded on screening and characterization of test bacteria (*Pseudomonas aeruginosa* MCCB 0035) for PGPR traits, various growth parameters, yield of cabbage, and influence of combination of NPK with *Pseudomonas aeruginosa* MCCB 0035 during the experiment. Further the recorded data were analyzed statistically and discussed.

The P-solubilizing activity was determined by the microbial biochemical ability to produce and release organic acids through their carboxylic group chelates and cations (mainly Ca) bound to phosphate, converting them into the soluble forms. In the current study, it was reaffirmed that the phosphate solubilization by different PSBs was involved with the production of organic acids (Rashid *et al.*, 2004). The inverse relationship observed between the pH and soluble-P concentration which indicated that organic acid production by these PSB strains plays a significant role in the acidification of the medium, facilitating the Phosphate solubilization (Table 1). Similar inverse relationship between pH and soluble phosphate was reported earlier by (Illmer and Schinner 1995). The bacteria *Pseudomonas aeruginosa* MCCB 0035 was helpful in phosphate solubilization *in vitro* after a time period of 10 days. Several parameters such as halo zone diameter 01.90cm, colony diameter 0.50cm, Phosphate solubilization index (PSI) of 4.80cm and Phosphate solubilization efficiency (PSE) of 280.00% was observed. These P solubilizing soil bacteria could serve as efficient bio fertilizers for improving the P-nutrition of crop plants. The advantage of using natural soil isolates over the genetically manipulated or the one which has been isolated from a different environmental set up is the easier adaptation and succession when inoculated into the plant rhizosphere. Phosphate solubilizing microbes play important role in improving the growth and yield of a variety of crops through organic phosphorus mineralization (Alori *et al.*, 2017).

Preliminary experiments on Zn solubilization by plate assays revealed effective solubilization of Zn compounds by *Glucanoacetobacter diazotrophicus* strains and expressed high levels of solubilized Zn existing as free Zn^{2+} ions as well as Zn chelates (Alloway, 2004). Zinc solubilization was observed having halo zone diameter of 1.70cm, colony diameter 0.60mm, zinc solubilization index (ZSI) 3.83cm, zinc solubilization efficiency (ZSE) 183.33%. Observations revealed that the isolate was found to be positive for zinc solubilization (Table 2).

Several researchers have tested the ability of *Pseudomonas aeruginosa* to produce IAA and consequently, considered as IAA producing rhizobacteria. It also have been studied that IAA biosynthesis is greatly influenced by L-TRP precursor. Addition of L-TRP (an auxin precursor) to the media increased the auxin production by several folds (Frankenberger and Arshad 1995). Here the production of IAA by *Pseudomonas aeruginosa* MCCB 0035 after a time period of 24 hours, L-tryptophan produced light pink color (positive) and without tryptophan produced light yellow color.

After a time period, shelf-life determination of *Pseudomonas aeruginosa* MCCB 0035 was analyzed. During the entire sampling period, gram negative rod shape bacteria were observed, without any contamination and cfu/ml count**.**

Influence of *Pseudomonas aeruginosa* MCCB 0035 with different doses of NPK revealed the highest germination percentage in the treatments T_5- NPK (full dose) + *P. aeruginosa* MCCB 0035, with 73.33% as compared to T_0 treatment 53.33%. Whereas highest vigour index (56.66%) was also noticed in the same treatment T_5. Similar results have also been reported by Lucy *et al.* (2004) during the treatment combinations.

Among the different treatments, the maximum number of leaves, maximum shoot length of 30.0cm (Table-4) and maximum plant height of 30.86cm was observed in the treatment T_5 {NPK (full dose) + *P. aeruginosa* (carrier based Full dose)}. Treatment T_5, recorded 88.17% increase in plant height, compared to control T_0 at 100 DAT. The plant height in treatment T_5, was found to be significant, when compared with T_1, T_2, T_3, T_4, T_6, T_7, and T_8 treatments, respectively (Table 3). The similarity in results has also been earlier reported by Ibukunoluwa Moyin-Jesu (2015). Among all the treatments, highest value (87.28%) of lateral roots per plant of cabbage at harvesting was observed in treatment T_5. The least value (18.33cm) of number of lateral roots per plant of cabbage was observed in control having no treatment.

The highest value of fresh head weight (1583.33g) of cabbage at harvesting was observed in treatment T_5. The least value of number of fresh head weight (383.33g) of cabbage was observed in control having no treatment.

Dry root weight (g) of cabbage was measured at harvesting where T_5- NPK (full dose) + *P. aeruginosa* MCCB 0035 (Carrier based Full dose) was observed to be the most effective among all other treatments, showing the highest values of dry root weight (9.50g) of cabbage at harvesting. The least value of number of dry root weight (3.92g) of cabbage was observed in control which received no treatments. The dry root weight obtained in T_5 treatment was found to be significant, when compared with T_1, T_2, T_3, T_4, T_6, T_7, and T_8 treatments, respectively. Dry stem weight of cabbage was measured at harvesting. Treatment T_5, (NPK full dose + *P. aeruginosa* MCCB 0035 Carrier based full dose) was observed to be the most effective among all other treatments, showing the highest values of dry stem weight (22.08g) of cabbage. Krestini *et al.*

(2020) evaluated microbial consortium with NPK fertilizers resulting in maximum yield plant height and plant population. The least value of dry stem weight (7.65g) of cabbage was observed in control which received no treatments. Treatment- T_5 recorded 96.30% increase in dry stem weight of cabbage plant as compared to control (T_0) at 100 DAT. The dry stem weight of T_5 was found to be significant, when compared with treatments T_1, T_2, T_3, T_4, T_6, T_7, and T_8 respectively. Baeshen, (2016) reported some plant growth promoting pigments like pyocyanin produced by some strain of *Pseudomonas aeruginosa* that may significantly increase their height.

Head diameter of cabbage was measured at harvesting. Treatment, T5- NPK (full dose) + *P. aeruginosa* MCCB 0035 (Carrier based Full dose) was observed to be the most effective among all other treatments, showing the highest values of head diameter (17.80cm) of cabbage at harvesting. The similar findings were also reported by Singh and Pandey (2010) where they found significant cabbage head yield with application of NPK in combination with biofertilizer. The least value of head diameter (9.33cm) of cabbage was observed in control having no treatment.

Harvest index of cabbage was measured after harvesting. Among the different treatments, the harvest index of 756.93% of T_5 was found to be significant, when compared with treatments T_1, T_2, T_3, T_4, T_6, T_7, and T_8 respectively. The least value of harvest index (368.47%) of cabbage was observed in control. Treatment T_5, recorded 48.67% increase in harvest index as compared to control at 100 DAT (Table 6). Verma and Maurya (2013) have also confirmed the finding while using NPK with *Pseudomonas fluorescens.*

In the present study it was observed that *Pseudomonas aeruginosa* MCCB 0035 was found to be positive for phosphate solubilization efficiency (280.00%), zinc solubilization efficiency (183.33%) and positive result for IAA production with observance of light pink color. Strain *Pseudomonas aeruginosa* MCCB 0035 supported a population of 8.0×10^{-8} cfu/ml after 35 days. This strain *Pseudomonas aeruginosa* MCCB 0035 and NPK exhibited a germination percentage of 73.33% and vigor index of 56.66%. Similarly Rizvi *et al*. (2013) reported enhanced root nodulation in Phosphate solubilizing bacteria *Pseudomonas fluorescens* treatments.

The performance of microbial consortium copulated with *Pseudomonas* spp. was always beneficial in respect to yield and soil health (Soumya, 2020). Field experiment with cabbage plants suggested that treatment T_5, NPK full dose + *P. aeruginosa* (carrier based full dose) exhibited highest plant height (30.86cm), maximum number of leaf (23.33), maximum number of unfolded leaf (25.00), maximum shoot length (30.00cm), highest stem length (Table-5) (28.66cm), maximum number of lateral root / plant (60.33), maximum root weight (7.81g), maximum stem weight (22.08), maximum head weight (1583.33g), maximum head diameter (17.80 cm) and maximum harvest index (756.93g). Fitriatin *et al.* (2021) also studied about combined application of biofertilizers with NPK combination, resulting in enhanced growth and yield of the crop.

It was concluded that treatment T_5 (NPK full dose + *P. aeruginosa* carrier based full dose) was better than other treatments and this treatments T_5 can be recommended for the growth of cabbage under field condition. Verma *et al.* (2014) and (2017) reported highest nutrient values and highest physicochemical properties as pH, EC, Organic carbon when the plants were treated with *Pseudomonas* spp.

Table 1: Qualitative assay for phosphate solubilization test.

***P. aeruginosa* MCCB 0035**	**Solubilization zone (cm)**	**Colony diameter(cm)**	**Phosphate solubilization index (cm)**	**Phosphate Solubilization efficiency (%)**
2 days	1.27 ± 0.06	0.50 ± 0.10	3.53 ± 0.16	153.33± 0.32
4 days	1.50 ± 0.10	0.50 ± 0.10	4.00 ± 0.20	200.00± 0.40
6 days	1.70 ± 0.10	0.50 ± 0.10	4.40 ± 0.35	240.00± 0.70
8 days	1.80 ± 0.10	0.50 ± 0.10	4.60 ± 0.20	260.00± 0.40
10 days	1.90 ± 0.10	0.50 ± 0.10	4.80± 0.20	280.00± 0.40
S. Ed. (±)	0.085			
C. D. (P = 0.05)	0.179			

Table 2: Qualitative assay for Zinc solubilization test.

***P. aeruginosa* MCCB 0035**	**Solubilization zone(cm)**	**Colony diameter(cm)**	**Zinc solubilization index (cm)**	**Zinc solubilization efficiency (%)**
24 hours	1.50 ± 1.10	0.60 ± 0.10	3.50 ± 1.20	150.00 ± 4.40
48 hours	1.57 ± 0.06	0.60 ± 0.10	3.61 ± 0.16	161.66 ± 0.32
72 hours	1.70 ± 0.10	0.60 ± 0.10	3.83 ± 0.16	183.33 ± 0.32
S. Ed. (±)	0.057			
C. D. (P = 0.05)	0.121			

Table 3: Effect of *Pseudomonas aeruginosa* MCCB 0035 and NPK on plant height of cabbage.

Treatments	Plant height (cm) at varying time duration of days after transplanting (DAT)				
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
T_0- Control	9.66 ± 1.10	15.16 ± 0.95	14.03 ± 0.38	14.77±1.15	16.40 ± 1.70
T_1- NPK (Full dose)	14.83 ± 0.59	21.9 ±1.44	25.33 ± 1.10	25.87±0.58	27.46 ± 1.18
T_2- NPK (Half dose)	13.16 ± 0.59	21.6 ± 1.22	23.33 ± 0.78	24.03±0.47	27.1 ± 1.18
T_3- *P. aeruginosa* (Full dose)	15.16 ± 0.40	23.43 ± 0.95	25.46 ± 0.70	26.00±0.56	28.83 ± 0.50
T_4- *P. aeruginosa* (Half dose)	12.93 ± 0.45	20.96 ± 1.08	24.1 ± 0.61	4.67±0.72	26.9 ± 1.04
T_5- NPK (full dose) + *P. aeruginosa* (Full dose)	17.03 ± 1.50	25.73 ± 1.15	27.36 ± 1.15	29.90±0.70	30.86 ± 1.33
T_6- NPK (full dose) + *P. aeruginosa* (Half dose)	12.8 ± 0.69	23.36 ± 0.95	24.86 ± 0.64	26.87±1.24	28.96 ± 0.68
T_7- NPK (half dose) + *P. aeruginosa* (Full dose)	12.73 ± 0.58	17.4 ± 1.05	23.73 ± 1.33	24.03±0.64	27.66 ± 1.02
T_8- NPK (half dose) + *P. aeruginosa* (Half dose)	10.83 ± 0.49	15.4 ± 1.05	22.66 ± 0.64	22.97±0.75	25.2 ± 1.25
S. Ed. (±)	1.265	1.766	1.419	1.271	1.831
C. D. (P = 0.05)	0.596	0.833	0.669	0.599	0.864

Table 4: Effect of *Pseudomonas aeruginosa* MCCB 0035 and NPK on shoot length (cm) of cabbage at varying time duration of days after transplanting (DAT).

Treatments	Shoot length (cm) at varying time duration of days after transplanting (DAT)				
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
T_0- Control	7.00± 1.04	14.33± 1.01	12.90± 0.53	13.76±1.15	15.13±2.05
T_1- NPK (Full dose)	11.40± 1.05	20.86±1.43	24.20±1.00	23.53±1.15	26.5±1.13
T_2- NPK (Half dose)	11.20± 1.22	20.63± 1.16	22.16±1.01	22.96±0.49	25.86±1.07
T_3- *P. aeruginosa* (Full dose)	13.70± 1.13	22.26± 1.15	24.46±1.00	25.16±0.61	27.56±0.55
T_4- *P. aeruginosa* (Half dose)	12.70± 0.70	20.00± 1.31	23.16±0.59	23.66±0.51	25.83±1.18
T_5- NPK (full dose) + *P. aeruginosa* (Full dose)	16.07± 0.67	24.63± 1.07	26.56±1.04	29.06±0.67	30.00±1.14
T_6- NPK (full dose) + *P. aeruginosa* (Half dose)	12.80± 0.64	22.20± 0.95	23.86±0.57	26.1±1.39	28.03±0.50
T_7- NPK (half dose) + *P. aeruginosa* (Full dose)	12.80± 0.53	16.36± 1.17	22.76±0.85	22.96±0.68	26.86± 0.95
T_8- NPK (half dose) + *P. aeruginosa* (Half dose)	11.50± 1.00	14.33± 1.01	21.46±0.64	21.93±1.15	24.23±1.14
S. Ed. (±)	1.877	1.814	1.337	1.180	1.843
C. D. (P = 0.05)	0.885	0.855	0.630	0.556	0.869

Table 5: Effect of *Pseudomonas aeruginosa* MCCB 0035 and NPK on stem length (cm) of cabbage at varying time duration of days after transplanting (DAT).

Treatments	Stem length (cm) at varying time duration of days after transplanting (DAT)				
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
T_0- Control	6.00 ±1.08	12.50± 1.15	12.63± 0.67	12.97±1.25	14.60±2.00
T_1- NPK (full dose)	10.26 ± 1.11	18.93± 1.42	23.27±1.16	23.53±0.49	25.33±1.15
T_2- NPK (half dose)	9.97 ± 1.21	18.7± 1.14	21.23±0.85	21.90±0.62	24.66±1.15
T_3- *P. aeruginosa* (full dose)	12.50 ± 1.13	20.36± 1.25	23.37±0.96	23.93±0.57	26.33±0.58
T_4- *P. aeruginosa* (half dose)	11.37 ± 0.95	17.9± 1.30	22.5±1.01	22.93±0.48	24.66±1.15
T_5- NPK (full dose) + *P. aeruginosa* (full dose)	15.17 ± 0.67	22.7± 1.25	25.5±1.00	27.93±0.74	28.66±1.15
T_6- NPK (full dose) + *P. aeruginosa* (half dose)	11.87 ± 1.68	20.5± 0.95	22.70±0.36	25.00±1.14	26.66±0.58
T_7- NPK (half dose) + *P. aeruginosa* (full dose)	11.77 ± 0.55	14.43± 0.91	21.67± 1.02	22.03±0.64	25.33±1.15
T_8- NPK (half dose) + *P. aeruginosa* (half dose)	10.43± 0.83	12.23± 0.91	20.57±0.72	21.10±1.13	22.66±1.15
S. Ed. (±)	1.877	1.881	1.383	1.493	1.910
C. D. (P = 0.05)	0.885	0.887	0.652	0.704	0.900

Table 6: Effect of *Pseudomonas aeruginosa* MCCB 0035 and NPK on Harvest index (%) of cabbage at harvest.

Treatments	Dry mass of harvest component	Shoot dry mass	Harvest index (%)
T_0- Control	55.75 ± 1.11	15.13 ± 2.05	368.47 ± 3.16
T_1- NPK (Full dose)	132.07 ± 2.04	26.50 ± 1.13	498.37 ± 3.17
T_2- NPK (Half dose)	130.05 ± 1.73	25.86 ± 1.07	502.90 ± 2.80
T_3- *P. aeruginosa* (Full dose)	174.34± 0.84	27.56 ± 0.55	632.58 ± 1.39
T_4- *P. aeruginosa* (Half dose)	171.42 ± 0.76	25.83 ± 1.18	663.64 ± 1.94
T_5- NPK (full dose) + *P. aeruginosa* (Full dose)	227.08 ± 2.65	30.00 ± 1.14	756.93 ± 3.79
T_6- NPK (full dose) + *P. aeruginosa* (Half dose)	188.75 ± 2.69	28.03 ± 0.50	673.38 ± 3.19
T_7- NPK (half dose) + *P. aeruginosa* (Full dose)	171.48 ± 1.12	26.86 ± 0.95	638.42 ± 2.07
T_8- NPK (half dose) + *P. aeruginosa* (Half dose)	157.41 ± 2.47	24.23 ± 1.14	649.64 ± 3.61
S. Ed. (±)	15.244	1.843	17.087
C. D. (P = 0.05)	7.190	0.869	8.059

CONCLUSION

Combined effect of bio priming (*Pseudomonas aeruginosa* MCCB 0035) and chemical fertilizers (NPK) were evaluated using various methodologies like solubilization assay, qualitative assay, harvest index, vigour index and different growth parameters to measure and evaluate the synergistic properties of the fertilizers along with microbial population that resulted in considerably enhanced yield as well as luxurious plant growth characters of cabbage (*Brassica oleracea* L. var. *capitata)* in comparison to sole application of fertilizer or bioagent only. The integrated approach resulted in promotion of phosphate solubilization efficiency, zinc solubilization efficiency, IAA production efficiency whereas in plant growth characters it enhanced germination percentage, vigor index, plant height, number of leaves, number of unfolded leafs, shoot length, stem length, lateral roots, root weight, head weight, head diameter and harvest index.

FUTURE SCOPE

During the study it was found out that performance of dual treatments (mineral fertilizers + bio priming) was better in comparison to sole applications of mineral fertilizers or bio agent. In future prospects the mineral fertilizers may be replaced with manures/composts where the microbial populations are self-increasing. But if it is primed or inoculated with beneficial microbes it may enhance the yield and quality of produce by producing growth hormones and immunization against several diseases which induced systemic acquired resistance occurred with the plant growth promoting rhizobacteria.

Acknowledgement. The authors highly acknowledge Professor and Head, Department of Industrial Microbiology, JIBB, SHUATS, Allahabad for all the facilitation of laboratory as well as field to complete the research work successfully.

Conflict of Interest. None.

REFERENCES

Alloway, B. J. (2004). Zinc in Soils and Crop Nutrition. Brussels, Belgium. *International Zinc Association,* p. 1-116.

Alori, T. E., Glick, B. R. and Babalola, O. O. (2017). Microbial Phosphorus solubilisation and its potential for use in sustainable agriculture. *Frontiers in Microbiology*, (8): 971-974.

Anonymous. (2020). Directorate of Agriculture Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare.

Baeshen, A. Ali (2016). Use of *Pseudomonas aeruginosa* as Fertilizer in *Eruca sativa. International Journal of Current Microbiology and Applied Sciences, 5*(10): 301-312.

Ibukunoluwa Moyin-Jesu, E. (2015). Use of different organic fertilizers on soil fertility improvement, growth and head yield parameters of cabbage (*Brassica oleraceae* L). *International Journal of Recycling of Organic Waste in Agriculture*, *4*(4), 291-298.

Fitriatin, B. N., Dewi, V. F. and Yuniarti A. (2021). The impact of bio-fertilizers and NPK fertilizers application of soil phosphorus availability and yield of upland rice in tropic dryland. *E3S Web of Conferences*, 232, 03012.

Frankenberger, W. T. and Arshad, M. (1995). Phytormones in Soils. *Marcel Dekker Incorporated*, New York, 35-71.

Glick, B. R. (2012). Plant Growth-Promoting Bacteria: Mechanisms and Applications. Hindawi Publishing Corporation, *Scientifica*. Volume 2012, article ID 963401, p. 1-15.

Glick, B. R., Patten, C. L., Holguin, G. and Penrose, G. M. (1999). Biochemical and Genetic Mechanisms Used by Plant Growth Promoting Bacteria. Imperial College Press, London. p. 267.

Hungria, M., Franchini, J., Campo, R. and Graham, P. (2005). The Importance of Nitrogen Fixation to Soybean Cropping in South America. In: Werner, D. and Newton, W., Ed., Nitrogen Fixation in Agriculture, Forestry, Ecology, and the Environment, Springer, Berlin, 25-42.

Illmer, P. and Schinner, F. (1995). Solubilization of inorganic calcium phosphates - Solubilisation mechanisms, *Soil Biology and Biochemistry*, *27*(3): 257-263.

King, E. O., Ward, M.K., Rancy, D. E. (1954). Two simple media for the demonstration of pyocyanin and fluorescein. *Journal of Laboratory and Clinical Medicine*, *44*, 301-307.

Kloepper, J. W. and Schroth M. N. (1978). Plant growth promoting rhizobacteria on raddish. International Proceedings. Of the 4th International Conference on Plant Pathogenic Bacteria, p. 879-882.

Kloepper, J. W., Lifshitz, R. and Zablotowicz, R. M. (1989). Free-living bacterial inoculation for enhancing crop productivity. *Trends in Biotechnology*, (7): 39-44.

Krestini, E. H., Susilawati, A. and Hermanto, C. (2020). Effect of NPK fertilizer and microbial consortium to growth and production of Garlic (*Allium sativum* L.) *BioWeb of Conferences*, *20*, 03010.

Lucy, M., Reed, E., Bernard, R. and Glick, B. R. (2004). Applications of free living plant growth-promoting rhizobacteria. Department of Biology, University of Waterloo, Waterloo, Kluwer Academic Publishers. Printed in the Netherlands, (86): 1–25.

Parmar, P. and Sindhu, S. S. (2013). Study on Potassium Solubilization by Rhizosphere Bacteria: Influence of Nutritional and Environmental Conditions. Department of Microbiology, CCS Haryana Agricultural University, Hisar, 125004, India *3*(1): 25-31.

Rashid, M., Samina, K. Najma, A. Alam, S. and Latif F. (2004). Organic acids production and phosphate solubilisation by phosphate solubilising microorganisms under in vitro conditions. *Pakistan Journal of Biological Sciences*, *7*(2): 187-196.

Rizvi, R. Mahmood, I. and Tiyagi, S. A. (2013). Potential role of organic matters and phosphate solubilizing bacteria on the growth and productivity of Fenugreek. *Journal of Agricultural Science and Technology*, (15): 639-647.

Saravanan, V. S., Kalaiarasan, P., Madhaiyan, M. and Thangaraju, M. (2007). Solubilization of insoluble zinc compounds by *Gluconacetobacter diazotrophicus* and the detrimental action of zinc ion (Zn^{2+}) and zinc

chelates on root knot nematode *Meloidogyne incognita*. *Letters in Applied Microbiology*, *44*(3): 235-241.

Soumya, S. Sreejith, S. and Remakanthan, A. (2020). Combined effect of *Pseudomonas* spp. Consortium and fertilizer with micronutrients and enhanced yield of *Amaranthus tricolor* (L.). *Proceedings of the National Academy of Sciences, India Section B: Biological* Sciences *90*, 1083-1092.

Singh, P.K. and Pandey, M. (2010). To study the effect of Integrated Nutrient Management on yield and nutrient uptake in cabbage. *Indian Journal of Hill Farming*, *23*(2): 39-41.

Verma, R. and Maurya, B. R. (2013). Effect of bio-organics and fertilizers on yield and nutrient uptake by cabbage. *Annals of plant and soil research*, *15*(1): 35-38.

Verma, R., Maurya B. R., Meena V. S., Dotaniya, M. L., Deewan, P. and Jajoria, M. (2017). Enhancing production potential of cabbage and improved soil fertility status of Indo-gangetic plain through application of bio-organics and mineral fertilizers. *International Journal of Current Microbiology and Applied Sciences*, *6*(3): 301-309.

Verma, R., Maurya, B. R. and Meena, V. S. (2014). Integrated effect of bio-organics with chemical fertilizer on growth, yield and quality of cabbage. *Indian Journal of Agricultural Sciences*, *84*(8): 914-919.

How to cite this article: Komal Singh, Ebenezer Jeyakumar, J.P. Singh and Deepak Kumar Jaiswal (2022). Combined Effect of *Pseudomonas aeruginosa* MCCB 0035 with NPK on Growth and Yield Attributes of Cabbage (*Brassica oleracea* L. var. *capitata)*. *Biological Forum – An International Journal*, *14*(3): 1252-1258.