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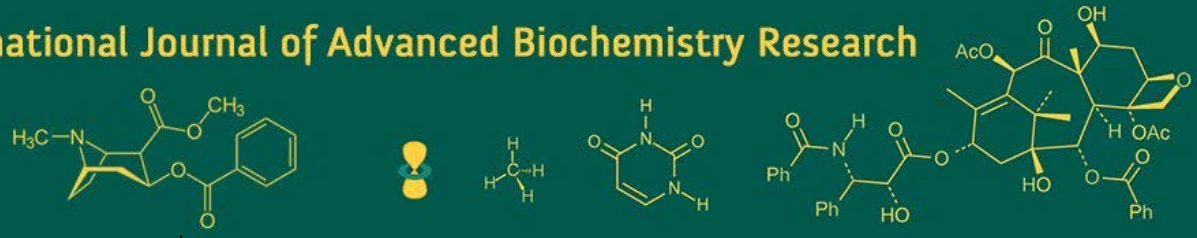

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Perspective of plant growth promoting rhizobacteria and biopesticides on growth and yield of cabbage

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Abstract
Our study examines the effect of biopesticides and PGPR on the growth performance of cabbage (*Brassica oleracea* L. var. *capitata*). The CRD trial consisted of four replications and seven distinct treatment combinations. The treatments were as follows: T_1 (Absolute control), T_2 (Application of chemical pesticides), T_3 (Inoculation of PGPR), T_4 (Application of *Trichoderma*), T_5 (Inoculation of PGPR + Neem cake), T_6 (Application of *Trichoderma* + Neem cake), and T_7 (Inoculation of PGPR + *Trichoderma* + Neem cake). The combination of PGPR + *Trichoderma* + Neem cake inoculation produced the highest growth qualities, as measured by the number of leaves per plant (16), according to the results. Aphid incidence was absent, and T_7 (Inoculation with PGPR + *Trichoderma* + Neem cake) showed no damaged leaves per plant (mean value 0) compared to other treatments, while T_1 (control) showed the highest number of damaged leaves per plant. In comparison to other treatments, the application of PGPR + *Trichoderma* + Neem cake resulted in the significantly highest fruit weight (1.14 kg/fruit) in cabbage. In terms of yield and biocontrol efficacy, the combination of PGPR, *Trichoderma*, and Neem cake treatment demonstrated the best results on cabbage.

Keywords: Cabbage, PGPR and biopesticide, *Trichoderma*, neem cake

Introduction
Cabbage (*Brassica oleracea* var. *capitata*) is a dicotyledonous biennial crop but is grown as an annual cole crop (Smith, 1995) [5] and belongs to the Cruciferae (Brassicaceae) family. It contains essential vitamins, minerals, and a small amount of protein with good caloric value (Haque *et al.*, 2006) [4]. Cabbage can be grown on all types of soil with a pH range between 5.5 and 6.5 (Chadha, 2006) [2]. The optimum temperature for cabbage growth is 15–18 °C. Brassicaceous plants represent one of the major leafy vegetables worldwide (Ayaz *et al.*, 2006) [1]. Cabbage is India's second most important crop in the cole group. It is grown throughout the year, except during one or two months of extreme heat. The word "cabbage" is derived from the French word *caboche*, meaning "head" (Majors Dhaliwal, 2017) [3]. Additionally, the Latin name *Brassica* comes from the Celtic word *bresic*, which also means cabbage. Cabbage is grown worldwide, including in Europe, India, Indonesia, Malaysia, and the Philippines. India is the world's second-largest cabbage producer, with an annual production of 60 lakh MT. Cabbage is India's fourth most widely grown vegetable crop. It is a significant source of vitamins, especially A, C, and B, along with several minerals, notably calcium and potassium. There is growing evidence of the health benefits of cabbage, particularly due to its calcium and potassium content. However, the extensive use of chemical fertilizers in cabbage cultivation can be expensive and cause significant environmental problems. Large amounts of chemical fertilizers are used to replace soil nitrogen (N) and phosphorus (P), leading to high environmental costs and pollution. Therefore, the experiment is planned to evaluate the effect of PGPR inoculation, along with biopesticides, on the growth and yield of cabbage.

Materials and Methods
Study site and experiment design
The study was conducted in the Department of Agricultural Microbiology, College of Agriculture, Raipur (C.G.) during the *rabi* season of 2019–20. The study employed a completely randomized design with four replications, each containing seven treatments: T_1

(Absolute control), T_2 (Application of chemical pesticides), T_3 (Inoculation of PGPR), T_4 (Application of *Trichoderma*), T_5 (Inoculation of PGPR + Neem cake), T_6 (Application of *Trichoderma* + Neem cake), and T_7 (Inoculation of PGPR + *Trichoderma* + Neem cake). The horticultural nursery of IGKV provided the Ezangad variety of cabbage (*Brassica oleracea* L. var. *capitata*) seeds, which were sprouted in a tray with cocopeat.

Seedling transplanting, application of biofertilizer and after care

Surface soils were randomly collected from a depth of 6 inches (15 cm) near the College of Agriculture, Raipur, to construct a composite sample. The soils were thoroughly mixed. A perfectly proportioned mixture of soil, sand, and compost (1:1:1) was placed in each container. The collected soil samples were labeled and stored in polythene bags for physicochemical and microbial analysis.

Composite cultures of *Azotobacter*, PSB, and *Azospirillum* are included in PGPR. Isolates were obtained from the Department of Agricultural Microbiology, College of Agriculture, Raipur, microbiology repository. PGPR inoculation was applied as a root dip for seedlings at sowing and as a soil treatment at 5 g per pot when flowering started. *Trichoderma* was applied to the soil at the time of flower initiation at 5 g per pot and at 100 g/liter of water for seedling treatment during transplanting. Before planting, neem cake was applied as a base soil treatment at 5 grams per pot. The plants were spaced 45 cm apart each way. Plant observations, including cabbage growth, were recorded regularly. The fruits were hand-picked when they reached marketable size. Immediately following each harvest, the fruits were weighed and subjected to further observations. The percentage of survivors was also recorded.

Survival percentage

The germination in each treatment was recorded at 15 days after transplanting. Number of seedlings were counted and expressed as survival percentage.

$$\text{Survival (\%)} = \frac{\text{Total number of seedlings survived}}{\text{Total no. of seedlings sown}} \text{x } 100$$

The effects of various treatments were recorded at 15, 30, 45, and 60 days after transplanting, as well as at harvest, based on parameters such as the number of leaves per plant. Aphids, a common insect pest, were observed on the leaves, along with signs of leaf damage. At the time of harvest, the weight of the curd and biomass accumulation were also noted. To examine plant growth and yield traits, four plants were randomly selected and labeled for each treatment and replication, with further observations recorded.

Results and Discussion

Plant height

Plant height is an important indicator of growth and is commonly used to monitor the effects of various treatments on crop development. The data were recorded at five different stages: 15, 30, 45, and 60 days after transplanting, and during harvest. The experimental results for cabbage, presented in Table 1, clearly show that the maximum plant height (22.97 cm) was observed in T_7 (Inoculation of PGPR + *Trichoderma* + Neem cake), while the minimum plant height (19.31 cm) was noted in T_1 during harvest.

Survival percentage and shoot and root biomass

Table 1 data indicates that treatments T_3, T_4, T_5, T_6, and T_7 (Inoculation of PGPR, Application of *Trichoderma*, Inoculation of PGPR + Neem Cake, Application of *Trichoderma* + Neem Cake, and Inoculation of PGPR + *Trichoderma* + Neem Cake) had the highest percentage of cabbage survivorship (100%), while treatments T_1 and T_2 (Absolute control and Application of chemical pesticides) had the lowest percentage (98.4%).

When cabbage was harvested, T_7 (Inoculation of PGPR + *Trichoderma* + Neem Cake) had the highest shoot dry weight (6.07 g/plant), considerably higher than T_3 and T_5 (5.83 and 5.95 g/plant, respectively). Similarly, T_7 (Inoculation of PGPR + *Trichoderma* + Neem Cake) had the highest root dry weight (2.65 g/plant), while T_1 had the lowest shoot dry weight (4.32 g/plant) and the lowest root dry weight (2 g/plant).

Table 1: Efficacy of PGPR and Biopesticides on survival and growth parameter of cabbage.

Treatments	Treatment details	Survival (%)	Shoot DW (g/plant)	Root DW (g/plant)	Plant height (At Harvest)
T_1	Control	98.4	4.32^{C}	2.00	19.31
T_2	chemical pesticides	98.4	5.01^{bc}	2.12	21.50
T_3	PGPR	100	5.83^{a}	2.21	21.47
T_4	*Trichoderma*	100	5.45^{ab}	2.18	21.16
T_5	PGPR + Neem cake	100	5.95^{a}	2.32	22.27
T_6	*Trichoderma* +Neem cake	100	5.60^{ab}	2.22	22.06
T_7	PGPR +*Trichoderma* +Neem cake	100	6.07^{a}	2.65	22.97
CD (0.05)		-	0.720	NS	1.80

Number of clean leaves, damaged leaves and incidence of aphids in leaves per plant

The quantity of clean leaves in cabbage is displayed in Table 2. The T_7 (Inoculation of PGPR + *Trichoderma* + Neem Cake) protocol recorded the highest number of leaves per plant at 16.00, while the T_1 protocol recorded the lowest number of leaves per plant at 14.00 (Absolute control). The maximum number of damaged leaves per plant in cabbage was recorded at 2.33 in T_1. The least amount of damaged leaves per plant was reported to be 0 for T_6 (*Trichoderma* + Neem Cake) and T_7 (Inoculation of PGPR + *Trichoderma* + Neem Cake). The incidence of aphids per plant was highest in treatment T1 (Absolute Control) at 2.17 and lowest in treatment T_7 (0).

Table 2: Efficacy of PGPR and Biopesticides on incidence of insect/pests in cabbage

Treatments	Treatment details	Damaged leaves per plant	No. of Aphids in leaves	No. of clean leaves/plant
T_1	Control	2.33	2.17	14.00
T_2	Chemical pesticides	1.66	0.50	14.5
T_3	PGPR	0.33	0.66	15.00
T_4	*Trichoderma*	0.33	0.58	14.33
T_5	PGPR + Neem cake	0.33	0.58	15.33
T_6	*Trichoderma* + Neem cake	0	0.50	14.92
T_7	PGPR + *Trichoderma* + Neem cake	0	0	16.00

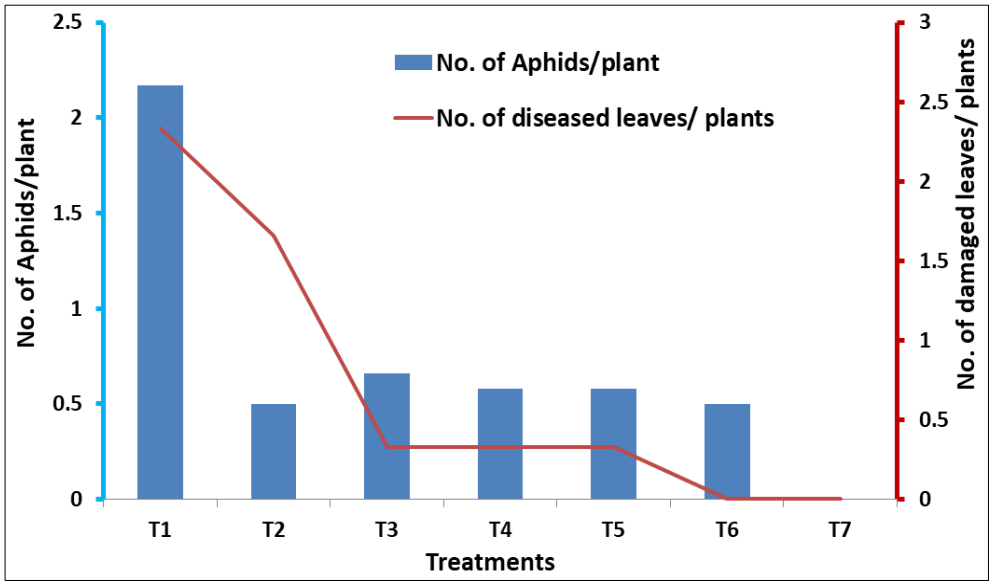

Fig 1: Efficacy of PGPR and Biopesticides on incidence of insect/pests in cabbage

Fruit yield / plant (kg)

The maximum number of fruits per four plants in cabbage was recorded as 4 in T_7, T_6, T_5, T_4, T_3, and T_2, while the minimum number of fruits (3) was observed in T_1 (Table 3). In cabbage, T_7 (Inoculation of PGPR + *Trichoderma* + Neem Cake) recorded the maximum fruit yield (1.14 kg/fruit), which was on par with T_5 (1.10 kg/fruit), followed by T_6 (1.05 kg/fruit) and T_3 (1.05 kg/fruit). The minimum fruit yield per plant was recorded in treatment T_1 (Absolute Control) at 0.87 kg/fruit (Table 3).

Table 3: Efficacy of PGPR and Biopesticides on characteristics of cabbage

Treatments	Treatment details	Total No. of curds from 4 plants	Weight/Curd (kg)
T_1	Control	3	0.87^{d}
T_2	Chemical pesticides	4	0.97^{C}
T_3	PGPR	4	1.05^{b}
T_4	*Trichoderma*	4	1.04^{b}
T_5	PGPR + Neem cake	4	1.10^{a}
T_6	*Trichoderma* +Neem cake	4	1.05^{b}
T_7	PGPR +*Trichoderma* +Neem cake	4	1.14^{a}
CD(0.05)		-	0.042

Conclusions

Taking into account input costs, it can be said that PGPR and biopesticide inoculation have proven to be the most successful treatments in terms of cabbage growth and fruit yield, as well as in reducing insect and pest populations. However, the results are preliminary, and more testing is required to yield more reliable conclusions and ensure the long-term success of cabbage growth in response to inoculation.

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