Role of Bio-formulation on Enhancement of Seed Quality and Yield in Garden Pea (*Pisum sativum* L.)

ABSTRACT

A research work was conducted at Assam Agricultural University, Jorhat during rabi season of 2021-2022 to evaluate the effect of different bio-formulations on enhancement of seed quality and yield in garden pea. The laboratory analysis were conducted in Complete Randomized Design for seed vigour characteristics whereas the field experiment was laid out in factorial Randomized Block Design for assessing plant growth and yield attributing characters. The experiment involved two varieties of garden pea *viz*., Arkel and DS-10, each having seven treatments with three replications.

The treatments comprised of T_1- untreated control, T_2- Hydropriming, T_3- seed priming with *Trichoderma viride* @ 5g/kg, T_4- PSB @ 10g/kg, T_5- *Rhizobium* @ 20 g/kg, T_6- PSB @ 10g/kg + *Rhizobium* @ 20 g/kg and T_7- *Pseudomonas fluorescens* @ 10 g/kg. Before sowing, the seeds of both the varieties were soaked in water for 4 hours and bio-primed with the above mentioned bio-formulations. The results revealed significant difference amongst the treatments for most of the plant growth promoting and yield attributing characters. T_6 exhibited highest performance for most of the characters. Varietal performance of DS-10 was found better than Arkel. Laboratory observations also recorded the maximum germination (%) and seed vigour index I & II in the T_6 treatment. However, significant increase in germination related characters and early seedling growth was exhibited by all the treatments over the control. The experiment thus revealed that although all bio-formulations *viz.*, PSB, *Rhizobium*, *Trichoderma viride*, *Pseudomonas fluorescens* alone and in combination could improve seed quality, seed yield & yield attributing characters but the best performance could be achieved in T_6 i.e. by applying PSB@ 10g/kg + *Rhizobium* @ 20 g/kg. Therefore, it could be suggested that seed treatment with bio-formulations should be done for better seed production and seed yield in garden pea.

Keywords: Garden pea; rhizobium; phosphate solubilizing bacteria (PSB); Trichoderma viride; Pseudomonas fluorescens; seed vigour index (SVI).

1. INTRODUCTION

Pea (*Pisum sativum* L.), one of the most popular annual legume crop of India, belongs to the family Leguminosae (Fabaceae) and sub-family Papilionoideae. It is a protein rich, self-pollinated, cool season vegetable crop grown throughout the world. There are two subspecies: *Pisum sativum* var. hortense, i.e. the garden pea with white flowers, and *Pisum sativum* var. arvense, i.e. the field pea with coloured blooms. Basically this crop is largely grown for its green tender pods and green seeds which are mostly used as vegetables and serve as excellent food source for human consumption. It is the third most important pulse crop in the world. India is ranked second, next to China both in terms of area and production (FAO, 2022). Major pea producing states in India are Uttar Pradesh, Bihar, Madhya Pradesh, Karnataka, Rajasthan, Punjab, Haryana, Himachal Pradesh, West Bengal and Assam. In the northern plains, peas are grown during the *rabi* season from the beginning of October to the end of November. It is highly nutritive and contains high proportion of protein (25%), amino acids, sugars (12%), carbohydrate, vitamins A and C, calcium and phosphorus and a small quantity of iron [1]. Straw of garden pea is used as fodder for livestocks. Its cultivation plays a vital role in promoting sustainable agriculture by maintaining soil fertility through biological nitrogen fixation in association with symbiotic *Rhizobium* prevailing in the root nodules [2].

Modern agriculture is becoming more and more reliant upon the supply of synthetic inputs such as chemical fertilizers and pesticides. However, long term application of chemicals reduces soil fertility and crop yield in the intensive cropping systems [3]. Synthetic chemicals used in agriculture has a detrimental effect on agro-ecosystem and also result in health hazards. Hence, application of bio-formulations in crops is a sustainable approach from both ecological and economic viewpoint. The seed has consistently been a key factor in agriculture. The yield and quality of crop production are greatly influenced by seed quality. As food demand rises, it has become a challenge to produce high quality seeds in an efficient and effective manner. Therefore, some successful strategy must be used to ensure crop growth and increase seed yield. One of them is seed priming, which can be used as a seed invigoration treatment for rapid germination and early seedling establishment. Due to abiotic stress and various environmental conditions, the proportion of seed germination, field emergence and seedling vigour has been negatively impacted, which eventually leads to poor agricultural output. Therefore, to promote healthy and uniform germination as well as to maintain the vigour and viability of seeds, bio-priming offers one of the greatest alternatives to chemical fertilizers & pesticides. Keeping these facts in view, the present study on the “Role of bio-formulations on enhancement of seed quality and yield in garden pea” was undertaken, which aimed at organic cultivation of garden pea by using seed priming treatments with different priming agents to hasten the rate of germination, improve seedling vigour, crop yield, soil fertility, resistance to biotic and abiotic stresses & ultimately enhance seed quality & yield.

2. MATERIALS AND METHODS

The present investigation was conducted during rabi season, 2021-22 at Instructional Cum Research (ICR) Farm of Assam Agricultural University, Jorhat (Assam) which is located at 26° 45/ N latitude, 94° 12/ E longitude and 87 m altitude above the mean sea level. The climate of Jorhat experiences a tropical monsoon rainforest with the temperature during winter ranges from 8°-15°C and during summer ranges from 35°-38°C. The soil in the experimental site was sandy loam in texture with pH 7.5. The experimental field was thoroughly prepared by ploughing, leveling and finally brought to a fine tilth. Farm yard manure (FYM) and vermicompost@ 5 tonnes/ha were applied to the experimental area at the time of final land preparation. The field experiment was laid out in Factorial Randomized Block Design with three replications. Total sixty seeds were sown per plot by maintaining a row to row distance of 30 cm and plant to plant distance of 10 cm with plot size 1.8 sq.m (2m x 0.9m). Irrigation was done manually as per requirement at several crop stages including seedling emergence stage, active vegetative stage and flowering stage to pod filling stage. To maintain the plant population, manual thinning and weeding were done twice at 15-20 days after sowing and throughout the vegetative growth stage. The experiment comprised of seven treatment combinations involving three replications. Details of the experimental treatments are shown in Table 1.

Healthy, uniform and dry seeds of two garden pea varieties *viz*. Arkel and DS-10 were used. Untreated dry seeds were used as control (T_1) to compare the effect of priming treatments. For hydro priming, the garden pea seeds were soaked in water for 4 hours and then re-dried to initial moisture content. For bio-priming, the seeds were surface sterilized with 1.0% sodium hypochlorite (NaOCl) solution for 5 minutes and then dried. After drying, the seeds were washed three times with distilled water that had been sterilized and dried on sterilized blotter paper [4]. The weight of the talc based bioagent formulations were measured out on a weighing balance in accordance with dose in order to cover the whole surface of seeds with the bioagents. The surface sterilized and dried seeds were bio-primed by soaking in the bio-formulation of *Trichoderma viride*, *Pseudomonas fluorescens*, Phosphate solubilizing bacteria (PSB) and *Rhizobium* spp. Then the seeds were shade dried to initial moisture content and sown in the field. A small portion of seeds were kept for laboratory analysis which was conducted in Complete Randomized Design for seed vigour characteristics *viz*., germination (%), seedling length (cm), seedling dry weight (mg), seed vigour index I (SVI-I) and seed vigour index II (SVI-II). Field observations on plant growth promoting and yield attributing characters such as field emergence (%), final plant stand (no. per plot), days to 50% flowering, plant height (cm), number of branches per plant, leaves per plant, pods per plant, seeds per pod and seed yield per plant (g) were also recorded. The data collected for each character was analyzed with the help of OPSTAT software.

2.1 Observations Recorded in Laboratory

The seeds of both the varieties were germinated by following between paper method as per the recommendations of ISTA (2004). Fifty seeds were taken in three replications for all the treatments and tested for standard germination by placing the seeds equidistantly between two sheets of germination paper soaked in water, then rolled and tagged and incubated inside germinator at 30°C. Germination percentage was calculated by the following formula as given by ISTA (2004).

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds used}} \times 100$$

On 8th day of final count, ten germinated normal seedlings were randomly selected from each replication for measurement of seedling length. The root and shoot lengths were measured from

Comment [JG1]: Take recent year of ISTA references. Is too old.

Table 1. Details of seed priming treatments

T_1	Control (un-treated)
T_2	Hydration (4 hours) + redrying
T_3	Hydration (4 hours) + redrying + *Trichoderma*@ 5 g/kg
T_4	Hydration (4 hours) + redrying + PSB @ 10 g/kg
T_5	Hydration (4 hours) + redrying + *Rhizobium* @ 20 g/kg
T_6	Hydration (4 hours) + redrying + PSB @ 10 g/kg + *Rhizobium* @ 20g/kg
T_7	Hydration (4 hours) + redrying + *Pseudomonas fluorescens* @ 10 g/kg

each selected normal seedlings with the help of a measuring scale. The average seedling length was expressed in centimeters. Ten normal seedlings selected for measuring seedling length were used to calculate seedling dry weight. Seedlings were put in butter paper bags and kept in hot air oven at 60□C for 48 hours. Seedling dry weight was recorded and mean value was expressed in milligrams. Seed vigour index-I & II were calculated by determining the germination percentage and average seedling length or average seedling dry weight as per the formula given by Abdul Baki and Anderson [5]. SVI-I = Germination (%) x Average seedling length (cm), SVI-II = Germination (%) x Average seedling dry weight (mg).

2.2 Observations Recorded in Field

For field emergence, the number of seedlings that emerged in the field everyday from the first day after sowing until 15 days after sowing were counted from the middle row of each plot on a daily basis and their cumulative number was calculated. Field emergence percentage is calculated using the following formula:

$$\text{Field emergence percentage (\%)} = \frac{\text{Cumulative no.of seedlings emerged}}{\text{Total no.of seeds sown}} \times 100$$

Total number of plants obtained in each plot at the end of the crop season was recorded as final plant stand. Data for days to 50% flowering was recorded as the total number of days from the date of sowing to the time at which 50% of the plants within a plot showed flowering. Plant height of five randomly selected plants were recorded at the time of maturity from the ground level to the tip of the plant and mean height was calculated in centimeters. Number of branches per plant was recorded from five randomly selected plants in each plot and the average was calculated thereafter.The total number of leaves per plant was counted from the selected plants in each plot per treatment and the average value was taken. The data for number of pods per plant was expressed as total no. of effective pods on each of the selected plant at maturity stage and then average was worked out. For calculation of number of seeds per pod, five pods were randomly selected from each plant per plot. The pods were dried under sun and seeds were extracted. Number of seeds obtained from each pod were counted and average was calculated. Five randomly selected plants from each treatment per replication were harvested at complete maturity stage. The seeds from each harvested plant were weighed with the help of an electric balance and average was calculated and expressed as seed yield per plant in gram.

2.3. Statistical analysis

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3. RESULTS AND DISCUSSION

3.1 Analysis of Variance for Different Characters

Analysis of variance for the characters that were evaluated in the laboratory showed highly significant variations among the treatments for germination %, seedling length, seedling dry weight, SVI-I & SVI-II. Variation among the two varieties were observed to be highly significant for all the characters. Interaction of variety and treatment showed significant variations for germination %, seedling length, seedling dry weight and SVI-I. However, it was found non-significant for SVI-II.

Under field conditions, variation among the treatments were observed to be highly significant for all the characters namely, field emergence (%), final plant stand (no./plot), days to 50% flowering, Plant height (cm), no. of branches/plant, no. of leaves/plant, no. of pods/plant, no. of seeds/pod and seed yield/plant (g). It also showed highly significant variations among the two varieties for all the plant growth and yield attributing characters. Interaction of variety and treatment showed significant variations for final plant stand (no./plot), no. of leaves/plant, no. of pods/plant, no. of seeds/pod and seed yield/plant (g). However, there were no significant differences for field emergence (%), days to 50% flowering, plant height (cm) and no. of branches/plant.

3.2 Effect of Bio-formulations on Seed Quality Characters

The findings pertaining to seed quality characters *viz.*, germination percentage, seedling length, seedling dry weight, seed vigour index I & II are presented in Table 4 and Table 5.

As evident from the data presented in Table 4, the maximum germination percentage (96.83%) was recorded in a combined seed priming treatment with PSB @ 10 g/kg + *Rhizobium* @ 20 g/kg (T_6) which was statistically at par with T_5 (94.17%) where the seeds were bioprimed with *Rhizobium* @ 20 g/kg followed by T_7 *i.e.*, seed priming with *Pseudomonas fluorescens* @ 10

g/kg. The untreated control exhibited lowest germination percentage. The mean germination (%) in different priming treatments ranged from 74.33% to 96.83%. All the treatments had significantly higher germination (%) as compared to untreated control. The priming treatments showed significant variations on germination (%). Significant variations were also observed in variety and interaction of variety with treatment. Among the variety x treatment interaction V_2 (DS-10) recorded highest germination (98%) in T_6.

It was obvious from the study that seed priming with bioagents *viz. Trichoderma*, *Rhizobium*, *Pseudomonas* and PSB led to noticeably increased germination rate as compared to other treatments. Findings also exhibited that combined inoculation of bioagents result in higher seed germination (%). Similar results of seed germination due to biopriming have also been reported by Sharma et al., [6], who carried out an investigation to find out the effect of biopriming on seed germination and seed vigour in soybean where the seeds were treated with different bioagents *viz.Trichoderma spp*, *Pseudomonas fluorescens* and Phosphate solubilizing bacteria and exhibited improved germination as compared to untreated control.

Different seed priming treatments showed significant increase in seedling length and seedling dry weight as compared to untreated control. Maximum mean seedling length (23.40 cm) was recorded in T_3 (seed priming with *Trichoderma* @ 5 g/kg) which was statistically at par with T_7 (seed treatment with *Pseudomonas fluorescens* @ 10 g/kg) and T_6 (seed treatment with PSB @ 10 g/kg + *Rhizobium* @ 20 g/kg). Among the variety x treatment interaction, highest seedling length was recorded in DS-10 variety when bio primed with *Trichoderma viride*. These results were in accordance with Naik, M., [7] who reported that when garden pea seeds were bio primed with *Trichoderma viride* and *Pseudomonas fluorescens* for 4 hours, it significantly increased the seedling length as compared to control and other treatments. Similar increase in seedling length was recorded in French bean, when the seeds were treated with *Rhizobium* and *Trichoderma spp*. [8]. From the study, maximum seedling dry weight (135.67 mg) was recorded in T_7 (seed priming with *Pseudomonas fluorescens* @ 10g/kg) which was statistically at par with T_3 (seed priming with *Trichoderma* @ 5g/kg) and T_6 (seed priming with PSB @ 10 g/kg + *Rhizobium* @ 20 g/kg). The current results were in consistent with Monalisa et al., [9] who reported increased seedling dry weight due to seed bio-priming in common bean. Increased germination (%), root and shoot length of the seedlings might be the causes of rise in seedling dry weight.

The data presented in Table 5 revealed that there were significant variations in seed vigour index-I and and seed vigour index-II as a result of different priming treatments. It was observed that combined application of PSB @ 10 g/kg + *Rhizobium* @ 20 g/kg (T_6) showed highest value for both the seed vigour indices. While the lowest value was recorded in untreated control. Regarding the variety, DS-10 showed higher seed vigour indices than Arkel variety. Highest seed vigour index as a result of application of bio-formulations was recorded in T_6 might be due to greater germination percentage, seedling length and seedling dry weight. The results were in agreement with Vinay et al., [10] and Pandey et al., [11] who reported that combined application of *Rhizobium* and PSB resulted in high seed vigour index in garden pea and field pea respectively. The present findings revealed that all the priming treatments had considerably increased the value for SVI-I & SVI-II as compared to control. According to results, bio-formulated seeds had higher seed vigour indices than the untreated control seeds. From the present study, it was observed that hydro priming also improved seed germination, seedling length, seedling dry weight and seed vigour indices; however, the effective bio priming treatments were found to be significantly better than hydro priming.

3.3 Effect of Bio-formulations on Plant Growth and Yield Attributing Characters Observed under Field Condition

The findings pertaining to growth parameters *viz*., Field emergence (%), Final plant stand (no./plot), days to 50% flowering, plant height (cm), no. of branches per plant, no. of leaves per plant are presented in Table 6 and Table 7 respectively. Seed yield and yield attributing characters *viz*., no. of pods per plant, no. of seeds per pod and seed yield per plant are listed in Table 8.

From the field study, data recorded for field emergence revealed that there were significant variations in emergence (%) due to different priming treatments, but the interaction of variety

and treatment exhibited no significant difference among themselves. Highest value of field emergence (92.72%) was recorded in T_6 which was statistically at par with T_4 whereas lowest value was recorded in untreated control. Highest field emergence (%) in T_6 was due to application of *Rhizobium* and Phosphate solubilizing bacteria. This improved the microbial activity which made vital biomolecules available to the plants during early stages of germination [12]. Final plant stand was found to be highest in T_6 (57.17 no's) where the seeds were treated with combined application of *Rhizobium* + PSB. It was followed by T_5 (seed treatment with *Rhizobium*) and T_7 (seed treatment with *Pseudomonas fluorescens*). The results were in agreement with Vinay et al., [10] who reported increased field emergence percentage and other plant growth promoting characters due to combined application of *Rhizobium* and PSB. In the study, data obtained for days to 50% flowering showed significant variations among the treatments but the interaction between variety and treatment was found non-significant. Days to 50% flowering was observed to be the earliest in T_6 (43.17) which was statistically at par with T_3 (43.33). Late flowering was observed in Control T_1 (48.67) where no priming agents were applied. The early flowering could be attributed to the application of bio-formulations which in turn caused flower initiation.

The highest plant height was observed in T_6 *i.e.*, seed treatment with PSB @ 10 g/kg + *Rhizobium* @ 20 g/kg (61.17) followed by T_5(56.63). Treatment mean was found significant for plant height but interaction due to variety and treatment showed no significant variation. The highest plant height in T_6 was due to the application of *Rhizobium* which increased the population of Rhizobia in the root zone. This resulted in high fixation of nitrogen from the atmosphere to the soil. *Rhizobium* could access more phosphorus with the addition of PSB, which lead to an increase in root nodules. Phosphorus plays an important role in cell division and development which ultimately lead to an increase in plant height in garden pea [13]. The results were in accordance with Mukherjee, D. [14] who noted a considerable increase in plant height due to combined application of *Rhizobium* and PSB along with recommended dose of Fertilizer in field pea.

From the experimental findings, it was observed that different priming agents had significant effect on number of branches per plant but interaction due to variety and treatment showed no significant difference. Highest branches per plant (20.08) was recorded in T_6, which was statistically at par with T_5 (19.03) followed by T_4 whereas lowest number of branches observed in untreated control (T_1). Negi et al., [15] reported similar results where the branches per plant were increased when the seeds were bio primed with *Rhizobium* and PSB. Highest leaves per plant (65.44) was recorded in T_6 (PSB @ 10 g/kg + *Rhizobium* @ 20 g/kg) followed by T_5. The mean values of leaves per plant in different priming treatments ranged from 43.33 to 65.44. All the priming treatments significantly enhanced the leaves per plant as compared to control.

Statistical analysis of data for pods per plant revealed that there were significant differences among the priming treatments, varieties and the combination of treatment and variety (Table 8). Highest pods per plant (14.48) was recorded in T_6 *i.e.*, Seed priming with *Rhizobium*+ PSB followed by T_7 (13.62) which was statistically at par with T_4(13.45). The pods per plant was directly related to the yield of the plant because the higher the number of pods, the higher the yield would be. The results were in agreement with Sharma et al., [16] who carried out an investigation in soybean and reported that the use of bio-fertilizers like *Rhizobium* and PSB results in higher number of pods per plant.

In the present study, significant difference in seeds per pod was observed due to application of different priming agents. Seed priming with *Rhizobium* + PSB recorded the maximum seeds per pod (7.90). It was found higher in DS-10 variety than Arkel, since the pod length was higher in DS-10 which contained more seeds per pod. Lower number of seeds per pod was recorded in untreated control. In addition to pods per plant, seeds per pod also have an impact on overall seed yield. The highest seeds per pod in T_6 may be attributed due to the action of different bio-agents, which enhanced nutrient uptake, vegetative growth and better photosynthesis. This increased the plant's biomass and raised the amount of proteins and carbohydrates resulting in higher accumulation of seeds. This in turn produced more seeds per pod. Similar findings on higher number of seeds per pod was reported by Pandey et al., [11] in field pea.

Seed yield is an important consideration in any study relating to seed production of a crop. Analysis of data on seed yield, revealed that all the treatments were found to enhance seed yield

Table 2. ANOVA for germination and seed vigour characteristics from laboratory evaluation as influenced by different priming treatments

Source of variation	df	Mean squares				
		Germination %	Seedling length	Seedling dry weight	SVI-I	SVI-II
Variety (V)	1	224.024**	2.297**	19.805**	183,076.396**	5,543,817.970**
Treatment (T)	6	365.468**	48.609**	118.345**	871,600.577**	11,087,950.559**
V x T	6	18.802*	5.687**	6.764**	47,625.481**	227,005.482
Error	28	7.429	0.204	0.449	5,751.884	142,448.786
CV (%)		2.987	2.067	4.433	3.547	3.072

*- Significant at 5% probability level **- Significant at 1% probability level

Comment [JG3]: Which test is used?

Table 3. ANOVA for plant growth and yield attributing characters from field evaluation as influenced by different priming treatments

Source of variation	df	Mean squares								
		Field emergence (%)	Final plant stand (no./plot)	Days to 50% flowering	Plant height (cm)	No. of branches per plant	No. of leaves per Plant	No. of pods per plant	No. of seeds per pod	Seed yield per plant (g)
Replication	2	1.467	4.571	2.643	15.982	6.385	2.283	0.041	0.039	0.127
Variety (V)	1	56.443**	46.095**	148.595**	149.688**	27.656**	138.539**	2.333**	82.320**	9.666**
Treatment (T)	6	167.684**	58.524**	23.635**	400.556**	43.524**	307.350**	20.301**	1.217**	56.413**
V x T	6	3.139	5.651**	3.206	5.466	1.073	66.115**	0.404*	0.313**	1.733**
Error	26	5.550	1.571	2.335	8.315	2.923	11.659	0.150	0.042	0.302
CV (%)		2.736	2.372	3.369	5.715	10.315	6.341	3.129	2.825	3.697

*- Significant at 5% probability level **- Significant at 1% probability level

Comment [JG4]: Which test is used?

Table 4. Mean performance of germination (%), seedling length (cm) & seedling dryweight (mg) due to different priming treatments

Treatments	Germination (%)			Seedling length (cm)			Seedling dry weight (mg)		
	Arkel (V1)	DS 10 (V2)	Mean	Arkel (V1)	DS 10 (V2)	Mean	Arkel (V1)	DS 10 (V2)	Mean
T_1	68.33	80.33	74.33	15.66	15.38	15.52	124.60	123.97	124.28
T_2	77.67	84.00	80.83	18.28	18.84	18.56	127.70	128.00	127.85
T_3	87.67	90.00	88.83	24.57	22.23	23.40	136.10	135.17	135.63
T_4	84.33	87.00	85.67	21.19	20.99	21.09	133.27	133.93	133.60
T_5	92.33	96.00	94.17	21.00	21.59	21.30	131.87	134.23	133.05
T_6	95.67	98.00	96.83	22.50	23.25	22.87	134.00	136.80	135.40
T_7	89.33	92.33	90.83	20.79	24.97	22.88	133.17	138.17	135.67
Mean	85.05	89.67	87.36	20.57	21.04	20.81	131.53	132.90	132.22
	Variety	Treatment	V x T	Variety	Treatment	V x T	Variety	Treatment	V x T
CD (p<0.05)	1.732	3.240	4.582	0.287	0.537	0.760	0.426	0.796	1.126
SE.m (±)	0.595	1.113	1.574	0.099	0.184	0.261	0.146	0.273	0.387

*Note

Table 5. Mean performance of Seed Vigour Index-I & Seed Vigour Index-II due todifferent priming treatments

Treatments	Seed Vigour Index-I			Seed Vigour Index-II		
	Arkel (V1)	DS 10 (V2)	Mean	Arkel (V1)	DS 10 (V2)	Mean
T_1	1070.38	1,236.02	1,153.20	8,515.03	9,961.50	9,238.27
T_2	1,419.22	1,582.28	1,500.75	9,916.66	10,751.27	10,333.97
T_3	2,153.50	2,003.08	2,078.29	11,931.07	12,165.53	12,048.30
T_4	1,787.62	1,826.13	1,806.88	11,239.40	11,652.03	11,445.72
T_5	1,938.60	2,072.88	2,005.74	12,176.17	12,886.60	12,531.38
T_6	2,153.00	2,278.31	2,215.66	12,819.50	13,406.83	13,113.17
T_7	1,857.99	2,305.96	2,081.97	11,897.27	12,757.53	12,327.40
Mean	1768.61	1900.66	1834.64	11,213.59	11,940.19	11,576.89
	Variety	Treatment	V x T	Variety	Treatment	V x T
C.D (p <0.05)	48.191	90.156	127.500	239.820	448.663	NS
SE.m (±)	16.550	30.962	43.787	82.361	154.083	217.906

*Note

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Comment [JG6]: Statistical test need, p<0.05

Table 6. Mean performance of field emergence (%), final plant stand and days to 50% flowering due to different priming treatments

Treatments	Field emergence (%)			Final plant stand (no./plot)			Days to 50% flowering		
	Arkel (V1)	DS 10 (V2)	Mean	Arkel (V1)	DS 10 (V2)	Mean	Arkel (V1)	DS 10 (V2)	Mean
T_1	75.44	80.67	78.05	47.33	49.00	48.17	47.00	50.33	48.67
T_2	79.11	82.22	80.66	48.00	50.67	49.33	45.33	48.67	47.00
T_3	86.00	88.00	87.00	52.67	54.00	53.33	40.67	46.00	43.33
T_4	89.55	91.66	90.61	53.33	53.00	53.17	44.00	47.67	45.83
T_5	88.11	89.44	88.77	54.00	55.67	54.83	42.00	48.00	45.00
T_6	92.11	93.33	92.72	56.33	58.00	57.17	41.67	44.67	43.17
T_7	84.33	85.55	84.94	51.00	57.00	54.00	43.67	45.33	44.50
Mean	84.95	87.27	86.11	51.81	49.00	50.41	43.48	47.24	45.36
	Variety	Treatment	V x T	Variety	Treatment	V x T	Variety	Treatment	V x T
C.D (p <0.05)	1.503	2.811	NS	0.800	1.496	2.116	0.975	1.824	NS
SE.m (±)	0.514	0.962	1.360	0.274	0.512	0.724	0.333	0.624	0.882

*Note

Table 7. Mean performance of plant height, branches per plant and leaves per plant due to different priming treatments

Treatments	Plant height (cm)			Branches per plant			Leaves per plant		
	Arkel (V1)	DS 10 (V2)	Mean	Arkel (V1)	DS 10 (V2)	Mean	Arkel (V1)	DS 10 (V2)	Mean
T_1	35.89	39.34	37.62	11.89	13.18	12.53	41.78	44.89	43.33
T_2	40.85	43.38	42.12	13.44	15.22	14.33	45.78	47.78	46.78
T_3	48.08	51.54	49.81	15.89	17.44	16.67	54.11	57.22	55.66
T_4	52.22	52.73	52.48	17.33	18.80	18.07	55.33	52.88	54.11
T_5	54.15	59.11	56.63	18.95	19.11	19.03	58.11	55.11	56.61
T_6	58.43	63.91	61.17	18.63	21.53	20.08	62.56	68.33	65.44
T_7	50.37	56.42	53.40	14.22	16.43	15.33	46.55	63.44	54.99
Mean	48.57	52.35	50.46	15.76	17.39	16.58	52.03	55.66	53.85
	Variety	Treatment	V x T	Variety	Treatment	V x T	Variety	Treatment	V x T
CD (p <0.05)	1.839	3.441	NS	1.091	2.040	NS	2.178	4.075	5.762
SE.m (±)	0.629	1.177	1.665	0.373	0.698	0.987	0.745	1.394	1.971

*Note

Comment [JG7]: Statistical test need, p<0.05

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Comment [JG8]: Statistical test need, p<0.05

Table 8. Mean performance of pods per plant, seeds per pod & seed yield per plant (g) due to different priming treatments

Treatments	Pods/plant			Seeds/pod			Seed yield/plant (g)		
	Arkel (V1)	**DS 10 (V2)**	**Mean**	**Arkel (V1)**	**DS 10 (V2)**	**Mean**	**Arkel (V1)**	**DS 10 (V2)**	**Mean**
T_1	9.10	10.00	9.55	4.93	8.10	6.52	8.98	11.34	10.16
T_2	10.13	10.33	10.23	5.57	8.40	6.98	11.28	12.15	11.72
T_3	12.00	12.23	12.12	5.37	8.90	7.13	12.87	15.25	14.06
T_4	13.20	13.70	13.45	6.07	8.93	7.50	16.01	17.14	16.57
T_5	12.80	13.40	13.10	6.40	8.77	7.58	16.38	16.43	16.41
T_6	13.87	15.10	14.48	6.80	9.00	7.90	18.84	19.02	18.93
T_7	13.80	13.43	13.62	5.93	8.57	7.25	16.37	16.11	16.24
Mean	12.13	12.60	12.37	5.87	8.67	7.27	14.39	15.35	14.87
	Variety	**Treatment**	**V x T**	**Variety**	**Treatment**	**V x T**	**Variety**	**Treatment**	**V x T**
C.D ($p < 0.05$)	0.247	0.462	0.653	0.131	0.245	0.346	0.351	0.656	0.928
SE.m (±)	0.084	0.158	0.223	0.045	0.084	0.119	0.120	0.224	0.317

*Note

Comment [JG9]: Statistical test need, p<0.05

as compared to control. Seed priming with *Rhizobium* and PSB (T_6) recorded the maximum seed yield per plant (18.93) which was followed by treatment T_4 (16.57). There were significant variations among the treatments, varieties and combination of treatment and variety. The reason for higher seed yield recorded in T_6 might be due to beneficial effect of *Rhizobium* and PSB that enhanced field emergence resulting in more number of pods per plant and seeds per pod. This ultimately increased the seed yield in garden pea. Similar kind of studies were carried out by Lohitha et al., [17] who reported higher seed yield in chickpea when the seeds were bio primed with *Rhizobium* and PSB. Rani et al., [18] also reported that grain yield in field pea was enhanced by combined inoculation of biofertilizers.

4. CONCLUSION

In order to ensure a good crop production, modern agricultural technologies demand that every seed should readily germinate and produce vigorous seedlings. To produce good crop, the seeds should be properly invigorated by adopting various seed invigoration techniques like seed priming. From the present study, it could be concluded that seed priming with combined application of PSB + *Rhizobium* for 4 hours exhibited better performance in seed quality, yield and its attributing characters as compared to other treatments under field and laboratory conditions. From this investigation, combined application of PSB @10g/kg + *Rhizobium* @ 20g/kg may be promoted for future recommendation as a seed priming treatment in pea. However, multi-location trials in larger area should be done to confirm the benefits of biopriming before recommendation to farmers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

REFERENCES

1. Bhat TA, Gupta M, Mahdi SS, Ganai MA, Bhat HA, Bhat JA, Wani IA, et al. Growth, yield and economics of field pea (*Pisum sativum* L.) as influenced byphosphorus and bio-fertilizers under subtropical conditions of Jammu. Journal of Pure and Applied Microbiology. 2013;7:1-8.
2. Negi S, Singh RV, Dwivedi OK. Effect of biofertilizers, nutrient sources and lime on growth and yield of garden pea. Legume Research. 2006;29:282-285.
3. Dadhich SK, Somani LL, Shilpkar D. Effect of integrated use of fertilizer P, FYM and biofertilizers on soil properties and productivity of soybean-wheat crop sequence. J. Adv. Dev. Res. 2011;2:42-46.
4. Jain A, Singh S, Sarma KB, Singh B. Microbial consortium–mediated reprogramming of defence network in pea to enhance tolerance against Sclerotiniasclerotiorum. Journal of Applied Microbiology. 2012;112(3):537-550.
5. Abdul-Baki AA, Anderson JD. Vigour determination in soybean seed by multiple criteria. Crop Science. 1973;13(2):630-633
6. Sharma P, Bhatt A, Kanwar R. Influence of Seed biopriming with microbial inoculants on seed quality parameters in Soybean [*Glycine max* (L.) Merril]. Legume Research-An International Journal. 2016;1-7.
7. Naik M. Effect of Biopriming on seed quality and management of seed borne pathogens in Garden Pea (*Pisum sativum* L.). M.sc Thesis, Orrisa University of Agriculture and Technology, Bhubaneswar.2015 ;4-12.
8. Negi S, Bharat NK, Kaushal R, Rohiwala P. Screening of bioagents for seed biopriming in French bean (*Phaseolus vulgaris* L.) under Laboratory condition. IJCS. 2020;8(3):790-793.
9. Monalisa SP, Beura JK, Tarai RK, Naik M. Seed quality enhancement through biopriming in common bean (*Phaseolus vulgaris*. L). Journal of Applied and Natural Science. 2017;9(3):1740-1743.
10. Vinay, Sharma R, Bharat NK, ThakurKS, Kumar P. Effect of seed coating and foliar spray treatments on plant growth, seed

yield and economics of seed production in Garden Pea (*Pisum sativum* L.). Indian Journal of Ecology. 2022;49(2): 378-382.
11. Pandey V, Dahiya OS, Mor VS, Yadav R, Peerzada JOH, Brar A. Impact of integated nutrient management on seed yield and its attributes in field pea (*Pisumsativum* L.) Chemical Science Review and Letters. 2017;6(23):1428-1431.
12. Subba, Rao NS. Soil microorganisms and plant growth. Oxford and IBH Publishers, New Delhi, India. 1986;335.
13. Das DK. Introductory Soil Science. 3rd ed. Kalyani Publishers, Ludhiana.1996;351-353.
14. Mukherjee D. Integrated nutrient management practices on growth and yield of field pea (*Pisum sativum* L.) under mid hill condition. International Journal of Agricultural Sciences. 2016;12(2):309-313.
15. Negi S, Bharat NK, Kumar M. Effect of seed biopriming with indigenous PGPR, Rhizobia and *Trichoderma sp*. on growth, seed yield and incidence of diseases in French bean (*Phaseolus vulgaris* L.). Legume Research. 2021;44 :593-601.
16. Sharma P, Bhatt A, Jyoti B. Effect of seed bio-priming with microbial inoculants on plant growth, yield and yield contributing characters in soybean (*Glycine max*. L). International Journal of Economic Plants. 2018;5:53-58.
17. Lohitha B, Dutta A. Biopriming in chickpea (*Cicer arietinum* L.), An eco-friendly approach for quality seed production.The Pharma Innovation Journal. 2022; 11(2):375-379.
18. Rani S, Kumar P, Yadav AK. Effect of biofertilizers in conjunction with chemical fertilizers on growth behavior and profitability of field Pea (*Pisum sativum* L.) grown in Western plains of Haryana. Chemical Science Review and Letters. 2017;6:801-805.