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Effect of Seed Treatments and Different Levels of Nitrogen on Plant Growth and Seed Yield of Pea (*Pisum sativum*)

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ABSTRACT

A field experiment was carried out at the vegetable farm in the University of Agriculture, Faisalabad, in 2013-2014 to identify the role of different seed treatments (Rhizobium and Germinator) and nitrogen fertilizer level (0, 22.5, and 45 kg/ha) on growth and yield parameters of two pea cultivars (Meteor and Alena). The outcomes indicated that seed treatments and an optimal amount of nitrogen drastically enhanced emergence percentage, plant height, nodulation, and yield features. Rhizobium and Germinator combined to create the best effect in Growth and productivity, proposing a method for sustainable gain in pea yield under low-input conditions. The experiment was replicated three times in a factorial design where the effect was randomized under a randomized complete block design (RCBD). Interactions and treatments showed considerable variations in most of the parameters. Np + Germinator + 45 kg N/ha treatment recorded maximum emergence (69.4%), plant height (75.4 cm), chlorophyll content (16.32 g/mg), biomass (41.5 g) and harvest index (61%), especially in cultivar Meteor. The Rhizobium and Germinator treatment fared not very well on its own. There was a significant synergistic effect between the combined use of bio-fertilizers with nitrogen, giving a significant mean effect on vegetative Growth, yield components, and physiological characteristics of the plants. This practice has the potential to enhance the production of peas in sustainable agricultural systems. The trial compared pea seed inoculation with Rhizobium and Germinator and nitrogen on Growth and yield in the two cultivars. Aggregate treatments particularly enhanced emergence, biomass and seed yield in the field.

INTRODUCTION

Pea (*Pisum sativum* L.) belongs to the family Leguminosae and is indigenous to the Southeast or Central Asia. It prospers in cooler weather conditions as well as in areas with ample moisture. In their case, they are commonly produced in low temperatures worldwide. Peas serve as a source of nutritious food, either consumed as a vegetable or used in the preparation of soup. Peas are rich in nutrition, as they are abundant in complex carbohydrates (42.65%), protein (27.8%), vitamins and minerals, dietary fiber, and antioxidant compounds (Siddiqui et al., 2023). Peas are cultivated worldwide due to their diverse applications, including food and fodder. Pea is the third legume grain of importance, following soybean and common beans (Dadlani & Yadava, 2023). Peas are also more protein-rich, containing various types of essential amino acids, particularly lysine. In 2012, fresh pea grain was grown on 15,500 hectares in Pakistan, yielding 6,838.7 kg ha-1 and totaling 106,000 tons. The world's fresh pea production spans 2.266 million hectares, with an average yield and production of 8.1 tonnes/ha, totaling 18.49 million tonnes. In Pakistan, the growth and production of dry peas were 8.350 million hectares and 718.6 kg ha-1, respectively, in the year 2012. It produced 60 thousand tonnes. Compared to the previous year, the world acreage stood at 6.59 million hectares, with a yield of 1,490.8 kg ha-1, which translated to 7 billion kg of production in the current year (Prasad, 2021).

Protein, enzymes, and chlorophyll structure contain nitrogen, which is a vital element (Mittal et al., 2020). Urea and ammonium nitrate fertilizers contain nitrogen, which is detrimental, prompting scientists to develop sustainable

ways of feeding. Pea utilizes very little soil nitrogen at any single growing season; the estimated quantity used is 22 kg N ha-1 of soil (Singh, 2018). In low-nitrogen content soil, the growth of pea plants becomes slow, and lateral branches do not develop. Additionally, a high concentration of mineral nitrogen enhances elongation of both main and lateral shoots. An increase in above-ground biomass causes crop lodging, leading to the deterioration of plant parts, which makes pea cultivation for seed slightly more challenging (Kim et al., 2023). Pea rotation with cereal crops can break cereal disease cycles, improve soil tilth, and improve soil fertility by fixing atmospheric nitrogen into plant-available form as it forms symbiotic relationships with soil bacteria *Rhizobium leguminosarum* (Valenzuela, 2024).

A biofertilizer is a rhizobium inoculum that assists legume plants in fixing nitrogen by means of biological nitrogen fixation. About 70-85 million tons of nitrogen are fixed through biological nitrogen fixation systems, accounting for 50% of the world's total nitrogen fixation and equivalent to the output of all synthetic fertilizer factories (Nosheen et al., 2021). N2 fixation plants are important because they increase N uptake and play an important role in the bio-fertilization system as plant growth-promoting rhizobacteria (PGPR). Rhizobia occur naturally in the soil; somewhere they are absent and sometimes less in number depending on the crop sown before (Greenwood, 1965). Giffard et al. (2022) observes that genetically rhizobacteria were diverse under arable fields as compared to relatively undisturbed grasslands. Therefore, legume inoculation is an old agricultural practice used for more than a century by introducing rhizobia into soil. Legumes react to Rhizobium inoculation by forming unique structures on their roots and occasionally stems, called nodules (Alaswad et al., 2019). Much research has been done on (PGPR) plant growth-stimulating rhizobacteria, comprising the isolation of specific bacterial strains for different legume species the addition of inoculants containing *Rhizobium leguminosarum* bv. Viciae is useful in some studies involving field peas. Sible et al. (2021) studied the effect of nitrogen, compost, and *Rhizobium* inoculant on yield attributes, dry matter production, pea yield, and nodulation on pea (*Pisum sativum*) cv. IPSA Motorshuti-3. The maximum dry weight and nodule counts were obtained in the Rhizobium inoculant only. Green and dry seed gave maximum values of 8.38 t/ha and 2.97 t/ha, respectively. The values were reached when 90 kg of Nitrogen per Hour was applied. When compared to the control, seed inoculation with Rhizobium *Leguminosarum, Azospirillum*, and Pseudomonas has yielded significant results in terms of applying 75 kg of urea per hectare. Seed inoculation significantly affects the number of pods per plant, grain weight, grain yield, number of nodules, weight of nodule, and final plant height (Diagne et al., 2020). Tahat et al. (2020) found that by full irrigation and rhizobium inoculation, grain yield may be significantly increased. Better results can be obtained by the treatment with Rhizobium as compared to chemical fertilizer. By the combined application of Rhizobium and micronutrients (B, Mn, Mo, Mg, and SO3), pea production can be significantly increased, which reduces the cost of nitrogen fertilizer. Shahid et al. (2020) suggested that by foliar application of micronutrients (Fe, Mn, and Zn), pod weight, pod length, green seed/ pod, weight of 100 green seed, NPK, carbohydrates (%), and protein content (%).

The global average yields of dry pea are 1490.8 kg ha-1, of which half is produced by Pakistan (718.6 kg ha-1). To achieve higher yields of peas per acre, a combination of high-yielding cultivars, effective fertilizer use, and a range of seed treatments, including those that incorporate nitrogen-fixing bacteria such as Rhizobium, is required (Gulati et al., 2022). Seed germination and emergence have a significant impact on crop stand establishment. Various seed treatments are being used in agriculture to improve crop stand in vegetables. These days, new grade fertilizers are in use, which, when coated/dressed on seeds, not only improve germination but also invigorate the young seedlings (Hasanuzzaman et al., 2023). Seed Germinator is one of such products released by NFC Institute, Faisalabad. It contains both nitrate (5-6%) and amide form (9-10%) of nitrogen as well as phosphorus (35-36%), potassium (6-7%), and calcium (6-7%); the elements most important for healthy seedlings production. Therefore, the seed Germinator was also used in this study (Mittal et al., 2020b).

Objectives

1. To evaluate the effect of Germinator (NFC Faisalabad product), Rhizobium, and different levels of nitrogen fertilizer on the emergence percentage of pea cultivars (Alena and Meteor).
2. To check the effect of Germinator (NFC Faisalabad product), Rhizobium, and different levels of nitrogen fertilizer on plant growth and yield attributes of pea cultivars.
3. To check the effect of Germinator (NFC Faisalabad product), Rhizobium, and different levels of nitrogen fertilizer on seed yield of both pea cultivars (Alena and Meteor) and their response to different fertilizer and seed treatments.

MATERIALS AND METHODS

The impact of treating pea seeds using Rhizobium and germinator in the absence or presence of various levels of nitrogen fertilizers on the growth of plants and seed yield of two pea cultivars was conducted in 2013-14 at a vegetable farm of the Institute of Horticultural Sciences, University of Agriculture, Faisalabad.

Materials

Seeds of two pea cultivars, viz., Meteor and Alena, were purchased from a registered seed corporation in Faisalabad. *Rhizobium* for pea was collected from Ayub Agriculture Research Institute (AARI), Faisalabad. Germinator (Amide Nitrogen 9-10%, Nitrate nitrogen=5-6%, P2O5= 35-36%, K2O= 6-7% and Ca=6-7%) was purchased from NFC Institute, Faisalabad. Urea, DAP, and NPK zarkheez are used as a source of NPK. Acetone was purchased from a registered chemical supplier.

Methodology

Seeds of two pea cultivars (Meteor and Alena) were inoculated with *Rhizobium* for peas (Np) by following the method. Dissolve 100 grams of sugar in 500 ml of water.

Then, add two packets of bio-fertilizer (*Rhizobium*) for 10 kg of pea seeds and mix the bio-fertilizer with the seeds. Let the seed dry for 30 minutes in the shade. So that seed is ready for sowing.

Seeds of both pea cultivars were also treated with a germinator by the following method. Seeds were first soaked in water containing a germinator at a concentration of 10g per 5kg of seeds. The seed was mixed thoroughly and allowed to dry. On October 24, 2013, untreated and treated (using Np and germinator) were placed in the field on one-meter-wide raised beds in plots with different levels of nitrogen, i.e., Control (0 kg), half dose of recommended fertilizer (22.5 kg/ ha), or full dose (45 kg/ha) of nitrogen. Phosphorus and potash had been applied at 90 kg/ha. Three seeds were placed at a distance of 30 cm, and on each side of the beds, one meter wide. During sowing and later when needed, the field was irrigated. One plant per hole was retained after the first real leaf appeared, and the other plants were removed. Weeding and earthing up to support the plants were the same cultural practices in all experimental plots.

Treatment Details

Factor 1: Cultivars

1. Meteor
2. Alena

Factor 2: Seed and/or Fertilizer Treatment

T_1: Control (no nitrogen and no seed treatment)
T_2: Inoculation of seed with Rhizobium (Np)
T_3: Nitrogen @ 45 kg/ha
T_4: Seed treatment with Germinator
T_5: Np + 22.5 kg N/ha
T_6: Np + 45 kg N/ha
T_7: Germinator+ 22.5 kg N/ha
T_8: Germinator+ 45 kg N/ha
T_9: Np+ Germinator
T_{10}: Np+ Germinator + 22.5 kg N/ha
T_{11}: Np+ Germinator + 45 kg N/ha

Data Collection

The data was recorded for the following parameters.

1. Emergence (%)
2. Plant height (cm)
3. No. of branches/plant
4. Chlorophyll content (µg/mg Fw)
5. Node bearing the first flower
6. Days from flowering to pod maturity (days)
7. No. of pods/plant
8. Pod length (cm)
9. Pod weight (mg)
10. No. of seeds/pod
11. Total biomass (g)
12. Harvest index

Procedure for Recording the Observations

Emergence (%)

To calculate the emergence percentage, the count of the plants on days after seeding was taken. Seeds of both cultivars were sown in 12 holes per treatment per replication. The following formula calculated emergence percentage of both varieties

Plant Height (cm)

The height of four plants was measured by recording the length of each plant in centimeters (cm) from the base to the top at maturity, and then the average was determined.

No. Of Branches Per Plant

The number of branches was randomly calculated for each selected plant, and then the average was determined.

Chlorophyll Content (µg/mg Fw)

The concentration of chlorophyll was calculated according to procedure. The new leaves of the plant were picked and frozen. The 100 mg of leaves was ground using a mortar and pestle with an 80% solution of acetone at a low temperature of 4 °C. The absorbance of the resulting solution at 646 nm was measured after centrifugation of the extract at 14,000 rpm for 5 minutes using a spectrophotometer (Obluchinskaya et al., 2022).

Total chlorophyll, chlorophyll a and chlorophyll b were calculated using the following formula.

The chlorophyll a formula is (12.21x A663 - 2.81x A645).
The chlorophyll b formula is (20.13 x A646 5.03 x A663).
The total chlorophyll is (a + b) chlorophyll.

Node Bearing the First Flower

The number of nodes on the first flower of each treatment was recorded on selected plants, and then the average was calculated.

Days From Flowering to Pod Maturity (Days)

Three plants of each treatment were selected, and three flowers were tagged to determine the number of days between flowering and pod maturity. These calculations were then averaged.

No. of Pods Per Plant

The pods of each selected plant were counted, and the mean was calculated.

Pod Length (cm)

Four pods were picked from each plant, and the length of one pod was measured using a measuring tape; the mean was then calculated.

Pod Weight (mg)

Four pods were picked and weighed on an electric balance for each plant, and the mean was obtained.

No. of Seeds Per Pod

The pods were manually cracked open, and the seeds were counted. Having then counted out all the seeds of each plant, we divided that Figure by the number of pods to obtain the average number of seeds per pod.

Total Biomass (g)

The entire plant, including the roots, was excised at the ground surface and weighed in grams.

Harvest index

Harvest index for each plot was calculated by using the formula:

$$H.I = \frac{Seed\ Yeild}{Biomass} \times 100$$

Experimental Layout and Statistical Analysis

The experiment was conducted using a randomized complete block design with factorial components. Data was analyzed statistically using Fisher's analysis of

variance technique (Paul & Barari, 2022). The treatment means were compared by Duncan's multiple range test at 5% probability level (Belali et al., 2022).

RESULT

Table 1

Interactive effect of cultivars and various treatments on emergence percentage of pea

Treatments	Cultivar	Emergence % & Significance	Cultivar	Emergence % & Significance
T_1	**Meteor**	47.2 abc	**Alena**	44.4 abcd
T_2	**Meteor**	44.4 abcd	**Alena**	30.5 e
T_3	**Meteor**	61.1 ab	**Alena**	52.7 abc
T_4	**Meteor**	55.5 abc	**Alena**	36.1 abcde
T_5	**Meteor**	61.1 ab	**Alena**	49.9 abc
T_6	**Meteor**	63.8 ab	**Alena**	52.7 abc
T_7	**Meteor**	63.8 ab	**Alena**	44.4 abcd
T_8	**Meteor**	66.6 a	**Alena**	58.3 ab
T_9	**Meteor**	58.3 ab	**Alena**	38.8 abcde
T_{10}	**Meteor**	49.9 abc	**Alena**	41.6 abcd
T_{11}	**Meteor**	69.4 a	**Alena**	55.5 abc

- Meteor experienced increased emergence (58.3%) as compared to Alena (45.9%).
- The greatest level of emergence occurred with Np + Germinator + 45 kg N/ha (T_{11}) and Germinator + 45 kg N/ha (T_8) which was either 62.4 percent.
- Interaction (V x T) is significant; CV = 21.3%.

Table 2

Interactive effect of cultivars and various treatments on plant height and number of branches of pea

Treatments	Cultivar	Plant Height (cm) & Significance	No. of Branches & Significance	Cultivar	Plant Height (cm) & Significance	No. of Branches & Significance
T_1	**Meteor**	36.6 gh	2.75 ab	**Alena**	25.5 h	2.75 ab
T_2	**Meteor**	62.1 abcd	2.03 ab	**Alena**	54.3 cdef	1.78 ab
T_3	**Meteor**	44.4 efg	2.75 ab	**Alena**	51.5 cdefg	3.50 ab
T_4	**Meteor**	46.4 defg	1.61 ab	**Alena**	43.2 fg	1.36 b
T_5	**Meteor**	61.3 abcd	1.61 ab	**Alena**	54.6 cdef	2.20 ab
T_6	**Meteor**	53.7 cdef	3.33 ab	**Alena**	56.0 cdef	3.88 a
T_7	**Meteor**	57.5 bcdef	3.33 ab	**Alena**	54.0 cdef	3.91 a
T_8	**Meteor**	53.9 cdef	3.58 ab	**Alena**	53.5 cdef	3.58 ab
T_9	**Meteor**	75.4 a	2.83 ab	**Alena**	65.7 abc	2.75 ab
T_{10}	**Meteor**	56.1 cdef	3.41 ab	**Alena**	73.3 ab	3.55 ab
T_{11}	**Meteor**	60.6 abcde	3.50 ab	**Alena**	61.3 abcd	2.83 ab

Plant Height

- The two cultivars did not differ statistically (Meteor 53.9 cm, Alena 55. 3 cm).
- The trend was that T_1 Plant height recorded the lowest.
- Height of plants, Np + Germinator (T_9: 70.5 cm) Np + Germinator, 22.5 kg N/ha (T_{10}: 64.7 cm) had the highest values.
- There is a significant interaction effect of variables V and T; CV = 9.72%.

No. of Branches

- Meteor (2.92) is not statistically different from Alena (2.80).
- The smallest number of branches was found when only Germinator was used (T_4: 1.49).
- Highest number of branches was obtained at Germinator + 22.5 kg N/ha (T_7: 3.62) and Np + 45 kg N/ha (T_6: 3.61).
- The Interaction (V x T) effect is important, CV = 27.89.

Table 3

Interactive effect of cultivars and various treatments on total chlorophyll contents of pea

Treatments	Cultivar	Total Chlorophyll Contents (µg/mg Fw) & Significance	Cultivar	Total Chlorophyll Contents (µg/mg Fw) & Significance
T_1	**Meteor**	14.20 ab	**Alena**	8.25 c
T_2	**Meteor**	12.60 b	**Alena**	12.99 ab
T_3	**Meteor**	11.67 b	**Alena**	11.60 b
T_4	**Meteor**	14.14 ab	**Alena**	12.14 b
T_5	**Meteor**	12.78 b	**Alena**	13.99 ab
T_6	**Meteor**	14.60 ab	**Alena**	14.29 ab
T_7	**Meteor**	11.41 b	**Alena**	14.37 ab
T_8	**Meteor**	14.33 ab	**Alena**	14.78 ab
T_9	**Meteor**	12.78 b	**Alena**	13.08 ab
T_{10}	**Meteor**	14.71 ab	**Alena**	13.66 ab
T_{11}	**Meteor**	16.32 a	**Alena**	12.28 b

- Both cultivars (Meteor = 13.59, Alena = 12.86) do not differ significantly in their growth rates.
- Control (T_1: 11.23 µg/mg FW) had the lowest chlorophyll content.
- The greatest values were received in Germinator + 45 kg N/ha (T_8: 14.55 g/mg Fw), Np + Germinator + 22.5 kg N/ha (T_{10}: 14.19 g/mg Fw) and Np + Germinator + 45 kg N/ha (T_{11}: 14.30 g/mg Fw).
- V x T = not significant; CV = 13.50(statistical significance).

Table 4

Interactive effect of cultivars and various treatments on chlorophyll "a" and "b" of pea

Treatments	Cultivar	Total Chlorophyll "a" Contents (µg/mg Fw) & Significance	Total Chlorophyll "b" Contents (µg/mg Fw) & Significance	Cultivar	Total Chlorophyll "a" Contents (µg/mg Fw) & Significance	Total Chlorophyll "b" Contents (µg/mg Fw) & Significance
T_1	**Meteor**	11.58 abc	2.62 cdef	**Alena**	6.38 d	1.86 f
T_2	**Meteor**	10.05 abc	2.54 cdef	**Alena**	10.44 abc	2.55 cdef
T_3	**Meteor**	9.70 bc	1.97 ef	**Alena**	8.56 cd	3.04 bcd
T_4	**Meteor**	11.22 abc	2.91 bcde	**Alena**	9.24 bcd	2.90 bcde
T_5	**Meteor**	10.18 abc	2.59 cdef	**Alena**	11.11 abc	2.88 bcde
T_6	**Meteor**	11.79 ab	2.81 bcdef	**Alena**	11.28 abc	3.00 bcd
T_7	**Meteor**	8.45 cd	2.96 bcde	**Alena**	10.85 abc	3.51 bc
T_8	**Meteor**	11.82 ab	2.50 cdef	**Alena**	11.04 abc	3.74 ab
T_9	**Meteor**	10.01 bc	2.77 bcdef	**Alena**	10.26 abc	2.82 bcdef
T_{10}	**Meteor**	11.87 ab	2.84 bcdef	**Alena**	9.25 bcd	4.41 a
T_{11}	**Meteor**	13.19 a	3.13 bcd	**Alena**	9.81 bc	2.46 def

Chlorophyll a

- Meteor (10.90 µg/mg Fw) was much higher than Alena (9.84 µg/mg Fw).
- The highest value was observed in Control (8.98 µg/mg Fw), while the lowest values were recorded in Np + Germinator + 45 kg N/ha (11.50 µg/mg Fw), Germinator + 45 kg N/ha (11.43 µg/mg Fw), and Np + 45 kg N/ha (11.53 µg/mg Fw).
- Interaction effect (V x T): Significant (CV = 15.78%).
- Most efficient treatment: Meteor x Np + Germinator + 45 kg N/ha (T_{11} = 13.19) g/mg Fw.
- Lowest: Alena x Control (T_1 = 6.38 µg/mg Fw).

Chlorophyll b

- Alena (3.01 µg/mg Fw) counted significantly higher than that of Meteor (2.69 ug/mg Fw).
- Lowest in Control (2.24 µg/mg Fw), highest in Np + Germinator + 22.5 kg N/ha (3.62 µg/mg Fw).
- Interaction effect (V x T): Significant (CV = 18.13%).
- Treatment with best results: Alena x Np + Germinator + 22.5 kg N/ha (T_{10} = 4.41 µg/mg Fw).
- Alena x Control (T_1 = 1.86 µg/mg Fw).

Table 5

Interactive effect of cultivars and various treatments on node bearing and pod maturity first flower of pea

Treatments	Cultivar	No. of Nodes & Significance	Pod Maturity & Significance	Cultivar	No. of Nodes & Significance	Pod Maturity & Significance
T_1	**Meteor**	7.35 abcd	24.6 de	**Alena**	7.66 abc	27.6 abcd
T_2	**Meteor**	7.91 abc	27.3 abcd	**Alena**	6.25 d	22.6 e
T_3	**Meteor**	9.08 a	30.6 a	**Alena**	8.78 ab	29.3 abc
T_4	**Meteor**	7.51 abcd	30.3 a	**Alena**	7.33 abcd	30.0 ab
T_5	**Meteor**	7.91 abc	30.6 a	**Alena**	8.08 ab	29.0 abc
T_6	**Meteor**	8.23 ab	29.3 abc	**Alena**	7.72 abc	30.6 a
T_7	**Meteor**	8.50 ab	26.0 bcde	**Alena**	8.75 ab	28.6 abcd
T_8	**Meteor**	8.11 ab	30.6 a	**Alena**	7.86 abc	30.6 a
T_9	**Meteor**	7.91 ab	26.0 bcde	**Alena**	8.32 ab	25.6 cde
T_{10}	**Meteor**	8.68 ab	30.6 a	**Alena**	7.47 abcd	29.0 abc
T_{11}	**Meteor**	6.75 ab	29.0 abc	**Alena**	7.41 abcd	29.0 abc

No. of Nodes

- Cultivar effect: It is not significant (Meteor = 7.99, Alena = 7.78).
- Maximum nodes: Meteor x N @ 45kg/ha (T_3 = 9.08).
- Lowest nodes: Alena x Rhizobium (T_2 = 6.25).
- Average range: 6.375-9.042 to first flower.
- V x T interaction: Significant (CV = 10.73%).

Pod Maturity

- Cultivar effect: Meteor (28.6 days) - Alena (28.3 days) have no difference (significant).
- Shortest maturity: Alena x Rhizobium (T_2 = 22.6 days).
- The latest maturity Europe Meteor x N @ 45 kg/ha, Germinator, Np + 22.5 N, Germinator + 45 N, and Np + Germinator + 22.5 N (30.6 days).
- General range: 22.6 -30.6 days.
- Interaction (V x T): It is significant (CV = 9.19%).

Table 6

Interactive effect of cultivars and various treatments on number of pods and pod length per plant of pea

Treatments	Cultivar	No. of Pods & Significance	Pod Length (cm) & Significance	Cultivar	No. of Pods & Significance	Pod Length (cm) & Significance
T_1	**Meteor**	10.7 defghi	7.3 ab	**Alena**	7.7 ghi	7.2 ab
T_2	**Meteor**	9.1 efghi	7.2 ab	**Alena**	8.2 ghi	7.6 a
T_3	**Meteor**	11.9 defgh	7.1 ab	**Alena**	8.6 fghi	6.8 ab
T_4	**Meteor**	3.2 hi	6.8 ab	**Alena**	4.0 hi	6.0 ab
T_5	**Meteor**	15.8 cdefg	7.0 ab	**Alena**	18.4 cdefg	7.2 ab
T_6	**Meteor**	12.9 cdefgh	7.7 a	**Alena**	0.06 i	7.4 a
T_7	**Meteor**	17.6 cdefg	7.9 a	**Alena**	19.6 cde	7.2 ab
T_8	**Meteor**	10.5 defghi	7.1 ab	**Alena**	10.1 efghi	7.1 ab
T_9	**Meteor**	42.6 a	7.6 a	**Alena**	23.2 bc	7.9 a

T_{10}	**Meteor**	19.0 cdef	8.0 a	**Alena**	33.0 ab	7.6 a
T_{11}	**Meteor**	15.7 cdefg	7.9 a	**Alena**	21.0 cd	7.4 a

No. of Pods

- Cultivar effect: Meteor (42.6 pods) performed well in comparison to Alena (33.0 pods).
- Still greatest number of pods: Meteor x Np+ Germinator (T_9 = 42.6 pods).
- The best one followed Np by best result was Alena x Np + Germinator + 22.5 N (T_{10} = 33 pods).
- Minimum pod number: Alena 45 kg N/ha + Np.
- Total range: 0.06 pods/plant- 42.6 pods/plant.
- Interaction (V x T): Significant (CV = 23.23%).

Pod Length

- Cultivar effect: Meteor (8.0 cm) and Alena (7.9 cm) were practically equal.
- Most pods: Meteor x Np + Germinator + 22.5 N/ha (T_{10} = 8.0 cm).
- Peak values Meteor (T_7, T_{11} = 7.9 cm), Alena (T_9 = 7.9 cm).
- The shortest pods: Alena x Germinator (T_4 = 6.0 cm).
- V x T: Significant (CV = 6.09%).

Table 7

Interactive effect of cultivars and various treatments on pod weight and number of seeds per pod of pea

Treatments	Cultivar	Pod Weight (mg) & Significance	Seed Per Pod & Significance	Cultivar	Pod Weight (mg) & Significance	Seed Per Pod & Significance
T_1	**Meteor**	1216.7 b	2.16 bc	**Alena**	1120.0 b	2.28 bc
T_2	**Meteor**	1396.7 b	3.52 abc	**Alena**	1546.7 ab	3.25 abc
T_3	**Meteor**	1416.7 b	2.40 abc	**Alena**	1263.3 b	4.56 a
T_4	**Meteor**	1206.7 b	1.74 c	**Alena**	1406.7 b	2.39 abc
T_5	**Meteor**	1460.0 ab	3.24 abc	**Alena**	1513.3 ab	3.00 abc
T_6	**Meteor**	1520.0 ab	1.90 bc	**Alena**	1230.0 b	3.42 abc
T_7	**Meteor**	1450.0 ab	2.82 abc	**Alena**	1286.7 b	2.80 abc
T_8	**Meteor**	1316.7 b	2.87 abc	**Alena**	1290.0 b	3.17 abc
T_9	**Meteor**	1370.0 b	3.30 abc	**Alena**	2133.3 a	4.08 ab
T_{10}	**Meteor**	1350.0 b	3.67 abc	**Alena**	1536.7 ab	2.72 abc
T_{11}	**Meteor**	1310.0 b	3.00 abc	**Alena**	1390.0 b	2.08 bc

Pod Weight

- In the case of cultivar effect, Meteor (1364.8 mg) and Alena (1428.8 mg) were statistically equivalent.
- Overall Treatment effect: The largest pod weight was gotten in Np + Germinator (1751.7 mg).
- Interaction effect (V x T) was significant (CV = 15.99).
- Best mixture: Alena x Np + Germinator (2133.3 mg, the highest of all).
- The other high performers were Meteor x Np + 45 kg N/ha (1520 mg) and Alena x Rhizobium (1546.7 mg) and Alena x Np + 22.5 kg N/ha (1513.3 mg).
- Minimal pod weight: Alena x Control (1120 mg).

No. of Seeds Per Pod

- Cultivar effect: Alena (3.07 seeds/pod) is a bit more than Meteor (2.78 seeds/pod) and not significantly different.
- Most seeds/pod: Np + Germinator (3.69 seeds/pod).
- Lowest Germination: Germinator alone (2.06 seeds/pod).
- Interaction effect (V x T): Significant (CV = 23.85%).
- Alena × Nitrogen @ 45 kg/ha (4.56 seeds/pod, highest).
- Other good performers: Alena x Np + Germinator (4.08), Meteor x Np + Germinator + 22.5 kg N/ha (3.67).
- Most distributive combination: Meteor X Germinator (1.74 seeds/pod).

Table 8

Interactive effect of cultivars and various treatments on total biomass and harvest index of pea

Treatments	Cultivar	Total Biomass (g) & Significance	Harvest Index & Significance	Cultivar	Total Biomass (g) & Significance	Harvest Index & Significance
T_1	**Meteor**	16.5 bcdefg	46.1 ab	**Alena**	5.2 fg	45.4 ab
T_2	**Meteor**	20.7 abcdef	39.5 ab	**Alena**	26.3 abcd	40.2 ab
T_3	**Meteor**	15.9 cdefg	45.9 ab	**Alena**	12.9 defg	39.0 ab
T_4	**Meteor**	9.61 efg	21.9 b	**Alena**	2.3 g	35.2 ab
T_5	**Meteor**	23.4 abcde	56.8 a	**Alena**	33.4 abcd	51.7 a
T_6	**Meteor**	21.9 abcdef	46.3 ab	**Alena**	19.8 abcdef	40.3 ab
T_7	**Meteor**	25.0 abcd	55.8 a	**Alena**	23.8 abcde	46.9 ab
T_8	**Meteor**	17.0 bcdefg	43.6 ab	**Alena**	18.1 bcdefg	41.2 ab
T_9	**Meteor**	33.9 ab	61.0 a	**Alena**	25.3 abc	52.8 a
T_{10}	**Meteor**	33.2 abc	57.6 a	**Alena**	41.5 a	47.5 ab
T_{11}	**Meteor**	23.0 abcde	60.2 a	**Alena**	25.6 abcde	54.5 a

Total Biomass

- Cultivar effect: There was no significant difference in terms of the overall biomass- Meteor (21.1 g) vs. Alena (20.5 g).
- The best: Np + Germinator + 22.5 kg N/ha (32.4 g).
- Less: Germinator single (5.4 g).
- V x T: Significant (CV = 46.81%)
- best combination: Alena x Np +Germinator+ 22.5 kg N/ha (41.5 g, highest).
- Good yields: Meteor x Np + Germinator (33.9 g) Alena x Np + 22.5 kg N/ha (33.4 g).
- Lowest mixture: Alena x Germinator (2.3 g).

Harvest Index

- Cultivar effect: there was no difference between Meteor (48.6) and Alena (45.0).
- There is a significant treatment effect overall.
- Maximum harvest index: Np + Germinator + 45 kg N/ha (57.4), Np + Germinator (56.9) and Np + 22.5 kg N/ha (54.2).
- Lowest: Germinator solo (28.5).
- Interaction (V x T is significant, CV = 17.94%):
- Best combination: Meteor = Np + Germinator (61.0, highest), then Meteor = Np + Germinator + 45 kg N/ha (60.2).
- The worst combination: Meteor x Germinator (21.9)

DISCUSSION

Emergence Percentage

The findings indicated that the emergence of seeds was significantly affected by nitrogen fertilizer, Rhizobium inoculation, and Germinator treatments, and varietal differences were also evident. In general, Meteor had a greater emergence (58.3%) than Alena (45.9%). The greatest level of emergence was observed in Meteor with the treatment Np + Germinator + 45 kg N/ha (T_{11}, 69.4%) and in Alena with the treatment Germinator + 45 kg N/ha (T_8, 58.3%) as mentioned in **Table 1**. It was found that the highest emergence occurred in both cultivars in the Rhizobium inoculation control (T_1), with the lowest in Alena, specifically in the Rhizobium treatment (T_2) (47.2% and 30.5% in Meteor and Alena, respectively). The important interaction (V x T, CV = 21.3%) indicates that cultivar responses varied across treatments, with the interventions of adding combined nitrogen and Germinator being the most active. These findings supported our results in which Dadlani and Yadava (2023b) found no significant effect of the rate of nitrogen application on the percentage of pea seed emergence.

Plant Height and No. of Branches

The findings indicated that plant height and the branch number in pea have been significantly affected by seed inoculation and the use of nitrogen, with an interplay between cultivars and treatments. There was no statistically significant difference in biometric plant height between Meteor (53.9 cm) and Alena (55.3 cm); maximum height, however, was attained by Np + Germinator (T_9: 70.5 cm) and by Np + Germinator + 22.5 kg N/ha (T_{10}: 64.7 cm), signifying a synergistic effect of Rhizobium and Germinator in medium nitrogen. The lowest value was recorded in the control (T_1: 31.0 cm) as shown in **Table 2**. Regarding the branches, both cultivars tend to yield a similar result, with Meteor averaging 2.92 and Alena averaging 2.80. The maximum number of branches was found using Germinator + 22.5 kg of N/ha (T_7: 3.62) and Np + 45 kg of N/ha (T_6: 3.61), and the lowest number of branches was in the treatment of Germinator cultivation alone (T_4: 1.49). These results are also consistent with those of Muthusamy et al. (2023), who indicated a boosted growth and branch development of legumes when using biofertilizers and N inputs, and Pankaj et al. (2025), who assigned potentiation of pea biomass and productivity due to the use of combined microbial inoculants and N addition. The large interaction of V x T (CV = 9.72% plant height; CV = 27.89% branch) indicates that the cultivar response varies according to treatment.

Total Chlorophyll Contents

In the leaves of peas, seed treatment, nitrogen application, and their combinations had significant effects on total chlorophyll content. Generally, there was no significant variation between the two cultivars, with Meteor having an average of 13.59 µg/mg Fw compared to Alena, at 12.86 µg/mg Fw. The lowest value of Chlorophyll was observed in the control (T_1, 11.23g/mg Fw), indicating that untreated plants or those not given any N had a low photosynthetic pigment. The greatest chlorophyll contents were found in treatments with a mixture of Germinator and nitrogen: Germinator + 45 kg N/ha (T_8: 14.55 mu g/mg Fw), Np + Germinator + 22.5 kg N/ha (T_{10}: 14.19 mu g/mg Fw), and Np + Germinator + 45 kg 225 kg N/ha (T_{11}: 14.30 mu g/mg Fw) indicating a synergism between as described in **Table 3**. The present study is similar in its outcomes to the findings of Santamaría et al., (2020) who concluded that microbial inoculation and N fertilizer led to higher chlorophyll in legumes and Mittal et al. (2020c) who showed that chlorophyll and other photosynthetic pigments and plant growth improved with combined biofertilizer and nitrogen application. There was no significant interaction between cultivar and treatment (CV = 13.50%), and therefore, responses were similar across cultivars.

Chlorophyll "a" and "b" Contents

Chlorophyll a and chlorophyll b contents of pea leaves were markedly affected by cultivar, nitrogen application, and seed treatment with biofertilizers and Germinator. As mentioned in **Table 4** both species had higher chlorophyll a (Meteor 10.90 cg/mg Fw, Alena 9.84 cg/mg Fw) and lower chlorophyll b (Meteor 2.69 cg/mg Fw, Alena 3.01 cg/mg Fw) values. The lowest chlorophyll a and chlorophyll b were observed in the control (T_1: 8.98 and 2.24 mcg/mg Fw, respectively), whereas chlorophyll a was highest in Meteor treated with Np + Germinator + 45 kg N/ha (T_{11}: 13.19 mcg/mg Fw) and chlorophyll b was highest in Alena treated with Np + Germinator + 22.5 kg N/ha (T_{10}: 4.41 mcg/ There was a significant pigment interaction (V x T) with both pigments showing difference in responses to treatments. Taken together, the combined effect of nitrogen, Rhizobium, and Germinator increases the level of photosynthetic pigments, thus potentially increasing growth and yield. Additionally, Yadav et al. (2023) reported that nitrogen-biofertilizer synergy significantly increased chlorophyll in legumes, and Lu et al. (2020) also observed a significant increase in chlorophyll a and b with integrated nutrient management.

No. of Nodes and Pod Maturity

Nitrogen and Rhizobium seed treatment, as well as Germinator seed treatment, significantly affected the number of flowers and pod maturity in peas. There were no significant cultivar differences in nodes (Meteor = 7.99, Alena = 7.78) or pod maturity (Meteor = 28.6 days, Alena = 28.3 days). The maximum yield was recorded in Meteor treated with nitrogen at 45 kg/ha (T_3 = 9.08), while the lowest yield was observed in Alena with Rhizobium alone

(T_2 = 6.25) as described in **Table 5**. The length of time taken for pod maturity was delayed in nitrogen and biofertilizer treatments, ranging from 22.6 days in Alena x Rhizobium (T_2) to 30.6 days in the treatments including Meteor x N @ 45 kg/ha, Germinator, Np + 22.5 N, and Np + Germinator + 22.5 N. Interaction effects (V x T) were significant, with CV values reaching 10.73% and 9.19%, indicating that different cultivars respond differently to treatments. These findings underscore the importance of combining nutrient and biofertilizer applications in maximizing vegetation growth and reproductive time. This was also noted by Sheteiwy et al. (2021) and Grover et al. (2021), who observed a positive response in legumes following combined nitrogen and Rhizobium soil treatments, which improved node formation and the flowering cycle.

No. of Pods and Pod Length

Pods per plant and pod length in pea were significantly affected by the combined application of Rhizobium, Germinator, and nitrogen. The Meteor generated a higher number of pods (42.6 in T_9: Np + Germinator) than Alena (33.0 pods in T_{10}: Np + Germinator + 22.5 kg N/ha), demonstrating a cultivar difference. The lowest Pod was during Alena, which received Np + 45 kg N/ha (T_6 = 0.06 pods). According to **Table 6** Pod length also had minor cultivar differences (Meteor = 8.0 cm, Alena = 7.9 cm), and longer pods were recorded between Meteor x Np + Germinator + 22.5 kg N/ha (T_{10} = 8.0 cm) and Alena x Np + Germinator (T_9 = 7.9 cm), with the shortest pods recorded in Alena x Germinator (T_4 = 6.0 cm). The interaction effects between compound and cultivar are significant for both traits (CV = 23.23% for pod number, CV = 6.09% for pod length), suggesting that both traits react differently to the two biofertilizer and nitrogen combinations. These findings are consistent with those of Nosheen et al. (2021b) and Bulgari et al. (2019), which demonstrate that combining seed treatment with Rhizobium and the addition of nitrogen have a positive impact on pod development and the characteristics of pea crops.

Pod Weight and No. of Seeds Per Pod

In pea, the effect of cultivar, treatment, and their interaction was significant in the weight of pods as well as seeds per pod. In total, compared to Meteor, Alena yielded marginally better pod weight (1428.8 mg), but the improvement was not significant. Regarding the treatments, the product Np + Germinator (T9) produced the greatest pods weighing (1751.7 mg), and the combination Alena x Np + Germinator produced the highest (2133.3 mg). Other good treatments were: Meteor x Np + 45 kg N/ha (1520 mg) and Alena x Rhizobium (1546.7 mg). The least weight of the pod was recorded in the Alena x Control (1120 mg) treatment as shown in **Table 7**. The pods that originally contained the greatest number of seeds were in Np + Germinator (3.69 seeds/pod), followed by Alena x Nitrogen at 45 kg N/ha with 4.56 seeds/pod. The lowest mean seed number was in the Meteor x Germinator (1.74 seeds/pod). The interaction between cultivar (V) and time (T) was significant in both traits (CV = 15.99% for pod weight and 23.85% for seeds/pod), indicating a differential response among cultivars. These results align with the current research by Sharma et al. (2023) and Of et al. (2023), who observe the synergistic role of biofertilizers and nitrogen in promoting pod development and reproductive performance.

Total Biomass and Harvest Index

Treatment and cultivar X treatment significantly affected total biomass and harvest index in pea; however, the effect of cultivar was not significant. In general, there were no bragging rights between Meteor and Alena in terms of biomass production (21.1 g vs. 20.5 g). The total biomass was the highest in Np + Germinator + 22.5 kg N/ha (T_{10}: 32.4 g), and the optimum combination was Alena x Np + Germinator + 22.5 kg N/ha (41.5 g). Other significant treatments included Meteor × Np + Germinator (33.9 g) and Alena × Np + 22.5 kg N/ha (33.4 g), whereas the lowest biomass was observed with Alena × Germinator (2.3 g) as mentioned in **Table 8**. The harvest index was also subject to treatments; the best results were obtained with Np + Germinator + 45 kg N/ha (57.4%), Np + Germinator (56.9%), and Np + 22.5 kg N/ha (54.2%). In contrast, Meteor x Np + Germinator (61.0%) proved to be the optimal combination. The lowest index was registered with Germinator only (28.5). The results indicate large interaction effects between biofertilizer and nitrogen applications on both traits (CV = 46.81% for biomass; 17.94% for harvest index), which signify synergistic effects. The findings align with those of Change (2023) and Boyd et al. (2020), who have determined that integrated nutrient management is an effective solution for increasing yield and efficiency.

CONCLUSION

Nitrogen fertilizer with seed treatment by Germinator significantly promoted seed emergence, with a peak percentage recorded in T_8 (Germinator + 45 kg N/ha). In Meteor, the best percentage of seed germination was registered in Np + Germinator + 45 kg N/ha (T_{11}), and in Alena, in T_8. Rhizobium increased the height of the plants, and Germinator with Meteor gave the tallest plants under Np + Germinator (T_9) and Alena under Np + Germinator + 22.5 kg N/ha (T_{10}). The highest branching occurred in Germinator + 22.5 kg N/ha (T_7) and Germinator + 45 kg N/ha (T_8), with Meteor being most responsive to T_8 and Alena having the most branches under T_7 and Np + 45 kg N/ha (T_6). Nitrogen was shown to have increased chlorophyll, with T_3 having the highest total chlorophyll, T_{11} in the Meteor, and T_8, T_7, and T_6 having the highest chlorophyll in Alena. Chlorophyll a was found to be highest in T_6 in general, but in Meteor, it was under T_{11}, and in Alena, it was under T_6. Chlorophyll b was maximized in T_{10}, but it was maximized in T_{11} in Meteor and in T_{10} in Alena. Nitrogen also affected reproductive characters: these traits had longer nodes bearing first flowers in T_3, whereas maximum flowering-to-maturity duration was experienced under T_8. Abbreviation is bold. Combined treatments performed better in terms of pod attributes, with the widest number of pods per plant in Meteor under T_9 and Alena under T_{11}, the longest pods in T_{10} and T_9, and

the heaviest pods in Meteor under T_8 and Alena under T_9. The number of seeds per pod was maximum in T9; however, differences existed between the cultivars (T_{10} in Meteor, T_3 in Alena). Biomass peaked under cultivars in T_{10} and in cultivars Np; however, the highest harvest index was at Np + Germinator + 45 kg N/ha (T_{11}).

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