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Effect of Plant Growth Regulators, Biofertilizers and Antioxidants on Physio-morphological, Yield and Quality Attributes of Field Pea (*Pisum sativum* var. Arvense)

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Abstract

The field pea crop was very suitable for many areas but due to less soil fertility the quality and quantity of grains was reduced. The growth parameters like plant height, number of leaves, number of branches all was affected and same in the yield parameters like number of pods per plant, number of seeds per pod, etc. The flower initiation was delayed, and weather conditions were not in the favor always. So, the plant growth regulators were required to reduces this stress from the field pea crop. A field experiment was conducted in the rabi season of 2022 at the research farm of Lovely Professional University (India). The treatments comprised with plant growth regulators (NAA (naphthalene acetic acid) and GA_3 (gibberellic acid) @ 25 and 50 ppm), antioxidants (acetylsalicylic acid and ascorbic acid @ 100 and 200 ppm), biofertilizers (rhizobium and PSB (phosphate solubilizing bacteria)) and control in randomized block design. Growth regulators showed profound results in case of morphology of plant whereas antioxidants effect was not remarkable. The biofertilizers improved the root growth and development. All the treatments statistically showed best result as compared to control. Among all treatments GA_3@50 ppm showed best result in case of physio-morphological characters viz., plant height, number of leaves, number of branches, leaf area, and chlorophyll index as they increase as the dose of concentration increased. GA_3 had a profound effect on hastening the initiation of flowering by 3 - 5 days over control, whereas other plant growth regulators, antioxidants did not affect the days to flowering. NAA has profound effect on the quality attributes i.e., seedling length, seedling dry weight, and vigor index as compared to GA_3. In case of yield attributes GA_3 and PSB resulted better over other treatments. The result suggested that the use of GA_3 and NAA as plant growth regulators are most beneficial for the growth, yield, and phenology of field pea.

Keywords

Responsible consumption and production, Life on land, Growth regulators, Antioxidants, Biofertilizers, Phenology

Introduction

Pulses, sometimes called "poor man's meat", are members of the legume family, the Leguminosae. Since there is a growing need for protein-rich raw material for animal feed or intermediary product for human nutrition, there is renewed interest in these crops. They contain 22.4% protein and are considered highly digested [1]. The pulse crop field pea (*Pisum sativum* L.) is widely grown in India. When it comes to pea production, India ranks only behind Russia. Protein, carbohydrates, vitamins A and C, calcium, and phosphorus can all be found in abundance in peas. It is represented as one of the worlds most seasoned cultivated crop [2]. It was first cultivated around the turn of the last 10,000 years, in its native Middle Eastern region. India is a major producer of both the grain and vegetable varieties of peas. Plants are grown for their seeds, animal use, forage, and green manure [3]. It is the second highest yielding grain legume after the widespread bean (*Vicia faba* L.*),* and one of the six most important pulses crops grown worldwide. The field pea, a staple grain legume in Asia, can help people eat well by providing a large quantity of protein at a low cost. With 1.8 g of fat, 62.1 g of carbohydrates, 22.5 g of protein, 0.15 g of riboflavin, 0.72 mg of thiamine, 2.4 mg of niacin, 64 mg of calcium, and 4.8 mg of iron per 100 g of dry grains, you may have a healthy, protein-rich lunch [3]. The field pea can help with two of the most widespread micronutrient deficits because of its high levels of naturally occurring iron and zinc. The primary causes of lower or uncertain production include poor sowing techniques, incorrect crop geometry, avoiding the use of biofertilizers, other cross-cultural procedures, and climate unpredictability [4].

Little progress has been made to improve output, and yields have lagged those of grain, despite the possibility of high consumption of field peas to help eliminate hidden hunger. Statistics given by the food and agriculture organisation of the United Nations show that approximately 7% of global pea production comes from the Indian field. Uttar Pradesh is the largest state in India by both land and production, followed by Madhya Pradesh and Jharkhand. However, in terms of productivity, Rajasthan is the most successful state in India, followed by Punjab and Jharkhand. Maharashtra and Chhattisgarh both had very poor output. Biofertilizers, although just one type of fertiliser, are a highly effective nutrition addition [3]. Pea is one of the few leguminous crops for which the use of biofertilizers has shown particularly promising outcomes. Seed yield was positively impacted by rhizobia inoculation because of the enhanced root nodulation that resulted from higher root growth and the availability of more nutrients. This led to robust plant growth and dry matter output. Rhizobium and PSB play a crucial role in N_2-determination and P-solubility, making them extremely valuable organisms. Rhizobium is the most important biofertilizer out of several. In a mutualistic relationship with legumes, the bacterium rhizobium fixes atmospheric nitrogen [4].

The use of phytohormones as plant sprays or as seed treatments has achieved outstanding improvements in the yield and quality of numerous vegetable crops. Light, temperature, moisture, nutrients, and other environmental conditions impacted the efficacy of plant growth regulators. Effectiveness of a plant growth regulator based upon concentrations, application methods, and timing. Some plant growth regulators, such as GA_3, speed up the maturation of plants by promoting cell elongation and therefore growth, cell division in shoot elongation, flowering, and seed germination. The NAA is widely utilized as a plant growth regulator. The effects of auxins and other growth regulators on plants are extensive and diverse. The administration of NAA has been shown to have varying impacts on different plants, including accelerating rooting, controlling flowering, preventing fruit drop, and increasing fruit development [4]. The sudden surge in pea cultivation over the past few years has resulted in a severe shortage of seeds, and the gap between supply and demand has only widened. This study was conducted to determine the impact of biofertilizers and plant growth regulators on the development and productivity of field pea (*P. sativum* L.) with the goal of increasing the seed yield per unit area and standardising the method to be utilized for the increased production of pea seeds.

The objectives of present study were to: (i) To find out the efficacy of plant growth regulators on growth and yield of field pea, (ii) To assess the effect of antioxidants and biofertilizers on growth, flowering, and yield of field pea, and (iii) To investigate the combination of different chemical formulation.

Materials and Methods

Planting materials and experimental condition

The seeds of field pea variety Punjab-89 were obtained from the seed production unit of PAU, Ludhiana used as planting material. The present field investigation was conducted at the experimental field of Lovely Professional University, Phagwara (Punjab, India) situated at 31°15'47" North, 75°41'20" East during the rabi season of 2022 - 2023. Biofertilizers (rhizobium and PSB), plant growth regulators (GA_3 and NAA) and antioxidants (ascorbic acid and acetyl salicylic acid) were among the 11 treatments tested in a randomised block design experiment. Treatments comprised with two levels of NAA (25, 50 ppm), GA_3 (25, 50 ppm), ascorbic acid (100, 200 ppm), acetyl salicylic acid (100, 200 ppm), rhizobium, PSB, and control. The experimental plot size was 3 x 4 m^2. The seeds were planted with a row-to-row spacing of 30 cm and a plant-to-plant spacing of 10 cm using the line sowing method. In every plot, the ideal amounts of nitrogen, phosphorus, and potassium kg/ha were spread everywhere. In addition to the full doses of phosphorus (60 kg/ha) and potassium (40 kg/ha), an optimal dose of nitrogen (25 kg N/ha) was applied, with half of the dose supplied at the time of seed sowing.

Used chemicals information for this study

1. Biofertilizers (rhizobium and PSB).
2. Plant growth regulators (GA_3 and NAA). NAA helps to prevent premature fruit dropping and thinning. GA_3 helps to enhance induction of flower bud break.
3. Antioxidants (ascorbic acid and acetyl salicylic acid). Ascorbic acid helps in regulating photosynthesis, hormone biosynthesis and regenerating other antioxidants. Acetyl salicylic acid helps to prevent plant damage caused by abiotic stress like weather.

Levels of chemical

Two levels of NAA (25 and 50 ppm), GA_3 (25 and 50 ppm), ascorbic acid (100 and 200 ppm), and acetyl salicylic acid (100 and 200 ppm).

Growth attributes and seed quality parameters

Five plants from each replicate were randomly chosen to record data on germination %, plant height (cm), number of primary branches, days to 50% flowering, chlorophyll index, dry weigh (g), leaf area (cm^2), seedling length (cm), seedling dry weight (mg), and vigor index for each treatment.

Yield attributes and seed nutrient content parameters

Number of pods per plant, seeds per pod, pod length (cm), and pod weight (g) was measured from randomly choose five plants from each treatment whereas pod yield (kg/ha), haulm yield (kg/ha), and seed index were calculated from 1 m^2 area. Seed protein % and nitrogen % was recorded from the seeds at the time of harvesting by using Micro Kjeldahl's method [5].

Statistical analysis

The statistics was calculated using the mean values. The latest release of SPSS, version 22 was used for the statistical analysis. An analysis of variance was performed to examine the data and compare the means. Only differences between treatment means that were statistically significant at the 0.05 level were included for analysis and interpretation. To understand the impact of treatments at the 5% level of significance ($p < 0.05$), the least significant difference test and DMRT was performed.

Results and Discussion

A study was designed to assess the impact of seed treatment with biofertilizers and plant growth regulators on the growth and yield parameters of field pea. Different seed treatments, including Rhizobium and PSB at 15 g, GA_3 at (25 and 50 ppm), NAA (25 and 50 ppm), acetyl salicylic acid (100 and 200 ppm), and ascorbic acid (100 and 200 ppm) was applied to field peas. As a control, untreated seeds were used to compare the treated seeds quality and yield to those of the treated seeds. Seeds were examined for their growth, quality, and yield characteristics.

Effect of growth regulators, biofertilizers, and antioxidants on growth parameters of field pea

Table 1 displays data on the growth characteristics of field pea (cv. PB-89) because of the use of growth regulators. In comparison to the control group, plants treated with growth regulator (GA_3) were much taller, more leaf area (cm^2), highest dry weight (g), maximum chlorophyll index (SPAD), and had more branches per plant. Plants that were drenched with water only grew to a height of 42.3 cm. The taller plants of 67.67 cm recorded under GA_3@50 ppm which was followed by GA_3@25 ppm with 63.42 cm. In case of plant height (cm), the seeds treated with biofertilizers viz., Rhizobium and PSB recorded taller plants as compared to ascorbic acid, NAA, and acetyl salicylic acid. GA_3 effect on internode elongation provides an explanation for this phenomenon [6]. Growth-promoting effects of GA_3 are attributed to an increase in cell number and size. In a study on the garden pea variety Bonneville both 50 and 100 ppm GA_3 were applied to the plants, with the latter producing longer vines [7].

To raise the stature of garden pea cv. Arkel; Piper [8], applied larger concentrations of auxins (up to 45 ppm NAA) and gibberellins (200 ppm GA_3). Shi et al. [9] and Glogoza et al. [10] also reported using gibberellins to encourage shoot elongation. Maximum expansion in leaf area (17.23 cm^2) recorded in those plots where seeds treated with GA_3 at 50 ppm which was at par with leaf area (16.27 cm^2) with GA_3@25 ppm. GA_3 facilitates the process of cell elongation by inducing the absorption of water and nutrients into the cellular structure of plants. Therefore, there is an augmentation in cellular dimensions, hence resulting in the development of larger and more extensive foliage [4]. Second highest leaf area (15.23 cm^2) recorded in PSB treated plots. Minimum leaf area (9.79 cm^2) recorded in those plots where seeds remain untreated. Maximum dry weight (17.06 g) observed with the treatment of seed with GA_3@50 ppm which was followed by GA_3@25 ppm with 15.76 g dry weight that might be due to the increased expansion of cells, elongation of stems, and stimulation of photosynthetic activity caused by GA_3 which frequently led to an augmented buildup of biomass. The biomass encompasses both the aerial and underground parts of plants, hence leading to a positive augmentation in the amount of dry matter [11]. Minimum dry weight (5.90 g) was recorded in control plots. In chlorophyll index also significant variation recorded in treated and untreated plots. Highest chlorophyll index recorded (46.48 SPAD) in GA_3@50 ppm which was non-significant with GA_3@25 ppm and PSB@15 g with 44.73 and 44.35 SPAD. GA_3 can enhance the plant's ability to absorb and assimilate nutrients, including essential minerals like nitrogen, which is a component of chlorophyll molecules.

Increased nutrient availability can lead to higher chlorophyll production and a boosted chlorophyll index. Remaining treatments were significant among themselves [12]. Lowest chlorophyll index (34.23 SPAD) was recorded in control.

Table 1: Effect of plant growth regulators, antioxidants, and biofertilizers on physio-morphological parameters of field pea (Data is in the form of mean ± SD at $p < 0.05$. The mean followed by different letters was significantly different at $p < 0.05$, according to DMRT for separation of means).

Treatments	Plant height (cm)	Leaf area (cm^2)	Dry weight (g)	Chlorophyll index (SPAD)	Number of branches	Days to 50% flowering
T_0- Control	42.33 ± 1.25^{g}	9.79 ± 0.78^{f}	5.90 ± 0.54^{e}	34.23 ± 1.35^{f}	4.23 ± 0.25^{f}	45.13 ± 0.74^{a}
T_1- NAA (25 ppm)	52.38 ± 0.64^{f}	12.77 ± 0.82^{e}	9.72 ± 0.98^{e}	39.08 ± 1.06^{cd}	10.67 ± 0.47^{e}	41.47 ± 0.52^{d}
T_2- NAA (50 ppm)	54.63 ± 0.78^{e}	13.33 ± 0.74^{de}	10.95 ± 1.19^{de}	39.38 ± 1.00^{cd}	11.33 ± 0.69^{d}	42.43 ± 0.42^{c}
T_3- GA_3 (25 ppm)	63.42 ±1.17^{b}	16.27 ± 0.63^{ab}	15.76 ± 0.86^{abc}	44.73 ± 1.09^{a}	14.17 ± 0.87^{bc}	38.57 ± 0.31^{e}
T_4- GA_3 (50 ppm)	67.67 ± 0.92^{a}	17.23 ± 0.80^{a}	17.06 ± 0.70^{a}	46.48 ± 0.67^{a}	17.17 ± 0.52^{a}	38.37 ± 0.29^{e}
T_5- Acetyl salicylic acid (100 ppm)	56.80 ± 0.86^{de}	12.27 ± 0.82^{e}	9.35 ± 0.41^{bc}	39.18 ± 1.21^{cd}	12.40 ± 0.94^{d}	43.90 ± 0.54^{b}
T_6- Acetyl salicylic acid (200 ppm)	57.80 ± 1.59^{d}	12.33 ± 0.79^{e}	11.27 ± 0.33^{cd}	40.63 ± 1.31^{bc}	13.00 ±0.54^{cd}	43.33 ± 0.25^{c}
T_7- Ascorbic acid (100 ppm)	54.63 ± 0.87^{e}	12.37 ± 0.84^{e}	12.83 ± 0.45^{bc}	36.54 ± 0.79^{e}	9.59 ± 0.77^{e}	43.63 ± 0.49^{b}
T_8- Ascorbic acid (200 ppm)	56.49 ± 0.94^{de}	13.47 ± 0.86^{de}	13.90 ± 0.42^{abc}	37.77 ± 0.86^{de}	10.67 ± 0.39^{e}	43.37 ± 0.39^{b}
T_9- Rhizobium as seed treatment (15 g)	60.50 ± 0.62^{c}	14.53 ± 0.56^{cd}	14.60 ± 0.73^{abc}	42.03 ± 1.18^{b}	13.63 ± 0.48^{bcd}	42.57 ± 0.42^{c}
T_{10}- PSB as seed treatment (15 g) for 12 h	61.60 ±0.67^{bc}	15.23 ±0.74^{bc}	15.60 ±0.57^{ab}	44.35 ± 1.29^{a}	14.73 ±0.71^{b}	42.50 ± 0.45^{c}

Table 1 showed that GA_3@50 ppm resulted in the highest number of primary branches per plant (17.17 respectively), followed by PSB@15g with 14.73 branches. GA_3 has the capability to stimulate the quiescent axillary buds, so initiating their growth and subsequent differentiation into branches. The phenomenon of axillary bud activation is frequently attributed to increased branching that is commonly observed because of GA_3 treatment. Although growth regulators were much higher than control [4, 13]. In comparison the control (4.23), recorded minimum number of primary branches. The number of days it took for flowers to open was similar in the PSB, rhizobium and NAA@50 ppm and maximum days noted in control groups, but it was shortest (38.37, 38.57) in plants treated with the GA_3 concentrations 25 and 50 ppm. The shorter time to first flowering observed with 100 ppm GA_3 in Bonneville Garden pea compared to NAA and control was consistent with data from Chan and Gresshoff [7]. They found that the plants' early response to flowering was due to their faster vegetative development and greater nutrition. This result is in similar with the findings of Chan and Gresshoff [7], Strydhorst et al. [14] and Kumar et al. [15]. The variation in the number of branches may be due to vigorous growth of plants due to priming. Arman et al. [16] obtained similar results in terms of maturity when seeds were treated with 5 ppm GA_3.

Effect of growth regulators, biofertilizers, and antioxidants on yield characters of field pea

When compared to the control group, all the yield characteristics (number of pods per plant, pod length (cm), pod weight (g), number of seeds per pod, and seed yield (kg)) increased significantly when growth regulators were applied. When compared to ascorbic acid, acetyl salicylic acid and NAA, GA_3 treated seeds yielded much better results (Table 2). The maximum number of pods produced by a plant was 18.8 when 50 ppm GA_3 was used, while the minimum was 7.8 in control. However, the increase in pods per plant with increasing GA_3 concentration was not statistically significant to PSB at 15 g. GA_3 can promote earlier flowering in plants. Early flowering can extend the period during which flowers are available for pollination, increasing the chances of successful pollination and pod formation [4, 7, 17]. The administration of 50 ppm GA_3 resulted in the longest pods (10.10 cm), followed by 25 ppm GA_3 (9.01 cm), while the untreated seeds resulted in the shortest pods (5.7 cm). Growth hormone GA_3 and biofertilizer PSB both resulted in a similar increase in pod length (cm). GA_3 promotes cell elongation, including cells in the developing pods. Longer cells contribute to longer pod length. Longer pods can potentially accommodate more seeds, providing additional space for seed development [18-20]. Maximum pod weight (6.39 g) recorded in GA_3@50 ppm which was followed by PSB@15 g and GA_3@25 ppm. Lowest pod weight (3.24 g) was recorded in control. Treatment with 50 ppm GA_3 resulted in the highest number of seeds per pod (8.33) and the highest seed index (19.33 g), both parameters significantly increased above the control.

One measure of seed quality is the seed index, or the weight of one hundred seeds. GA_3 can influence the process of fertilization and seed set within the pods. It may increase the likelihood of successful pollination and fertilization, resulting in more seeds per pod. Raj et al. [20], Basuchaudhuri [21], Chatterjee and Choudhuri [22] reported that growth regulators may function in sucrose absorption, and our results support this hypothesis. GA_3 has been shown to have a crucial role in plant development [7, 9, 14]. Pod yield and haulm yield recorded maximum (2008.67 kg/ha and 2675.33 kg/ha) with the application of GA_3 at 50 ppm. Whereas in pod yield GA_3@25 ppm and PSB also recorded same result as per GA_3@50 ppm. Minimum pod yield and haulm yield (999.67 and 1463.33 kg/ha) observed in control. El-Araby et al. [13] observed comparable outcomes in their study on pea plants. Specifically, they found that Rhizobium inoculation generally enhanced root nodulation by promoting root growth and increasing nutrient availability. These improvements in turn facilitated robust plant growth and dry matter production, leading to improved flowering and pod formation. Ultimately, these positive effects on seed yield were observed by Kumar et al. [15].

Effect of growth regulators, antioxidants, and biofertilizers on seed quality parameters and seed nutrient content

Table 2: Effect of plant growth regulators, antioxidants, and biofertilizers on yield and yield parameters of field pea (Data is in the form of mean ± SD at $p < 0.05$. The mean followed by different letters was significantly different at $p < 0.05$, according to DMRT for separation of means).

Treatments	No. of pods per plant	Seeds per pod	Pod length (cm)	Pod weight (g)	Pod yield (kg/ha)	Haulm yield (kg/ha)	Seed index (g)
T_0- Control	7.50 ± 0.61^f	3.00 ± 0.82^e	5.70 ± 0.50^d	3.24 ± 0.29^g	996.67 ± 17.00^f	1463.33 ± 60.18^d	14.70 ± 0.51^c
T_1- NAA (25 ppm)	9.83 ± 0.72^e	5.67 ± 0.47^d	6.53 ± 0.31^{cd}	3.59 ± 0.14^{fg}	1222.67 ± 50.45^e	1889.33 ± 50.45^c	16.67 ± 0.52^b
T_2- NAA (50 ppm)	10.53 ± 0.77^e	6.00 ± 0.82^{cd}	7.00 ± 0.16^c	4.11 ± 0.18^{def}	1315.33 ± 58.21^{de}	1915.33 ± 51.53^c	16.95 ± 1.18^b
T_3- GA_3 (25 ppm)	16.23 ± 0.73^{bc}	7.20 ± 0.28^b	9.01 ± 0.56^b	5.36 ± 0.23^b	1889.33 ± 24.23^b	2456.00 ± 65.56^b	18.30 ± 0.24^{ab}
T_4- GA_3 (50 ppm)	18.80 ± 0.78^a	8.33 ± 0.47^a	10.10 ± 0.57^b	6.39 ± 0.1^a	2008.67 ± 57.58^a	2675.33 ± 91.55^a	19.33 ± 0.41^a
T_5-Acetyl salicylic acid (100 ppm)	13.40 ± 0.94^d	5.83 ± 0.24^{cd}	8.09 ± 0.46^b	3.87 ± 0.37^{ef}	1370.00 ± 69.03^d	1970.00 ± 74.15^c	16.75 ± 0.96^b
T_6- Acetyl salicylic acid (200 ppm)	15.50 ± 0.62^c	6.33 ± 0.47^{bcd}	8.34 ± 0.55^b	3.66 ± 0.13^{fg}	1556.33 ± 89.42^c	1889.67 ± 46.15^c	17.34 ± 0.30^b
T_7- Ascorbic acid (100 ppm)	13.40 ± 0.83^d	5.33 ± 0.47^d	8.30 ± 0.46^b	4.60 ± 0.21^{cd}	1328.67 ± 100.98^{de}	2062.00 ± 117.65^c	17.24 ± 0.84^b
T_8- Ascorbic acid (200 ppm)	13.63 ± 0.17^d	6.00 ± 0.00^{cd}	8.12 ± 0.22^b	4.35 ± 0.17^{de}	1371.00 ± 72.89^d	2371.00 ± 72.89^b	16.66 ± 0.98^b
T_9- Rhizobium as seed treatment (15 g)	15.37 ± 0.48^c	6.44 ± 0.42^{bcd}	8.64 ± 0.32^b	4.90 ± 0.37^{bc}	1651.67 ± 8.13^{bc}	2351.67 ± 15.68^b	16.87 ± 0.67^b
T_{10}- PSB as seed treatment (15 g) for 12 h	17.67 ± 0.90^{ab}	6.83 ± 0.24^{bc}	8.90 ± 0.38^b	5.23 ± 0.10^b	1734.33 ± 39.89^b	2367.67 ± 84.01^b	18.02 ± 0.25^{ab}

As can be seen in table 3, after the administration of the growth regulators all the quality indicators for the seeds (germination %, seedling length (cm), seedling dry weight (mg), and seedling vigor index) significantly increased in comparison to the control. There was significant effect of the plant growth regulators on seed germination. Maximum germination % (97.06) observed in GA_3@25 ppm which was at par with NAA 50 ppm with 96.7% germination, respectively [11, 22, 23]. When compared to GA_3, NAA effects on seedling length and seedling vigor index were more pronounced, and they increased considerably with increasing concentrations of GA_3. The maximum seedling length (27.91 cm) was recorded in NAA@50 ppm which was at par with 27.9 cm seedling length in GA_3@50 ppm. NAA and GA_3 have different modes of action in plants. While NAA primarily affects root growth, GA_3 is more focused on shoot and stem growth. The combination of NAA root-promoting properties and the moderate concentration chosen (50 ppm) may have resulted in the observed increase in seedling length [24, 25]. Shortest seedling length (20.77 cm) was observed in control. Seedling dry weight also recorded maximum (39.07 mg) in NAA@50 ppm and followed by GA_3@50 ppm with 37.23 mg that could be due to NAA is known for its ability to stimulate root growth and development. At a concentration of 50 ppm, NAA likely promoted a robust and extensive root system. A well-developed root system can enhance nutrient and water uptake, resulting in increased overall plant growth and dry weight [26]. Highest vigor index (2722.25) was recorded in GA_3 which was followed by NAA@50 ppm with 2698.31 vigor index [27]. Least vigor index (1803.35) was recorded in control. The nutrient content in the seeds were significantly increased by the application of three plant growth regulators (Table 3). The nitrogen content was found to be maximum (3.78%) in the treatments with NAA@50 ppm followed by NAA@25 ppm and the values increased with increasing concentration of growth hormones. Maximum protein (21.8%) was found in the treatment with 50 ppm NAA followed by NAA@25 ppm with 20.8% that might be due to which application of NAA to pea plants has the potential to induce root growth, hence potentially enhancing the absorption of nutrients, such as nitrogen, from the soil. Increased root growth can potentially contribute to a subsequent rise in total plant growth, thereby leading to a potential elevation in protein production [26, 27].

Correlation

A Pearson's correlation coefficient for plant growth characters, yield characters along with quality characters were studied among themselves and found positive as shown in table 4, figure 1, and figure 2. The value of correlation coefficient varied from 0.181 to 0.996, that indicated these parameters were highly significant and inter correlated with each other. The data revealed that seedling length and vigor index showed the greatest correlation coefficient (0.996), however least correlation coefficient (0.181) was observed for pod yield and protein %.

Conclusion

This study findings demonstrated that the chemically treated field pea seeds with GA_3@50 ppm showed the best result as comparison to antioxidants. The present investigation concluded that the field pea seeds (variety PB-89) treated with biofertilizer and plant growth regulators gave best result as compared to used antioxidants as NAA used with two different levels (25 and 50 ppm). The application of GA_3 at 50 ppm led to improved growth, quality, yield, and yield attributes. Therefore, it was recommended to administer GA_3 at 50 ppm and Rhizobium treatment at a dosage of 15 g. The recommendations provided are derived from a four-month pe-

Table 4: Simple correlation between different growth parameters, yield parameters, and seed quality parameters.

Variable	r
Plant height and number of branches	0.927**
Plant height and chlorophyll index	0.922**
Plant height and dry weight	0.905%**
Plant height and leaf area	0.932**
Pod yield and seed index	0.914**
Pod yield and seeds per pod	0.232*
Pod yield and protein %	0.181*
Pod yield and nitrogen %	0.237**
Pod yield and pods	0.938**
Seedling length and seedling weight	0.845**
Seedling length and vigor index	0.996**

Note: *Indicates correlation significant at 5% level of significance, **Correlation is significant at the 0.01 level (2-tailed).

Table 3: Effect of plant growth regulators, antioxidants, and biofertilizers on seed quality and seed nutrient content in field pea (Data is in the form of mean ± SD at p < 0.05. The mean followed by different letters was significantly different at p < 0.05, according to DMRT for separation of means).

Treatments	Seedling length (cm)	Seedling dry weight (mg)	Vigor index	Germination %	Protein %	Nitrogen %
T_0- Control	20.77 ± 0.37^e	17.03 ± 0.41^g	1803.35 ± 38.48^d	86.83 ± 0.39^e	15.80 ± 0.33^g	2.68 ± 0.10^f
T_1- NAA (25 ppm)	27.17 ± 0.42^ab	36.70 ± 0.50^ab	2589.31 ± 60.85^ab	95.28 ± 0.78^d	20.80 ± 0.33^b	3.32 ± 0.04^b
T_2- NAA (50 ppm)	27.91 ± 0.54^a	39.07 ± 0.26^a	2698.31 ± 39.06^a	96.70 ± 0.49^ab	21.80 ± 0.16^a	3.78 ± 0.06^a
T_3- GA_3 (25 ppm)	26.75 ± 0.54^b	37.17 ± 0.29^b	2596.38 ± 58.25^a	97.06 ± 0.28^ab	18.92 ± 0.41^de	3.13 ± 0.06^cd
T_4- GA_3 (50 ppm)	27.90 ± 0.29^a	37.23 ± 0.68^b	2722.25 ± 42.41^a	97.57 ± 0.49^e	19.23 ± 0.21^cd	3.20 ± 0.05^c
T_5- Acetyl salicylic acid (100 ppm)	26.77 ± 0.34^b	29.57 ± 0.53^f	2588.26 ± 27.33^ab	96.70 ± 0.33^ab	17.90 ± 0.29^f	2.98 ± 0.03^e
T_6- Acetyl salicylic acid (200 ppm)	25.80 ± 0.49^cd	32.37 ± 1.03^e	2492.34 ± 51.90^b	96.60 ± 0.51^ab	18.36 ± 0.21^ef	3.04 ± 0.02^de
T_7- Ascorbic acid (100 ppm)	25.36 ± 0.11^d	33.47 ± 0.76^de	2402.07 ± 2.52^bc	94.73 ± 0.45^d	18.16 ± 0.21^f	3.07 ± 0.03^de
T_8- Ascorbic acid (200 ppm)	26.27 ± 0.21^bc	34.70 ± 0.78^cd	2510.21 ± 23.48^ab	95.57 ± 0.52^cd	18.83 ± 0.33^de	3.11 ± 0.04^cd
T_9- Rhizobium as seed treatment (15 g)	26.97 ± 0.45^b	36.50 ± 0.99^b	2600.39 ± 37.85^a	96.43 ± 0.21^bc	19.63 ± 0.25^c	3.20 ±0.02^c
T_{10}- PSB as seed treatment (15 g) for 12 h	26.50 ± 0.51^bc	35.00 ± 0.37^c	2554.75 ± 57.03^ab	96.40 ± 0.29^bc	19.20 ± 0.22^cd	3.26 ± 0.02^c

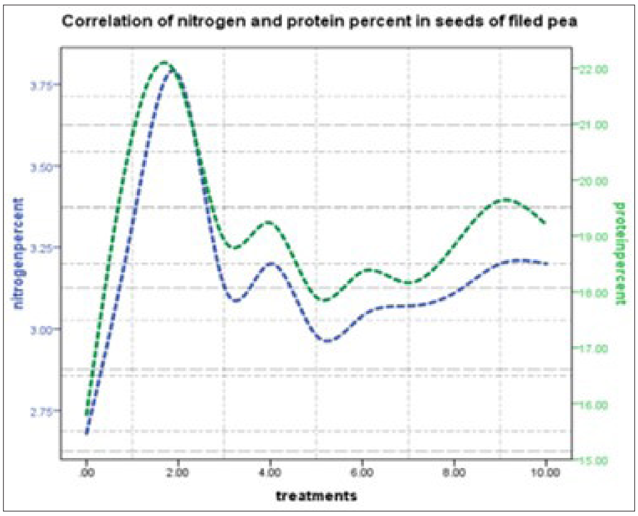

Figure 1: Correlation between nitrogen and protein percentage.

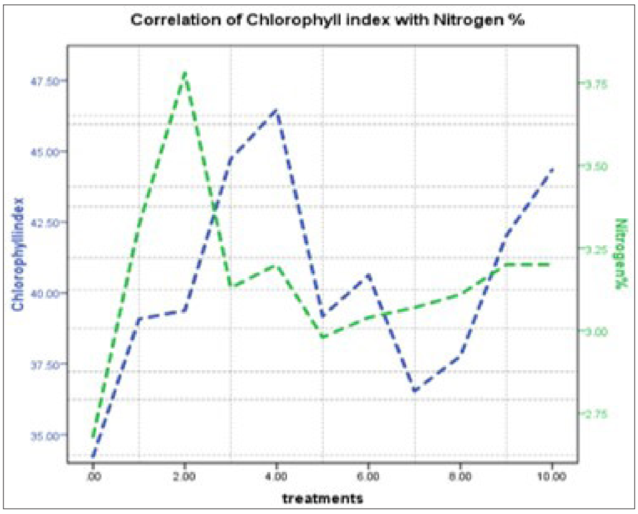

Figure 2: Correlation between chlorophyll and nitrogen percentage.

riod of experimentation. Consequently, additional research is necessary to formulate reliable recommendations. According to this study the field pea (variety PB-89) quality and quantity both were enhanced, similarly the same chemical composition can be used for other varieties to reduce the food scarcity and increase food security.

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Conflict of Interest

The authors declared that they have no conflict of interest with respect to this work.

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