Influence of Foliar Applications of IAA, NAA and GA$_3$ on Growth, Yield and Quality of Pea (Pisum sativum L.)

Arifa Nazeer, Khalid Hussain, Ahmad Hassan$^1$, Khalid Nawaz, Zobia Bashir, Syed Saqib Ali, Nida Zainab, Muhammad Qurban, Ghulam Yasin$^2$

**ABSTRACT**

**Background:** Pea is the most important crop and vegetable in the world but it has low yield. There is a need to find the ways for the improvement of crop productivity. Plant growth regulators (PGRs) are extensively used in many crops for enhancement of yield and quality. This study was designed to find the influence of PGRs on growth, yield and quality of pea cultivars grown in Pakistan.

**Methods:** Pot experiments were conducted to evaluate the effect of various plant growth regulators (IAA, NAA and GA$_3$) on pea during 2018-19. Four cultivars of pea, i.e., Meteor, Green cross, Sultan and Dollar were used in these experiments. There were 0, 100 and 200 mmol L$^{-1}$ levels for each hormone that were applied as foliar spray after 14 days of germination. Experiment was laid down in completely randomized design (CRD) with three replicates.

**Result:** Morphological, biochemical and yield attributes significantly increased in four cultivars of pea except variety Sultan for few parameters. Cultivar Meteor showed highly positive increasing effects on growth and yield attributes as compared to other treatments. Catalases (CAT) activities were increased and peroxidase dismutase (POD) activities were reduced. It can be concluded that reduction in POD activities helped to increase the defense mechanism of plants and high CAT activities caused better balance in plant metabolism as a result growth, yield and quality of pea were increased. All the variables including shoot length, shoot biomass, number of fruits, total seed yield, carbohydrates and protein had positive correlation with phytohormones. These outcomes might be good indicators to predict the best pea cultivars that can have positive promising response for growth, yield and quality traits under plant growth regulators (PGR).

**Key words:** GA$_3$, Growth, IAA, NAA, Pea, Yield.

**INTRODUCTION**

Pea is the most important legume yield cultivated for different reasons and can be used world-wide for numerous advantages (Macas et al., 2007; Devi and Singh, 2016). It contains large quantities of carbohydrates and 86-87 percent of other digestible nutrients, since pea is a good animal feed (Ouafi et al., 2016). In the globe, approximately 700 million individuals eat legumes as part of their diet. It is used for several purposes, namely medicine, paper, timber and petroleum for the production of the human product (Rahman et al., 2013).

In crop growth and development, auxins as Indole acetic acid (IAA) plays an extremely effective role (Dimkpa et al., 2009). According to Hussain et al. (2011), foliar spray of IAA is very useful for the enhancement of yield and plant growth. It was noted that auxins increased the number of pods and seeds and the yield of seeds in Pea (El-Shraif and Hegazi, 2009). Naphthalene acetic acid (NAA) applications increased the plant length, number of fruit and seed yield in many plant species (Lee, 1990). NAA had influence on various physiological activities such as photosynthesis, respiration rate with higher amount of carbohydrates and dry matter (Singh et al., 2015). Gibberellins are used to boost the development of plant, transport of ion and uptake of nutrients. Gibberellic acid (GA$_3$) increased the seed germination, elongation of the stem, extension of leaves and floral growth (Rosenvasser et al., 2006). Positive response have been also noted for pea for organic and inorganic nutrients (Pawar et al., 2016). Foliar use of the GA$_3$ plays a crucial role in enhancing the absorption of nutrients, morphological and physiological attributes of plants (Shomell et al., 2011). Pal (2019) showed faster plant growth, plant yield and quality for garden peas when treated with PGR, particularly IAA and NAA. Increase in yield and seed quality were noted by the applications of IAA and GA$_3$ (Khandaker et al., 2018). In the light of above mentioned literature, experiments were carried out to find the efficacy of IAA, NAA and GA$_3$ on pea cultivars for better growth and yield by evaluating various morpho-physiological, biochemical attribute and antioxidant activities.
MATERIALS AND METHODS

Pot experiments were conducted at the research area, University of Gujrat, Pakistan during 2018-19 on four cultivars of pea i.e. Meteor, Green cross, Sultan and Dollar. Pots of 30cm diameter were used in this experiment which were filled by 10kg of sandy loam soil. There were seven treatments of plant growth regulators which were applied after 14 days of germination. There were following treatments:

\[ T_1 = \text{Control (No hormone)} \]
\[ T_2 = 100 \text{ mmol} \cdot \text{L}^{-1} \text{ of IAA} \]
\[ T_3 = 200 \text{ mmol} \cdot \text{L}^{-1} \text{ of IAA} \]
\[ T_4 = 100 \text{ mmol} \cdot \text{L}^{-1} \text{ of NAA} \]
\[ T_5 = 200 \text{ mmol} \cdot \text{L}^{-1} \text{ of NAA} \]
\[ T_6 = 100 \text{ mmol} \cdot \text{L}^{-1} \text{ of GA}_3 \]
\[ T_7 = 200 \text{ mmol} \cdot \text{L}^{-1} \text{ of GA}_3 \]

Concentrations of plant growth regulators were proposed based upon previous studies. The proposed concentrations have not been evaluated on selected cultivar of pea. Experiments were laid down in completely randomized design (CRD) with three replicates. Data was recorded at vegetative and maturity stages. Vegetative data were collected after 21 days of treatments for morphological and biochemical parameters such as shoot and root lengths, number of leaves, leaf area, chlorophyll contents, antioxidant activities, carbohydrates and protein contents. Yield attributes were noted at maturity i.e. number of legumes and seeds per plant and total yield per plant. Chlorophyll contents (a, b and total chl.) was evaluated using the Arnon method (1949). Chance and Maehley (1955) method was used to find out the antioxidant activities. Total carbohydrates contents were determined following the method of Krishnaveni et al. (1984). Total soluble protein contents were calculated by the procedures of Bradford (1976).

Analysis of Variance (ANOVA) was used to data analysis through Minitab (Version: 19.2.0, Coventry, UK). The comparison of mean values was contrasted with that using the Duncan’s New Multiple Range Test (DMRT) at probability level of 5% which was used to check the difference among mean values by the method of Steel and Torrie (1986).

RESULTS AND DISCUSSION

Results obtained from this study are given below.

Morphological and derivative attributes

Results for morphological attributes indicated that shoot and root lengths and weights were significantly enhanced by the foliar spray of IAA and NAA at both vegetative and maturity stages (Table 1). Effect of PGRs was highly significant for shoot and root lengths of pea. Maximum shoot length was measured at \( T_5 \) in Green cross and minimum in Dollar at \( T_4 \) at both stages (Fig 1A). V4 (Dollar) showed maximum increase in root length at 200 mmol·L\(^{-1}\) of NAA (Fig 1B).

Table 1: Means squares (MS) from the Analysis of Variance (ANOVA) for various morphological attributes of pea due to IAA, NAA, and GA\(_3\). (continued)

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>MS of shoot length at vegetative stage</th>
<th>MS of root length at vegetative stage</th>
<th>MS of shoot fresh weight at vegetative stage</th>
<th>MS of root fresh weight at vegetative stage</th>
<th>MS of shoot dry weight at maturity stage</th>
<th>MS of root dry weight at maturity stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hormones</td>
<td>81.25**</td>
<td>24.612***</td>
<td>28.757***</td>
<td>5.888***</td>
<td>0.231**</td>
<td>0.178**</td>
</tr>
<tr>
<td>Cultivar</td>
<td>3567.580***</td>
<td>373.309***</td>
<td>17.821ns</td>
<td>3.822***</td>
<td>0.3756***</td>
<td>0.451***</td>
</tr>
<tr>
<td>Interaction Hor×Var</td>
<td>81.250***</td>
<td>159.510***</td>
<td>32.946***</td>
<td>8.422***</td>
<td>0.033***</td>
<td>0.115***</td>
</tr>
<tr>
<td>Error</td>
<td>8.007</td>
<td>18.952</td>
<td>5.787</td>
<td>8.125</td>
<td>0.231**</td>
<td>0.011**</td>
</tr>
<tr>
<td>Total</td>
<td>111.00</td>
<td>111.00</td>
<td>111.00</td>
<td>111.00</td>
<td>111.00</td>
<td>111.00</td>
</tr>
</tbody>
</table>

rs = non-significant, *, **, *** = significant at \( P < 0.05, 0.01, \) or 0.001, respectively.
Influence of Foliar Applications of IAA, NAA and GA on Growth, Yield and Quality of Pea (*Pisum sativum* L.)

cross) and minimum in V4 (Fig 1C and D). Effect of IAA, NAA and GA was highly significant on root fresh and dry weights (Table 1). Maximum root weight was noted in cultivar Dollar at 10 and 200 mmol L\(^{-1}\) of IAA (Fig 1E and F). Maximum number of leaves was extant in cultivar at both growth stages (Fig 2A). ANOVA indicated that hormonal effect was significant on leaf area at both stages while varietal response was highly significant (Table 2). Cultivar Meteor showed maximum leaf area at 200 mmol L\(^{-1}\) of NAA (Fig 2B). Leaf area ratio was highly significant with its interaction and varietal response (Table 2). Result indicated that effect of IAA, NAA and GA on relative growth rate (RGR) and net assimilation rate (NAR) were non-significant at both stages (Table 2 and Fig 2).

Fig 1: Effect of Indole acetic acid, Naphthalene acetic acid and gibberellins on various morphological parameters of pea at vegetative and maturity stages.
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### Biochemical attributes

Results from Table 3 indicated that the impact of various plant growth hormones was highly significant on chlorophyll contents i.e. chl a, b and total chl in all cultivars of pea at vegetative and maturity stages. Green cross showed high contents of chl 'a' at 100 to 200 mmol·L⁻¹ of IAA at both stages (Fig 3A). Cultivar Dollar showed maximum chl b and total chl contents at 100 to 200 mmol·L⁻¹ of IAA as compared to NAA, GA₃ (Fig 3 B and C). Table 3 narrated that impact of PGRs on carotenoids contents was highly significant at both stages. Cultivar Meteor showed high contents of carotenoids at vegetative stage with level of 10 ppm GA₃, while at maturity maximum carotenoids contents were obtained at 200 mmol·L⁻¹ of IAA in Green cross (Fig 3D).

### Antioxidant activities

Catalases (CAT) and peroxidases (POD) activities were determined to find the response of pea cultivars for different plant growth regulators. Effect of PGRs was significant for CAT and POD activities (Table 3 and 4). There were high concentrations of CAT at 100 mmol·L⁻¹ of IAA at vegetative stage while 200 mmol·L⁻¹ of NAA showed created significant variations at maturity stage (Fig 3E). In most of treatments POD activities were reduced at both stages of growth. Results indicated that Dollar showed high concentration of POD activity at 20ppm of IAA in all cultivars of pea at both stages (Fig 3F).

### Quality attributes

Quality character such as total carbohydrates and protein contents were measured. Effect of PGRs was highly significant on total carbohydrate at vegetative and maturity stages (Table 4). All the cultivars showed increased value for carbohydrates. Meteor showed maximum increasing effects at vegetative stage linked to other cultivars (Fig 4A). Effect of PGRs was highly significant for total protein contents at vegetative stage, while it was also significant at maturity stage (Table 4). Determined increase was observed in Meteor at both the stages. Green cross showed the reduction in total protein contents in all the treatments and at both stages of growth (Fig 4B).

### Yield attributes

To assess the yield attributes, number of legumes, number of seeds per legume and total seed weight was calculated. Table 4 showed that the effect of various plant growth hormones on all yield parameters including as number of legumes, seeds and weight. Number of legumes per plant was increased in Green cross, Sultan and Dollar by the foliar applications of PGRs (Fig 4A). Maximum number of seeds/legume was counted at 100 mmol·L⁻¹ of GA₃ in cultivar Meteor. Maximum yield was also calculated in Meteor at 200 mmol·L⁻¹ of IAA (Fig 4B). Cultivar Sultan produced low yield as compared to all other cultivars (Fig 4C).

### Correlations

Pearson correlation for various growth, quality and yield attributes is given in Table 7. All the variables including shoot
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![Graphs and diagrams illustrating the effects of IAA, NAA, and GA₃ on various physiological parameters of pea.](image)

**Table 3:** Means squares (MS) from the Analysis of Variance (ANOVA) for physiological activities attributes of pea due to IAA, NAA and GA₃.

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>df</th>
<th>MS of leaf area ratio at vegetative stage</th>
<th>MS of leaf area ratio at maturity stage</th>
<th>MS of RGR</th>
<th>MS of NAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td>6</td>
<td>2287586.6***</td>
<td>71407.7***</td>
<td>0.112ns</td>
<td>1.038ns</td>
</tr>
<tr>
<td>Cultivar</td>
<td>3</td>
<td>7387904.2***</td>
<td>1855568.2***</td>
<td>0.943***</td>
<td>9.564ns</td>
</tr>
<tr>
<td>Interaction Hor×Var</td>
<td>18</td>
<td>1031762.3**</td>
<td>808794.3***</td>
<td>0.163ns</td>
<td>2.668*</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>440320.4</td>
<td>128238.5</td>
<td>0.114</td>
<td>1.404</td>
</tr>
<tr>
<td>Total</td>
<td>111</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ns= non-significant; *, **, *** = significant at P < 0.05, 0.01, or 0.001, respectively.
Fig 3: Effect of Indole acetic acid, Naphthalene acetic acid and gibberellins on various biochemical parameters of pea at vegetative and maturity stages.

length, shoot biomass, number of fruits, total seed yield, carbohydrates and protein had positive correlation with phytohormones. When the concentration of phytohormones increased then the growth, yield and quality of pea is also increased.

Results indicated that foliar applications of IAA, NAA and GA₃ substantially increased the morphological, physiological biochemical and yield attributes of pea. Similarly, Bhandari et al (2009) reported that the application of IAA (10 ppm) more efficiently enhanced dry weight of root rather than higher concentration (50 ppm) of IAA. Malik et al. (1992) claimed that the foliar application of IAA on pea enhanced fresh weight of shoot by stimulating branch formation and increasing the number of branches. The same outcomes were noted by applying IAA on cowpea that enhanced shoot dry weight (Khalli and Manndurah, 1989). Many researchers claimed that naphthalene acetic acid (NAA) also enhanced plant’s dry matter very efficiently in plants (Patel and Saxena, 1994). The foliar spray of NAA (100-200ppm) increased the shoot dry weight of maize
Table 4: Means squares (MS) from the Analysis of Variance (ANOVA) for photosynthetic pigments of pea due to IAA, NAA and GA$_3$.

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>df</th>
<th>MS of chl a at vegetative stage</th>
<th>MS of chl a at maturity stage</th>
<th>MS of chl b at vegetative stage</th>
<th>MS of chl b at maturity stage</th>
<th>MS of chl at vegetative stage</th>
<th>MS of chl at maturity stage</th>
<th>MS of total carotenoids at vegetative stage</th>
<th>MS of total carotenoids at maturity stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects Hormones</td>
<td>6</td>
<td>6.480***</td>
<td>8.814***</td>
<td>0.001**</td>
<td>5.779***</td>
<td>6.403***</td>
<td>1.52*</td>
<td>0.003**</td>
<td>0.002**</td>
</tr>
<tr>
<td>Cultivar</td>
<td>3</td>
<td>0.003***</td>
<td>0.001***</td>
<td>0.003***</td>
<td>0.002***</td>
<td>0.003***</td>
<td>1.711*</td>
<td>0.01***</td>
<td>0.004***</td>
</tr>
<tr>
<td>Interaction Hor×Var</td>
<td>18</td>
<td>8.814***</td>
<td>4.1369**</td>
<td>0.001**</td>
<td>5.6144***</td>
<td>3.880***</td>
<td>1.605***</td>
<td>0.002**</td>
<td>0.001**</td>
</tr>
<tr>
<td>Total</td>
<td>111</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*; **; *** = significant at $P < 0.05, 0.01, or 0.001, respectively.

Fig 4: Effect of Indole acetic acid, Naphthalene acetic acid and gibberellins on various biochemical parameters of pea at vegetative and maturity stages.

Table 5: Means squares (MS) from the Analysis of Variance (ANOVA) for antioxidant and quality attributes of pea due to IAA, NAA and GA$_3$.

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>df</th>
<th>MS of CAT at vegetative stage</th>
<th>MS of CAT at maturity stage</th>
<th>MS of POD at vegetative stage</th>
<th>MS of POD at maturity stage</th>
<th>MS of carbohydrate at vegetative stage</th>
<th>MS of carbohydrate at maturity stage</th>
<th>MS of Protein at vegetative stage</th>
<th>MS of Protein at maturity stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects Hormones</td>
<td>6</td>
<td>0.013***</td>
<td>0.025***</td>
<td>0.024*</td>
<td>0.023*</td>
<td>0.155***</td>
<td>0.012***</td>
<td>0.006**</td>
<td>0.012**</td>
</tr>
<tr>
<td>Cultivar</td>
<td>3</td>
<td>0.040***</td>
<td>0.058***</td>
<td>0.037**</td>
<td>0.037**</td>
<td>0.176***</td>
<td>0.172***</td>
<td>0.141***</td>
<td>0.018**</td>
</tr>
<tr>
<td>Interaction Hor×Var</td>
<td>18</td>
<td>0.001***</td>
<td>0.026***</td>
<td>0.027**</td>
<td>0.028***</td>
<td>0.062***</td>
<td>0.012***</td>
<td>0.013***</td>
<td>0.0150***</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>0.00</td>
<td>0.002</td>
<td>0.008</td>
<td>0.008</td>
<td>0.003</td>
<td>8.432</td>
<td>0.001</td>
<td>0.004</td>
</tr>
<tr>
<td>Total</td>
<td>111</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*; **; *** = significant at $P < 0.05, 0.01, or 0.001, respectively.

(Akter, 2010). The foliar spray of GA$_3$ (200ppm) on soya bean resulted in maximum values of leaf number, plant height, branch number and number of flowers was also maximum under the treatment of GA$_3$ and NAA at 200ppm and 45 ppm respectively Deotale et al. (1998). It was noted that 1.86 mg/L NAA was useful for shoot development in pea (Sharma et al., 2017). NAA can be used for the growth and leaf development in plants as Kelaiya et al. (1991) noted an increased the leaf area as in groundnut by NAA applications.

It was noted that the applications of auxin pea physiological activities were enhanced in four cultivars. Khavari-Nejad et al. (2013) also noted that the application of GA$_3$ improved the photosynthetic efficiency of tomato by enhancing the production chlorophyll a and b and other accessory pigments of photosynthetic apparatus. The enhanced concentration of chlorophyll a and b in leaves treated with IAA was also noted by Kaya et al. (2010). IAA and GA$_3$ influenced the physiological mechanisms like cell division, cell elongation, photosynthetic efficiency and translocation of food.

These antioxidant mechanisms play an important role in controlling the metabolism of plants. Khalid et al. (2017) revealed that the treatment of IAA on plants activated catalytic ability of many enzymes. Synkova et al. (2006) claimed that auxin enhance the production and development
Phytohormones used 50.869** MS of total seed yield 2.131***

Table 6: Means squares (MS) from the Analysis of Variance (ANOVA) for yield attributes of pea due to IAA, NAA and GA3.

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>df</th>
<th>MS of number of legumes</th>
<th>MS of number of seeds/legume</th>
<th>MS of total seed yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects Hormones</td>
<td>6</td>
<td>1.550*</td>
<td>5.389***</td>
<td>50.869**</td>
</tr>
<tr>
<td>Cultivar</td>
<td>3</td>
<td>4.738***</td>
<td>38.5***</td>
<td>13.974***</td>
</tr>
<tr>
<td>Interaction HorxVar</td>
<td>18</td>
<td>3.633***</td>
<td>2.131***</td>
<td>0.422**</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>0.672</td>
<td>0.529</td>
<td>0.2480</td>
</tr>
<tr>
<td>Total</td>
<td>111</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*, **, *** = significant at P < 0.05, 0.01, or 0.001, respectively.

Table 7: Pearson correlation coefficients for growth, yield and quality attribute of pea.

<table>
<thead>
<tr>
<th>Phytohormones</th>
<th>Total seed yield</th>
<th>Number of fruits</th>
<th>Shoot length</th>
<th>Shoot biomass</th>
<th>Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total seed yield</td>
<td>0.237820089</td>
<td>0.63279086</td>
<td>0.959377109</td>
<td>0.953315582</td>
<td>0.962331032</td>
</tr>
<tr>
<td>Number of fruits</td>
<td>0.902597211</td>
<td>0.98738279</td>
<td>0.829393656</td>
<td>0.953315582</td>
<td>0.962331032</td>
</tr>
<tr>
<td>Shoot length</td>
<td>0.989105751</td>
<td>0.092245993</td>
<td>0.359492412</td>
<td>0.950041248</td>
<td>0.99506495</td>
</tr>
<tr>
<td>Shoot biomass</td>
<td>0.991869784</td>
<td>0.991869784</td>
<td>0.950041248</td>
<td>0.99506495</td>
<td>0.962331032</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>0.640464031</td>
<td>0.898269202</td>
<td>0.753995308</td>
<td>0.520433653</td>
<td>0.732989</td>
</tr>
<tr>
<td>Proteins</td>
<td>0.529</td>
<td>&lt;0.001</td>
<td>0.529</td>
<td>0.529</td>
<td>0.529</td>
</tr>
</tbody>
</table>

r value >0 indicates positive correlation.

of different plant organs by stimulating the efficiency of antioxidant enzymes. IAA also improved the antioxidant activity of different enzymes like POD, SOD and CAT in wheat (Szychynska-Hebda et al., 2007). The concentration of chlorophyll a molecule, proteins, carotenoid and monosaccharide was increased by the foliar spray of auxin of Chlorella vulgaris (Piotrowska and Bajguz, 2014). Results also indicated the improvement on pea fruit and seeds yields by the applications of IAA, NAA and GA3. Similarly, Beheshti (2010) noted high yield outcomes in sorghum genotypes (Sorghum bicolor L. Moench) under drought stress. Australian Journal of Crop Science. 4: 185-189.


**REFERENCES**


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