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Influence of Foliar Applications of IAA, NAA and GA_3 on Growth, Yield and Quality of Pea (*Pisum sativum* L.)

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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-Shraiy and Hegazi, 2009). Naphthalene acetic acid (NAA) applications increased the plant length, number of fruit and 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 (Shomeili *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.

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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_0= Control (No hormone)
T_1= 100 mmol·L^{-1} of IAA
T_2= 200 mmol·L^{-1} of IAA
T_3= 100 mmol·L^{-1} of NAA
T_4= 200 mmol·L^{-1} of NAA
T_5= 100 mmol·L^{-1} of GA_3
T_6= 200 mmol·L^{-1} 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 revealed that the impact of hormones was highly significant on plant biomass production in all the cultivars. V4 (Dollar) had maximum shoot weight at T_3. However, at maturity stage maximum biomass was present in V2 (Green

Table 1: Means squares (MS) from the Analysis of Variance (ANOVA) for various morphological attributes of pea due to IAA, NAA and GA_3.

Source of Variance	df	MS of shoot length at vegetative stage	MS of shoot length at maturity stage	MS of root length at vegetative stage	MS of root length at maturity stage	MS of shoot fresh weight at vegetative stage	MS of shoot fresh weight at maturity stage	MS of shoot dry weight at vegetative stage	MS of shoot dry weight at maturity stage
Main effectsHormones	6	143.852***	170.812***	59.102***	28.827**	5.862***	2.635***	0.023*	0.070***
Cultivar	3	567.580***	373.309***	62.579***	17.821ns	3.822***	28.757***	0.3756***	0.451***
IInteractionnHor×Var	18	81.250***	159.510***	24.612***	32.946***	8.422**	5.888***	0.033***	0.115***
Error	84	8.007	18.952	5.787	8.125	0.178	0.231	0.010	0.011
Total	111								

ns= non-significant; *,**, *** = significant at P≤ 0.05, 0.01, or 0.001, respectively.

cross) and minimum in V4 (Fig 1C and D). Effect of IAA, NAA and GA_3 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_3 on relative growth rate (RGR) and net assimilation rate (NAR) were non-significant at both stages (Table 2 and Fig 2).

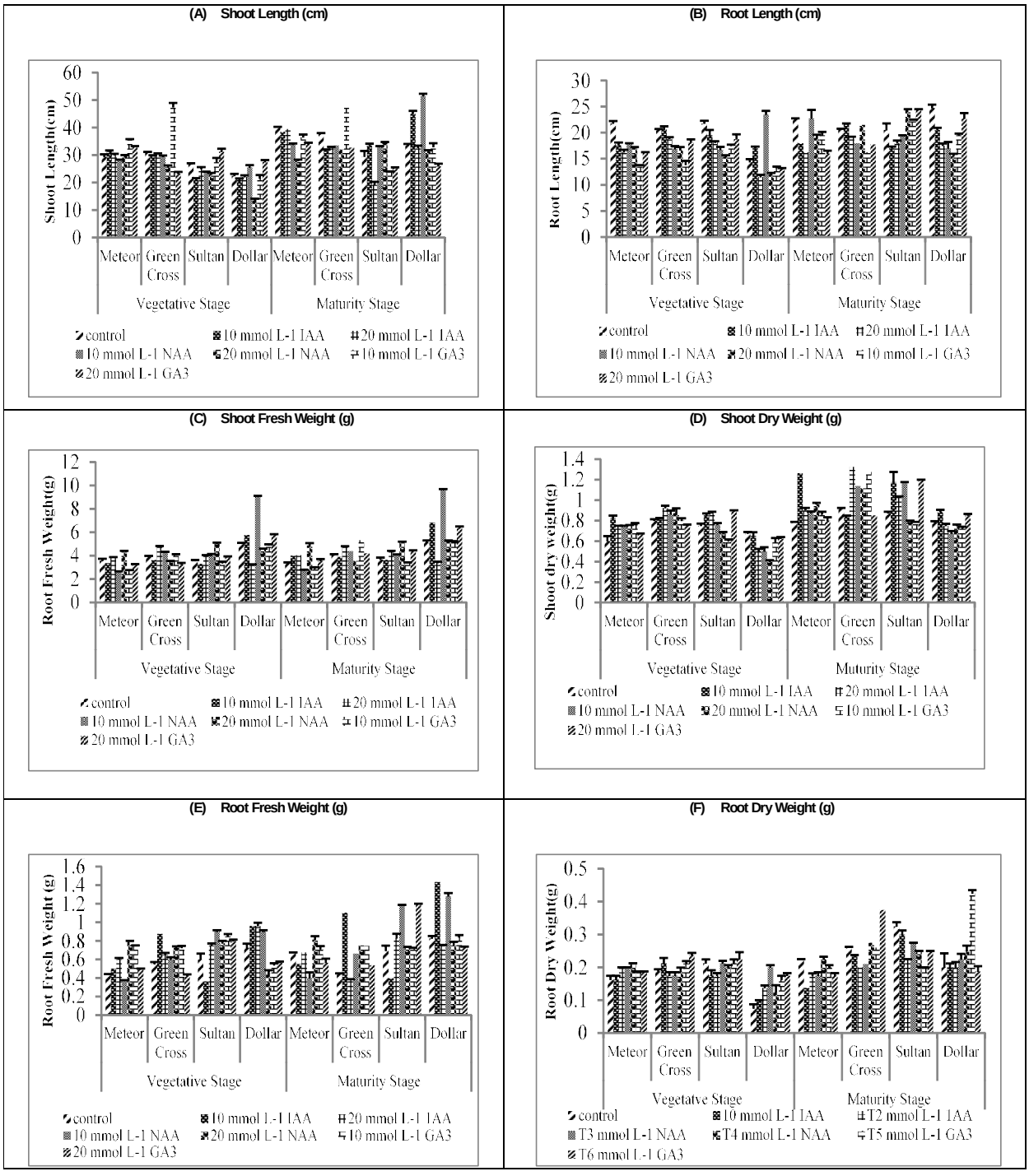

Fig 1: Effect of Indole acetic acid, Naphthalene acetic acid and gibberellins on various morphological parameters of pea at vegetative and maturity stages.

Table 2: Means squares (MS) from the Analysis of Variance (ANOVA) for morphological attributes of pea due to IAA, NAA and GA_3.

Source of Variance	df	MS of root fresh weight at vegetative stage	MS of root fresh weight at maturity stage	MS of root dry weight at vegetative stage	MS of root dry weight at maturity stage	MS of number of leaves at vegetative stage	MS of number of leaves at maturity stage	MS of leaf area at vegetative stage	MS of leaf area at maturity stage
Main effectsHormones	6	0.069***	0.070*	0.005*	0.009*	20.529*	11.372**	452590.8**	233942.6*
Cultivar	3	0.157***	0.451***	0.020***	0.033***	41.889**	25.032***	1012524.5***	833943.1***
InteractionHor×Var	18	0.145***	0.115***	0.002ns	0.014***	14.799ns	9.352***	171759.9ns	219684.1**
Error	84	0.0131	0.011	0.001	0.003	8.735	3.389	14716.2	81043.7
Total	111								

ns= non-significant; *,**, *** = significant at P≤ 0.05, 0.01, or 0.001, respectively.

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, GA_3 (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 GA_3, while at maturity maximum carotenoids contents were obtained at 200 mmo·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 GA_3 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

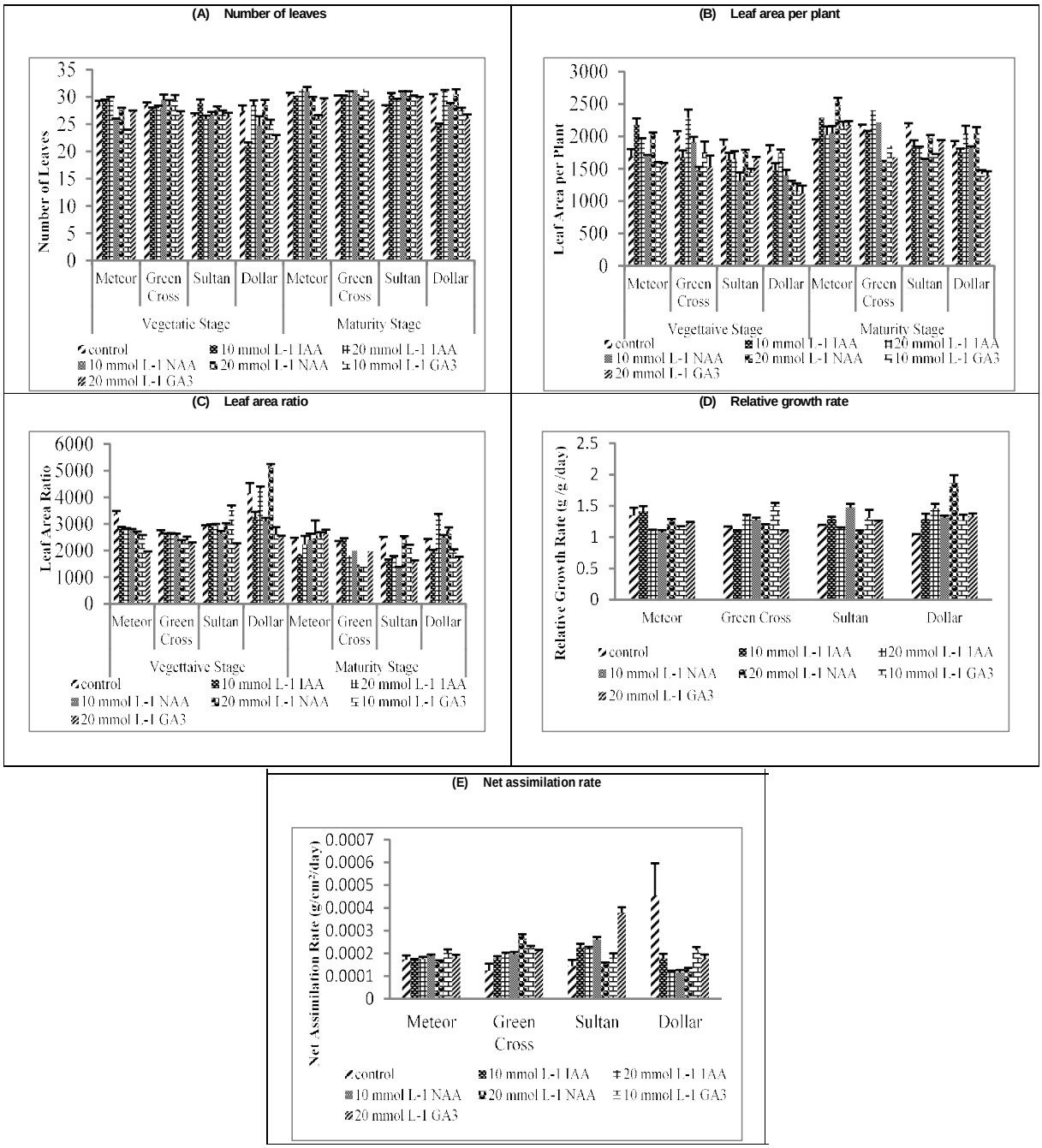

Fig 2: Effect of Indole acetic acid, Naphthalene acetic acid and gibberellins on various morphological parameters of pea at vegetative and maturity stages.

Table 3: Means squares (MS) from the Analysis of Variance (ANOVA) for physiological activities attributes of pea due to IAA, NAA and GA_3.

Source of Variance	df	MS of leaf area ratio at vegetative stage	MS of leaf area ratio atmaturity stage	MS of RGR	MS of NAR
Main effects Hormones	6	2287586.6***	71407.7***	0.112ns	1.038ns
Cultivar	3	7387904.2***	1855568.2***	0.943***	9.564ns
Interaction Hor×Var	18	1031762.3**	808794.3***	0.163ns	2.668*
Error	84	440320.4	128238.5	0.114	1.404
Total	111				

ns= non-significant; *,**, *** = significant at P≤ 0.05, 0.01, or 0.001, respectively.

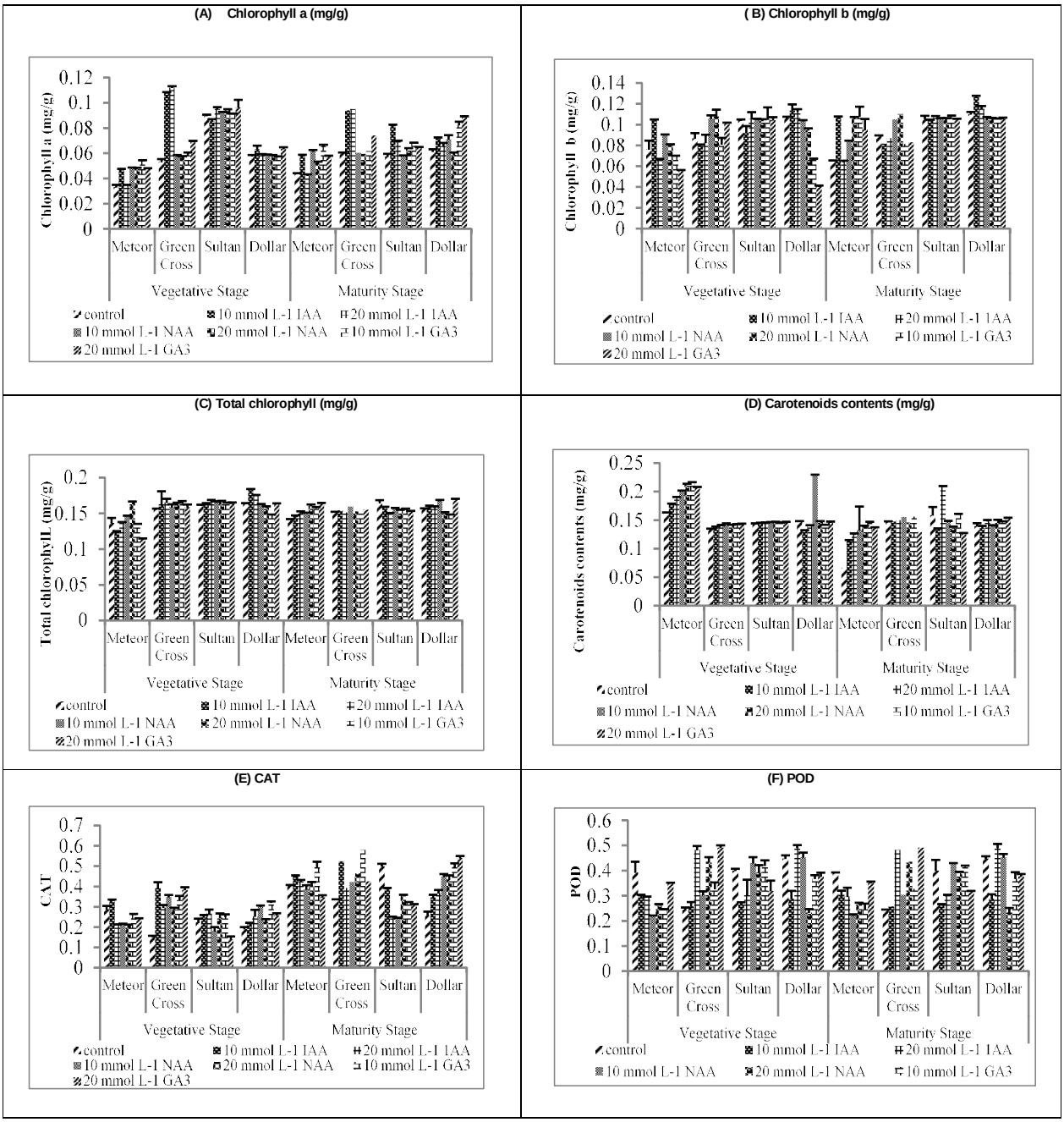

Fig 3: Effect of Indole acetic acid, Naphthalene acetic acid and gibberellins on various biochemical parameters of pea at vegetative and maturity stages.

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 GA_3 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 (Khalil 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.

Source of Variance	df	MS of chl a at vegetative stage	MS of chl a at maturity stage	MS of chl b at vegetative stage	MS of chl b at maturity stage	MS of total chl at vegetative stage	MS of total chl at maturity stage	MS of carote--noids at vegetative stage	MS of carote -noids at maturity stage
Main effects Hormones	6	6.480***	8.814***	0.001**	5.779***	6.403***	1.52*	0.003**	0.002**
Cultivar	3	0.003***	0.001***	0.003***	0.002***	0.003***	1.711*	0.01***	0.004***
Interaction Hor×Var	18	8.814***	4.1369**	0.001**	5.6144***	3.880***	1.605***	0.002**	0.001**
Error	84	1.947	1.720	4.146	9.958	8.770	5.119	9.832	6.743
Total	111								

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

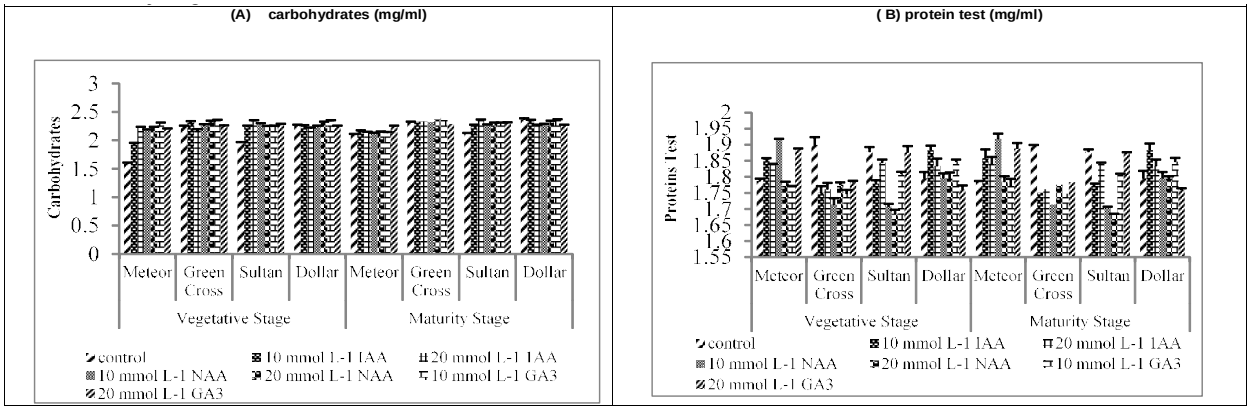

Fig 4: Effect of Indole acetic acid, Naphthalene acetic acid and gibberellins on various biochemical parameters of pea at vegetative and maturity stages.

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.

Source of Variance	df	MS of CAT at vegetative stage	MS of CAT at maturity stage	MS of POD at vegetative stage	MS of POD at maturity stage	MS of carbohydrate at vegetative stage	MS of carbohydrate at maturity stage	MS of Protein at vegetative stage	MS of Protein at maturity stage
Main effects Hormones	6	0.013**	0.025***	0.024*	0. 023*	0.155***	0.012***	0.006**	0.012*
Cultivar	3	0.040***	0.058***	0.037**	0.037**	0.176***	0.172***	0.141***	0.018**
Interaction Hor×Var	18	0.001***	0.026***	0.027***	0.028***	0.062***	0.012***	0.013***	0.0150***
Error	84	0.00	0.002	0.008	0.008	0.003	8.432	0.001	0.004
Total	111								

*,**, *** = 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

Table 6: Means squares (MS) from the Analysis of Variance (ANOVA) for yield attributes of pea due to IAA, NAA and GA_3.

Source of Variance	df	MS of number of legumes	MS of number of seeds/legume	MS of total seed yield
Main effects Hormones	6	1.550*	5.389***	50.869**
Cultivar	3	4.738***	38.5***	13.974***
Interaction Hor×Var	18	3.633***	2.131***	0.422**
Error	84	0.672	0.529	0.2480
Total	111			

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

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

	Phytohormones	Total seed yield	Number of fruits	Shoot length	Shoot biomass	Carbohydrates
Total seed yield	0.237820089					
Number of fruits	0.902597211	0.63279086				
Shoot length	0.98738279	0.388627821	0.959377109			
Shoot biomass	0.989105751	0.092245993	0.829393656	0.953315582		
Carbohydrates	0.991869784	0.359492412	0.950041248	0.999506495	0.962331032	
Proteins	0.640464031	0.898269202	0.908689272	0.753995308	0.520433653	0.732989

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 (Szechynska-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 GA_3. Similarly, Beheshti (2010) noted high yield outcomes in sorghum due to the applications of hormones. The foliar application of IAA also enhanced grains weight in wheat (Sentelhas *et al*. and *Cassia absus* (Hussain *et al*., 2011). The application of indole acetic acid stimulated rapid cell division by enhancing seed weight Arif *et al*. (2001).

CONCLUSION

It can be concluded that IAA, NAA and GA_3 increased the growth attributes, physiological activities, quality and yield of pea. All the variables including shoot length, shoot biomass, number of fruits, total seed yield, carbohydrates and protein had positive correlation with phytohormones. 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 inreased. 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 plants growth regulators (PGR).

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