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EFFECT OF FOLIAR APPLICATIONS OF IAA AND GA_3 ON GROWTH, YIELD AND QUALITY OF PEA (*PISUM SATIVUM* L.)

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Abstract

Experiments were conducted at University of Gujrat, Pakistan during growing seasons of 2016-17 and 2017-18 to evaluate the effect of foliar applications of GA_3 and IAA on pea. Four cultivars of pea i.e. Aleena, Classic, Green grass and Meteor were given seven foliar treatments i.e. 0 (control), 50, 100 ppm both for IAA and GA_3 and two combined treatments of IAA+GA_3 (50 and 100 ppm). Experiment was laid down in completely randomized design with four replicates. Data was collected at seedling and vegetative stages, while yield attributes were calculated at maturity. It was noted that shoot and root lengths, shoot fresh and dry weights, leaf area, net assimilation and relative growth were significantly increased by the foliar applications of IAA, GA_3. Photosynthetic and transpiration rates, total protein and carbohydrates, fibre contents, Ca^{2+} and K^+ were significantly changed by IAA and GA_3 separately and in combine treatments. Combine treatments of IAA and GA_3 had better effects rather than separate treatments. IAA had better effects as compared to GA_3. POD activities were reduced and CAT activities were enhanced by foliar applications of IAA and GA_3. It was concluded that high rate of photosynthesis resulted high biomass production and yield. High Transpiration rates helped to uptake nutrients from soil efficiently that resulted high accumulation of Ca^{2+} and K^+. Reduction in POD activities helped to increase the defence mechanism of plants and high CAT activities caused better balance in plant metabolism as a result growth, yield and quality of pea were increased. These outcomes can be used as a good indicator for researchers to evaluate the pea cultivars response towards plant growth regulators (PGR) to predict for promising yield and quality traits.

Key words: Growth, Yield, Quality, Pea, IAA, GA_3

Introduction

Pea (*Pisum sativum* L.) also known as garden pea is an intrinsic species of southwest Asia. It is among the first harvests to be cultivated by humans and uninhabited forms can still be found in Afghanistan, Iran and Ethiopia. According to FAO data it is the second most vital food in the world after reciprocal bean (María *et al*., 2009). Garden pea is well-thought-out as money-spinner to the mountain farmers as they get high reward due to off-season agriculture (Jaipaul *et al*., 2011). Pea and other legumes are required in crop alternations because they assist in disintegration of disease and pest's cycles, provide nitrogen, improve soil microbe multiplicity and action, improve soil combination, save soil water and deliver economic diversity. Peas are harvested as green composts and cover yields because they mature fast and give nitrogen to the soil (Berhane *et al*., 2016). Pea is a yearly growing cool season nitrogen fixing yield having high ratio of consumable protein (23-33%) beside with supplementary biomolecules such as carbohydrates and vitamins (Hafiz *et al*., 2014).

Plant hormones have been extensively used in farming fields to increase crop yield (Savita *et al*., 2012). The processes affected comprise primarily of growth, differentiation and development, however supplementary processes, for example stomatal movement, might also be disturbed (Petri, 2010). PGRs have been used to increase the growth and yield of major cereal crops, including wheat, and have already become commercialized in the EU, USA and Japan (Jahan *et al*., 2019). Maximum tissues showed response linked with auxin amount as several organs react and show diverse response to unequal amounts of auxin which is present internally. The chief auxin present in plant is (IAA) indole acetic acid (Jutta, 2000). Auxin, comprising IAA, include a collection of stimulators driven through tryptophan, elaborating in maximum features of developing plant (Singh *et al*., 2015). Indole acetic acid (IAA) is a kind of auxin that controls plant growth and progress (Savita *et al*., 2011).

Plant hormones mainly gibberellins (GAs) are important for many developmental processes in plants, seed germination count, stem elongation, trichome and leaf expansions, pollen maturation and flowering stimulation (Jean *et al*., 2013). Gibberellins have been observed to be involved in numerous physiological developments (Yang, 2012). GAs endorse flower initiation during long days but it support the process of bolting just when the days were short (Mutasa *et al*., 2010). In growth of a plant auxin and gibberellins (GA) recorded significant stimulus in plants development, also frequently detected to response in link to each. This interlink can be due to collaborating consequences on separate or joint activity routes, may be single hormone influencing the quantity at objective organ of the supplementary hormone. Mutual activity of auxin and GA_s was observed many times during elongation of main stems, process that is enhanced through hormones acting synergetically (Husen *et al*., 2016).

Fruit ripening along development was studied in *Solanamly coparsicum* through appliance of gibberellic acid and auxin, ovaries without pollination showed activity when supplied with GA_3 and auxin (Juan *et al*., 2009). Plants developed fruits without seeds and did not need reproductive phase when supplied with any of the two hormones (Maaike *et al*., 2009).

In the light of above available literature these experiments were performed to determine the comparative effect of the IAA and GA_3 separately and in combined applications for growth, yield and quality of different cultivars of pea.

Materials and Methods

Experiments were performed to study the effect of IAA and GA_3 on growth, seed yield and quality for four pea cultivars (Meteor, Aleena, Green Grass and Classic) at research area of University of Gujrat, Pakistan during the growing seasons of 2016-17 and 2017-18. This experimental area of district Gujrat lies between 32° to 35° North latitudes and 73° 45' East longitudes. This district has moderate climate. During peak summer, the daytime temperature rises up to 45°C, but the hot spells are relatively short due to the proximity of the Azad Kashmir Mountains. During the winter months the minimum temperature may fall below 2°C. The average rainfall Gujrat 67 cm. Foliar application of IAA (indole-acetic acid) and GA_3 (Gibberellic acid) were applied after 14 days of plant sprouting. Following levels of hormones were applied:

T_0 = 0 ppm (control) T_1 = 50 ppm IAA
T_2 = 100 ppm IAA T_3 = 50 ppm GA_3
T_4 = 100 ppm GA_3
T5 = 50 ppm IAA *&* 50 ppm GA_3 (combine treatments)
T_6 = 100 ppm IAA *&*100 ppm GA_3 (combine treatments)

Data was collected at seedling stage (14 days after treatment), vegetative stage (28 days after treatment) and yield attributes were calculated at maturity. Morphological and physiological attributes were studied at seedling and vegetative stages. Plants were uprooted, washed and then shoot and root lengths (cm) were noted by scale. Shoot and root fresh weights (g) of plants were noted by electrical balance. Plants were oven dried at 65ºC for 4-5 days to record the dry weights. Leaf area per plant (cm^2) was calculated by tracing the leaves on graph paper. Total yield was calculated at maturity by weighing seed weight. Total soluble proteins were measured by the method of Bradford (1976).

Healthy fresh leaves were taken to calculate the gas exchange attributes by LCA-4 ADC portable open system infrared gas analyzer (IRGA) (Analytical Development Company, Hoddesdon, England). Ca^{2+} and K^+ contents were measured using flame photometer (Jenway, PEP-7). Peroxidase (POD) and Catalase (CAT) activities were noted by the method of Chance and Maehly (1955). Total carbohydrates were measured by Anthron Method. Analysis of variance was computed by COSTAT computer package. Duncan's New Multiple Range test (DMRT) was used to compare the mean values at 5% level of probability (Steel & Torrie, 1980).

Results

The results obtained form the above mentioned two years experiments were as under.

Morphological and yield studies: Data obtained from Analysis of Variance (ANOVA) for morphological studies of pea i.e. shoot and root lengths, shoot fresh and dry weights, leaf area, net assimilation and relative growth rates are given in Tables 1-2. The means comparisons are presented in figs. 1-3. Effect of IAA and GA_3 were highly significant on pea at seedling and vegetative stages (Table 1). Treatments applied in combinations (IAA+GA_3) showed maximum lengths as compared to separate treatments. Maximum shoot and root lengths were noted in cultivar Meteor and minimum in Classical cultivar at both stages of growth (Figs. 1-2). Shoot fresh and dry weights were increased significantly at seedling and vegetative stages by the foliar applications of IAA and GA_3 (Table 2). Cultivar Classic showed higher weights as compared to other cultivars. Most promising increase was present in treatment of 100 ppm IAA in combination with equal concentrations of GA_3 (Fig. 2).

Leaf area per plant was significantly increased in all the cultivars at all treatment levels but IAA in combination with GA_3 showed highly significant effect on leaf area (Table 2). Maximum leaf area per plant of pea was noted in cultivar Meteor at both the stages of growth (Fig. 3-A). ANOVA showed that IAA and GA_3 have a significant effect on RGR and NAR in pea (Table 2). Maximum values of RGR and NAR were observed in Classic cultivar (Fig. 3b-c).

Pea yield was significantly increased by the applications of IAA and GA_3 separately and in combinations Table 2). Maximum yields were calculated at 50 ppm IAA+50 ppm GA_3 (Fig. 4). High yield was calculated in cultivar Classic and low yield was given by Meteor.

Physiological studies: Physiological attributes i.e. photosynthetic and transpiration rates were studied in pea under the influence of IAA and GA_3 at both stages of growth. Effect of IAA and GA_3 was significant on photosynthetic rate. GA_3 effect was highly significant when applied separately and in combination with IAA as well (Table 3). Maximum photosynthetic rate was noted in cultivar Classic at seedling stage and in Green Grass at vegetative stage (Fig. 5-a). Transpiration was also high with the applications of IAA and GA_3. It was highly significant by GA_3 applications and was significantly changed by IAA (Table 3). Variations among cultivar was non-significant by GA_3. High rate of transpiration was noted in cultivar Classic at both stages of growth (Fig. 5-b). Combinations of both hormones (IAA+GA_3) also showed significant results.

Nutritive/quality attributes: Different nutritive or quality attributes were studied to find the efficacy of hormones (IAA and GA_3) in pea. The effect of IAA and GA_3 was significant on total protein contents in seeds of pea. There were highly significant effects on total protein contents when IAA and GA3 were applied in combination (Table 3). Variations among cultivars found non-significant. Maximum protein contents was measured in cultivar Classic and minimum in Meteor (Fig. 6-a). Effect of IAA was significant on total carbohydrates contents of pea while the GA_3 effect was non-significant. There were highly significant effects when IAA and GA_3 were applied in combinations (Table 3). Maximum total carbohydrates contents were found in Cultivar Green Grass and minimum contents were present in cultivar Aleena (Fig. 6-b). Fibre contents were significantly changed by IAA in pea while the effect of GA3 was non-significant. It was highly significant effects when IAA and GA_3 were applied in combination (Table 3). Maximum fibre contents were noted in cultivar Classic and minimum in Meteor (Fig. 6-c).

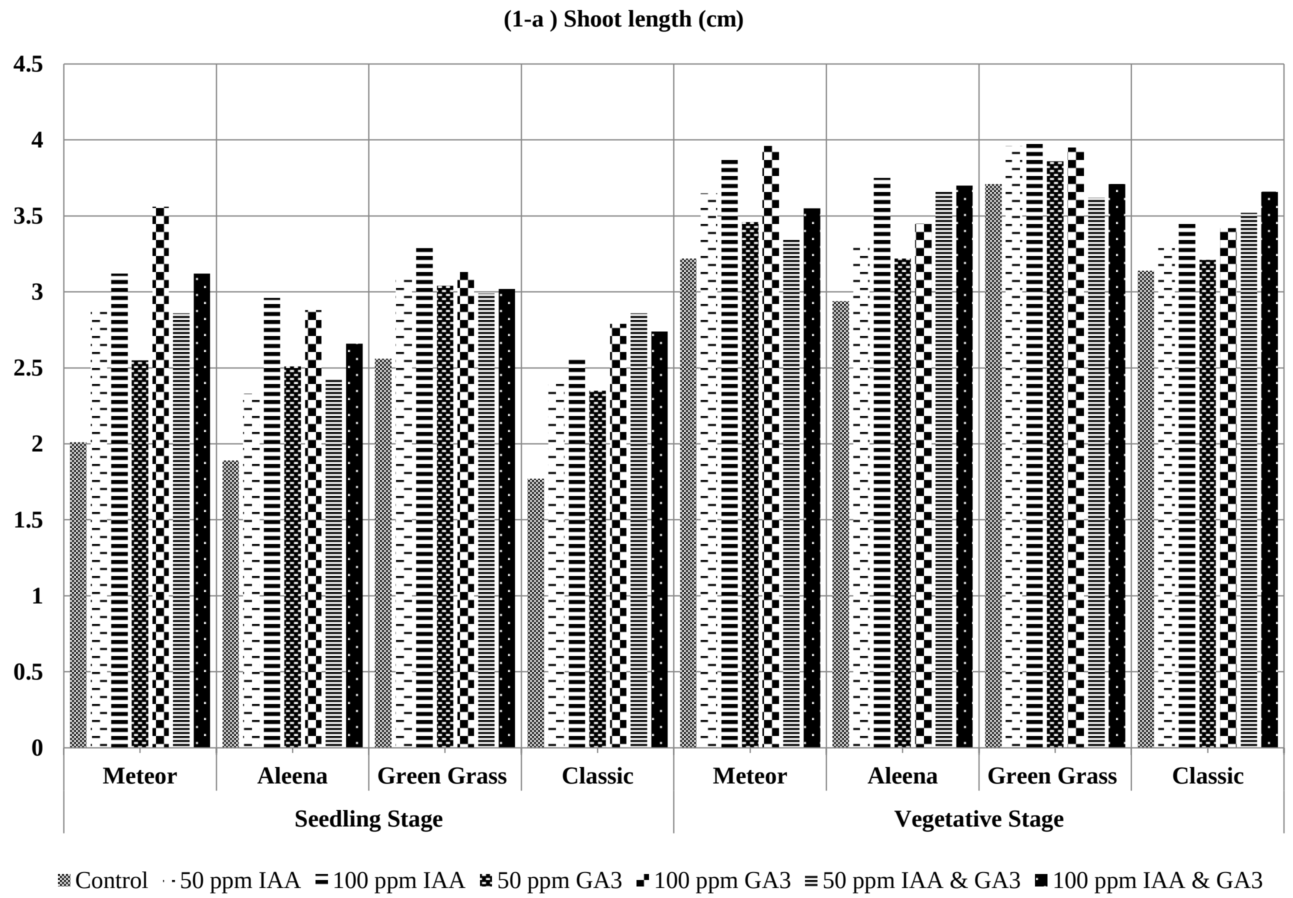
Table 1. Means squares from ANOVA for morphological attributes of pea under IAA and GA_3 applications.

Sources	df	MS of shoot length at seedling stage	MS of shoot length at vegetative stage	MS of root length at seedling stage	MS of root length at vegetative stage	MS of shoot fresh weight at seedling stage	MS of shoot fresh weight at vegetative stage
IAA	4	836.07**	109.04**	20.39**	11.55**	5.65**	65.51***
GA_3	1	45.64***	103.04***	59.67**	10.91***	0.02***	1.01**
Cultivar	3	47.35*	101.53*	38.24**	10.78*	1.41**	14.64***
IAA x GA_3	4	43.54***	989.26***	13.16**	10.42***	6.79ns	0.32***
IAA x Cultivar	12	36.66**	101.86*	58.34*	11.14**	5.87**	1.32*
GA_3 x Cultivar	3	49.91ns	102.08ns	19.74*	11.44ns	5.58ns	0.10ns
IAA x GA_3 x Cultivar	12	430.85*	100.46**	23.26**	10.97*	4.49**	0.05**
Error	120	43388.56	982.76	27.93	10828.69	5.32	0.14
Total	159						

*, **, *** = Significant; ns = Non-significant

Table 2. Means squares from ANOVA for morphological and yield attributes of pea under IAA and GA_3 applications.

Sources	df	MS of shoot dry weight at seedling stage	MS of shoot dry weight at vegetative stage	MS of leaf area at seedling stage	MS of leaf area at vegetative stage	MS of relative growth rate	MS of net assimilation rate	MS of total yield per plant
IAA	4	146.06**	2.26**	3220.8*	0.124**	0.122***	0.170***	12.154*
GA_3	1	248.47***	0.55***	9.02**	0.812**	0.011**	0.005**	12.361***
Cultivar	3	286.09*	0.69*	3495.07*	0.028**	0.0288**	0.034**	9.125*
IAA x GA_3	4	130.48***	0.15***	5.10***	130.48***	0.002***	0.001***	0.879***
IAA x Cultivar	12	128.48*	0.31*	116.72*	138.24**	0.005*	0.003*	12.781*
GA_3 x Cultivar	3	255.77ns	0.19ns	15.07**	245.79*	8.490ns	7.301ns	6.451*
IAA x GA_3 x Cultivar	12	128.67**	0.18**	19.21**	28.67***	0.005**	0.007*	4.069***
Error	120	154.15	0.23	32.80	166.15	12.025	22.451	82.945
Total	159							



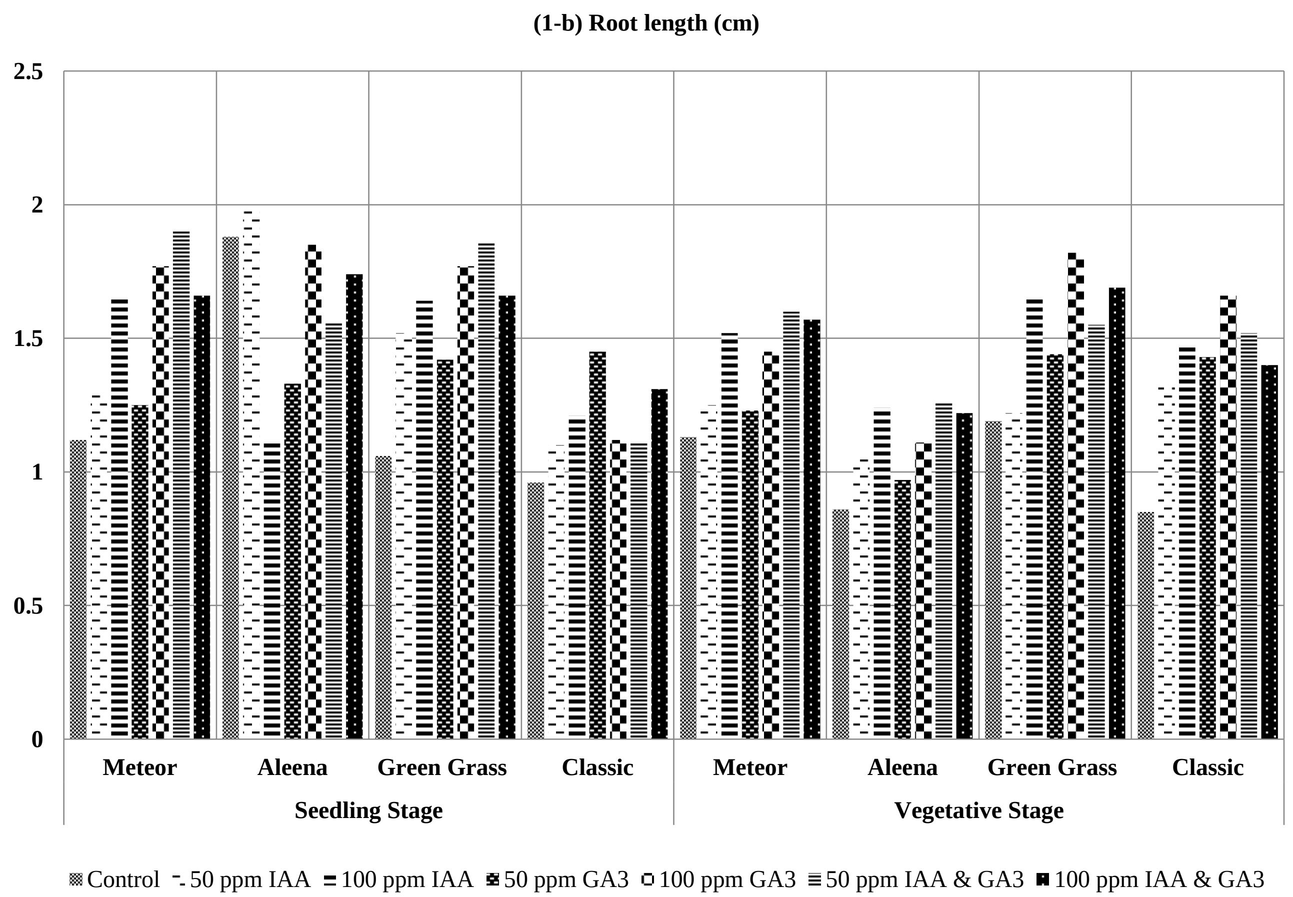
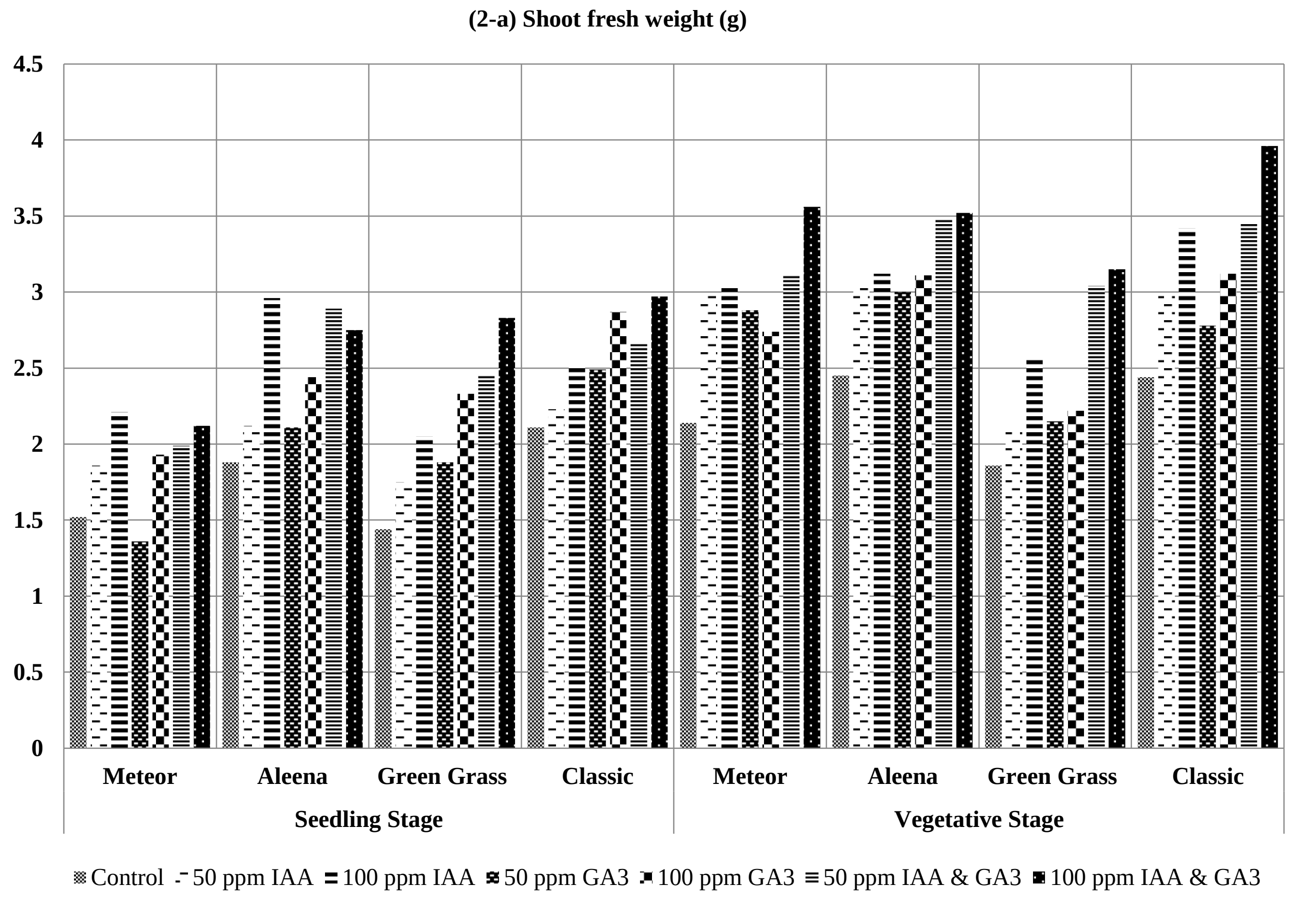


Fig. 1. Effect of IAA and GA3 on shoot and root lengths (cm) of Pea (*Pisum sativum* L.).



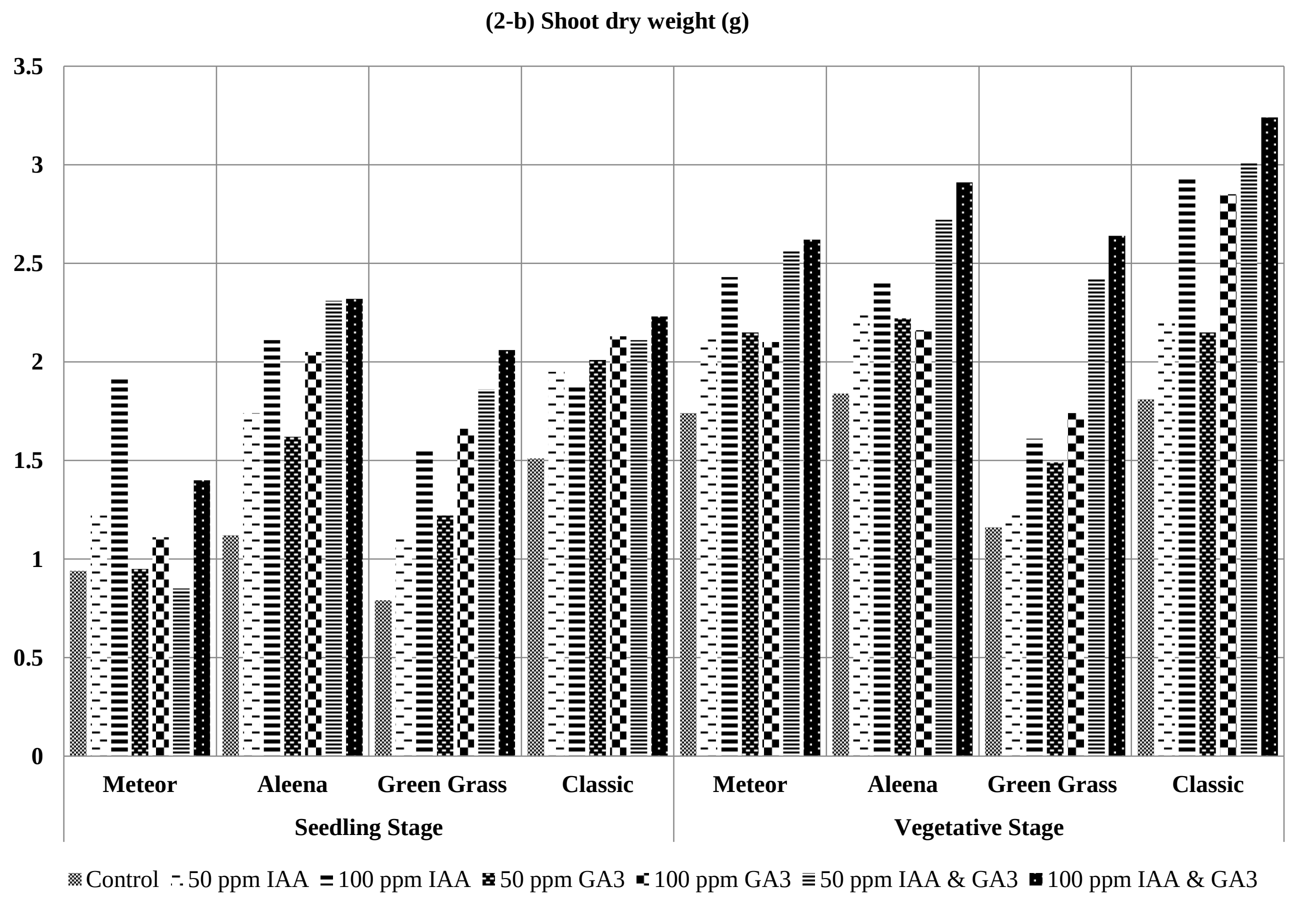


Fig. 2. Effect on IAA and GA3 of shoot fresh and dry weights (g) of Pea (*Pisum sativum* L.).

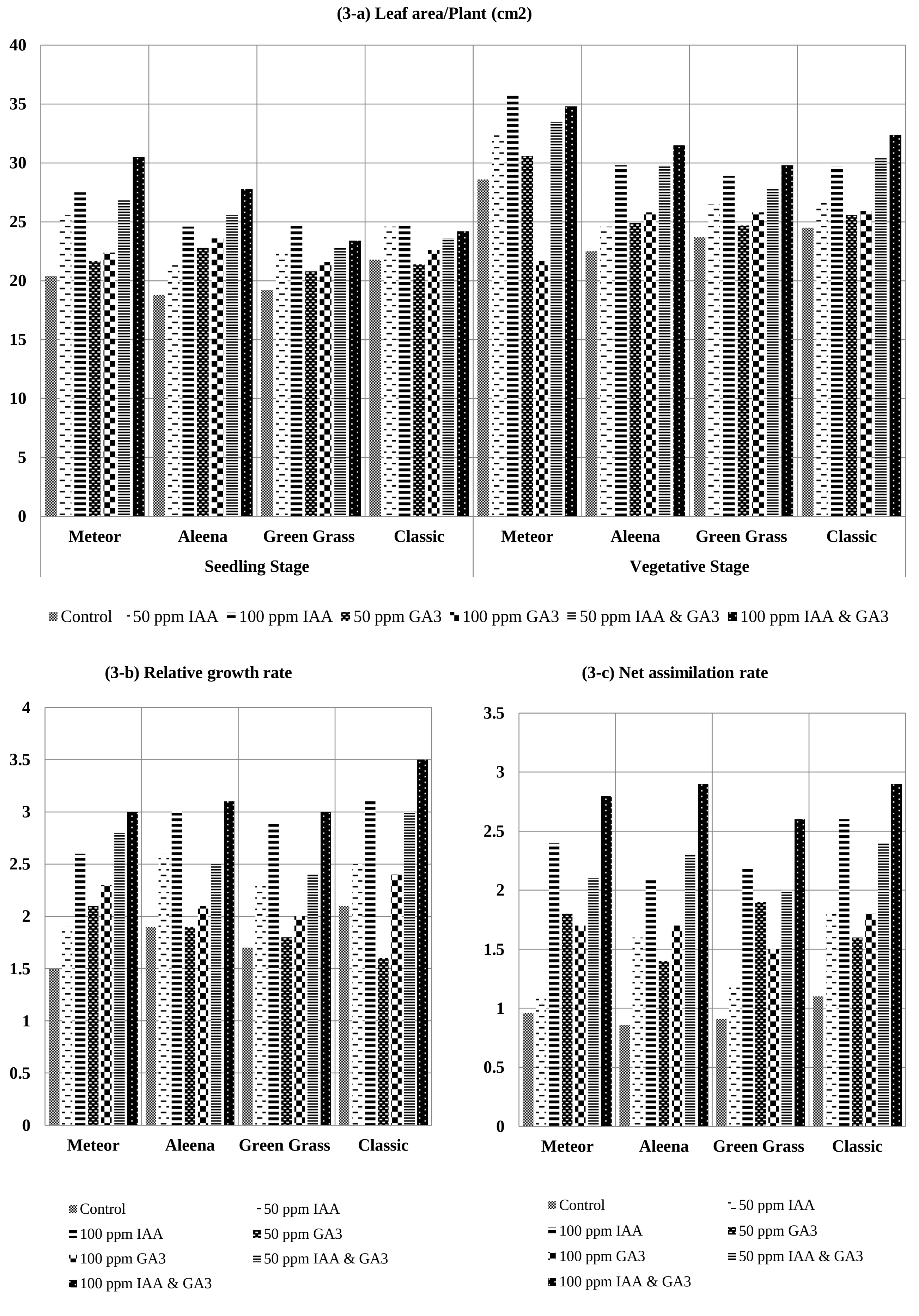


Fig. 3. Effect of IAA and GA3 on leaf area/plant, relative growth rate and net assimilation rate of Pea (*Pisum sativum* L.).

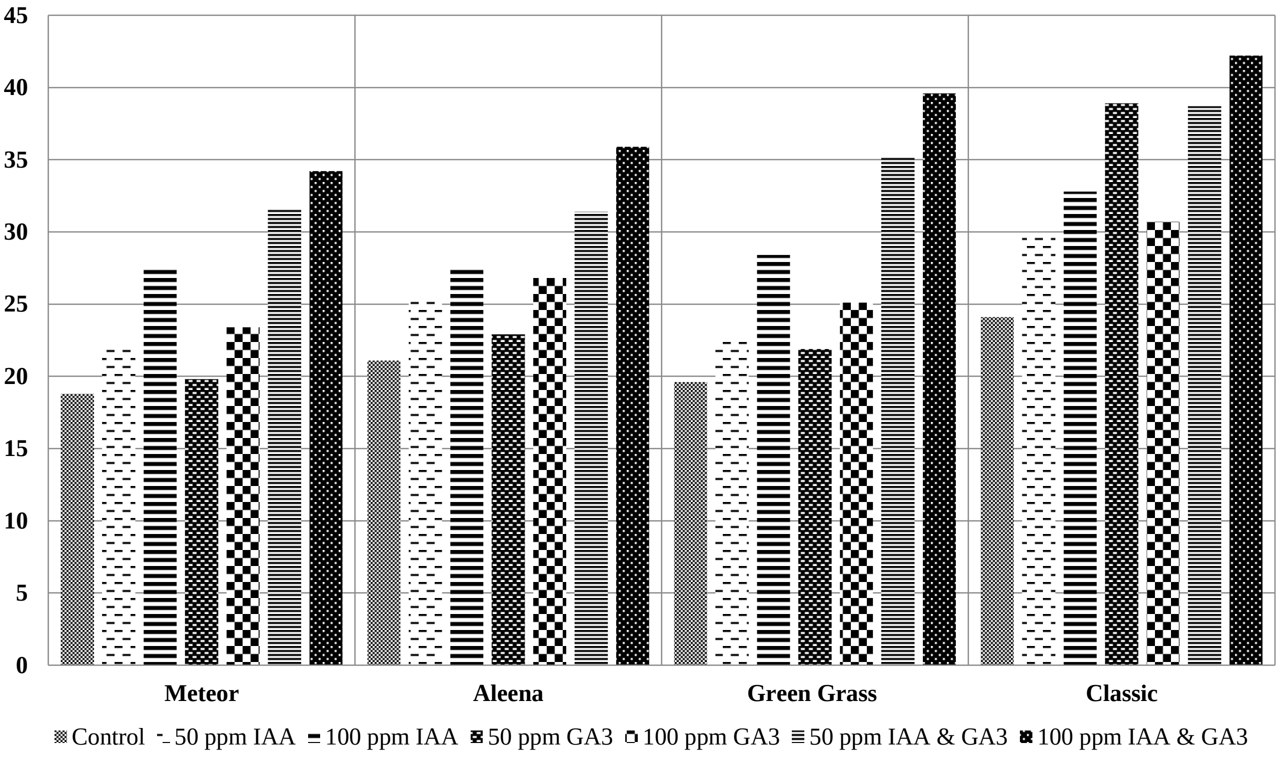


Fig. 4. Effect of IAA and GA3 on yield/plant (g) of Pea (*Pisum sativum* L.).

Ionic contents: For ionic studies of pea Ca^{2+} and K^{+} were evaluated. Effect of IAA and IAA+GA_3 were highly significant on Ca^{2+} contents of pea while the effect of GA_3 was significant but it was non-significant on cultivars (Table 4). Similar trend was found at seedling and vegetative stages. Maximum Ca^{2+} contents were found in cultivar Classic and minimum in Meteor (Fig. 7-a). Similarly, K^{+} contents changed highly significantly by IAA and IAA+GA_3 treatments (Table 4). Effect of GA_3 was also found significant. Among cultivars effect was non-significant. Maximum K^{+} was calculated in Meteor at seedling stage and in Classic at vegetative stage (Fig. 7-b).

Antioxidant activities: POD (Peroxidases) and CAT (Catalases) were measured to find the hormonal response at different growth stages. There was highly significant effect of IAA and IAA+GA_3 (Table 5). The effect of GA_3 was also significant. POD activities reduced by the applications of hormones (IAA and GA_3), while CAT activities were enhanced (Fig. 8a-b). Maximum reduction of POD was noted in Meteor. In case of CAT activities, maximum increase was observed in Green Grass (Fig. 8-b).

Discussion

From the above mentioned results, it was noted that morphological, physiological, yield and biochemical attributes were significantly increased by the applications of IAA and GA_3. Similar result was found in pea plants under the foliar applications of IAA by Khalid *et al.*, (2017). The increase in morphological attributes might be due to the reason that auxin and gibberellins (GA) produced the significant stimulus in plants development. It was observed that plant growth regulators at different concentrations had a great positive effect on yield parameters of soybean. IAA with higher concentrations (150 ppm) showed the maximum number of green pods, pod length and pod weight. GA_3 and IAA applied together showed higher accumulation of net photosynthesis rate and subsequently synthesized more C: N ratio that enhanced the growth of the plants (Sudadi, 2012).

Auxin, comprising IAA, contains a collection of stimulators driven through tryptophan that is involved in the development of maximum plant growth features (Singh *et al*., 2015). Indole acetic acid is one of the thoroughly studied hormone that is involved in growth and development of plants that follows the production of indole-3-acetic: tryptophan (Trp)-dependant and Trp-independent pathways (David *et al*., 2014).

Action of GA_S and auxin are correspondence for controlling cell growth and cellular development. Auxin influence GA transmission along with production of GA. Root elongation requires motivation of GA_s that was done through auxin. In *Pisum sativum* and *Nicotina tabbacum* shoot apices indicated less amount of GA in the main stems that could be overcome by spraying IAA exogenously (David *et al*., 2007). GA_s along IAA foliar spray showed the significant increase in shoot dry biomass Hormones act transmitters that as they engage in traveling stimulators to target cells making past observation to ecological conditions of identifying location (Fazal *et al.,* 2010). Experiment for investigating hormones in reference of genetically improvement occurred in stimulators showed that hormones had major impact on pattern of plant development. Impact of several hormones involved in morphogenesis of leaf and its formation studied within very short time. Auxin, cytokinetin and gibberallic acids are considered to have great impact in this regard (Darleen, 2005).

Table 3. Means squares from ANOVA for physiological and nutritive attributes of pea under IAA and GA_3 applications.

Sources	df	MS of photosynthetic rate at seedling stage	MS of photosynthetic rate at vegetative stage	MS of transpiration rate at seedling stage	MS of transpiration rate at vegetative stage	MS of total protein from seeds	MS of total carbohydrate from seeds	MS of total fibre contents from seeds
IAA	4	11.46*	0.48**	12.96**	5.99*	1.499*	393.12*	2.86*
GA_3	1	0.31**	0.06**	0.733***	3.23**	0.233*	409.59ns	0.31ns
Cultivar	3	13.16*	0.28*	24.51ns	32.77ns	10.924ns	380.20*	4.38ns
IAA x GA_3	4	0.17***	581.92***	2.25*	2.81**	0.701**	389.04**	0.04**
IAA x Cultivar	12	6.87*	451.79*	9.54*	10.01*	0.833*	398.53*	0.57*
GA_3 x Cultivar	3	0.26*	737.33*	0.89ns	4.61ns	1.537ns	393.56*	0.09**
IAA x GA_3 x Cultivar	12	2.32**	454.40*	1.58**	2.43*	0.203*	355.80*	0.19*
Error	120	72.93	184.18	52.88	55.76	0.464	342.59	0.61
Total	159							

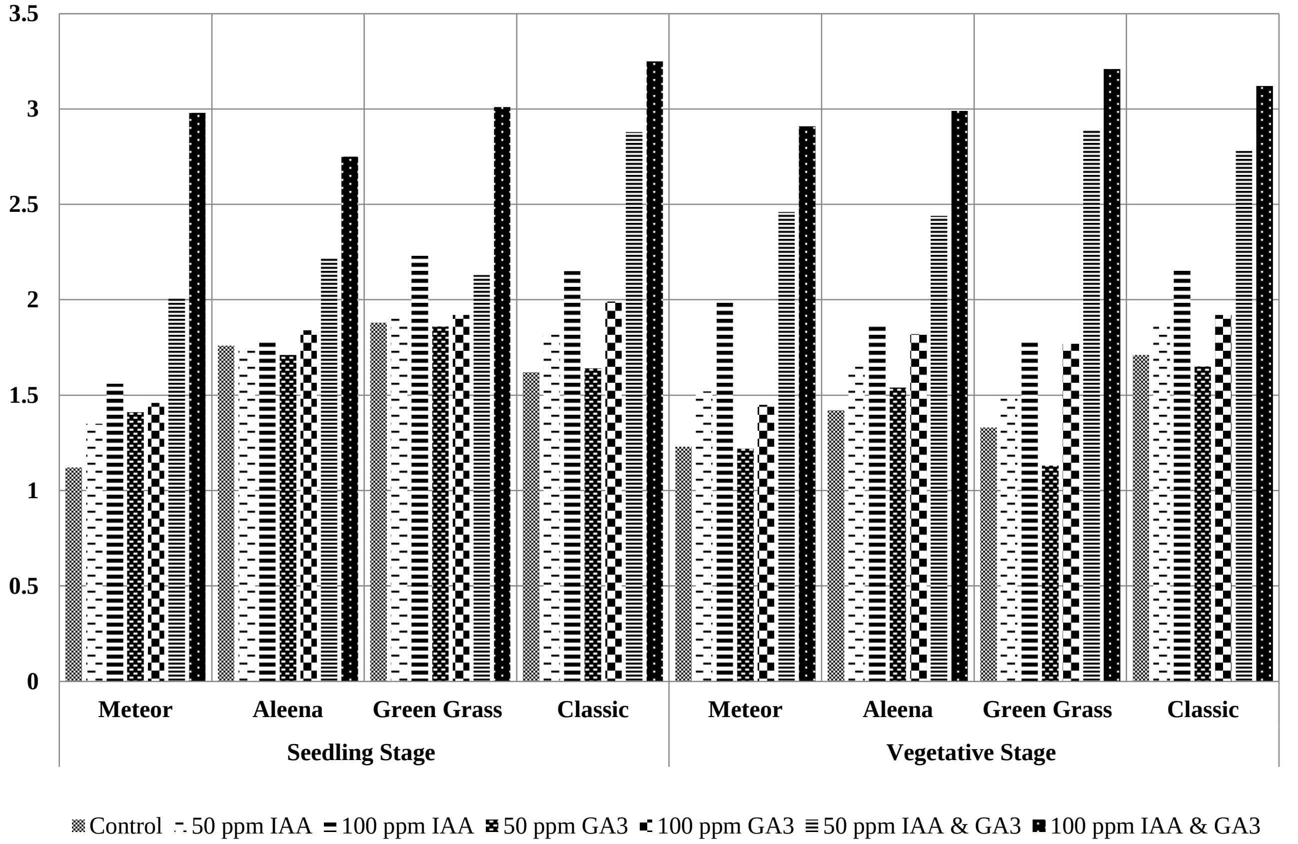
*, **, *** = Significant; ns = Non-significant

Table 4. Means squares from ANOVA for ionic concentrations of pea under IAA and GA_3 applications.

Sources	df	MS of Ca^{2+} contents at seedling stage	MS of Ca^{2+} contents at vegetative stage	MS of K+ contents at seedling stage	MS of K+ contents at vegetative stage
IAA	4	631.89***	15.27**	14.53**	3.63**
GA_3	1	5.62*	5.62*	3.65*	0.45*
Cultivar	3	2.86ns	8.95*	15.95ns	5.31*
IAA x GA_3	4	34.54***	8.62***	3.83*	0.95***
IAA x Cultivar	12	119.15*	9.92*	29.86**	2.48*
GA_3 x Cultivar	3	18.22**	6.07*	73.5ns	2.41*
IAA x GA_3 x Cultivar	12	110.15*	9.17*	53.56***	4.46**
Error	120	335.51	2.79	953.34	7.94
Total	159				

*, **, *** = Significant; ns = Non-significant

(5-a) Photosynthetic rate



(5-b) Transpiration rate

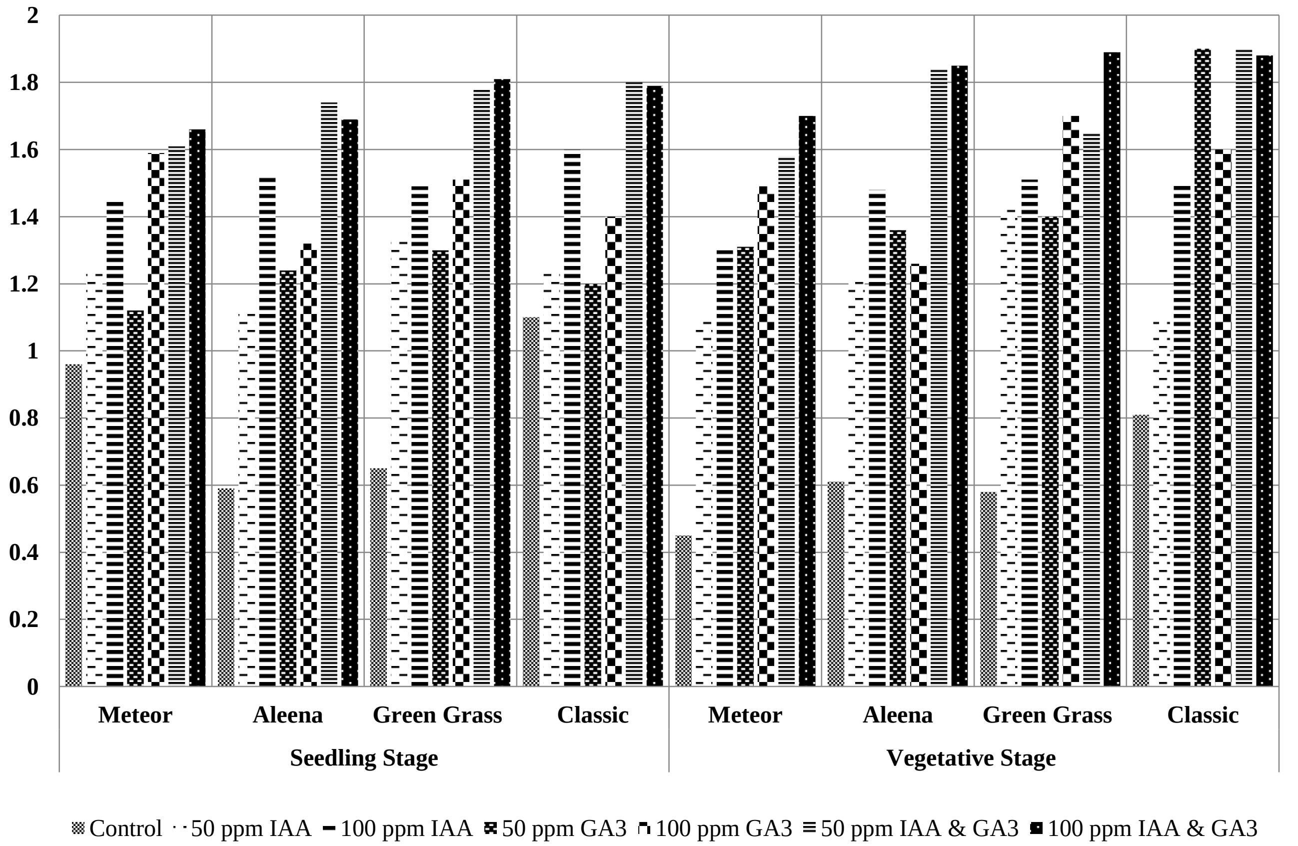


Fig. 5. Effect of IAA and GA3 on physiological attributes of Pea (*Pisum sativum* L.).

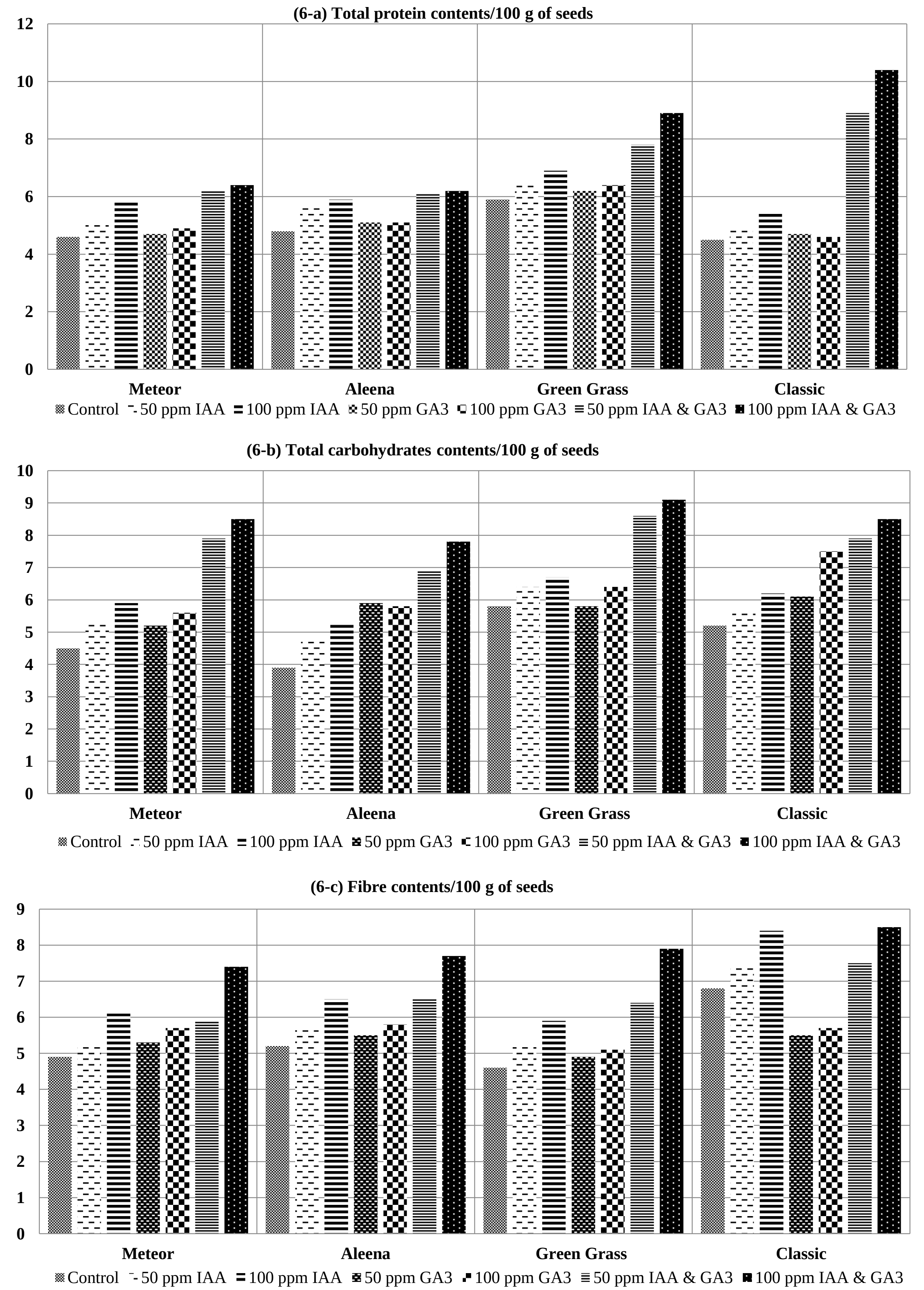
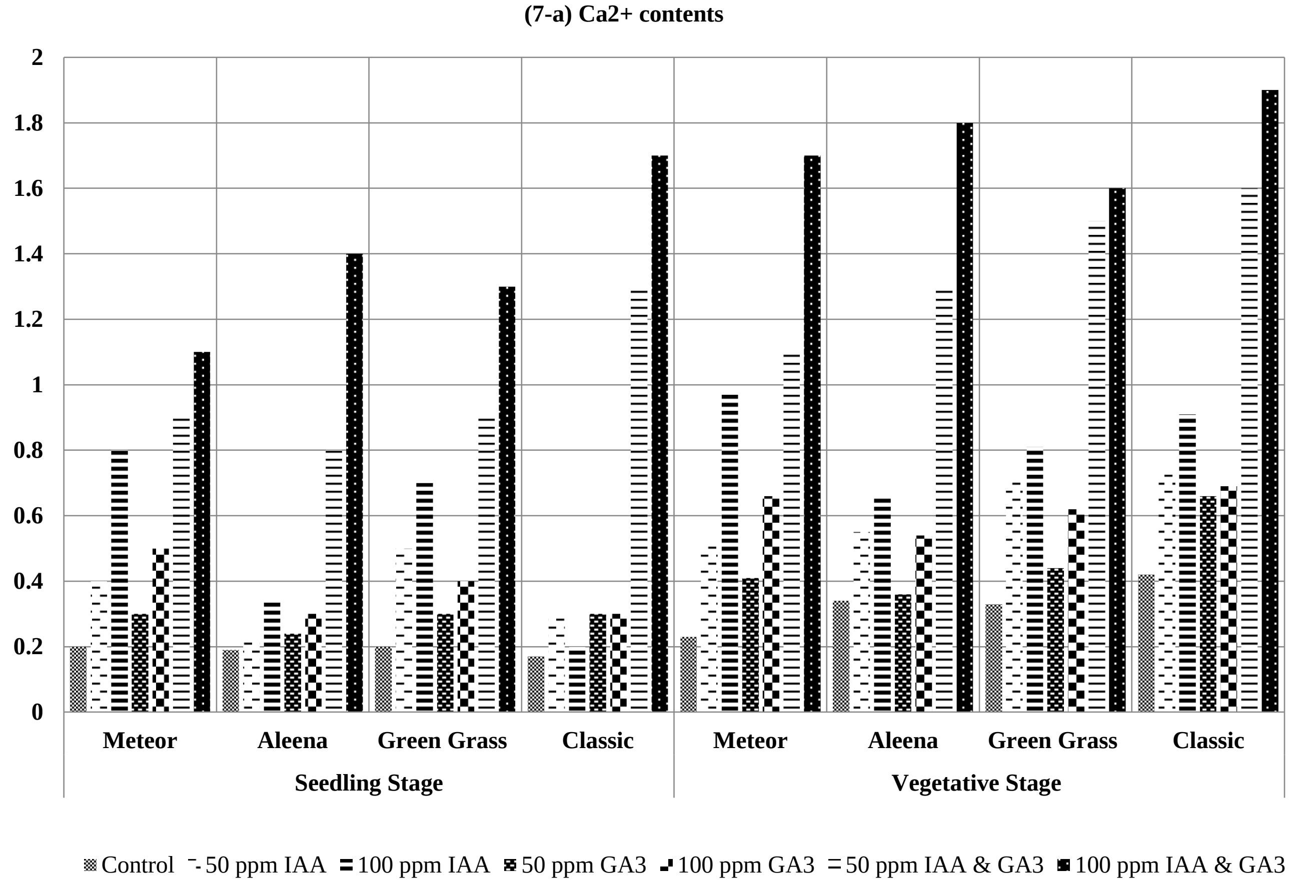


Fig. 6. Effect of IAA and GA3 on nutritive attributes of Pea (*Pisum sativum* L.).



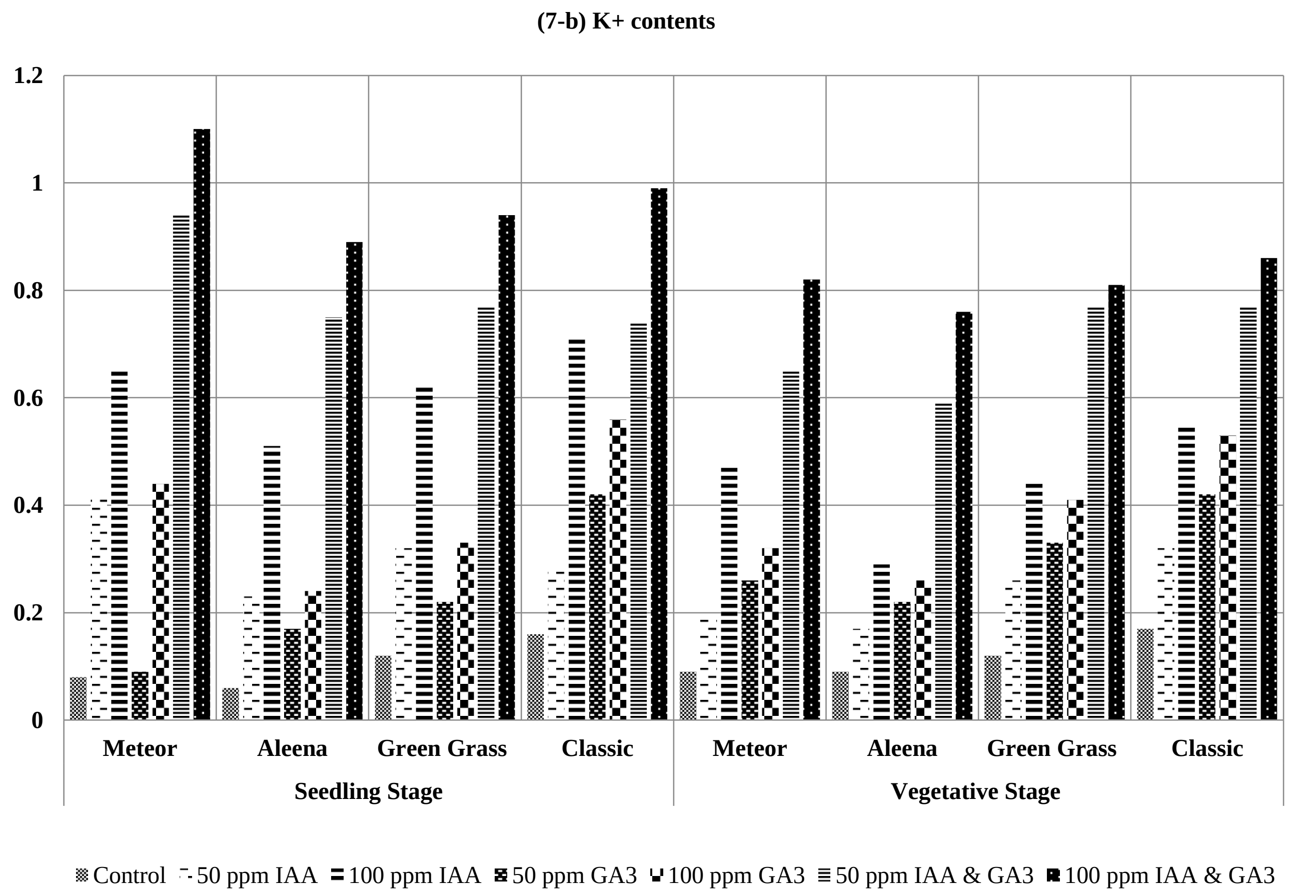
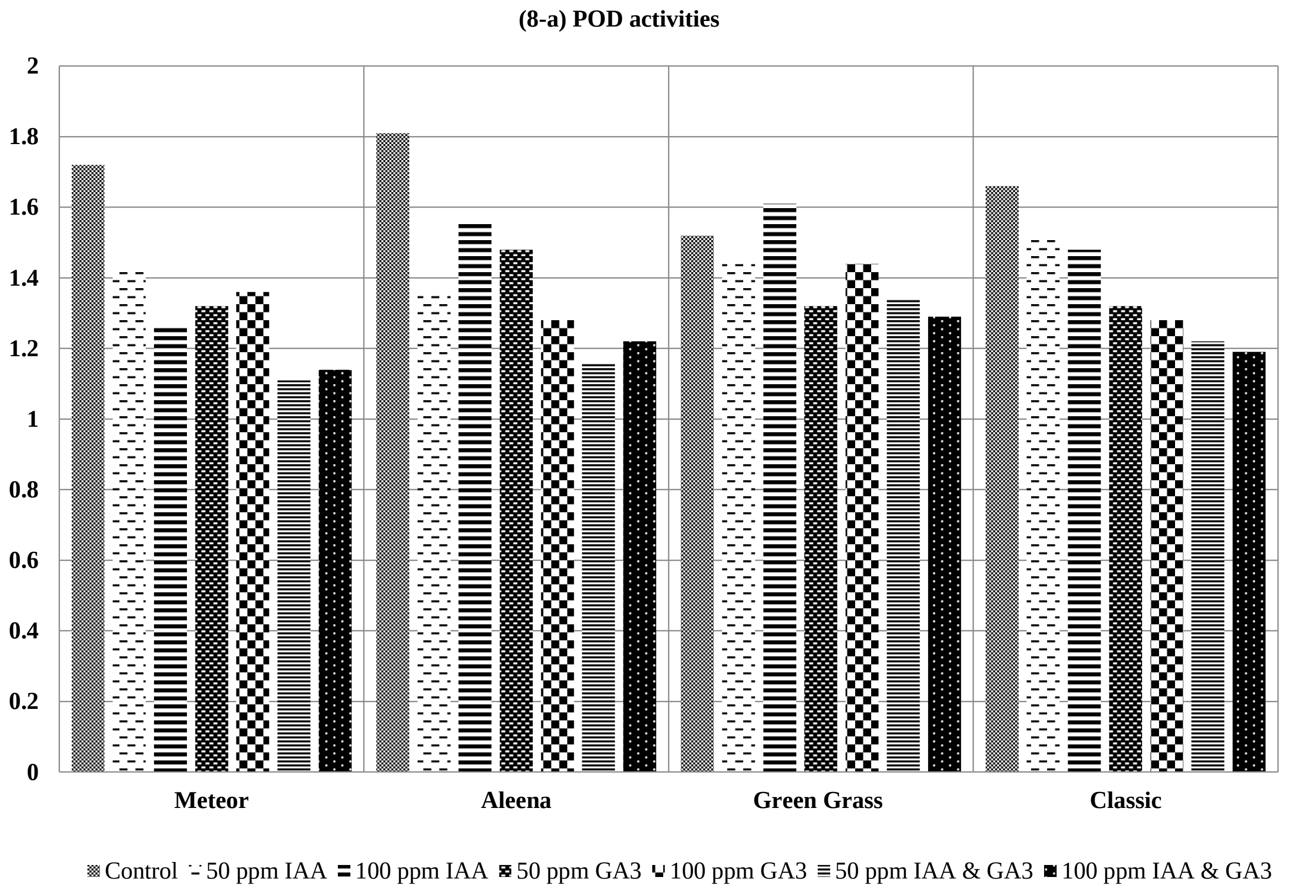


Fig. 7. Effect of IAA and GA3 on ionic concentrations of Pea (*Pisum sativum* L.).



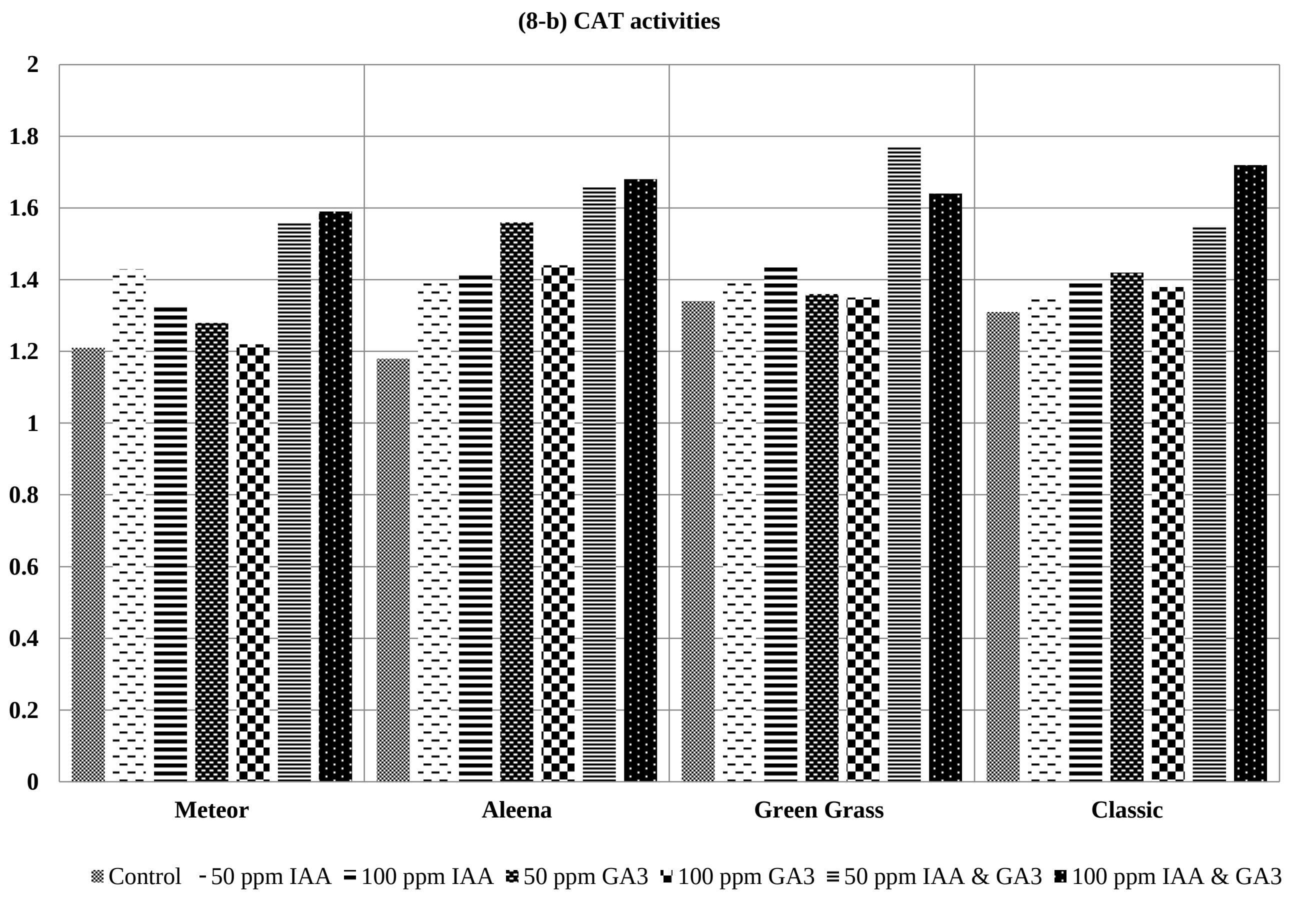


Fig. 8. Effect of IAA and GA3 on antioxident activities (POD and CAT) of Pea (*Pisum sativum* L.).

Table 5. Means squares from ANOVA for antioxidant activities of pea under IAA and GA_3 applications.

Sources	df	MS of POD activities	MS of CAT activities
IAA	4	531.22***	18.99**
GA_3	1	4.71*	4.55*
Cultivar	3	2.44ns	18.52*
IAA x GA_3	4	32.34***	7.25***
IAA x Cultivar	12	111.25*	10.01*
GA_3 x Cultivar	3	16.17**	8.12*
IAA x GA_3 x Cultivar	12	112.15*	17.89*
Error	120	425.86	84.89
Total	159		

*, **, *** = Significant; ns = Non-significant

Regulation of leaf expansion is also concerned with GA_3. For floral induction and largest plant height AG_3 at moderate level was observed as most suitable, the low quantity of AG3 permitted to build up the highest amount of biomass (Martha *et al*., 2007). Cell development and demarcation, organ growth and development controls by Auxin and gibberellins (GA). Once it was thought that auxin and gibberellins act mainly side by side via separate procedures. However, in recent times, it has been clearly demonstrated that there is interrelation of GA_s and auxin (Ross *et al*., 2000). Plant with foliar applications of growth hormones showed significant effect on number of seed per pod than the plants without hormones application (control) As a result of efficient photosynthetic activity due to Gibberellins action that trigger the growth system thus as a result it enhance carbohydrate building and also dry matter substance (Shittu *et al*., 2009).

Changes in antioxidant activities results are in accordance with the findings of Synková *et al*. (2004). They showed that foliar application of IAA affected the plants by activating enzymes and improving enzyme activity within the cell Reduction of POD activity was due to the less passage ability through cell wall because IAA affected the POD activity by stopping or initiating the manufacturing ability (Lagrimini, 1997). So, these activities are useful in maintaining the balance in plant metabolism (Tognetti *et al*., 2012).

Conclusion

It was concluded that high photosynthetic rate resulted high biomass production and pod yield. High Transpiration rates, increased the uptake nutrients from soil that resulted high accumulation of Ca^{2+} and K^+. Reduction in POD activities increased 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. These outcomes can be a good indicator for researchers to evaluate the pea cultivars response towards plant growth regulators (PGR) to predict for promising yield and quality traits.

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