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Using Some Growth Regulators for Improving Growth and Productivity of Pea under Late Sowing Conditions

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Abstract: Two field experiments were conducted at private farm, El Gammaliah, Dakahlia Governorate, Egypt during the two successive winter seasons of 2018 and 2019 to study the effect of some growth regulators applied as (soaking, spray and combined) on pea plants grown under late sowing conditions. Fourteen treatments were arranged in randomized complete block with three replicates. The treatments were control; soaking in water; soaking in IAA (indole-3-acetic acid) at 25 ppm, NAA (1- naphthalene acetic acid) at 25 ppm, GA_3 (gibberellic acid) at 200 ppm and BR (brassinolide) at 5 ppm; spray with the same growth regulators at the same concentrations; and the combined between them (soaking with spray). The studied characteristics were plant height; number of branches plant^{-1}; stem diameter; plant fresh and dry weight; number of seeds pod^{-1}; average pod weight; number of pods plant^{-1}; total green pods yield fed^{-1} and leaves content of nitrogen, phosphorus and potassium (%) and DPPH (free radical scavenging activities). The combined method (soaking with spray) recorded the highest results in all studied characteristics followed by spray and soaking methods, respectively. Moreover, NAA recorded the best result compared with other growth regulators under the experimental conditions. From the results of this study, it can be suggested that using NAA at 25 ppm as seed soaking for 2 hours before sowing and spraying three times was an effective practice to overcome the adverse effect on pea plants grown under late conditions.

Key words: Pea · Soaking · Spray · Growth regulators · Growth · Yield

INTRODUCTION

Pea (*Pisum sativum* L.) is one of the most important leguminous vegetable crops in Egypt for local consumption and exportation. It is the second most important food legume in the world after common bean [1]. Pods of pea contain high amount of protein (21-25 %), carbohydrates, amino acids, vitamins, phosphorus, iron, magnesium and calcium and low contents of fiber. Pea is a cool climate vegetable crop whereas the growing period is extended under cool conditions. Its cultivation requires cool weather and partly moist climatic condition and the increase in temperature above 20°C decreases the yield and quality of immature seeds [2]. At the late sowing date, relatively high temperature and dry climate are unsuitable for flowering and pod development of pea [3].

Therefore, it is necessary to improve the growth and productivity of pea growing under stress conditions at late seasons. Plant growth regulators are one of the promising approaches to improve the productivity of crops under biotic and abiotic stress conditions. Plant growth regulators are organic substances synthesized chemically and when they are produced endogenously by plants, they called phytohormones or plant hormones [4, 5]. They help the plants adapt to changing environments, by mediating plant growth and development, nutrient allocation and source/sink transitions [6]. Also, they play an essential role in the regulation of signal transduction pathway involved in the induction of plant stress response and may be useful to return metabolic activities to their normal levels [7, 8].

Auxin is the first class growth regulator that was discovered. IAA (indole-3-acetic acid) is the natural auxin while the synthetic produce auxins are NAA (1- naphthalene acetic acid) and IBA (indole-3-butyric acid) [9]. Auxin is involved in mediating a number of essential plant growth and developmental processes, such as cell elongation, division and differentiation, induction of root growth and flower and fruit development, nutrient allocation and source-sink relationship [6, 10]. Additionally, auxin plays a vital role in plant responses to different biotic and abiotic stresses

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where it integrates stress signals from different plant hormones and modulate redox pathway to regulate root development as a stress-induced morphological response [11].

Another plant hormone is gibberellic acid (GA_3) belongs to gibberellins (GAs) which are a large family of tetracyclic di-terpenoid plant growth substances. Gibberellic acid (GA_3) regulating several processes of plant development like cell elongation and cell division, cell wall extensibility, seed germination, stem and hypocotyl elongation, leaf expansion, induction of floral initiation, sex determination and flower and seed development [12-14]. Exogenous application of GA_3 can helps the plants to adapt the abiotic stresses. GA_3 has been shown to be beneficial for providing a mechanism to regulate the metabolic process as a function of sugar signalling and antioxidative enzymes and has a crosstalk with SA in the regulation of source-sink relation under abiotic stress [15].

Brassinolide (BR) belonging to brassinosteroids (BRs) is a new class of plant hormones that play an essential role in plant development. It is a natural plant hormone first isolated from the pollens of rapeseed plant (*Brassica napus* L.) [16]. Brassinosteroids (BRs) regulate multiple physiological and development processes including seed germination, cell division and elongation, vascular differentiation, rhizogenesis, flowering, senescence, abscission, maturation, regulation of carbohydrate assimilation and allocation and activation of photosynthesis [17, 18]. In addition, BRs induced the synthesis of IAA and GA in plant [19], stimulated the synthesis of heat-shock proteins and antioxidant enzymes and can be used as an antistress agent in a wide range of biotical and abiotic stresses [20].

The effect of growth regulators varies under different concentrations, methods of application, time of application, weather conditions, stress and genotypic differences [21, 22]. Therefore, this study aimed to evaluate the effect of some growth regulators with different methods on growth, yield and quality of pea under stress conditions at late season.

MATERIALS AND METHODS

The present study was carried out on pea plants (*Pisum sativum* L.) cv. Master-B in a private farm, El-Gammaliah, Dakahlia Governorate, Egypt during the two successive seasons of 2018 and 2019 to study the effect of some growth regulators (IAA, NAA, GA_3 and BR) applied as soaking, foliar and combination between soaking and foliar application, in addition to soaking in water and control (spraying with tap water) treatments. The experimental soil was clay loam with pH 8.20, EC 1.13 $ds.m^{-1}$, organic matter 2.42 %, available nitrogen 44.20 mg kg^{-1}, available phosphorous 4.64 mg kg^{-1} and available potassium 352.00 mg kg^{-1}. The mean monthly temperature and relative humidity during 2018 and 2019 seasons prevailing in El-Gammaliah region are presented in Table (1).

Seeds were inoculated before sowing with root nodules bacteria (*Rhizobium leguminosarum*) and sown on 20^{th} January in the first and second season. Seeds were planted on rows with 20 cm spacing among rows and 10 cm among plants. The experimental design was complete randomized block design (CRBD), with three replicates. The plot area was 12 m^2 and included 3 ridges; each ridge was 5 m length and 0.80 m width. All recommended cultural practices for pea production were followed according to the Egyptian Ministry of Agriculture. The experiment included 14 treatments as shown in Table (2).

The seeds were soaked for two hours before sowing and the foliar treatments were applied three times (at 15, 30 and 45 days after sowing). The above growth regulators were obtained from Al-Gommhoria Company for chemicals. The seeds of pea were obtained from Horticulture Research Institute (HRI), Agricultural Research Center (ARC), Egypt.

The Following Data Was Recorded

Vegetative Growth Traits: Ten plants from each plot were randomly taken at 50 days after sowing from each plot to determine plant height (cm), number of branches $plant^{-1}$, stem diameter (cm), fresh weight $plant^{-1}$ and dry weight $plant^{-1}$ in each season.

Pod Yield and its Components: At harvest time, number of seeds pod^{-1}, average pod weight (g), number of pods $plant^{-1}$ and total green pods yield fed^{-1} were determined.

Chemical Contents: Samples of leaves from each plot were randomly taken to measure and determine the following parameters: N (%) according to [23], P (%) according to the method of [24], K (%) according to [25] and antioxidants activity (free radical scavenging activities) towards the stable free radical DPPH(1, 1-diphenyl-2-picrylhydrazyl) was determined by the method of [26] and expressed as μgmL^{-1}.

Table 1: Monthly temperature and relative humidity of the experimental site (El-Gammaliah, Dakahlia Governorate) during 2018 and 2019

Month	Air temperature (°C) Min	Air temperature (°C) Max	Relative humidity (%)
		2018	
January	11.78	18.64	69.22
February	12.89	20.94	67.19
March	14.45	25.21	55.34
April	16.35	26.63	57.59
		2019	
January	9.65	18.11	59.89
February	10.70	19.36	63.70
March	12.17	21.03	63.85
April	14.38	23.92	59.19

Table 2: Details of the studied treatments

Treatments	Details
T_1	Control.
T_2	Soaking in water.
T_3	Soaking in IAA (indole-3-acetic acid) at 25 ppm.
T_4	Soaking in NAA (1- naphthalene acetic acid) at 25 ppm.
T_5	Soaking in GA_3 (gibberellic acid) at 200 ppm.
T_6	Soaking in BR (brassinolide) at 5 ppm.
T_7	Spray with IAA (indole-3-acetic acid) at 25 ppm.
T_8	Spray with NAA (1- naphthalene acetic acid) at 25 ppm.
T_9	Spray with GA_3 (gibberellic acid) at 200 ppm.
T_{10}	Spray with BR (brassinolide) at 5 ppm.
T_{11}	Soaking and Spray with IAA (indole-3-acetic acid) at 25 ppm.
T_{12}	Soaking and Spray with NAA (1- naphthalene acetic acid) at 25 ppm.
T_{13}	Soaking and Spray with GA_3 (gibberellic acid) at 200 ppm.
T_{14}	Soaking and Spray with BR (brassinolide) at 5 ppm.

Statistical Analysis: The data were analyzed using SAS software Version 9.1 according to [27] and the differences among means were compared by using Duncan's multiple range tests (DMRT) at 0.05 levels according to [28].

RESULTS AND DISCUSSION

Vegetative Growth: The response of pea plants to soaking, spraying and the combined treatments of growth regulators are presented in Table (3). Concerning soaking treatments, all soaking treatments increased vegetative growth attributes compared with control plant. The seeds soaked in brassinolide (BR) exhibited the tallest plants while the values of other studied characters (number of branches plant^{-1}, stem diameter and fresh and dry weight) were highest in naphthalene acetic acid (NAA) followed by gibberellic acid (GA_3), indole acetic acid (IAA), brassinolide (BR) and water soaking treatments, respectively.

As to spray treatments, the differences between them and control were significant in all parameters. Brassinolide spray treatment recorded the highest values of plant height only, whereas naphthalene acetic acid treatment gave the highest values in other parameters, i.e., number of branches plant^{-1}, stem diameter, plant fresh weight and plant dry weight in the two seasons.

The combined treatments between spray and soaking (Table 3) showed significant effect on vegetative growth characters of pea plants. Soaking pea seeds and spraying with brassinolide exhibited the tallest plants while soaking and spraying with naphthalene acetic acid gave the highest values of other parameters compared with all studied treatments in both seasons of the study followed by GA_3, IAA and BR.

Brassinolide application either as soaking or spraying or combined gave the highest plants of pea compared with other treatments. That may be due to the role of brassinolide in cell elongation and divisional activities by activating cell wall loosening enzymes [29] and synthesis of IAA and GA_3 in plant and the increase in plant height may probably due to their cumulative action [19]. Also, BRs promote lateral root development through increasing acropetal auxin transport [30]. Under normal growth or stress conditions, brassinolide can regulate heat shock proteins (HSPs) and can induce heat tolerance of stressed plants [31].

Table 3: Effect of growth regulators on vegetative growth traits of pea in the two seasons of 2018 and 2019, respectively

Treatments	Plant height (cm)		No of branches plant^{-1}		Stem diameter (cm)		Plant fresh weight (g)		Plant dry weight (g)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	51.00h	51.00d	1.07h	1.00i	0.290f	0.295f	13.967j	15.02m	5.007g	5.120i
Soaking										
Water	52.00h	52.00d	1.33gh	1.50h	0.303ef	0.305ef	17.883i	19.550l	6.723ef	6.033h
IAA	57.00de	57.00bc	1.53fg	1.80fg	0.310de	0.315de	19.580g	21.000i	6.007f	6.300h
NAA	54.00g	54.00cd	2.00de	2.40d	0.315cd	0.320de	21.670e	23.417g	8.103c	8.303d
GA_3	55.00fg	56.33c	1.93de	2.00ef	0.312de	0.317de	19.767fg	21.900h	6.193f	6.900g
BR	58.00d	58.00bc	1.53fg	1.67gh	0.308de	0.319de	18.763h	19.967j	6.007f	6.127h
Spray										
IAA	56.00ef	58.00bc	2.13cd	2.37d	0.320bc	0.325d	21.507e	23.267g	7.083e	7.497ef
NAA	55.00fg	55.00cd	2.63ab	2.80 b	0.325bc	0.330cd	25.143c	27.667c	8.703bc	8.967b
GA_3	57.00de	57.33bc	2.33bc	2.53cd	0.323bc	0.327cd	23.200d	25.417e	7.973cd	8.500cd
BR	61.00c	60.66b	1.80ef	1.93ef	0.315de	0.320de	19.910f	21.933h	6.980e	7.200fg
Spray+Soaking										
IAA	66.00b	66.33a	2.50ab	2.73bc	0.335bc	0.340bc	26.207b	26.233d	8.200bc	8.693bc
NAA	56.00ef	56.33c	2.80a	3.10a	0.357a	0.364a	28.867a	30.147a	10.283a	10.717a
GA_3	62.00c	61.00b	2.60ab	2.83b	0.340ab	0.345b	26.393b	28.667b	8.917b	9.007b
BR	68.00 a	68.00a	1.80ef	2.03e	0.325bc	0.330d	23.117d	24.900f	7.283de	7.590e

Mean pairs followed by different letters are significantly different ($P < 0.05$) according to the Duncan's multiple range test.

The improvement effect of auxins (IAA and NAA) on pea vegetative growth may be related to the role of auxins in cell division and elongation and induction of root growth [10], leading to an increase in plant fresh weight. Likewise, IAA increases photosynthetic activities [32] and serves as a signaling molecule necessary for the coordination of growth and development of plant organs [33] improves nitrogen metabolism in pea plant grown under stress conditions and can alter the expression of stress responsive genes [34, 35].

Regarding GA_3, it stimulates cell division and elongation, increases internode length and improves nodulation via the positive effect on seedling roots [36, 37]. Furthermore, GA_3 improves the photosynthesis through its influence on photosynthetic enzymes, leaf area index, light interception and enhanced use efficiency of nutrients [38] and plays a crucial role in early plant responses to adverse environmental conditions by increasing SA biosynthesis [39].

Similar results were recorded by Shahid *et al*. [40] and Priya [16] on brassinolide, Husen *et al*. [41] and Aldesuquy *et al*. [42] on IAA, Vadeo [43] on NAA and Hussain *et al*. [44] on GA_3.

Pod Yield and its Component: Table (4) shows that soaking treatments significantly increased number of seeds pod^{-1}, average pod weight, number of pods plant^{-1} and total green pod yield fed.$^{-1}$ compared with control. NAA soaking treatment was the best followed by GA_3, IAA and water, respectively in both seasons. Also, NAA applied as spray recorded the highest values compared with other spraying treatments and control. Regarding the combined applications, soaking and spraying with NAA, GA_3, IAA and BR, respectively gave the highest values of all studied characters, i.e., number of seeds pod^{-1}, average pod weight, number of pods plant^{-1} and total green pod yield fed.$^{-1}$ compared with soaking or spraying treatments and control (Table 4) under stress condition (Table 1).

The improvement of pea pod yield in response to auxin and gibberellin treatments may be due to their role in uptake more nutrients, increasing photosynthetic rate and enhancing sink-source relationship, which led to increasing plant growth (Table 3), higher dry matter produced and transferred topods [45] and consequently increasing yield (Table 4).

Concerning brassinolide, it has an effective role in photosynthesis through increasing the activity of Rubisco enzyme and the capacity of CO_2 assimilation in the Calvin cycle [46]. Also, brassinolide induces more translocation of assimilates to the developing seeds during seed filling phase, thus improving the seed weight [40].

These results were agreed with those obtained by El-Sayed *et al*. [47] on brassinolide, Khalid *et al*. [48] on IAA, Thomson *et al*. [37] on NAA and Singh *et al*. [49] on GA_3.

Chemical Contents: Table (5) shows the impact of growth regulators (IAA, NAA, GA_3 and BR) as soaking or sprays or combined on leaves content of N, P, K and DPPH (free radical scavenging, an accepted mechanism for screening the antioxidant activity of plant extracts).

Table 4: Effect of growth regulators on yield traits of pea in the two seasons of 2018 and 2019, respectively

	No of seeds pod^{-1}		Average pod weight (g)		No of pods plant^{-1}		Total green yield fed $^{-1}$(ton/fed)	
Treatments	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	7.50h	7.70g	3.00f	3.10g	6.99e	7.06e	4.197i	4.399i
Soaking								
Water	8.067g	8.30f	3.20e	3.30f	7.20d	7.29d	4.615h	4.816h
IAA	8.50ef	8.70de	3.37de	3.44de	7.37cd	7.46c	4.931fg	5.129fg
NAA	8.70cd	8.90bc	3.46cd	3.57cd	7.41cd	7.50c	5.131de	5.351de
GA_3	8.60de	8.80cd	3.45cd	3.54cd	7.39cd	7.49c	5.101ef	5.307de
BR	8.30fg	8.60ef	3.30e	3.40ef	7.35cd	7.44c	4.847gh	5.061gh
Spray								
IAA	8.80cd	9.00bc	3.51c	3.59bc	7.45bc	7.55c	5.361cd	5.425cd
NAA	9.00cd	9.20bc	3.60ab	3.67ab	7.51bc	7.59c	5.411bc	5.565bc
GA_3	8.90cd	9.10bc	3.55bc	3.64ab	7.49bc	7.59c	5.315cd	5.529cd
BR	8.70cd	8.90bc	3.47cd	3.56cd	7.40cd	7.48c	5.131de	5.256ef
Spray+Soaking								
IAA	9.10bc	9.20bc	3.67ab	3.76ab	7.75a	7.75b	5.697ab	5.808ab
NAA	9.80 a	10.00a	3.75 a	3.83 a	7.80a	7.90a	5.844 a	6.048 a
GA_3	9.50ab	9.70a	3.71a	3.80a	7.78a	7.89ab	5.773ab	5.996a
BR	9.00cd	9.30b	3.60ab	3.68ab	7.64ab	7.74bc	5.506ab	5.693bc

Mean pairs followed by different letters are significantly different ($P < 0.05$) according to the Duncan's multiple range test.

Table 5: Effect of growth regulators on chemical composition of leaves in the two seasons of 2018 and 2019, respectively

	N%		P%		K%		DPPH (µg mL^{-1})	
Treatments	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	2.52l	2.40h	0.413b	0.418b	1.577h	1.650h	20.520i	19.813h
Soaking								
Water	2.52j	2.50gh	0.415b	0.420b	1.600h	1.700gh	27.866h	26.000g
IAA	2.73i	2.80ef	0.417b	0.422b	1.703fg	1.850f	51.514c	50.295c
NAA	2.95fg	3.00de	0.419b	0.424b	1.800de	1.950de	49.620d	49.187cd
GA_3	2.83h	2.93de	0.417b	0.423b	1.750ef	1.850f	35.666g	34.666f
BR	2.64j	2.70fg	0.416b	0.421b	1.653gh	1.750g	36.958g	35.333f
Spray								
IAA	3.00f	3.10cd	0.511a	0.515a	1.850de	1.950de	55.590b	53.333b
NAA	3.23d	3.300ab	0.511a	0.517a	2.000c	2.133bc	54.736b	53.467b
GA_3	3.10 e	3.20bc	0.511a	0.516a	1.898d	2.000d	45.366f	44.934e
BR	2.92g	3.00de	0.510a	0.515a	1.803de	1.900ef	47.608e	47.739d
Spray+Soaking								
IAA	3.31c	3.40ab	0.516a	0.518a	2.103b	2.200b	57.702a	54.333b
NAA	3.53a	3.60a	0.515a	0.520a	2.253a	2.350a	58.743a	56.968a
GA_3	3.41b	3.50ab	0.514a	0.519a	2.1990a	2.300a	45.000f	44.500e
BR	3.32c	3.30ab	0.512a	0.517a	2.000c	2.083c	51.000cd	47.500d

Mean pairs followed by different letters are significantly different ($P < 0.05$) according to the Duncan's multiple range test

It is clear that among soaking treatments, NAA recorded the highest content of N, P, K and DPPH in leaves compared with other treatments. The same trend was obtained in spray and combined treatments, which NAA came first and control was the latest in both seasons of the study. It is notable that the differences among all studied growth regulators applied in soaking or spray or combined were insignificant in both seasons of the study concerning phosphorous content. Among all investigated growth regulators, NAA applied as combined (soaking + spray) recorded the highest content of chemical constitutes followed by GA_3, IAA and BR (soaking + spray).

The enhancement in leaves content of nutrients and DPPH in response to auxin, maybe due to its important roles in lateral root formation and activates the plasma membrane H+-ATPase, provide the driving force for the uptake of numerous nutrients [50-52]. Additionally, auxin enhancing the activities of antioxidant enzymes such as POD, CAT and SOD in plants [53]. In pea, Ochoa [22] found that IAA increased CAT activity by protecting plants against oxidative stress.

In case of GA_3, it enhances nitrogen uptake due to the increase in shoot growth, which requires more N from the soil [38]. Ca^{2+} and other nutrients uptake increased by GA_3 application may be involved in stress tolerance by regulating antioxidant metabolism and reduced the lipid peroxidation of the cell membrane [54]. Also, GA_3 can regulate the metabolic process as a function of sugar signalling and antioxidative enzymes under abiotic stress [15].

Likewise, brassinolide changes root permeability and cation exchange capacity of the root and that enhanced water and nutrient uptake resulting in increased protein synthesis [55]. Besides, brassinolide enhanced the activities of antioxidant enzymes seemed to play an important role in scavenging the reactive oxygen species (ROS) [29] through regulating the expression of genes involved in the biosynthesis of antioxidant enzymes in plants [56].

Similar observations were found by Garg*et al*. [57] on brassinolide, Hussain *et al*. [44] on IAA, Singh *et al*. [58] on NAA and Husain *et al*. [59] on GA_3.

The results of this study suggested that using NAA at 25 ppm as seed soaking for 2 hours before sowing and spray 3 times (15, 30 and 45 days after sowing) was an effective practice to overcome the adverse effect on pea plants grown under late conditions.

REFERENCES

1. FAO, 2008. http://faostat.fao.org [accessed 10 November 2007].
2. Ali, M.Z., M.A. Aziz, M.A.I. Sarker, S. Mazumder, S.K. Paul, T.A. Mujahidi, M.S.A. Khan and M.S. Bhuiyan, 2016. Effect of sowing time based temperature variations on growth, yield and seed quality of garden pea. Bangladesh Agron. J., 19(1): 29-36.
3. Sirwaiya, S. and S.S. Kushwah, 2018. Assessment of different sowing dates and varieties on growth, yield and quality of seed in garden pea (*Pisum sativum* L.). Int. J. Curr. Microbiol. App. Sci., 7(3): 1387-1396.
4. Javid, M.G., A. Sorooshzadeh, F. Moradi, S.A.M.M Sanavy and I. Allahdadi, 2011. The role of phytohormones in alleviating salt stress in crop plants. AJCS, 5(6): 726-734.
5. Hameed, M., B. Sultana, F. Anwar, M. Aslam, M. Mushtaq and H. Munir, 2015. Changes in proximate composition, biochemical and antioxidant attributes of broccoli (*Brassica oleracea* l.) in relation to foliar application of selected plant growth regulators. Pak. J. Bot., 47(5): 1685-1691.
6. Husen, A., M. Iqbal and I.M. Aref, 2017. Plant growth and foliar characteristics of faba bean (*Vicia faba* L.) as affected by indole-acetic acid under water-sufficient and water-deficient conditions. Journal of Environmental Biology, 38: 179-186.
7. Ali, H.M., M.H. Siddiqui, M.O. Basalah, M.H. Al-Whaibi, A.M. Sakran and A. Al-Amri, 2012. Effects of gibberellic acid on growth and photosynthetic pigments of *Hibiscus sabdariffa* L under salt stress. Afr. J. Biotechnol., 11(4): 800-804.
8. Sayed, S.A and M.A.A. Gadallah, 2013. Gibberellic acid ameliorates the adverse effects of acid mist and improved antioxidant defense, water status and growth of acid misted sunflower plants. J. Biol. Earth Sci., 3(2): 275-285.
9. Farooq, M., M. Bakhtiar, M.N. Khan, I. Khan, K. Kakar, N. Ilyas, S. Khan, A. Qayum, M. Siddique and N. Ullah, 2018. Auxin biosynthesis, its role in plant growth, devolopment and physiological process. International Journal of Fauna and Biological Studies, 5(4): 23-27.
10. Kukavica, B., A. Mitrović, M. Mojović and S.V. Jovanović, 2007. Effect of indole-3-acetic acid on pea root growth, peroxidase profiles and hydroxyl radical formation. Arch. Biol. Sci. Belgrade, 59(4): 319-326.
11. Sharma, E., R. Sharma, P. Borah, M. Jain and J.P. Khurana, 2015. Emerging roles of auxin in abiotic stress responses. In: Pandey, G.K. (Eds.), Elucidation of abiotic stress signaling in plants. New York, Springer, pp: 299-328.
12. Taiz, L. and E. Zeiger, 2002. Plant Physiology. 3rd edition, Sinauer Associates, Inc., Sunderland, pp: 690.
13. Matsuoka, M., 2003. Gibberellin signaling: How do plant cells respond to GA signals?. J. Plant Growth Regul., 22: 123-125.
14. Yamaguchi, S., 2008. Gibberellin metabolism and its regulation. Annu. Rev. Plant Biol., 59: 225-251.
15. Iqbal, N., R. Nazar, M.I.R. Khan, A. Masood and N.A. Khan, 2011. Role of gibberellins in regulation of source-sink relations under optimal and limiting environmental conditions. Current Science, 100(7): 998-1007.
16. Priya, T., 2016. Effect of brassinosteroids (brassinolide) on morphophysiological, biochemical and antioxidant enzymes activity on field pea (*Pisum sativum* L.) genotypes under cadmium stress. M.Sc. Thesis, Banaras Hindu University, India.

17. Bajguz, A., 2007. Metabolism of brassinosteroids in plants. Plant Physiology and Biochemistry, 45: 95-107.
18. Bajguz, A., 2011. Brassinosteroids - occurrence and chemical structures in plants. In: Hayat, S. and Ahmad, A. (Ed.), Brassinosteroids: A class of plant hormone. Springer Science+Business Media, pp: 1-27.
19. Sengupta, K., N.C. Banik, S. Bhui and S. Mitra, 2011. Effect of brassinolide on growth and yield of summer green gram crop. Journal of Crop and Weed, 7(2): 152-154.
20. Gomes, M.M.A., 2011. Physiological effects related to brassinosteroid application in plants. In: Hayat, S. and Ahmad, A. (Ed.), Brassinosteroids: A class of plant hormone. Springer Science+Business Media, pp: 193-242.
21. Pagare, S.F., 2013. Effect of plant growth regulators on growth, seed yield and seed quality of pea (*Pisum sativum* L.) variety-phule priya.M.Sc. Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, India.
22. Ochoa, L., 2016. Evaluating the effects of the phytohormone indole-3-acetic acid in the response of green pea (*Pisum sativum* L.) to nanoscale CuO exposure in soil. M.Sc. Thesis, Open Access Theses & Dissertations, 712, the University Of Texas At El Paso, USA.
23. Chapman, H.D. and P.F. Pratt, 1978. Methods of Analysis for Soils, Plants and Waters. Univ. California Div. Agric. Sci., Priced Publication, Oakland, pp: 12-19.
24. A.O.A.C., 1980. Official Methods of Analysis, 12th ed Association of Official Analysis Chemists: Washington, D.C., USA.
25. Jackson, M.I., 1973. Soil Chemical Analysis. Prentice-Hall of India Private Limited, New Delhi, pp: 1-498.
26. Mensor, L.L., F.S. Menezes, G.G. Leitao, A.S. Reis, T.C. dos Santos, C.S. Coube and S.G. Leitao, 2001. Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. Phytotherapy Research, 15: 127-130.
27. Snedecor, G.W. and W.G. Cochran, 1990. Statistical Methods 6th ed. The Iowa state, Univ. Press, Amer, Iowa, U.S.A.
28. Duncan, D.B., 1955. Multiple Range and Multiple F test. J. Biometrics, 11: 1-42.
29. Tanveer, M., B. Shahzad, A. Sharma, S. Biju and R. Bhardwaj, 2018. 24 Epibrassinolide; an active brassinolide and its role in salt stress tolerance in plants: A review. Plant Physiology and Biochemistry, 130: 69-79.
30. Pattanachatchai, N., 2010. Brassinosteroids: Physiological roles in plants. Burapha Sci. J., 15(1): 133-142.
31. Mazorra, L.M., 2011. Brassinosteroid action and its relation with heat stress mechanisms in plants. In: Hayat, S. and Ahmad, A. (Ed.), Brassinosteroids: A class of plant hormone. Springer Science+Business Media, pp: 289-307.
32. Singh, G., 2015. Effect of different hormones on plant attribute and yield of field pea (*Pisum sativum* L.). M.Sc. Thesis, School of Agriculture, Lovely Professional University, Phagwara, India.
33. Aldesuquy, H., 2000. Effect of indol-3-yl acetic acid on photosynthetic characteristics of wheat flag leaf during grain filling. Photosynthetica, 38(1): 135-141.
34. Jain, M. and J.P. Khurana, 2009. Transcript profiling reveals diverse roles of auxin-responsive genes during reproductive development and abiotic stress in rice. FEBS J., 276: 3148-3162.
35. Gangwar, S. and V.P. Singh, 2011. Indole acetic acid differently changes growth and nitrogen metabolism in *Pisum sativum* L. seedlings under chromium (VI) phytotoxicity: Implication of oxidative stress. Scientia Horticulturae, 129: 321-328.
36. Akbari, N., M. Barani, E. Drikvand and H. Ahmadi, 2010. The effect of gibberellic acid (GA_3) on minerals of mungbean (*Vigna radiata* L. Wilczek) irrigated with different levels of saline water. Afr. J. Agric. Res., 5(4): 275-27.
37. Thomson, T., G.S. Patel, K.S. Pandya, J.S. Dabhi and Y. Pawar, 2015. Effect of plant growth substances and antioxidants on growth, flowering, yield and economics of garden pea, *Pisum sativum* L cv Bonneville. International Journal of Farm Sciences, 5(1): 8-13.
38. Khan, N.A., S. Singh, R. Nazar and P.M. Lone, 2007. The source-sink relationship in mustard. Journal of Plant Science and Biotechnology, 1(1): 10-18.
39. Alonso-Ramı´rez, A., D. Rodrı´guez, D. Reyes, J.A. Jime´nez, G. Nicola´s, M. Lo´pez-Climent, A. Go´mez-Cadenas and C. Nicola´s, 2009. Evidence for a role of gibberellins in salicylic acid-modulated early plant responses to abiotic stress in arabidopsis seeds. Plant Physiology, 150: 1335-1344.
40. Shahid, M.A., R.M. Balal, M.A. Pervez, T. Abbas, M.A. Aqeel, A. Riaz and N.S. Mattson, 2015. Exogenous 24-epibrassinolide elevates the salt tolerance potential of pea (*Pisum sativum* L.) by improving osmotic adjustment capacity and leaf water relations. Journal of Plant Nutrition, 38: 1050-1072.

41. Husen, A., M. Iqbal and I.M. Aref, 2016. IAA-.induced alteration in growth and photosynthesis of pea (*Pisum sativum* L.) plants grown under salt stress. J. Environ. Bio., 37: 421-429.
42. Aldesuquy, H.S., A.M. Mowafy, F. El-Mahdy and Y.A. Osman, 2018. Effect of indole-3-acetic acid and benzyl adenine on growth parameters and yield of *Pisum sativum* L. plants. J. Agric. Chem. and Biotechn., Mansoura Univ., 9(6): 147-150.
43. Vadeo, T., 2018. Effects of gibberellic acid and auxins on growth and yield on peas. International Journal of Advances in Science Engineering and Technology, 2: 42-44.
44. Hussain, K., S. Anwer, K. Nawaz, M.F. Malik, N. Zainab, A. Nazeer, Z. Bashir, S.S. Ali, E.H. Siddiqi, K.H. Bhatti and A. Majeed, 2020. Effect of foliar applications of IAA and GA_3 on growth, yield and quality of pea (*Pisum sativum* L.). Pak. J. Bot., 52(2): 447-460.
45. Patel, H.B., S.N. Saravaiya, S.J. Patil, D. Raj, H. Suthar and D.R. Bhanderi, 2018. Response of cluster bean to foliar application of PGRS on biochemical parameters. Int. J. Pure App. Biosci., 6(2): 1494-1498.
46. Yu, J.Q., L.F. Huang, W.H. Hu, Y.H. Zhou, W.H. Mao, S.F. Ye and S. Nogues, 2004. A role for brassinosteroids in the regulation of photosynthesis in *Cucumis sativus*. J. Exp. Bot., 55(399): 1135-1143.
47. El-Sayed, H.A., M.A.A. El-Sherbini and M.T.M. Al-Ashry, 2019. Improving sugar pea growth and quality by using some natural substances. J. Plant Production, Mansoura Univ., 10(3): 299-306.
48. Khalid, N., K. Hussain, K. Nawaz, E.H. Siddiqi, S.J. Khan, M. Shafiq, A. Majeed and F. Lin, 2017. Assessment of growth, yield and nutritional values of pea (*Pisum sativum* L.) by foliage applications of IAA. Pak. J. Bot., 49(2): 509-517.
49. Singh, T., P.K. Rai, G.M. Lal, R. Kumar and N. Ali, 2018a. Effect of plant growth regulators on growth seed yield and yield attribute of field pea (*Pisum sativum* L.). International Journal of Chemical Studies, 6(4): 41-43.
50. Palmgren, M.G., 2001. Plant plasma membrane H^+-ATPases: powerhouses for nutrient uptake. Annu. Rev. Plant Physiol. Plant Mol. Biol., 52: 817-845.
51. Takahashi, K., K. Hayashi and T. Kinoshita, 2012. Auxin activates the plasma membrane H^+-ATPase by phosphorylation during hypocotyl elongation in *Arabidopsis*. Plant Physiology, 159: 632-641.
52. Du, Y. and B. Scheres, 2018. Lateral root formation and the multiple roles of auxin. Journal of Experimental Botany, 69(2): 155-167.
53. Siddiqui, M.H., S.A. Alamri, M.Y.Y. Al-Khaishany, M.A. Al-Qutami, H.M. Ali and M.N. Khan, 2017. Sodium nitroprusside and indole acetic acid improve the tolerance of tomato plants to heat stress by protecting against DNA damage. Journal of Plant Interactions, 12(1): 177-186.
54. Siddiqui, M.H., M.H. Al-Whaibi and M.O. Basalah, 2011. Interactive effect of calcium and gibberellin on nickel tolerance in relation to antioxidant systems in *Triticum aestivum* L. Protoplasma, 248: 503-511.
55. Surendar, K.K., S. Vincent, M. Vanagamudi and H.Vijayaraghavan, 2013. Plant growth regulators and nitrogen responses on improving nutrient content of black gram (*Vigna mungo* L.). Plant Gene and Trait, 4(12): 66-69.
56. El-Mashad, A.A. and H.I. Mohamed, 2012. Brassinolide alleviates salt stress and increases antioxidant activity of cowpea plants (*Vigna sinensis*). Protoplasma, 249: 625-635.
57. Garg, P., A. Hemantaranjan and J. Pradhan, 2018. Mitigation effects of 24-epibrassinolide and thiourea in field pea (*Pisum sativum* L.) under drought stress. J. P. Sci. Res., 34(2): 227-233.
58. Singh, S.K., B.S. Tomar, A. Anand, S. Kumari and K. Prakash, 2018b. Effect of growth regulators on growth, seed yield and quality attributes in garden pea (*Pisum sativum* var *Hortense*) cv. Pusa Pragati. Indian Journal of Agricultural Sciences, 88(11): 82-86.
59. Husain, A.J., A.G. Muhmood and A.H. Alwan, 2018. Interactive effect of GA_3 and proline on nutrients status and growth parameters of pea (*Pisum sativum* L.). Indian Journal of Ecology, 45(1): 201-204.