Asian Journal of Crop Science

ISSN 1994-7879

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Asian Journal of Crop Science

ISSN 1994-7879
DOI: 10.3923/ajcs.2021.17.23

Research Article
Exogenous Auxin Role on Shallot (*Allium cepa* Var Aggregatum) Growth

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Abstract

Background and Objective: Shallot was reported with a high concentration of auxin, Indole Acetic Acid (IAA) and auxin's application might affect plant growth. However, the effect varies on plant species and genotype. This study aimed to determine the IAA concentration in shallot tissue and investigate the effect of exogenous IAA application on shallot vegetative growth, endogenous IAA and shallot bulb yield. **Materials and Methods:** The first study analyzed three different shallot tissues (root, bulb and leaf) from five different shallot cultivars (Bima, Mentes, Pancasona, Trisula and Maja). The second study was conducted using a randomized complete block design with two factors: Bima and Trisula cultivars and five exogenous IAA concentration levels. **Results:** The result showed that the bulb contains the highest IAA concentration and the application of exogenous IAA did not work significantly to affect shallot vegetative growth and bulb yield. However, the application of 10 mL L^{-1} of exogenous IAA increased the percentage of below-ground biomass and 5 mL L^{-1} of exogenous IAA increased total soluble solids and firmness. **Conclusion:** A high concentration of exogenous IAA altered biomass partitioning and a low concentration of exogenous IAA might improve shallot bulb yield quality.

Key words: Auxin, onions, phytohormones, plant growth regulator, shallot bulb

Citation: Sopha, G.A. and S. Hartanto, 2021. Exogenous auxin role on shallot (*Allium cepa* var aggregatum) growth. Asian J. Crop Sci., 13: 17-23.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Shallot (*Allium cepa* var aggregatum) is one of the most important vegetable crops in Indonesia. It is used in many Indonesian foods as an enhancer spice that makes Indonesian food tastier and aromatic. The quantity and quality of the shallot demand are increased due to the Indonesian population and Indonesian people's welfare. Several studies have been conducted to improve shallot growth and bulb yield through input production modification, including chemical fertilizer[1,2], organic fertilizer[3,4], soil amendments[5] and phytohormone[6] application. However, the results varied on the cultivar, location, season and treatments. One of the phytohormones that were used to improve shallot growth and bulb yield was auxin groups.

The application of 20 ppm Indole Acetic Acid (IAA) or Indole-3-Butyric Acid (IBA) on onion seedling roots increased vegetative onion growth and fresh bulb yield[7]. Moreover, the foliar application of IBA also positively impacted onion growth and bulb characteristics[8]. Furthermore, picloram application as an auxin source and 0.5 mg L^{-1} BA was increased seedling shoot onion meristem[9]. The IAA application positively impacted the growth, development and production of onions[6]. On the contrary, the minor effect was reported that NAA application did not significantly affect onion bulb dormancy[10]. Therefore, the shallot or onion response on auxin application might vary on the type of auxin, cultivar, concentration and plant stage.

The IAA is a common auxin form that participates in plant growth and development. Exogenous application of IAA may influence the role of auxin, for example, leaf abscission[11], development of floral bud and fruit[12], root growth[13] and plant toxicity response[14]. The effect of IAA on plant physiological process varies, it might enhance some process and restricts others depending on its concentration, plant species, plant physiological age[15] and environmental condition and IAA turns inactive when the IAA completes their roles[16].

The sources of IAA can come from chemical or organic materials. The chemical sources might harm the environment. Therefore, the possible organic IAA sources would be investigated. Shallot was reported to contain a high of IAA. However, the concentration depends on the section and cultivar. To address this issue, the first trial of this study was an investigation of IAA concentration from three sections (root, bulb and leaf) of five shallot cultivars. Moreover, the application of IAA might involve shallot growth, yield and quality. Therefore, this second trial aimed to investigate the effect of shallot's extract (contains exogenous IAA) concentration on shallot growth, bulb yield and bulb quality.

MATERIALS AND METHODS

Study area: The research was conducted from April-November, 2015 in the Indonesian Vegetable Research Institute (IVEGRI), located in Lembang, Bandung Barat, West Java, Indonesia (latitude: 6°48'S, longitude: 107°39'E, 120 m above sea level). The soil type is andisol with soil pH = 5.4 (acid), high of organic carbon 7.26%, total nitrogen 0.55%, the C/N ratio 13, low of available P (P-Bray = 12 mg P kg^{-1}) and high of potassium (K-Morgan = 804 ppm).

The research consisted of two activities analysis and selection of endogenous auxin from shallot tissues and a pot experiment to determine the IAA application's effect on shallot growth and bulb yield.

Selection of IAA: This research was comprised of several steps: extraction, purification and determination of shallot tissues. Five different shallot cultivars were used: Bima, Mentes, Pancasona, Trisula and Maja. Three different tissues were used: roots, leaves and bulbs. About 150 plants per cultivar were grown in a greenhouse and were sampling at 30 days after planting. The method was used based on previous studies[17].

Pot experiments: The pot trials were carried out using Randomized Complete Block Design with two factors and three replications were to determine the effect of auxin on shallot growth. The first factor being the cultivar, Bima and Trisula. Meanwhile, the sub-plot or second factor was the concentration of exogenous auxin, which were 0, 5, 7.5, 10 and 12.5 mL L^{-1}. The exogenous auxin was made from the bulb of shallot cultivar Bima and Trisulaas, the highest IAA source.

The shallot cultivar Bima and Trisula from Indonesian Vegetable Research Institute (IVEGRI) were used. Bima is an established cultivar recognized for its resistance to *Botrytis allii* and its adaptability to lowland with a potential yield of 10 t ha^{-1}. Similarly, Trisula is a dark red variety from IVEGRI adapted to the lowland with a higher potential yield of up to 23 t ha^{-1}. Both cultivars had different genetic grouping based on molecular and morphological traits[18].

The pot contained 2 kg of soils, with a single shallot plant per pot. The plants received a total of 1000 kg ha^{-1} of NPK over three stages, at planting time, 2 weeks after planting and 4 weeks after planting. Throughout the trial, the observations or measurements were plant height, number of leaves, number of tillers, endogenous auxin content, chlorophyll content, bulb yield and the bulb's quality (water content and texture).

RESULTS

IAA selection evaluation: In overview, bulb tissue contained the highest IAA concentration and leaf tissue contained the lowest concentration of IAA in Table 1. The highest concentration of IAA was gained by Bima's bulb that 6.014 mg kg^{-1}. In contrast, the lowest concentration of IAA was gained by Trisula's leaf of 0.280 mg kg^{-1}. On average, bulb tissue contained the highest IAA, 5.376 mg kg^{-1} that was 504% higher than leaf contained 1.066 mg kg^{-1}. Moreover, Bima had the highest IAA concentration per plant, which was about 10.335 mg $kg^{-1}$and the lowest cultivar was Pancasona, 6.208 mg kg^{-1}.

Pot experiment observation: The exogenous IAA application did not significantly affect plant height, number of leaves and number of the tiller of shallot at 4 weeks after planting in Table 2. Control treatment (0 mL L^{-1}) gave the highest height of Bima, 42.2 cm and 10 mL L^{-1} IAA for Trisula. The highest number of leaves, about 24.0, was achieved by application 12.5 mL L^{-1} in Bima cultivar and 5 mL L^{-1} gave the highest number of leaves of Trisula, 24.4 leaves. The highest number of tillers of Bima was gain by 12.5 mL L^{-1} of 4.2 tillers and the highest number of tillers of Trisula was achieved by 10.0 mL L^{-1}, 4.0 tillers.

In overview, there was no significant difference between IAA exogenous levels on shallot biomass but there was a significant effect of IAA on the percentage of biomass or biomass partitioning in Table 3. The highest plant biomass of Bima cultivar was achieved by applying 10 mL L^{-1} was about 2.00 g per plant that was not significantly different with the lowest plant biomass, control treatment about 1.35 g per plant. While the highest plant biomass of Trisula was gained by control treatment, 1.94 g per plant was not significantly different from the lowest plant biomass, 7.5 mL L^{-1} IAA about 1.25 g per plant.

The exogenous IAA application reduced the above-ground (leaves and stems) percentage and increased below-ground (roots and bulbs) biomass 4 weeks after planting. The highest percentage of below-ground biomass of Bima was achieved by application 7.5-12.5 mL L^{-1}about 50%. At the same time, the highest percentage of below-ground biomass of Trisula was achieved by application 10 mL L^{-1}, about 34%.

The exogenous IAA application did not significantly increase chlorophyll content but reduced endogenous IAA in Trisula's bulb in Table 4. The highest concentration of Bima's chlorophyll was gained by applying 12.5 mL L^{-1} IAA, which was about 2.20 mg g^{-1}. While control treatments achieved the highest concentration of Trisula's chlorophyll, 1.91 mg g^{-1} was not significantly different from other treatments.

The highest endogenous IAA contain was gained by controlling that 9.67 mg kg^{-1} and the lowest endogenous contain was achieved by applying 12.5 mL L^{-1} of IAA. There was a negative linear trend that increasing the rate of IAA reduced the endogenous IAA content.

In overview, 'Bima' had a better bulb yield than 'Trisula' and the application of exogenous IAA did not significantly

Table 1: Concentration of IAA from different tissues of five shallot cultivars

	Concentration of IAA (mg kg^{-1})			
Cultivar	Roots	Leaves	Bulbs	Total
Bima	3.895	0.426	6.014	10.335
Maja	2.504	0.317	5.071	7.892
Mentes	3.541	0.615	4.993	9.149
Pancasona	2.688	0.377	3.183	6.208
Trisula	3.94	0.28	4.619	8.839
Average	3.314	1.066	5.376	

Table 2: Effect of exogenous IAA on plant height, number of leaves and number of tillers at 4 weeks after planting

	Bima			Trisula		
Treatments IAA concentration (mL L^{-1})	Plant height (cm)	Number of leaves	Number of tillers	Plant height (cm)	Number of leaves	Number of tillers
0	42.2^{ns}	20.4^{ns}	4.1^{ns}	40.0^{ns}	22.8^{ns}	3.7^{ns}
5	40.6	19.8	3.8	39.4	24.4	3.9
7.5	41.4	19.8	3.9	39.7	19.8	3.2
10	41.8	19.5	3.8	41.8	23.8	4.0
12.5	40.1	24.0	4.2	40.9	23.6	3.9
CV (%)	4.2	15.1	16.0	4.1	16.6	24.0

*Mean values within a column followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test, ns: Not significant

Table 3: Effect of exogenous IAA on the plant biomass and percentage of biomass at 4 weeks after planting

	Bima			Trisula		
Treatment IAA concentration (mL L^{-1})	Plant biomass (g/plant)	Percentage biomass (%)		Plant biomass (g/plant)	Percentage biomass (%)	
		Above-ground	Below-ground		Above-ground	Below-ground
0	1.35^{ns}	73^{a}	27^{b}	1.94^{ns}	78^{a}	22^{b}
5	1.48	73^{a}	27^{b}	1.38	75^{a}	24^{b}
7.5	1.62	50^{b}	50^{a}	1.25	71^{ab}	29^{ab}
10	2.00	50^{b}	50^{a}	1.61	66^{b}	34^{a}
12.5	1.74	50^{b}	50^{a}	1.31	68^{b}	32^{a}
CV (%)	34	39	30	27	29	25

*Mean values within a column followed by the same letters are not significantly different at p<0.05 according to Duncan's Multiple range test, ns: Not significant

Table 4: Exogenous IAA's effects on chlorophyll content and endogenous IAA of 'Bima' and 'Trisula'

Treatments	Chlorophyll content (mg g^{-1})		Endogenous IAA content (mg kg^{-1})
IAA concentration (mL L^{-1})	Bima	Trisula	Trisula
0	1.98^{ns}	1.91^{ns}	9.67^{a}
5	1.66	1.88	9.53^{a}
7.5	1.79	1.37	9.29^{a}
10	2.17	1.59	4.07^{b}
12.5	2.2	1.12	3.64^{b}
CV (%)	11.71	19.34	31.69

*Mean values within a column followed by the same letters are not significantly different at p<0.05 according to Duncan's multiple range test, ns: Not significant

Table 5: Effect of exogenous IAA on shallot yield of 'Bima' and 'Trisula'

	Bima		Trisula	
Treatments IAA concentration (mL L^{-1})	Fresh bulb yield g/plant	t ha^{-1}*	Fresh bulb yield g/plant	t ha^{-1}*
0	54.50^{ns}	13.6	32.88^{ns}	8.2
5	54.78	13.7	34.22	8.6
7.5	51.26	12.8	36.76	9.2
10	50.88	12.7	38.56	9.6
12.5	51.8	13	36.68	9.2
CV (%)	12.68		16.18	

Mean values within a column followed by the same letters are not significantly different at p<0.05 according to Duncan's multiple range test, ns: Not significant, wap: Weeks after planting, *Population per ha approximately 250.000 plants

Table 6: Effect of exogenous IAA on water content, total soluble solids and texture of 'Bima' and 'Trisula'

	Bima			Trisula		
Treatments IAA concentration (mL L^{-1})	Water content (%)	TSS	Texture (mm sec^{-1} per 100 g)	Water content (%)	TSS	Texture (mm sec^{-1} per 100 g)
0	82.19^{ab}	17.16^{a}	1.15^{ab}	82.63^{b}	15.96^{b}	1.22^{ns}
5	81.82^{b}	16.88^{a}	1.05^{b}	82.13^{c}	16.64^{a}	1.17
7.5	82.67^{ab}	15.80^{bc}	1.38^{ab}	82.70^{b}	16.16^{b}	1.25
10	83.40^{a}	15.16^{c}	1.40^{a}	82.92^{ab}	15.84^{b}	1.19
12.5	82.04^{b}	16.52^{ab}	1.27^{ab}	83.17^{a}	15.92^{b}	1.17
CV (%)	0.8	3.04	13.56	0.23	1.28	12.59

*Mean values within a column followed by the same letters are not significantly different at p<0.05 according to Duncan's multiple range test, ns: Not significant, wap: Weeks after planting, TSS: Total soluble solids

affect shallot bulb yield in Table 5. Application of 5 mL L^{-1} IAA gave the highest fresh bulb yield for Bima cultivar, about 13.7 t ha^{-1}. While the 10 mL L^{-1} IAA application gave the highest fresh bulb yield of Trisula, about 9.6 t ha^{-1}, that was not significantly different from control and other treatments. On average, across the treatments, bulb yield of 'Bima' was 13.2 t ha^{-1}, 47% higher than 'Trisula' was about 9.0 t ha^{-1}.

There was a significant difference between treatments for shallot quality parameters, i.e., water content, total soluble solids and texture in Table 6. Application 12.5 mL L^{-1} IAA gave the lowest water content of Bima cultivar, 82.04% and 5 mL L^{-1} of IAA gave the lowest water content of Trisula, 82.13%. The highest percentage of total soluble solids of Bima was gained by control, 17.16%. In comparison, the highest

percentage of total soluble solids of Trisula (16.64%) was gained by application 5 mL L^{-1} of IAA. The most firmness of Bima and Trisula was gained by application 5 mL L^{-1} of IAA.

DISCUSSION

Bulb of shallot contained the highest amount of IAA compared to other section and Bima and Trisula had the highest concentration of the IAA (Table 1). This result was in line with other findings that the endogenous concentration of IAA was massively transported from above ground to below ground section[19]. Therefore, the shallot bulb was used as the exogenous IAA source and applied in the following experiment. In this experiment, the concentration of IAA was higher than[20] that found the total concentration of shallot IAA was 0.73-0.75 ppm. The higher result might occur due to the shallot section's separation, roots, bulb and leaf. In contrast, the previous experiment combined all sections (one shallot plant).

In overview, there was no effect of exogenous IAA application on shallot growth. However, the application of a high concentration of exogenous IAA altered biomass partitioning. About 10 and 12.5 mL L^{-1} of exogenous IAA increased the percentage of a below-ground section due to the exogenous IAA's effect on accelerating bulb formation. This effect was also reported on potato plants, that exogenous auxin stimulated root and tuber growth[21]. Auxin altered the leaves' cell wall permeability, resulting in photosynthate translocation to the below-ground section[22].

Moreover, there was no significant effect of IAA levels on the total biomass of shallot. On the contrary, exogenous auxin significantly affected *Zizania latifolia* biomass[23] and combined with cytokinin, improved the biomass and lipid of microalgae *Desmodesmus* sp[24]. A negative effect might occur when a high IAA concentration was applied that could inhibit cell propagation [25] and reduced plant biomass. The different response might occur due to the difference in plants genotype[21].

In this experiment, there was no significant effect of exogenous IAA application on shallot's chlorophyll content. In contrast, exogenous IAA application increased the chlorophyll of green alga (*Chlorella Vulgaris*)[25] and the exogenous auxin increased tomato's chlorophyll contained only after 5-15 days after application[26]. The difference effect might occur due to the existence of other phytohormones that involve the chlorophyll content. The IAA increased the number of chloroplasts but the chlorophyll content increased when applied with kinetin but not on IAA application alone[27].

A high concentration of exogenous IAA significantly reduced endogenous IAA concentration. Contrary to another study[28], that the endogenous level IAA untreated was lower than IAA-treated cutting. IN this experiment, the 10 and 12.5 mL L^{-1} exogenous IAA application decreased the endogenous IAA concentration but did not affect the plant biomass per plant. This phenomenon might occur due to shallot metabolic pathways that control the number of phytohormones. In the high concentration of exogenous IAA condition, plants inactive conjugate auxin[16]. Therefore, the application of a high concentration of exogenous IAA reduced the concentration of endogenous IAA. The formation of endogenous IAA decreased because the plants regulate to maintain phytohormone balancing. Phytohormones are a self-synthesized compound within the plants that can be moved from one part to another and have physiological effects even in low amounts[29].

Application 5 mL L^{-1} exogenous IAA improved shallot bulb yield quality that increased the total soluble solids and firmness and reduced water content percentage. Those characters might improve the shallot bulb's shelf life because total soluble solids and firmness affected the decay and weight loss during the storage duration [30]. Exogenous IAA did not terminate the onion bulb's dormancy but might involve the dormancy break[22].

CONCLUSION

The 10 mL L^{-1} exogenous IAA application reduced endogenous IAA concentration but increased the percentage of below-ground biomass. All exogenous IAA levels did not significantly affect shallot vegetative growth, total shallot biomass and shallot bulb yield. However, an application of 5 mL L^{-1}exogenous IAA might improve the shallot bulb's quality due to improving the bulb's total soluble solids and firmness.

SIGNIFICANCE STATEMENT

This study discovered exogenous IAA's effect on shallot physiology that can help understand phytohormone's role and improve shallot growth and bulb quality. This study will help the researcher uncover the critical areas of auxin on shallot that researchers could not explore.

ACKNOWLEDGMENT

The authors thank IVEGRI for funding the experiment under DIPA-BALITSA-2015.

REFERENCES

1. Darini, M.T., 2020. Response, correlation of growth analysis and shallot yield under different nitrogen fertilizer dosage and rhizobacteria source. J. Agron., 19: 131-137.
2. Sopha, G.A., R. Rosliani, R.S. Basuki, L. Liferdi and M.P. Yufdy, 2015. Correlation of plant nutrients uptake with shallot production in alluvial soils. Adv. Agric. Botanics, 7: 127-137.
3. Blay, E.T., E.Y. Danquah, J. Ofosu-Anim and J.K. Ntumy, 2002. Effect of poultry manure and/or inorganic fertilizer on the yield of shallot [*Allium cepa* var. *aggregatum* (G. Don)]. Adv. Hortic. Sci., 16: 13-16.
4. Sopha, G.A., 2020. Influence of plant density, compost and biofertilizer on true shallot seed growth in alluvial soil. Indonesian J. Agric. Sci., 21: 70 -77.
5. Sopha, G.A., A.M. Effendi, F. Aprianto and A. Firmansyah, 2021. The incorporation of lime and NPK fertilizer on shallot production in peat soil. IOP Conf. Ser.: Earth Environ. Sci., Vol. 653. 10.1088/1755-1315/653/1/012057.
6. Rizk, F., A. Shaheen and K. El-Habbasha, 1996. Flowering and seed yield of onion, *Allium cepa* L. plants as affected by dates of planting and some growth regulators. Egypt. J. Hort., 23: 113-127.
7. Singh, P., N. Tewari and P. Katiyar, 2002. Pre transplant seedling treatment with growth regulators and their effect on growth and bulb production in onion (*Allium cepa* L.). Progressive Agr., 2: 181-182.
8. Amin, A.A., E.S.M. Rashad and H.M.H. El-Abagy, 2007. Physiological effect of indole-3-butyric acid and salicylic acid on growth, yield and chemical constituents of onion plants. J. Applied Sci. Res., 3: 1554-1563.
9. Phillips, G.C. and K.J. Luteyn, 1983. Effects of picloram and other auxins on onion tissue cultures. J. Am. Soc. Hort. Sci., 108: 948-953.
10. Thomas, T.H., 1969. The role of growth substances in the regulations of onion bulb dormancy. J. Exp. Bot., 20: 124-137.
11. Jin, X., J. Zimmermann, A. Polle and U. Fischer, 2015. Auxin is a long-range signal that acts independently of ethylene signaling on leaf abscission in *Populus*. Front. Plant Sci., Vol. 6. 10.3389/fpls.2015.00634.
12. Li, W., Y. Zhou, X. Liu, P. Yu, J.D. Cohen and E.M. Meyerowitz, 2013. LEAFY controls auxin response pathways in floral primordium formation. Sci. Signal., 6: ra23-ra23.
13. Koltai, H., E. Dor, J. Hershenhorn, D.M. Joel and S. Weininger *et al*., 2010. Strigolactones' effect on root growth and root-hair elongation may be mediated by auxin-efflux carriers. J. Plant Growth Regul., 29: 129-136.
14. Zhu, X.F., Z.W. Wang, F. Dong, G.J. Lei, Y.Z. Shi, G.X. Li and S.J. Zheng, 2013. Exogenous auxin alleviates cadmium toxicity in *Arabidopsis thaliana* by stimulating synthesis of hemicellulose 1 and increasing the cadmium fixation capacity of root cell walls. J. Hazard. Mater., 263: 398-403.
15. Atif, M.J., M.A. Ahanger, B. Amin, M.I. Ghani, M. Ali and Z. Cheng, 2020. Mechanism of Allium crops bulb enlargement in response to photoperiod: A review. Int. J. Mol. Sci., Vol. 21. 10.3390/ijms21041325.
16. Tran, L.S.P. and S. Pal, 2014. Phytohormones: A Window to Metabolism, Signaling and Biotechnological Applications. 1st Edn., Springer, New York, ISBN: 978-1-4939-0490-7, Pages: 361.
17. Sandberg, G., A. Crozier, A. Ernstsen and B. Sundberg, 1987. High Performance Liquid Chromatography and the Analysis of Indole-3-Acetic Acid and Some of Its Decarboxylated Catabolites in Scots Pine (*Pinus sylvestris* L.). In: High Performance Liquid Chromatography in Plant Sciences, Linskens, H.F. and J.F. Jackson (Eds.)., Springer, Berlin Heidelberg, pp: 72-91.
18. Laila, A., E. Sulistyaningsih and A. Wibowo, 2013. Morphogenetic variation of shallot (*Allium cepa* L. Aggregatum group). Agric. Sci., 16: 1-11.
19. Tanimoto, E., 2005. Regulation of root growth by plant hormones-roles for auxin and gibberellin. Crit. Rev. Plant Sci., 24: 249-265.
20. Yunindanova, M.B., M.S. Budiastuti and D. Purnomo, 2018. The analysis of endogenous auxin of shallot and its effect on the germination and the growth of organically cultivated melon (*Cucumis melo*). IOP Conference Series: Earth and Environmental Science, August 20–24, 2017, Yogyakarta, Indonesia.
21. Kolachevskaya, O.O., S.N. Lomin, D.V. Arkhipov and G.A. Romanov, 2019. Auxins in potato: Molecular aspects and emerging roles in tuber formation and stress resistance. Plant Cell Rep., 38: 681-698.
22. Sharma, K., R.Y. Lee, S.W. Park and S.H. Nile, 2016. Importance of growth hormones and temperature for physiological regulation of dormancy and sprouting in onions. Food Rev. Int., 32: 233-255.
23. Li, J., Y. Guan, L. Yuan, J. Hou and C. Wang *et al*., 2019. Effects of exogenous IAA in regulating photosynthetic capacity, carbohydrate metabolism and yield of *Zizania latifolia*. Sci. Hortic., 253: 276-285.
24. Singh, J., D. Jain, P. Agarwal and R.P. Singh, 2020. Auxin and cytokinin synergism augmenting biomass and lipid production in microalgae *Desmodesmus* sp. JS07. Process Biochem., 95: 223-234.
25. Piotrowska-Niczyporuk, A. and A. Bajguz, 2014. The effect of natural and synthetic auxins on the growth, metabolite content and antioxidant response of green alga *Chlorella vulgaris* (Trebouxiophyceae). Plant Growth Regul., 73: 57-66.
26. Wu, Q., X. Tao, X. Ai, Z. Luo, L. Mao, T. Ying and L. Li, 2018. Effect of exogenous auxin on aroma volatiles of cherry tomato (*Solanum lycopersicum* L.) fruit during postharvest ripening. Postharvest Biol. Technol., 146: 108-116.

27. Volfová, A., L. Chvojka and A. Friedrich, 1978. The effect of kinetin and auxin on the chloroplast structure and chlorophyll content in wheat coleoptiles. Biol. Plant., 20: 440-445.
28. Nordstrom, A.C., F.A. Jacobs and L. Eliasson, 1991. Effect of exogenous indole-3-acetic acid and indole-3-butyric acid on internal levels of the respective auxins and their conjugation with aspartic acid during adventitions root formation in pea cuttings. Plant Physiol., 96: 856-861.
29. Salisburry, F.B. and C.W. Ross, 1991. Plant Physiology. 4th Edn., Wadsworth Publishing Company, Belmont, California.
30. Shehata, S.A., K.F. Abdelgawad and M.M. El-Mogy, 2017. Quality and shelf-life of onion bulbs influenced by biostimulants. Int. J. Veg. Sci., 23: 362-371.