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RESEARCH PAPER

Effects of Alginate Oligosaccharides on Growth and Yield of Onion

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ABSTRACT

Alginate oligosaccharides (AOS) are known for functions in regulating plant growth, development and stress resistance. In order to study the growth regulating behavior of AOS on three varieties of onion (V_1: BARI Piaz-I, V_2: BARI Piaz-IV and V_3: BARI Piaz-VI), 50, 100 and 200 ppm aqueous solution along with control treatment were applied as foliar spray during vegetative growth stage. The effects of different treatments on onion yield and yield components were studied at the Germplasm Center, Department of Horticulture, Patuakhali Science and Technology University during November 2021 to March 2022.The two-factor experiment was laid out in a Randomized Complete Block Design with three replications. Most of the parameters such as plant height, number of leaves, fresh weight of leaves, dry weight of leaves, length of bulb, fresh weight of bulb and yield (t/ha) were significantly influenced by the different varieties and AOS levels. Among the onion variety, BARI Piaz-IV had higher plant height (49.26 cm) and BARI Piaz-VI had the maximum fresh weight of bulb (45.31), the maximum length of bulb (5.00 cm) as well as the highest yield (16.31 t/ha). In case of AOS concentration, 100ppm AOS showed higher plant height (49.62 cm), the highest fresh weight of leaves (17.27 g) and dry weight of leaves (0.73 g). On the other hand, 200ppm AOS treatment showed the higher fresh weight of bulb (44.57g), and the maximum yield (16.04 t/ha) of onion. The present studied results suggest that application of 100ppm and 200ppm AOS as foliar spray is suitable for growth and yield of onion.

Key words: Alginate Oligosaccharides, Growth, Yield, Onion

Introduction

Onion (*Allium cepa* L.) belongs to the family *Amaryllidaceae* (Alliaceae), being one of the major and extensively used spices in Bangladesh, plays an important role in human diet. Onions have significant contributions to the nutritional requirements of human beings and have also medicinal values. It is primarily consumed for their unique flavor and for their ability to enhance the flavor and taste of other foods (Gebretsadik and Dechassa, 2018). Onion bulbs contain 89% water but are rich in many essential nutrients and compounds like biotin, vitamin C, quercetin, and antioxidants (Lisanti et al., 2016, Insani et al., 2016). Furthermore, sulfur (S)-containing compounds of onion have numerous health benefits which include diabetes prevention, skin health, an improved immune system, lowering of blood pressure and cholesterols, anti-inflammatory disease activity, stress relief, and anti-cancer properties(Insani et al., 2016, Fujiwara et al., 2016, Chu et al., 2017).

More than 170 countries cultivate onions for their domestic use as well as for trade. In 2016, the global area under onion cultivation was about 5 million ha with a production of 93 million tons (FAOSTAT, 2016). China, India, Bangladesh and the USA are the leading onion producing countries in the world. Among the leading onion producing countries, Bangladesh ranked third with yearly production is about 2.6 million tons with average yield of 11.5 tons per hectare (BBS, 2022). Agro-climatic conditions of Bangladesh are favorable for onion production and it is grown in all parts of Bangladesh. Due to increasing population and use of arable land in urbanization, it is very hard to expand the cultivable land area under onion cultivation. Therefore, it is an urgent need to follow appropriate management practice for increasing yield of onion in Bangladesh.

Low productivity of vegetables including onions is attributed to depleted soil fertility, poor agronomic practices such as unbalanced fertilizer application, attack of insect-pest and diseases. In addition, poor technical knowledge and skill of farmers and development agents in onion production are the main problems for the low productivity(Sekara et al., 2017). The optimum level of agronomic practices like plant population density and balanced use of fertilizers, high yielding variety, bio-stimulants, and plant hormone might be very effective for increasing productivity of onion. Application of bio-stimulant seems to be one of the important practices in view of convenience, cost and labor efficiency. Recently, there has been global realization of the important role of

bio-stimulant in agriculture for better growth and yield of crops.

Alginate Oligosaccharides (AOS) is a novel environment-friendly agricultural regulators, degradation product of sodium alginate extracted from brown seaweed, is a good for promoting plant growth, enhancing plant resistance, inhibiting plant pathogenic bacteria (Zhang et al., 2014). Due to its low molecular weight, lack of toxicity, biocompability and biodegradable polymer, it has gained increased attention in a wide range of fields including agricultural (Liu *et al*. 2015; Zhang *et al.* 2014). Recently, some researchers reported that AOS enhanced plant growth, development and productivity, which is mainly attributed to stimulation of plants immunity against microorganisms (Zhang et al., 2019, Li et al., 2018).They reported that application of AOS enhanced the antioxidant enzyme system, accelerated the biosynthesis and transport of auxin, regulates alicylic acid-mediated signaling pathway and ABA-dependent signal pathway to enhance drought tolerance(Zhang et al., 2019, Zhang et al., 2014, , Li et al., 2018). Research works of AOS on growth, yield attributes and yield of Onion is almost rare but some research work has been conducted on rice and wheat by using different concentration of AOS. Considering the above facts, the present research work was undertaken to study the effect of AOS on growth, yield attributes and yield of Onion.

Materials and Methods

Study location and treatment selection

The study was conducted at the Germplasm center, under the department of Horticulture of Patuakhali Science and Technology University during the period from November 2021 to March 2022.Two-factor experiment with twelve treatment combinations consisted of three varieties of onion viz., BARI piaz-I, BARI piaz-IV; BARI piaz- VI and three different levels of AOS (T_1:50ppm, T_2: 100ppm, T_3: 200ppm) with control(T_0) were sprayed as bio-stimulants in two times after 30 DAT and 45 DAT, respectively. Onion seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The two-factor experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications. To prepare 50 ppm AOS, 50 mg AOS powder was dissolved into 1000 ml tap water. Same procedures were followed in case of 100 ppm and 200 ppm AOS preparation. The 50 days young plant of assigned three onion varieties were transplanted in the main field. AOS was applied as foliar at 30 and 45 days after transplanting. The crop was harvested after 100 days of transplanting when the plant turned brown and bulb were matured. Randomly selected eight plants were harvested from each unit plot for recording growth and quality parameters and together with rest of entire plot for estimating yield.

Instrumental procedure

The plant height was measured in centimeter (cm) from the neck of the bulb to the tip of the longest leaf with the help of a measuring tape. Numbers of leaves including green and dry from eight selected plants were recorded from each plot. A simple balance was used to take the weight of fresh leaves and individual bulb. To determine dry weight, the leaves were sliced with a sharp knife, thereafter dried under scorching sunlight and kept in an oven at 80°C for drying until the constant weight reached at a certain point. After oven-dry, dry weight of leaves of individual plant was calculated and expressed in gram (g). Length of harvested bulb was measured with a slide caliper at the bottom of bulb to upper cut portion which was expressed in gram. After removing the roots and top portion of the bulb keeping only 2.0 cm with neck, the bulb weight was taken. All the leaves with pseudostem were removed from the plant keeping only 2 cm neck, and the weight of bulbs was taken by a simple balance in kilogram.

Statistical analysis

The collected data on different parameters under the study were statistically analyzed using SPSS software. The means for all the treatments were calculated and analysis of variance for all the characters was performed by F-variance test. The significance of the difference between means were separated with Duncan's Multiple Range Test (DMRT) taking the probability level (Gomez and Gomez1984).

Results and Discussion

Plant height (cm)

Plant height varied significantly among the varieties of onion at 30, 45, and 60 DAT. The maximum plant height (26.95 cm, 47.18 cm and 49.26cm) was recorded from BARI Piaz-IV whereas, the minimum plant height (19.95 cm, 36.34 cm and 39.07 cm) was noted in BARI Piaz-I at 30, 45, and 60 DAT, respectively. Admittedly, there wasno significance effect on 75 and 90 DAT. Where, numerically the maximum plant height 33.35 cm was found in 90 DAT with BARI Piaz-VI and the minimum was 32.40 cm with BARI Piaz-I (Fig. 1).

AOS application had also showed significant effect on plant height at 30, 45, and 60DAT while later stage 90 DAT had no significance effect. At 30 and 60 DAT, the maximum plant height (25.18cmand 48.47cm) was recorded from 200ppm AOS treatment while the minimum plant height (22.91cm and 41.03cm) was observed in control treatment. At 45 DAT, the maximum plant height 48.49cm was noted from 100ppm AOS treatment and the minimum plant height 37.64 cm was recorded from control treatment. Admittedly, there was no significance effect on 75 and 90 DAT. Where, numerically the maximum plant height 33.69 cm was found in 90 DAT at application of 200ppm AOS and the minimum was 31.87 cm at control treatment (Fig. 2).This results are in conformity with Li et al. (2018), they indicated that the application of alginate derived oligosaccharides @ 0.2%significantly increased the plant height of cucumber seedlings.

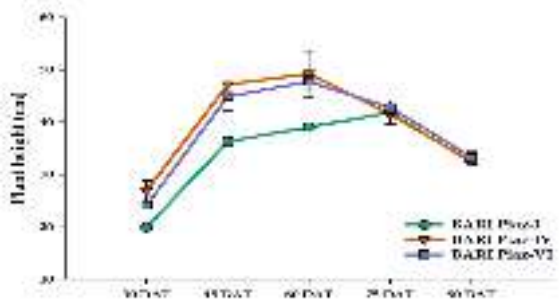

Figure 1: Effect of variety on plant height of onion (vertical bar represents standard error. (DAT=Days after transplanting)

Combined effect of variety and AOS application had also showed significant influence on plant height at 30, 45, 60, and 75 DAT while later stage 90 DAT had no significance effect (Table 1). At 30 DAT, the maximum plant height 28.33 cm was noted at 100 ppm AOS with BARI Piaz-I and the minimum plant height 11.93 cm was recorded at control treatment with BARI Piaz-IV. On the other hand, at 45, 60, 75 and 90 DAT, the maximum plant height (52.77cm, 54.23cm, 47.93cm and 35.93cm) was counted from 100ppm AOS treatment with BARI Piaz-IV and the minimum plant height (17.38cm, 36.40cm, 25.53cm and 30.00) was observed at control treatment with same variety, respectively (Table 1). In case of plant height of onion, height of plant was decreased after 60DAT. At vegetative stage plant grew vigorously as a result maximum plant height was counted but at reproductive stage growth of new leaves were ceased therefore plant exhibited shorter.

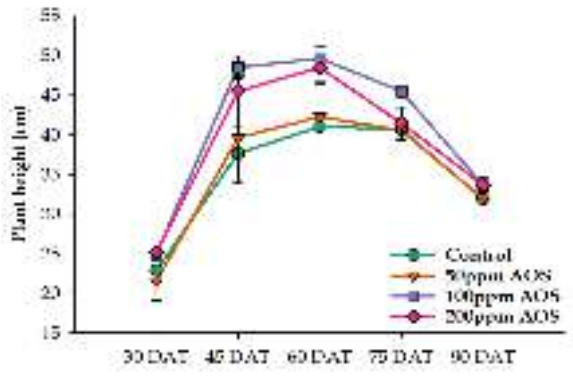

Figure 2: Effect of different AOS levels on plant height of onion (vertical bar represents standard error, DAT=Days after transplanting)

Table 1: **Combined effect of variety and AOS application on plant height of onion**

Variety	Treatment	Plant Height				
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
BARI Piaz-I	Control	26.60ab	43.73ab	47.47ab	41.33ab	34.27
	50ppm AOS	28.33a	48.73ab	49.70ab	43.23ab	35.13
	100ppm AOS	25.87ab	48.60ab	48.67ab	43.60ab	31.80
	200ppm AOS	27.00ab	47.67ab	51.20ab	43.00ab	32.20
BARI Piaz-IV	Control	11.93c	17.38c	25.53c	36.60b	30.00
	50ppm AOS	18.87bc	30.60bc	31.27bc	37.40b	32.40
	100ppm AOS	24.07ab	52.77a	54.23a	47.93a	35.93
	200ppm AOS	24.93ab	44.60ab	45.23abc	44.03ab	31.27
BARI Piaz-VI	Control	23.27ab	44.57ab	48.07ab	43.37ab	34.40
	50ppm AOS	24.43ab	46.80ab	47.87ab	41.77ab	30.47
	100ppm AOS	25.17ab	44.10ab	45.97abc	44.93ab	33.13
	200ppm AOS	23.60ab	44.20ab	48.97ab	37.33b	32.33
Significance level		**	**	*	**	NS
CV (%)		20.46	25.98	22.11	10.03	8.21

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).

*= Significant at 5% level of probability, **= Significant at 1% level of probability, NS = Not Significant, CV = coefficient of variation, DAT= Days after transplanting

Number of leaves per plant

The data showed significant effect of varieties on number of leaves per plants of onion at 30, 45, and 60 DAT. At 30 DAT, the maximum number of leaves per plants4.69 was recorded with BARI Piaz-IV and the minimum number of leaves per plants 3.90 was recorded in BARI Piaz-I. On the other hand, at 45 and 60 DAT, the maximum number of leaves plants^{-1} (5.92 and 8.08)was recorded with BARI Piaz-I and the minimum was (4.65 and 6.00) noted from BARI Piaz-IV, respectively. The maximum leaves per plants7.35 was found in BARI Piaz-VI and the minimum 6.87 leaves per plants was recorded in BARI Piaz-IV at 90 DAT (Table 2).

Highly significant variation on number of leaves per plants was observed after AOS application at 30, 45, and 60 DAT while later stage 75 and 90 DAT had no significance effect (Table 3). The maximum number of leaves plants^{-1} (4.53, 5.87 and 7.76) was marked with 100ppm AOS treatment and the minimum number of leaves per plants (3.84, 4.49 and 6.22) was counted from control treatment at 30, 45and 60 DAT, respectively (Table 3). However, increase in the number of leaves after application of AOS could be attributed to enhanced photo-assimilate production and cell division, and vegetative growth. This result shows that, AOS played an important role in leaf production and vigorous vegetative growth. Similar results were previously reported by Li et al. (2018) in case of cucumber seedlings.

Table 2: Effect of variety on number of leaves per plant of onion

Variety	Number of leaves per plant				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
BARI Piaz-I	3.90b	5.92a	8.08a	8.05	7.35
BARI Piaz-IV	4.69a	4.65b	6.00c	7.87	6.87
BARI Piaz-VI	3.97b	5.27b	7.03b	8.07	7.13
Significance level	**	**	**	NS	NS
CV (%)	16.36	12.48	10.13	10.63	15.34

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).
**= Significant at 1% level of probability, NS = Not Significant, CV = coefficient of variation, DAT= Days after transplanting

Table 3: Effect of different AOS levels on number of leaves per plant of onion

Treatment	Number of leaves per plants				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Control	3.84b	4.49c	6.22c	7.96	7.04
50ppm AOS	4.03ab	5.02bc	6.58bc	7.53	7.09
100ppm AOS	4.53a	5.87a	7.76a	8.38	7.24
200ppm AOS	4.33ab	5.73ab	7.60ab	8.11	7.09
Significance level	*	**	**	NS	NS
CV (%)	16.36	12.48	10.13	10.63	15.34

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).
*= Significant at 5% level of probability, **= Significant at 1% level of probability NS = Not Significant, CV = coefficient of variation, DAT= Days after transplanting

Table 4: **Combined effect of variety and AOS on number of leaves per plant of onion**

Variety	Treatment	Number of leaves/plants				
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
BARI Piaz-I	Control	2.40b	2.53c	3.73c	7.80bc	6.47
	50ppm AOS	3.80ab	4.47b	5.60bc	7.33cd	6.73
	100ppm AOS	4.80a	6.07ab	7.53ab	8.00bc	7.13
	200ppm AOS	4.60a	5.93ab	7.13ab	8.33abc	7.13
BARI Piaz-IV	Control	4.37a	5.40ab	7.33ab	7.13cd	6.87
	50ppm AOS	4.93a	6.00ab	8.00ab	8.00bc	7.73
	100ppm AOS	5.00a	6.40a	8.67a	7.60cd	7.47
	200ppm AOS	4.47a	5.87ab	8.33a	9.47a	7.33
BARI Piaz-VI	Control	3.93ab	5.20ab	6.80ab	6.53d	6.53
	50ppm AOS	4.13a	4.93ab	6.93ab	7.27cd	7.27
	100ppm AOS	3.87ab	5.53ab	7.07ab	9.53a	7.27
	200ppm AOS	3.93ab	5.40ab	7.33ab	8.93ab	7.47
Significance level		**	**	*	**	NS
CV (%)		16.36	12.48	10.13	10.63	15.34

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).
*= Significant at 5% level of probability, **= Significant at 1% level of probability NS = Not Significant, CV = coefficient of variation, DAT= Days after transplanting

Combined effect of variety and AOS application had also showed significant variation in respect of number of leaves plant^{-1} at 30, 45, 60, and75 DAT while later stage 90 DAT had no significance effect was noted (Table 4). BARI Piaz-IV plant treated with 100 ppm AOS showed the maximum number of leaves (5.00, 6.40 and 8.67) and the minimum number of leaves per plant (2.40, 2.53 and 3.73) was recorded from BARI Piaz-I without AOS treatment at 30, 45 and 60 DAT, respectively. But at 75 DAT, the maximum number of leaves per plant (9.53) was also counted from BARI Piaz-IV when treated with AOS 100 ppm whereas the minimum number of leaves per plant (6.53) was noted from same variety without AOS application (Table 4).

Fresh weight of leaves per plant (g)

Fresh weight of leaves/plant was measured at harvesting stage. The findings presented in table 5, 6 and 7 revealed significant effect of varieties and different AOS levels on fresh weight of leaves/plant at harvesting stage. Among varieties, the maximum fresh weight of leaves per plant was measured with variety BARI Piaz-I (19.81g) and the minimum fresh weight of leaves/plant was measured in the case of variety BARI Piaz-VI (14.73 g) (Table 5). Application of AOS had effect on fresh weight of leaves per plant. The maximum fresh weight of leaves/plant of 17.27 g was recorded with 100ppm AOS while the minimum fresh weight of leaves per plant of 15.43 g was observed under control treatment (Table 6). Combined effect of varieties and AOS levels had significant effect on fresh weight of leaves per plant. The maximum fresh weight of leaves per plant of 21.00 g was found in 200ppm AOS with BARI Piaz-IV at harvesting stage whereasthe minimum fresh weight of leaves per plant 13.00 g was recorded at control treatment in BARI Piaz-I (Table 7). Similar results were also recorded by Li et al. (2018), they reported that alginate derived oligosaccharides increased the fresh weight of cumber seedlings by increasing the diameter of plant, photosynthetic rate and maximum quantum of yield of photosystem. The variation of leaves fresh weight among the different varieties of onion might be due to the difference in adaptability of these cultivars to a particular environment.

Dry weight of leaves per plant (g)

Dry weight of leaves per plant was measured at harvesting stage. The findings presented in table 5, 6 and 7 revealed significant effects of varieties and different AOS levels on dry weight of leaves per plant at harvesting stage. Among varieties, the maximum dry weight of leaves per plant was measured with variety BARI Piaz-I (0.87 g) and the minimum dry weight of leaves per plant was measured in the case of both variety BARI Piaz-IV and BARI Piaz-VI (0.62 g) (Table 5). Application of AOS had also significant effect on dry weight of leaves per plant. The maximum dry weight of leaves per plant (0.73) gm was recorded with 100ppm AOS while the minimum dry weight of leaves per plant (0.67g) was observed under control treatment (Table 6).

Table 5: Effect of variety on fresh and dry weight of leaves per plant of onion

Variety	Fresh weight of leaves per plant(g)	Dry weight of leaves per plant(g)
BARI Piaz-I	19.81a	0.87a
BARI Piaz-IV	14.35b	0.62b
BARI Piaz-VI	14.73b	0.62b
Significance level	*	*
CV (%)	19.33	16.55

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).
*= Significant at 5% level of probability, at 1% level of probability NS = Not Significant, CV = coefficient of variation

Table 6: **Effect of different AOS levels on fresh and dry weight of leaves per plant of onion**

Treatment	Fresh weight of leaves per plant (g)	Dry weight of leaves per plant (g)
Control	15.43b	0.67b
50ppm AOS	15.97b	0.69b
100ppm AOS	17.27a	0.73a
200ppm AOS	16.51ab	0.72ab
Significance level	*	*
CV (%)	19.33	16.55

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).
*= Significant at 5% level of probability, CV = coefficient of variation

Combined effect of varieties and AOS levels had significant effect on dry weight of leaves per plant. The maximum dry weight of leaves per plant (0.93g) was found in 200ppm AOS with BARI Piaz-IV at harvesting stage and the minimum dry weight of leaves per plant (0.54g) was recorded at control treatment in BARI Piaz-I (Table 7).

Table 7: **Combined effect of variety and AOS on fresh and dry weight of leaves per plant of onion**

Variety	Treatment	Fresh weight of leaves/plant (g)	Dry weight of leaves/plant (g)
BARI Piaz-I	Control	13.00b	0.54b
	50ppm AOS	13.67b	0.60b
	100ppm AOS	15.22b	0.64b
	200ppm AOS	15.53b	0.68b
BARI Piaz-IV	Control	18.33ab	0.82ab
	50ppm AOS	19.37ab	0.82ab
	100ppm AOS	20.53a	0.91a
	200ppm AOS	21.00a	0.93a
BARI Piaz-VI	Control	13.01b	0.55b
	50ppm AOS	14.30b	0.61b
	100ppm AOS	14.39b	0.62b
	200ppm AOS	17.22ab	0.72ab
Significance level		*	*
CV (%)		19.33	16.55

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).
*= Significant at 5% level of probability, CV = coefficient of variation

Length of bulb (cm)

Length of bulb was measured at final harvest. The findings presented in table 8, 9 and 10 revealed significant effect of varieties and different AOS levels on length of bulb at final harvest. Among varieties, the maximum length of bulb (5.00 cm) was measured from BARI Piaz-VI and the minimum length of bulb (4.64 cm) was calculated from BARI Piaz-I (Table 8). Application of AOS had no effect on length of bulb. The maximum length of bulb (5.17 cm) was recorded with 200ppm AOS while the minimum length of bulb (4.46 cm) was observed under control treatment (Table 9). Combined effect of varieties and AOS levels had no significant effect on length of bulb. The maximum length of bulb (5.70 cm) was found in 200ppm AOS with BARI Piaz-IV at harvesting stage and the minimum length of bulb (4.33 cm) was recorded at control treatment in BARI Piaz-VI (Table 10). Length of bulb is increased after AOS application might be due to promoting effect of AOS on photosynthesis rate and assimilate product accumulation.

Fresh weight of bulb (g)

Fresh weight of bulb was measured at final harvest. The findings presented in table 8, 9 and 10 revealed significant effects of varieties and different AOS levels on fresh weight of bulb at harvesting stage. Among varieties, the maximum fresh weight of bulb (45.31g) was measured with variety BARI Piaz-VI and the minimum fresh weight of bulb (36.62 g) was measured in the case of variety BARI Piaz-I (Table 8).Application of AOS had no effect on fresh weight of bulb. The maximum fresh weight of bulb (44.57 g) was recorded from 200ppm AOS treated plant while the minimum fresh weight of bulb (35.19 g) was observed under control treatment (Table 9). Combined effect of varieties and AOS levels had no significant effect on fresh weight of bulb. The maximum fresh weight of bulb (54.83 g) was found in 200ppm AOS with BARI Piaz-VI at harvesting stage and the minimum fresh weight of bulb (21.57 g) was recorded at control treatment in BARI Piaz-IV (Table 10). Fresh weight of bulb was increased might be due to promoting effect of AOS on photosynthesis rate and assimilate product accumulation. AOS may accelerate the biosynthesis and transport of auxin, which helps in cell division and cell elongation as well as increase the bulb size.

Table 8: Effect of variety on bulb of onion

Variety	Length of bulb(cm)	Fresh weight of bulb(g)
BARI Piaz-I	4.64b	36.62ab
BARI Piaz-IV	4.74ab	35.62b
BARI Piaz-VI	5.00a	45.31a
Significance level	*	*
CV (%)	10.28	14.85

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).
*= Significant at 5% level of probability, NS = Not Significant, CV = coefficient of variation

Table 9: Effect of different AOS levels on bulb of onion

Treatment	Length of bulb(cm)	Fresh weight of bulb(g)
Control	4.46b	35.19b
50ppm AOS	4.72b	38.52b
100ppm AOS	4.83ab	38.44b
200ppm AOS	5.17a	44.57a
Significance level	*	*
CV (%)	10.28	14.85

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).
*= Significant at 5% level of probability, NS = Not Significant, CV = coefficient of variation

Table 10: Combined effect of variety and AOS on bulb of onion

Variety	Treatment	Length of bulb(cm)	Fresh weight of bulb (g)
BARI Piaz-I	Control	4.57bc	33.73ab
	50ppm AOS	4.70bc	35.43ab
	100ppm AOS	4.67bc	42.27ab
	200ppm AOS	4.63bc	48.33ab
BARI Piaz-IV	Control	4.33c	21.57b
	50ppm AOS	4.83bc	42.17ab
	100ppm AOS	5.13ab	44.33ab
	200ppm AOS	5.70a	43.20ab
BARI Piaz-VI	Control	4.33c	29.57b
	50ppm AOS	4.80bc	35.57ab
	100ppm AOS	4.67bc	39.17ab
	200ppm AOS	5.17ab	54.83a
Significance level		*	*
CV (%)		10.28	14.85

Different small alphabets (a, b, c …) in the same column represent the significant differences ($p<0.05$).
*= Significant at 5% level of probability, NS = Not Significant, CV = coefficient of variation

Yield (t/ha)

Yield was measured at after harvesting stage. The findings presented in figure 6, 7, and 8 revealed

significant effects of varieties and different AOS levels on yield at after harvesting stage. Among varieties, the maximum yield (16.31 t/ha) was measured with variety BARI Piaz-VI and the minimum yield (12.82 t/ha) was measured in the case of variety BARI Piaz-I (Fig. 6). Application of AOS had significant effect on yield of onion. The maximum yield (16.04 t/ha) was recorded from 200ppm AOS treated plant whereas, the minimum yield (12.66 t/ha) was observed from control treatment (Fig.7). Combined effect of varieties and AOS levels had significant effect on yield of onion The maximum yield (19.74 t/ha) was noted from 200ppm AOS treated BARI Piaz-VI while, the minimum yield (7.76 t/ha) was recorded from BARI Piaz-IV when no AOS was applied (Fig. 8). AOS application may increase yield of onion by increasing the photosynthetic rate and assimilate product accumulation, and promoting product transfer from leaves to bulb of onion. Li et al. (2023) reported similar results in case of Citrus fruits, they noted that AOS foliar application improved quality and sugar accumulation by increasing the photosynthetic rate and assimilate product accumulation and promoting sugar transfer from leaves to fruits. In another study, Zhao et al. (2022) reported that wheat yield was increased by increasing the number of spikes, the number of grains per spike and 1000 grain weight.

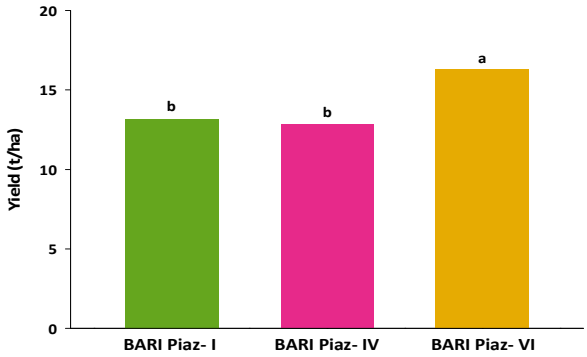

Figure 6: Effect of variety on yield of onion. Different small alphabets (a, b, c …) represent the significant differences ($p<0.05$)

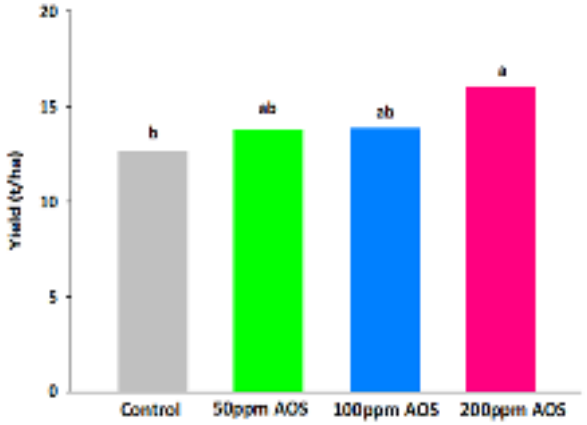

Figure 7: Effect of different AOS levels on yield of onion. Different small alphabets (a, b, c …) represent the significant differences ($p<0.05$)

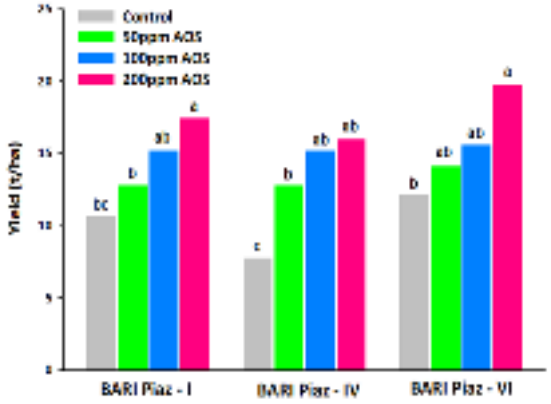

Figure 8: Combined effect of variety and AOS on yield of onion. Different small alphabets (a, b, c …) represent the significant differences ($p<0.05$)

Conclusion

Foliar application of AOS at vegetative stage enhanced the plant growth and development, which resulted increased yield of onion. From the above results it can be concluded that among the different onion varieties used in the present study, BARI Piaz -VI had superior performance in respect of yield of onion. Among the AOS concentration, application of 200ppm showed the highest performance in respect of growth and yield of onion. The present studied results suggest that BARI Piaz-VI variety gave superior performance when treated with 200ppm AOS. However, more experiments should be conducted with increased doses of AOS in different locations and seasons to draw a valid conclusion for improvement of onion yield.

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