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Response of plant bioregulators on growth parameters and plant growth analysis of onion (*Allium cepa* L.)

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Abstract
The experiment was carried out with a view to study the response of plant bioregulators on growth parameters and plant growth analysis of onion at Regional Horticultural Research Station of Navsari Agricultural University, Navsari (Gujarat) during *Rabi* 2018 and 2019. The number of leaves per plant at 45 DATP (7.92), 60 DATP (8.75) and 90 DATP (9.42) and days to maturity (129.17) were found significant on pooled analysis basis under the treatment T_1 (GA_3 25 mg l^{-1}). Among physiological parameters, treatment T_1 (GA_3 25 mg l^{-1}) found best for leaf area index at 60 DATP (2.85), as well as harvest index (93.72) in pooled analysis. Crop growth rate at 60-90 DATP (5.11 g m^{-2} day^{-1}) with T_3 (GA_3 75 mg l^{-1}), net assimilation rate at 60-90 DATP (0.107 g cm^{-2} day^{-1}) with T_8 (GA_3 25 mg l^{-1} + NAA 50 mg l^{-1}) and biomass duration (1287.50 g days) with T_2 (GA_3 50 mg l^{-1}) were found significant on pooled analysis basis.

Keywords: Plant bioregulators, NAA, GA_3, growth and plant growth analysis

Introduction
India is the world's second largest producer of vegetables (187.47 million tonnes) next only to China (Anonymous, 2019). Onion (*Allium cepa* L.) is an important and indispensable item in every kitchen as condiment cum vegetable in India. It is one of the important underground bulbous vegetable crops of Alliaceae family and is said to be native of Central Asia and Mediterranean region (Mc Collum, 1976) [8]. Plant growth regulators are organic compounds other than nutrients which in small amount promotes / inhibit or otherwise modify any physiological response in plant (Purohit, 2007) [16]. Plant bioregulators called as magic chemicals are new generation agrochemicals, when added in small quantity, modify the natural growth regulatory systems right from seed germination to senescence in several vegetable crops and also regulate and modify various physiological processes within the plant and they help to increase the yield (Weaver, 1972) [33].

Materials and methods
The field experiment was carried out at the vegetable research scheme, Regional Horticultural Research Station of the Navsari Agricultural University, Navsari, Gujarat, India during *Rabi* 2018 and 2019 on cv. Gujarat Junagadh Red Onion 11 to investigate the response of plant bioregulators on growth parameters and plant growth analysis of onion. The experiment was conducted in Randomized Block Design (RBD) with three replications, which included 12 treatments namely, T_1: GA_3 25 mg l^{-1}, T_2: GA_3 50 mg l^{-1}, T_3: GA_3 75 mg l^{-1}, T_4: NAA 25 mg l^{-1}, T_5: NAA 50 mg l^{-1}, T_6: NAA 75 mg l^{-1}, T_7: GA_3 25 mg l^{-1} + NAA 25 mg l^{-1}, T_8: GA_3 25 mg l^{-1} + NAA 50 mg l^{-1}, T_9: GA_3 25 mg l^{-1} + NAA 75 mg l^{-1}, T_{10}: GA_3 50 mg l^{-1} + NAA 50 mg l^{-1}, T_{11}: GA_3 75 mg l^{-1} + NAA 75 mg l^{-1} and T_{12}: Control. The foliar sprays were made at 30 days after transplanting during morning hours to avoid the dehydration effect. For recording different observations, ten plants of onion from each net plot area were selected randomly and tagged with labels.

Results and discussion

The data revealed that the plant height was significantly influenced by different treatments under both the years and showed non-significant under pooled analysis (Table 1). The highest plant height was obtained under the treatment of T_1 (GA_3 25 mg l^{-1}) might be due to increasing cell wall extensibility by GA_3. The exogenously applied GA might have activated the endogenous hormonal activates which ultimately led to leaf elongation in onion plant. It was also reported that GA_3 increasing plasticity of cell wall followed by hydrolysis of starch to sugars which lowers the water potential of cell, resulting in the entry of water into the cell causing elongation. Similar findings were reported for onion (Saleh and Abed, 1989; Sharma *et al.*, 1998; Tiwari *et al.*, 2003; Suseela *et al.*, 2005; Singh, 2006; Islam *et al.*, 2007; Rashid, 2010; Ouzounidu *et al*., 2011; Nagwa *et al.*, 2013; Omesh *et al*., 2018) [20, 24, 31, 5, 18, 9, 13] and for garlic (Singh *et al.*, 2014; Govind *et al*., 2015) [27, 2].

Table 1: Effect of different treatments on plant height (cm) at 45, 60 and 90 DATP of onion

Treatments	Plant height (cm)								
	45 DATP			60 DATP			90 DATP		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1: GA_3 25 mg l^{-1}	58.23	67.24	62.73	63.88	78.07	70.98	67.10	80.56	73.83
T_2: GA_3 50 mg l^{-1}	60.72	66.78	63.75	64.53	77.10	70.81	67.56	79.66	73.61
T_3: GA_3 75 mg l^{-1}	59.40	65.12	62.26	63.23	75.79	69.51	65.93	79.28	72.61
T_4: NAA 25 mg l^{-1}	61.98	64.92	63.44	64.95	73.25	69.10	66.76	76.54	71.65
T_5: NAA 50 mg l^{-1}	62.59	66.18	64.39	64.53	74.78	69.66	67.59	76.91	72.25
T_6: NAA 75 mg l^{-1}	62.06	65.24	63.65	64.11	72.54	68.33	67.43	75.60	71.52
T_7: GA_3 25 mg l^{-1}+ NAA 25 mg l^{-1}	58.28	61.90	60.09	63.62	68.71	66.16	67.81	71.24	69.53
T_8: GA_3 25 mg l^{-1} + NAA 50 mg l^{-1}	63.11	64.16	63.64	66.16	73.41	69.78	70.20	77.15	73.67
T_9: GA_3 25 mg l^{-1} + NAA 75 mg l^{-1}	60.34	67.18	63.76	62.96	74.85	68.91	65.20	77.40	71.30
T_{10}: GA_3 50 mg l^{-1} + NAA 50 mg l^{-1}	62.10	64.83	63.47	65.29	73.05	69.17	70.43	75.96	73.20
T_{11}: GA_3 75 mg l^{-1} + NAA 75 mg l^{-1}	57.48	66.27	61.88	61.68	76.99	69.34	65.46	79.31	72.39
T_{12}: Control	59.80	63.82	61.81	62.09	70.83	66.46	65.21	74.99	70.10
Year Mean	60.51	65.30	62.91	63.92	74.11	69.01	67.22	77.05	72.14
S. Em. ±	1.07	1.03	1.24	0.80	1.21	1.55	1.45	1.12	1.67
C.D. at 5%	3.15	3.02	NS	2.36	3.55	NS	NS	3.28	NS
C.V. %	3.08	2.73	2.90	2.18	2.83	1.03	3.75	2.51	3.12
YT: S. Em. ±			1.05			2.93			1.30
YT: C. D. at 5%			3.00			2.58			3.70

Results related to the mean number of leaves plant^{-1} at 45, 60 and 90 DATP of onion as affected by various treatments are provided in Table 2. The results of the pooled analysis of data indicated that the application of GA_3 25 mg l^{-1} (T_1) recorded the maximum number of leaves plant^{-1} (7.92) and was at par with the treatment T_{11} only. At 60 DATP, application of GA_3 25 mg l^{-1} (T_1) recorded maximum number of leaves plant^{-1} (8.75) and was at par with the treatment T_8 and T_{11}. At 90 DATP, the application of GA_3 25 mg l^{-1} (T_1) recorded the maximum number of leaves plant^{-1} (9.42) and was at par with the treatments T_{11} and T_8. The interaction of year × treatment was found non-significant.

The increase in number of leaves per plant is mainly due to enhanced cell elongation and cell division. It enhanced the photosynthesis, respiration and catalyse activities in plant, hence enhanced the number of leaves per plant. The increase in leaf number due to application of GA_3 was also reported earlier in onion (Singh *et al.*, 1983; Shishido and Saito, 1984; Salah *et al.*, 1989; Shakhda and Gajipara, 1998; Hye *et al.*, 2002, Shaikh *et al*., 2002; Subimal *et al.*, 2003; Tiwari *et al.*, 2003; Suseela *et al*., 2005; Patel *et al*., 2010;) [26, 25, 20, 23, 22, 29, 4, 31 30], tomato (Gupta and Gupta, 2000; Rai *et al*., 2006; Nibhavanti *et al*., 2006) [3, 17, 10] and garlic (Singh *et al.*, 2014; Govind *et al.*, 2015) [27, 2]. The plant height and number of leaves per plant linearly increased up to the maximum vegetative growth and thereafter decreased possibly due to the senescence and drying up of tip of the leaves.

Table 2: Effect of different treatments on number of leaves plant^{-1} at 45, 60 and 90 DATP of onion

Treatments	Number of leaves plant^{-1}								
	45 DATP			60 DATP			90 DATP		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1: GA_3 25 mg l^{-1}	7.67	8.17	7.92	8.20	9.30	8.75	9.07	9.77	9.42
T_2: GA_3 50 mg l^{-1}	6.90	7.87	7.38	7.77	8.30	8.03	8.73	8.77	8.75
T_3: GA_3 75 mg l^{-1}	7.03	7.87	7.45	7.63	8.93	8.28	8.10	9.33	8.72
T_4: NAA 25 mg l^{-1}	7.16	7.60	7.38	7.37	8.20	7.78	8.43	8.70	8.57
T_5: NAA 50 mg l^{-1}	6.80	7.30	7.05	7.20	8.63	7.92	8.53	9.03	8.78
T_6: NAA 75 mg l^{-1}	6.90	7.63	7.27	7.40	8.50	7.95	8.43	9.00	8.72
T_7: GA_3 25 mg l^{-1}+ NAA 25 mg l^{-1}	6.73	7.40	7.07	7.67	8.47	8.07	8.40	8.67	8.53
T_8: GA_3 25 mg l^{-1} + NAA 50 mg l^{-1}	6.57	7.53	7.05	7.83	9.20	8.52	8.53	9.73	9.13
T_9: GA_3 25 mg l^{-1} + NAA 75 mg l^{-1}	6.77	7.93	7.35	7.50	8.90	8.20	8.10	9.30	8.70
T_{10}: GA_3 50 mg l^{-1}+ NAA 50 mg l^{-1}	7.03	8.03	7.53	7.63	8.90	8.27	8.33	9.30	8.82
T_{11}: GA_3 75 mg l^{-1} + NAA 75 mg l^{-1}	7.43	8.03	7.73	8.03	8.99	8.51	8.97	9.47	9.22
T_{12}: Control	6.60	7.70	7.15	7.53	8.37	7.95	7.87	9.07	8.47
Year Mean	6.97	7.76	7.36	7.65	8.72	8.19	8.46	9.18	8.82
S. Em. ±	0.22	0.17	0.14	0.18	0.24	0.15	0.23	0.25	0.18

C.D. at 5%	0.64	0.50	0.38	0.54	0.71	0.42	0.68	0.72	0.51
C.V. %	5.41	3.78	4.59	4.16	4.78	4.53	4.75	4.65	4.70
YT: S. Em. ±			0.20			0.21			0.24
YT: C. D. at 5%			NS			NS			NS

The data pertaining to days to maturity as influenced by different treatments are presented in Table 3. The results were found to be non-significant during both the seasons whereas it was found significant in pooled analysis. An analysis of pooled mean data showed that treatment T_1 (GA_3 25 mg l^{-1}) recorded more number of days taken to maturity (129.17) and it was at par with the treatment T_2 (GA_3 50 mg l^{-1}). The plants under the influence of plant growth regulators recorded maximum growth in respect of height of plant, number of leaves *etc.* These plants treated with GA_3 25 mg l^{-1} required more days for their maturity. The control plants however, deprived of such growth regulators functions. Hence, attended early maturity. The results are in conformity with the findings of Singh (2006) [28].

Looking to the mean of pooled analysis, the results of leaf area index under 90 DATP showed non-significant represented in Table 3. During 60 DATP, the maximum leaf area index (2.85) was recorded with the application of T_1 (GA_3 25 mg l^{-1}) which was significantly at par with the treatment T_{10}. However, the values of leaf area index under different treatments were varied from 1.91 to 2.85. Whereas, the minimum leaf area index (1.91) was observed with the treatment T_8 (Table 3). GA_3 induced high leaf area index was reported in onion plants. The similar results also recorded by Nirmal *et al.* (1994) [11] in onion, Khan *et al*. (2006) [6] in tomato and Noor *et al*. (2017) [12] in french bean.

The crop growth rate under different treatments were affected by various treatments represented in Table 3. In pooled analysis, the results showed under crop growth rate was significant. The maximum crop growth rate (5.11 g m^{-2} day^{-1}) was observed with the treatment T_3 (GA_3 75 mg l^{-1}) which was significantly at par with the treatments. The minimum crop growth rate (2.68 g m^{-2} day^{-1}) was noted in T_4 (NAA 25 mg l^{-1}). The interaction of year × treatment was found non-significant. Whereas, for crop growth rate similar results were observed with Noor *et al.* (2017) [12] in French bean, Vishal *et al*. (2016) [32] in strawberry and Sarkar *et al.* (2002) [21] in soyabean.

Results related to the net assimilation rate were noticed in Table 4. Looking to the mean of pooled analysis, highest net assimilation rate (0.107 g cm^{-2} day^{-1}) was recorded with the treatment T_8 (GA_3 25 mg l^{-1} + NAA 50 mg l^{-1}) followed by T_3. The minimum net assimilation rate (0.043g cm^{-2} day^{-1}) was found with T_4. The interaction of year × treatment was found non-significant.

In pooled analysis, the harvest index of different treatments were represented in Table 4. The significantly maximum harvest index (93.72%) was recorded with application of T_1 (GA_3 25 mg l^{-1}) which was significantly at par with the treatments T_{10}, T_9, T_8, T_7, T_4 and T_3. Whereas, the minimum harvest index (86.87%) observed with T_{11} (GA_3 75 mg l^{-1} + NAA 75 mg l^{-1}). The interaction of year × treatment was found non-significant. A positive influence of GA_3 on harvest index was reported by Emonger (2007) in cow pea, Noor *et al*. (2017) [12] in french bean and Kumar *et al.* (2018) [7] in coriander.

The data related to the biomass duration of different treatments were mentioned in Table 4. In pooled analysis, the application of T_2 (GA_3 50 mg l^{-1}) recorded maximum biomass duration (1287.50 g days) which was significantly at par with the treatments T_{10}, T_5 and T_7. Whereas, the minimum biomass duration (1114.92 g days) was observed with the treatment T_{12} (Control). The interaction of year × treatment was found non-significant.

Table 3: Effect of different treatments on days to maturity, LAI at 60 and 90 DATP and crop growth rate (g m^{-2} day^{-1}) at 60-90 DATP in onion

Treatments	Days to maturity			Leaf Area Index (LAI) 60 DATP			Leaf Area Index (LAI) 90 DATP			Crop Growth Rate (g m^{-2} day^{-1}) at 60-90 DATP		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1: GA_3 25 mg l^{-1}	128.67	129.67	129.17	2.85	2.84	2.85	2.48	3.71	3.09	4.44	4.33	4.39
T_2: GA_3 50 mg l^{-1}	125.67	126.33	126.00	2.36	2.42	2.39	2.79	3.12	2.95	5.00	4.89	4.94
T_3: GA_3 75 mg l^{-1}	122.33	121.00	121.67	2.26	2.38	2.32	2.89	3.24	3.06	4.74	5.48	5.11
T_4: NAA 25 mg l^{-1}	121.00	126.00	123.50	2.37	2.41	2.39	2.99	3.27	3.13	2.62	2.74	2.68
T_5: NAA 50 mg l^{-1}	124.00	125.67	124.83	2.45	2.59	2.52	2.86	3.41	3.14	4.59	4.59	4.59
T_6: NAA 75 mg l^{-1}	120.67	123.00	121.83	2.55	2.60	2.57	3.09	3.33	3.21	4.85	4.48	4.66
T_7: GA_3 25 mg l^{-1}+ NAA25 mg l^{-1}	123.33	124.67	124.00	2.11	1.89	2.00	2.77	2.96	2.87	4.18	5.59	4.88
T_8: GA_3 25 mg l^{-1} + NAA 50 mg l^{-1}	119.67	119.00	119.33	1.91	1.91	1.91	2.53	2.92	2.73	4.37	5.78	5.07
T_9: GA_3 25 mg l^{-1} + NAA 75 mg l^{-1}	123.00	123.00	123.00	2.01	1.90	1.96	2.69	2.84	2.77	2.96	3.81	3.39
T_{10}: GA_3 50 mg l^{-1}+ NAA 50 mg l^{-1}	122.67	122.67	122.67	2.68	2.74	2.71	3.32	3.55	3.44	4.55	2.89	3.72
T_{11}: GA_3 75 mg l^{-1} + NAA 75 mg l^{-1}	121.33	122.00	121.67	2.16	2.04	2.10	2.78	3.00	2.89	3.66	4.93	4.30
T_{12}: Control	119.33	118.33	118.83	1.95	1.90	1.93	2.65	2.75	2.70	3.15	3.44	3.29
Year Mean	122.64	123.44	123.04	2.31	2.30	2.30	2.82	3.18	3.00	4.09	4.41	4.25
S. Em. ±	1.88	2.16	1.34	0.12	0.13	0.08	0.41	0.16	0.21	0.44	0.56	0.37
C.D. at 5%	NS	NS	3.79	0.35	0.38	0.23	NS	0.48	NS	1.28	1.64	1.06
C.V. %	2.66	3.03	2.85	8.89	9.67	9.28	24.89	8.88	17.84	18.44	21.99	20.44
YT: S. Em. ±			2.02			0.12			0.31			0.50
YT: C. D. at 5%			NS			NS			NS			NS

Table 4: Effect of different treatments on net assimilation rate (g cm^{-2} day^{-1}) at 60-90 DATP, harvest index (%) and biomass duration (g days) in onion

Treatments	Net Assimilation Rate (g $cm^{-2}day^{-1}$) at 60-90 DATP			Harvest Index (%)			Biomass Duration (g days)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1: GA_3 25 mg l^{-1}	0.060	0.057	0.059	91.67	95.77	93.72	1125.00	1162.50	1143.75
T_2: GA_3 50 mg l^{-1}	0.085	0.078	0.081	88.60	88.81	88.70	1227.50	1347.50	1287.50
T_3: GA_3 75 mg l^{-1}	0.083	0.086	0.085	84.05	91.64	87.84	1200.00	1220.00	1210.00
T_4: NAA 25 mg l^{-1}	0.043	0.042	0.043	88.39	92.61	90.50	1192.50	1155.00	1173.75
T_5: NAA 50 mg l^{-1}	0.069	0.066	0.068	87.92	90.78	89.35	1245.00	1260.00	1252.50
T_6: NAA 75 mg l^{-1}	0.075	0.066	0.071	87.77	92.65	90.21	1167.50	1147.50	1157.50
T_7: GA_3 25 mg l^{-1} + NAA 25 mg l^{-1}	0.069	0.103	0.086	89.89	92.25	91.07	1257.50	1222.50	1240.00
T_8: GA_3 25 mg l^{-1} + NAA 50 mg l^{-1}	0.107	0.107	0.107	88.82	93.55	91.18	1130.00	1147.50	1138.75
T_9: GA_3 25 mg l^{-1} + NAA 75 mg l^{-1}	0.057	0.071	0.064	90.05	92.59	91.72	1160.00	1172.50	1166.25
T_{10}: GA_3 50 mg l^{-1} + NAA 50 mg l^{-1}	0.066	0.040	0.053	90.91	93.61	92.26	1267.50	1275.00	1271.25
T_{11}: GA_3 75 mg l^{-1} + NAA 75 mg l^{-1}	0.076	0.086	0.081	83.91	89.84	86.87	1227.50	1197.50	1212.50
T_{12}: Control	0.058	0.070	0.064	89.23	86.31	87.77	1132.50	1097.33	1114.92
Year Mean	0.071	0.073	0.071	88.50	91.70	90.10	1194.38	1200.40	1197.39
S. Em. ±	0.007	0.008	0.006	1.62	1.65	1.20	23.65	39.31	22.79
C.D. at 5%	0.021	0.023	0.016	4.74	4.85	3.41	69.37	115.30	64.61
C.V. %	17.76	18.29	18.04	3.17	3.12	3.14	3.43	5.67	4.69
YT: S. Em. ±			0.008			1.64			32.44
YT: C. D. at 5%			NS			NS			NS

Conclusion

The effect of foliar application of GA_3 and NAA on growth characters namely, plant height at 45, 60 and 90 DATP found non-significant and number of leaves per plant at 45 DATP (7.92), 60 DATP (8.75) and 90 DATP (9.42) and days to maturity (129.17) found significant on pooled analysis basis. In all the growth parameters, treatment T_1 (GA_3 25 mg l^{-1}) found as a best treatment. Among physiological parameters, leaf area index at 60 DATP (2.85), harvest index (93.72) was found significant on pooled analysis basis, and treatment T_1 (GA_3 25 mg l^{-1}) found as a best treatment. Crop growth rate at 60-90 DATP (5.11 g m^{-2} day^{-1}) with T_3 (GA_3 75 mg l^{-1}), net assimilation rate at 60-90 DATP (0.107 g cm^{-2} day^{-1}) with T_8 (GA_3 25 mg l^{-1} + NAA 50 mg l^{-1}) and biomass duration (1287.50 g days) with T_2 (GA_3 50 mg l^{-1}) was found significant on pooled analysis basis.

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