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Effect of Foliar Application of Growth Regulators on Growth and Yield of Onion (*Allium cepa*)

Dabit Bista*, Dikshya Sapkota, Hemanta Paudel, and Gaurav Adhikari

Agriculture and Forestry University, Chitwan, Nepal

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ABSTRACT

A field experiment was conducted at Horticulture Farm of Agriculture and Forestry University, Rampur, Chitwan, Nepal from 1 December to30 April of 2018/19 to evaluate the effect of plant growth regulators on onion (Allium cepa cv. Nasik-53). The experiment was laid out in a Randomized Complete Block Design (RCBD) with 13 treatments. Growth regulators including: GA3 and NAA each at 75, 150 and 200 mg L^{-1} concentrations together with the combined forms were applied at 3 and 7 leaf stages of onion crop and the obtained data were compared with the control (distilled water spray) plants. Each treatment was replicated three times. The application of combination of 150 mg L^{-1} NAA at 3 leaf stage and 150 mg L^{-1} GA3 at 7 leaf stage resulted in highest values for plant height (76.67 cm), number of leaves (11.33), stem diameter (2.19 cm), bulb diameter (7.55 cm) and fresh weight (72.66 gm) while the control treatment resulted in the lowest values for all these attributes. Therefore, the combined application of 150 mg L^{-1} of NAA at 3-leaf stage and 150 mg L^{-1} of GA3 at 7 leaf stage can be recommended to enhance the growth and yield of onion.

Introduction

Onion (*Allium cepa* L.), an important vegetable crop in Nepal, stands at the third position in production among the vegetable crops in the world after tomato and cabbage (Acharya and Shrestha, 2018). Onion productivity in Nepal is (13.94 Mt/ha) low in comparison to neighboring countries like China (21.99 Mt/ha) and India (16.18 Mt/ha). Nepal has a per capita consumption of fresh onion of 7.7 kg, which is lower than the global average of 10.8 kg (Kaini, 2020). Koirala et al. (1995) reported that the onion production of Nepal is less than half of its annual demand, prompting the county to import 178500 tons of onion worth Rs. 5.62 billion in the fiscal year 2018/19. Nepal has already imported 8010 tons of onion worth Rs. 2950000 in the first month of this fiscal year 2020/21 (Kafle, 2020).

* Corresponding Author, Email: bistadabitraj@gmail.com
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Among the various interventions, using plant growth regulators (PGRs) is one of the easy methods to enhance onion productivity. The PGRs are organic compounds that in small amounts can modify the growth (Chaurasiya et al., 2014). These compounds naturally occur in plants but, when applied externally in small quantities, promote, inhibit or modify physiological processes. Rashid (2010) reported the potential of using different PGRs in improving the yield of onions. Safdari et al. (2014) suggested that growth regulators control the vegetative growth, flowering, fruiting, and seed production in plants, increasing production rate and quality as well as market-friendly products.

Gibberellins are one the major plant growth regulators with its gibbane structure which modifies growth, yield, and yield contributing characteristics of plants (Rafeekher et al., 2002). Asgharzadeh (2014) reported that the foliar spray of gibberellic acid increased the number of marketable bulbs in the total yield of onion. Plant height, number of leaves, bulb diameter, bulb weight, bulb yield, and total soluble solids of onion was significantly affected by NAA (Singh et al., 2019). Both gibberellic acid, the auxin form, Naphthalene acetic acid (NAA), and their combined treatments have slowly gained prominence through foliar application.

Although PGRs have the potential to increase the quality, yield, and yield components of onion, the effect of these PGRs has not been explored enough in the Nepalese context. We conducted this study with the objective of finding the effect of PGRs on the growth and yield of onion. This research investigates the effect of different plant growth regulators on the growth and yield of onions which can significantly help to increase the yield of onion.

Materials and Methods

Experimental details

A field experiment was conducted at the Olericulture farm of the Horticulture Department, Agriculture and Forestry University, Rampur, Chitwan, Nepal (27°40′ N, 84°30′ E, and 200 m.a.s.l), from 1 November, 2018 to 20 April, 2019. The location is characterized by subtropical climate with uni-modal rainfall patterns with peak rainfall during June/July.

The meteorological data for cropping season was extracted from the database at NASA power. The average maximum and minimum mean daily temperatures were 21.99 ˚C and 10.64 ˚C, respectively and the maximum precipitation was 28.45 mm (Fig. 1).

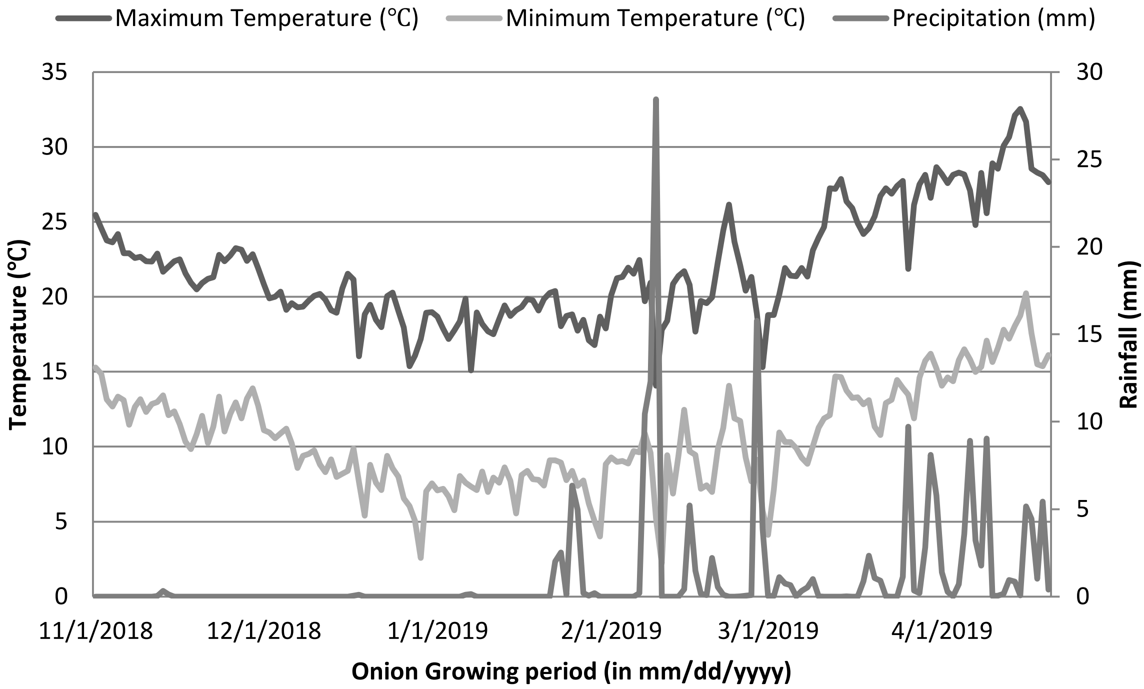

Fig. 1. Weather data of experimental location during the growing season of onion in 2018/19 at Rampur, Chitwan, Nepal (NASA power, n.d.)

Plant Material

The seeds of Nasik-53 were bought from local agro-vets. Nasik-53 is large bulbed red karif onions. These seeds were treated with 63% Mancozeb+ 12% Carbendazim W.P. (commercially known as SAFF) fungicides before planting.

Experimental design

The experiment was performed in randomized complete block design and each treatment was replicated thrice in the trial. The experiment consisted of thirteen treatments, which are described as follow:

T1	Control (water spray)
T2	NAA 75 mg L^{-1} at 3 leaf stage and at 7 leaf stage.
T3	NAA 150 mg L^{-1} at 3 leaf stage and at 7 leaf stage.
T4	NAA 200 mg L^{-1} at 3 leaf stage and at 7 leaf stage.
T5	GA3 75 mg L^{-1} at 3 leaf stage and at 7 leaf stage.
T6	GA3 150 mg L^{-1} at 3 leaf stage and at 7 leaf stage.
T7	GA3 200 mg L^{-1} at 3 leaf stage and at 7 leaf stage.
T8	GA3 75 mg L^{-1} at 3 leaf stage + NAA 75 mg L^{-1} at 7 leaf stage
T9	GA3 150 mg L^{-1} at 3 leaf stage + NAA 150 mg L^{-1} at 7 leaf stage
T10	GA3 200 mg L^{-1} at 3 leaf stage + NAA 200 mg L^{-1} at 7 leaf stage
T11	NAA 75 mg L^{-1} at 3 leaf stage + GA3 75 mg L^{-1} at 7 leaf stage
T12	NAA 150 mg L^{-1} at 3 leaf stage + GA3 150 mg L^{-1} at 7 leaf stage
T13	NAA 200 mg L^{-1} at 3 leaf stage + GA3 200 mg L^{-1} at 7 leaf stage

The chemicals were bought from nearby Agro-Vet, with each under the trade name of Gibberellic Acid and NAA. The plant growth regulators were prepared according to the concentration of different treatments and were sprayed with the knapsack sprayer, whereas distilled water was sprayed on the plants of control treatment.

The treatment was done twice, first at 3 leaf stage and second at 7 leaf stage. There were a total of 39 individual plots of 0.54 m^2, 15 cm between rows, and 10 cm between two individual plants, making almost 70 m^2. Each plot consisted of 49 plants, out of which 10 were taken as sample plants randomly, with a total population of 1911 plants in the overall experimental plot.

Agronomic practices

A fine tilth nursery bed was prepared by incorporating farmyard manure (FYM) 15 days prior to tillage. Line sowing was done on 1 December, 2018. A thin layer mixture of sand and soil was prepared to cover the sown seeds.

The land was tilled using primary tillage followed by two secondary tillage. Farmyard manure was incorporated 15 days before the transplantation, and one-month-old seedlings were transplanted on the main field on 5 January, 2019. From the recommended dose of NPK of 240:80:80 kg/ha, a full dose of potassium and phosphorus and half dose of nitrogen were applied during the basal application. The remaining dose of nitrogen was split into two doses and applied. At every 15 days interval, the field was irrigated. Similarly, the entire research field was made weed-free throughout the entire crop season.

Onions were harvested at maturity after 50% of the plants started drying and falling off their tops. The entire plants were pulled along with the leaves and left in the field. Finally, a sharp, clean knife was used to cut the foliage leaving a 2.5 cm top above the bulbs.

Data acquisition

Height of plant and leaves per plant was recorded to observe growth. In addition, to measure yield and yield contributing characteristics, stem diameter, bulb diameter, and the weight of the fresh bulb were collected.

Plant height was measured using measuring tape from the base to the top of the plant. The total number of leaves was counted numerically. Similarly, stem diameter and bulb diameter was measured by vernier calipers. The fresh weight of the onions was calculated using a digital scale of trade name WeiHeng.

Statistical analysis

The collected data were processed using MS Excel, and the analysis of variance (ANOVA) was performed using R-studio. Multiple comparisons among the means were tested using Duncan's Multiple Range Test (DMRT) at a 5% level of significance (Gomez and Gomez, 1984).

Results

Growth measurements

Height of plant

Table 1 show cases the marked influence of application of different treatments of growth regulators on plant height at different crop stages, i.e., 60 and 90 days after transplanting at a 0.1% level of significance. The maximum height (71.47 cm) was recorded in treatment T12 which is NAA 150 mg L^{-1} at 3 leaf stage and GA3 150 mg L^{-1} at 7 leaf stage, followed by T3 (68.33 cm) that is NAA 150 mg L^{-1} at both 3 and 7 leaf stages at 60 DAT. The height reported in T12 and T3 treatment was found statistically same. The least height was recorded on treatment T1 (45.00 cm) that is control.

A similar trend of plant height was recorded at 90 DAT, with treatment T12 reporting significantly maximum plant height (76.67 cm), followed by T3 (69.00 cm) and T8 (66.80 cm). The height reported from T3 and T8 was statistically similar. Treatment T1 reported the least height (53.53 cm).

Table 1. Effect of foliar application of plant growth regulators on the height of onion (*Allium cepa.*) in Rampur, Chitwan, Nepal, in 2018/2019

Treatments	Height of Plant (cm) Days after transplanting	
	60* **	**90** **
T1 (Control)	45.00^{f}	53.53^{f}
T2 (NAA 75 mg L^{-1})	59.60^{d}	62.27^{cd}
T3 (NAA 150 mg L^{-1})	68.33^{ab}	69.00^{b}
T4 (NAA 200 mg L^{-1})	57.27^{d}	59.80^{de}
T5 (GA3 75 mg L^{-1})	52.67^{e}	60.53^{de}
T6 (GA3 150 mg L^{-1})	56.73^{d}	61.07^{de}
T7 (GA3 200 mg L^{-1})	52.67^{e}	61.60^{cde}
T8 (GA3 75 mg L^{-1}+ NAA 75 mg L^{-1})	66.27^{bc}	66.80^{b}
T9 (GA3 150 mg L^{-1}+ NAA 150 mg L^{-1})	63.47^{c}	63.87^{c}
T10 (GA3 200 mg L^{-1}+ NAA 200 mg L^{-1})	56.57^{d}	59.17^{e}
T11 (NAA 75 mg L^{-1}+ GA3 75 mg L^{-1})	57.20^{d}	60.00^{de}
T12 (NAA 150 mg L^{-1}+ GA3 150 mg L^{-1})	**71.47^{a}**	**76.67^{a}**
T13 (NAA 200 mg L^{-1}+ GA3 200 mg L^{-1})	49.13^{e}	61.53^{cde}
SEM (±)	2.59	1.24
LSD (0.05)	3.57	2.47
C.V. %	3.64	2.34
F-value	38.76	43.32
Mean	58.18	62.75

Note: Means followed by a common letter superscript within a column are non-significantly different, whereas the means followed by different letter superscripts within a column are significantly different based on Duncan's Multiple Range Test (DMRT) at P=0.05; NS: Non-Significant; SEM: Standard Error of Mean; CV: Coefficient of Variation; *, ** and *** are significant at P=0.05, P=0.01 and P<0.001, respectively.

Number of leaves per plant

From Table 2, we can infer the highest number of leaves (8.27) from treatment T12 that uses NAA 150 mg L^{-1} at 3 leaf stage and GA3 150 mg L^{-1} at 7 leaf stage. Treatments T2 (7.90), T3 (8.07), T8 (7.87), T9 (7.90), T10 (7.87) and T11 (8.00) reported to have statistically similar number of leaves to the T12 treatment whereas, the lowest number of leaves was recorded on treatment T1 (6.30), which is control.

Table 2. Effect of foliar application of plant growth regulators on the number of leaves of onion (*Allium cepa.*) in Rampur, Chitwan, Nepal, in 2018/2019

Treatments	Leaves per Plant Days after transplanting	
	60* **	**90** **
T1 (Control)	6.30^{d}	9.00^{d}
T2 (NAA 75mg L^{-1})	7.90^{ab}	10.53^{abc}
T3 (NAA 150mg L^{-1})	8.07^{ab}	11.07^{ab}
T4 (NAA 200mg L^{-1})	7.57^{b}	10.53^{abc}
T5 (GA3 75mg L^{-1})	6.80^{c}	10.00^{bc}
T6 (GA3 150mg L^{-1})	7.07^{c}	10.67^{abc}
T7 (GA3 200mg L^{-1})	7.67^{b}	10.87^{ab}

T8 (GA3 75mg L-1+ NAA 75mg L-1)	7.87[ab]	10.90[ab]
T9 (GA3 150mg L-1+ NAA 150mg L-1)	7.90[ab]	10.40[abc]
T10 (GA3 200mg L-1+ NAA 200mg L-1)	7.87[ab]	10.60[abc]
T11 (NAA 75mg L-1+ GA3 75mg L-1)	8.00[ab]	10.81[ab]
T12 (NAA 150mg L-1+ GA3 150mg L-1)	**8.27[a]**	**11.33[a]**
T13 (NAA 200mg L-1+ GA3 200mg L-1)	6.87[c]	9.67[cd]
SEM (±)	0.04	0.16
LSD (0.05)	0.81	0.89
C.V. %	3.52	5.07
F-value	15.03	4.11
Mean	7.54	10.49

Note: Means followed by a common letter superscript within a column are non-significantly different, whereas the means followed by different letter superscripts within a column are significantly different based on Duncan's Multiple Range Test (DMRT) at P=0.05; NS: Non-Significant; SEM: Standard Error of Mean; CV: Coefficient of Variation; *, ** and *** are significant at P=0.05, P=0.02 and P<0.001, respectively.

Similar trends in the number of leaves were recorded at 90 DAT, with treatment T12 reporting significantly maximum number of leaves (11.33) and treatment T1 reporting the least (9.0). Similarly, treatments T3 (11.07), T7 (10.87), T8 (10.90) and T11 (10.81) reported statistically similar numbers of leaves to T12 treatment. Analysis of Variance clearly signifies the number of leaves is highly significant at different stages of crop growth at 60 and 90 DAT at 0.1% and 1% level of significance, respectively.

Yield and yield contributing observations

The stem diameter of the onion was also found to be significantly influenced by the different treatments of growth regulators at various concentrations, as shown in Table 3 at a 0.1% level of significance. The treatment T12 that uses NAA 150 mg L-1 at 3 leaf stage and GA3 150 mg L-1 at 7 leaf stage recorded maximum stem diameter (2.13 cm). It was followed by T8 (1.55 cm) using GA3 75 mg L-1 at 3 leaf stage and NAA 75 mg L-1 at 7 leaf stage, and T2 (1.53 cm) that use NAA 75 mg L-1 at both 3 and 7 leaf stages both of which was statistically similar. The smallest stem diameter was recorded on T1 (0.96 cm) which was under control.

Table 3. Effect of foliar application of plant growth regulators on the yield and yield contributing attributes of onion (*Allium cepa*) in Rampur, Chitwan, Nepal, in 2018/2019

Treatments	**Stem diameter (cm)*** **	**Bulb Diameter (cm)*** **	**Fresh weight (g)***
T1 (Control)	0.96[g]	3.93[e]	38.86[d]
T2 (NAA 75mg L-1)	1.53[b]	4.89[bcde]	57.10[abcd]
T3 (NAA 150mg L-1)	1.51[bc]	**7.32[a]**	62.06[abc]
T4 (NAA 200mg L-1)	1.18[efg]	4.31[cde]	58.53[abcd]
T5 (GA3 75mg L-1)	1.06[fg]	5.18[bc]	51.00[cd]
T6 (GA3 150mg L-1)	1.27[ef]	5.41[b]	53.40[abcd]
T7 (GA3 200mg L-1)	1.23[cdef]	5.25[bc]	55.07[abcd]
T8 (GA3 75mg L-1+ NAA 75mg L-1)	1.55[b]	4.06[de]	69.86[abc]
T9 (GA3 150mg L-1+ NAA 150mg L-1)	1.50[bcd]	4.93[bcd]	70.93[ab]
T10 (GA3 200mg L-1+ NAA 200mg L-1)	1.18[efg]	5.00[bcd]	66.26[abc]
T11 (NAA 75mg L-1+ GA3 75mg L-1)	1.26[def]	5.48[b]	63.73[abc]

Treatments	Stem diameter (cm)***	Bulb Diameter (cm)***	Fresh weight (g)*
T12 (NAA 150mg L^{-1}+ GA3 150mg L^{-1})	**.2.13[a]**	**7.55[a]**	**72.66[a]**
T13 (NAA 200mg L^{-1}+ GA3 200mg L^{-1})	1.36[b]	4.70[bcde]	53.73[abcd]
SEM (±)	0.009	0.15	66.18
LSD (0.05)	0.22	0.88	18.24
C.V. %	9.55	9.98	18.30
F-value	15.22	13.1	2.44
Mean	1.36	5.23	59.14

Note: Means followed by a common letter superscript within a column are non-significantly different, whereas the means followed by different letter superscripts within a column are significantly different based on Duncan's Multiple Range Test (DMRT) at P=0.05; NS: Non-Significant; SEM: Standard Error of Mean; CV: Coefficient of Variation; *, ** and *** are significant at P=0.05, P=0.02 and P<0.00 respectively.

Similarly, the application of different plant growth regulators was found to have a significant effect on the bulb diameter of the onion at a 0.1% level of significance. The highest bulb diameter (7.55 cm) was recorded in the T12 treatment that is NAA 150 mg L^{-1} at 3 leaf stage and GA3 150 ppm at 7 leaf stage, which is at par with the T3 treatment (7.32 cm) that uses NAA 150 mg L^{-1} at both 3 and 7 leaf stages whereas the smallest bulb diameter was recorded in the T1 treatment (3.93 cm) that is under control.

Finally, the growth regulators were also found to have a significant effect on the fresh weight of onion with most heavy (72.66 g) from T12 i.e. NAA 150 mg L^{-1} at 3 leaf stage and GA3 150 mg L^{-1} at 7 leaf stage followed by and at par with T9 (70.93 g) i.e. GA3 150 mg L^{-1} at 3 leaf stage and NAA 150 mg L^{-1} at 7 leaf stage while the least weight (38.86 g) was reported from T1 i.e. control.

Discussion

Plant growth regulators play an important role in altering the plant physiology affecting overall vegetative growth parameters and improving the production and productivity. The use of plant growth regulators were significantly increased the plant height of onion both at 60 DAT and 90 DAT as shown in Table 1. The trend was identical with the number of leaves at both 60 DAT and 90 DAT. Plant growth regulators are found to enhance the vegetative growth of plants through cell division, cell elongation and vascular tissue differentiation. Analysis of Variance showcases better yield attributes and yield from the plots treated with the plant growth regulators in comparison to control. All of the stem diameter, bulb diameter, and fresh weight were reported significantly superior to plot treated with water.

Gibberellins accelerate cell elongation and cell division in sub apical meristem region increasing the plant height. This increase is the result of an increase in auxin in plant tissues by inducing the tryptophan conversion to IAA promoting cell division and cell elongation. Kanwar and Khandelwal (2013) and Singh (2004) reported the increase in plant height with the application of gibberellic acid by increasing the length of internodes of marigold. Ouzounidou et al. (2011) agrees to this analogy with the report of the stem elongation of onion and garlic by 35% and 25% as compared to control. There was a significant increase in both dry and fresh shoot biomass of both onion and garlic that led to higher yields in the plots treated with GA3.

Similarly, NAA and GA3 performed better in comparison to the control plot in the trial conducted by Singh et al (2018). They also reported increased total yield, bulb fresh weight and diameter which may be due to cell division and rapid cell elongation induced by GA3 and NAA in the growing portion that helped increase the bulb size. Auxins play an important role in cell division, vascular tissue differentiation, and apical dominance. Both NAA and Gibberellic acid play a role in auxin production within plant metabolism. These research findings are parallel with the findings of Jyoti et al. (2018). GA3 and NAA when applied together was found to stimulate the plant growth with significant effect on plant height which was reported in Ud-deen (2009).

Sharma et al. (2013) supports the idea of increase in diameter and fresh weight of onion bulb and vegetative performance of onion plants by application of plant growth regulators. The improved vegetative traits of onion improved the photosynthesis in plants leading to accumulation of more photosynthates which in turn increased the number of bulb scales, and ultimately accelerate dry weight of onions (Jyoti, 2017). These findings were also supported by findings of Shukla et al. (2010) and Mondal and Shukla (2005) that showcased improved performance of onion when treated with GA3 and NAA plant growth regulators.

Conclusion

Different plant growth regulators have a significant effect on the growth and yield and yield attributing characters significantly. On the basis of our experiment, the best attributes were achieved from the application of NAA 150 mg L^{-1} at 3 leaf stage and GA3 150 mg L^{-1} at 7 leaf stage i.e. T12. Therefore, the application of NAA 150 mg L^{-1} at 3 leaf stage and GA3 150 mg L^{-1} at 7 leaf stage can be recommended for the onion to achieve the best yield and other plant attributes. Since our research findings are based on the data from a single season, at least an additional season hassle of study is recommended. The findings will be useful for the local farmers as well as the future research initiatives.

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Conflict of Interest

The authors have not declared any conflict of interests.

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