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Impact of indole-3-acetic acid and naphthalene acetic acid foliar application on onion growth with or without mulching

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Abstract

Onion is the most important crop throughout the world. Onion yield production in Pakistan is lower than in some other countries. Consumption of onions increases day by day due to an increase in population. An experiment was conducted at UAF Sub-campus Burewala during winter 2019-2020 to assess the effect of IAA and NAA on the growth, yield and development of onion. Three levels of IAA (100, 200, 300 ppm) and three levels of NAA (50, 100, 150 ppm) were tested under RCBD layout with fourteen (14) treatments and two replications. Different parameters like (Leaf length, Leaf number, Neck diameter, Rate of increase in leaf length, Leaf number increase rate, Rate of increase in neck diameter) were recorded and analyzed using Analysis of Variance (ANOVA). Results revealed that 100 ppm IAA, particularly under mulched conditions, significantly ($p \leq 0.05$) enhanced all morphological attributes. Although direct yield data were not collected, the substantial improvement in growth parameters suggests a potential increase in bulb yield. Keeping in view the results of the experiment onion crop with 100 ppm IAA is recommended.

1. Introduction

The cultivated Onion (*Allium cepa*) belongs to the family Alliaceae and is grown in a wide range of climates from temperate to tropical and is of great economic importance. Onions are the largest commercial crop in the world and are used for food and medicine in ancient times (Hossain *et al.,* 2008; Marrelli *et al.,* 2018; Yang *et al.,* 2004).

Despite its importance, onion productivity is often limited by suboptimal agronomic practices and unfavorable environmental conditions. Enhancing yield through sustainable agronomic interventions is essential to meet increasing demand. In this context, plant growth regulators (PGRs) have been widely studied for their potential to promote plant growth and improve crop productivity. Numerous plant growth and physiological processes are known to be altered and regulated by PGRs, or plant growth regulators.

One of the Auxin family's most advantageous PGRs is naphthalene acetic acid (NAA). Onion vegetative growth increased when NAA levels rose, as indicated by plant height, number of leaves per plant, and bulb diameter. IAA helps in the production of long roots with an increased number of root hairs and root laterals, which are involved in nutrient uptake (Abdoli *et al.,* 2013). According to Hussein *et al.* (2018), vitamin E at 100 ppm produced the largest overall bulb output with the best physical and chemical characteristics. Gibberellins and ethereal were next applied at 100 ppm. The maximum bulb output was obtained when ethereal was sprayed at 25 ppm; however, a greater average rate of bulbs was obtained when 50 ppm was used (Sravani *et al.,* 2020). Ethereal caused bulb initiation in onion (Habba, 2002).

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Okra and NAA application. Additionally, the majority of the parameters were found to be suppressed by the injection of NAA at greater doses (> 50 ppm). The majority of parameters and NAA concentrations showed a quadratic relationship, which further supported this finding. For example, when lower rates of NAA (10 and 30 ppm, respectively) were applied, the onset of first flowering occurred 7 and 5 days earlier. This was followed by a gradual delay as the concentration of NAA increased to its maximum level (110 ppm), which resulted in a maximum delay of 12.7 days in the onset of first flowering compared to the control (0 ppm NAA) (Abdo & Abdel-Aziz, 2009). Solanki and Rawat (2011) reported that foliar NAA treatment significantly affected the factors influencing the vegetative, reproductive, and yield formation of okra.

Among plant Growth regulators, Naphthalene acetic acid (NAA) and Indole acetic acid (IAA) can promote plant rooting, which are commonly used in plant cutting propagation (Abdoli *et al.,* 2013). Alongside plant growth regulators, mulching remains a reliable method for enhancing soil health and supporting better plant performance.

Mulching technologies are widely used and proven methods to increase crop yields, especially in arid regions. By modifying the microbial biomass (Chakraborty *et al.,* 2010), improving nutrient cycling (Kader *et al.,* 2017), decreasing soil CO_2 emissions (Dossou-Yovo *et al.,* 2015), preserving the soil organic carbon balance (Zribi *et al.,* 2015), and improving soil aggregate stability (Anikwe *et al.,* 2007), mulching the soil offers numerous additional advantages, decreasing plant infestation (Chakraborty *et al.,* 2010) and increasing soil enzyme activity (Fatima & Arora, 2019). Ultraviolet (UV) reflective mulches have become popular in the production of various crops for their ability to reduce insect pest pressure (Ren *et al.,* 2020). Row covering with polyethylene film (plastic mulch) has been adopted to modify soil microclimate, especially to increase soil temperature in agricultural production (Gordon et al., 2010)

2. Materials and Methods

2.1. Materials

Measuring cylinder of 100ml, 6 beakers of 1000ml and 6 conical flasks of 100ml. All these instruments are acquired from the horticulture laboratory of UAF Sub-Campus Burewala-Vehari. Distilled water is used for the solution preparation, which is used for the foliar application on onion plants. Six spray bottles and a Shower are purchased from the local market for the foliar application on onion plants.

2.2. Methods

Onion (*Allium cepa L.*) was sown on both sides of ridges, keeping plant distance at 4 inches, on 2 January 2021. Fertilizers were applied 2 weeks after onion seeding and transplanting. Urea 4.5 kg, DAP 4.0 kg, and SOP 3.7 kg on onion plants. Irrigation of onion plants was done on 19 February 2021, and the second irrigation was on 5 March 2021. Fourteen furrows were then divided into plots and subplots according to the experimental treatments (Table 1).

Table 1. Details of Experimental Treatments

Treatment No.	Factor A: Mulching	Factor B: Chemicals
T_1	Mulched	IAA 100ppm
T_2	Mulched	IAA 200ppm
T_3	Mulched	IAA 300ppm
T_4	Mulched	NAA 50ppm
T_5	Mulched	NAA 100ppm
T_6	Mulched	NAA 150ppm
T_7	Mulched	Control
T_8	Non-Mulched	IAA 100ppm
T_9	Non-Mulched	IAA 200ppm
T_{10}	Non-Mulched	IAA 300ppm
T_{11}	Non-Mulched	NAA 50ppm
T_{12}	Non-Mulched	NAA 100ppm
T_{13}	Non-Mulched	NAA 150ppm
T_{14}	Non-Mulched	Control

Each experimental unit had 10 plants of onion on both sides of ridges, seven ridges with mulched plants and seven ridges with non-mulched plants.

Two chemicals IAA, indole acetic acid (CHNO) and NAA, naphthalene acetic acid (CHO), were used for the foliar application. All these chemicals were obtained from the horticulture laboratory of UAF sub-campus Burewala-Vehari. Solutions of IAA and NAA with different concentrations were prepared from that stock solution according to demand.

2.2.1. Soil Condition

The experimental site at UAF Sub-campus Burewala is generally characterized by sandy loam soil with moderately alkaline pH (around 7.5), low organic matter, and limited available nitrogen and phosphorus, as commonly reported for the region's semi-arid conditions. These typical soil

conditions were considered while interpreting crop responses to the treatments.

2.2.2. Foliar Application

Each working solution was kept in a separate spray bottle. A shower is used for the application of chemicals in the form of very small droplets, so that these drops stay on the onion leaves for a long time and are absorbed by the onion leaves. The first foliar application is done on the date (17 March, 2021), the second spray is applied after 12 days of first application on date (29 March, 2021), third application is also done after 12 days of second spray on date (10 April, 2021). Moreover, the 12-day interval was selected based on preliminary field experience and common horticultural practice to allow sufficient plant recovery and hormone uptake between applications.

The control plots received no foliar spray, not even water, to serve as a true untreated control. This allowed comparison with hormone-treated plants and helped assess the sole effect of mulching where applicable.

The leaf length of 5 plants per treatment per replication was recorded by using a ruler from the neck of bulb to the tip of the leaf. Average was calculated and expressed in centimeters. This practice was performed three times, viz 17 March 2021, 29 March 2021 and 10 April 2021.

2.2.3.2. Leaf Number

Similar to plant height, Number of leaves of 5 plants per treatment per replication were counted down and average was expressed in a number and whole process was repeated three times, viz 17 March 2021, 29 March 2021 and 10 April 2021.

2.2.3.3. Neck Diameter

The neck diameter of five plants per treatment was calculated by using Vernier caliper. Average was calculated and expressed in centimeters. Three readings were recorded on 17 March 2021, 29 March 2021 and 10 April 2021, respectively.

2.2.3.4. Weather conditions

Temperature and rainfall data were recorded and compiled in the form of graph (Figure 1). The maximum rainfall recorded was less than 8mm and temperature ranging 15- 35°C from 2nd January 2021, the seeding transplantation

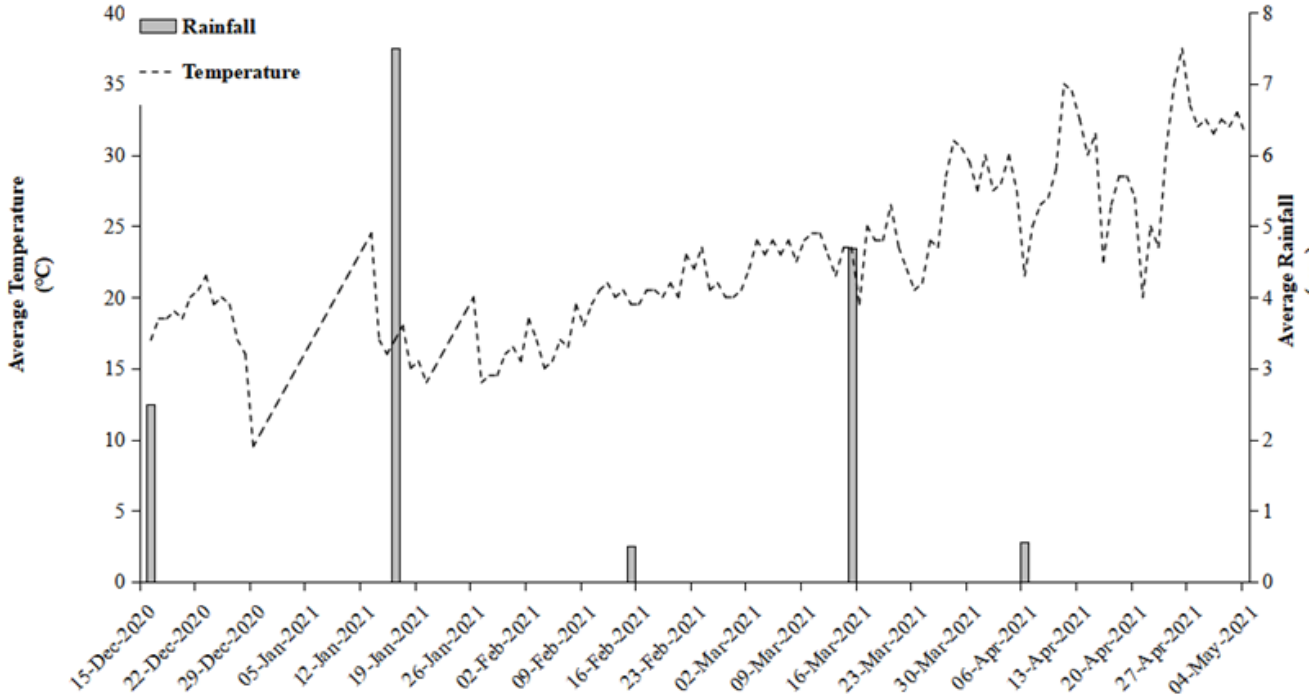

Figure 1. Temperature and rainfall during the onion growing season from 2nd Jan 2021 to 10 April 2021

2.2.3. Parameters Studied

2.2.3.1. Leaf Length

of onion to the end of the experiment, 10 April 2021, were normal and optimum during the crop growing season. It is concluded that weather conditions have no significant effect on crop and the results are completely affected by IAA and NAA foliar spray and mulching.

2.3. Results

Leaf length was significantly affected by both growth regulator dose and mulching on all observation dates (17 March, 29 March, and 10 April 2021). The main effects of dose and mulch were significant at the 5% level (Table 2). Their interaction also showed a significant effect on improving leaf length (Figure 2). The highest leaf length was recorded in 100 ppm IAA with mulch, while the lowest was observed in NAA without mulch.

The dose and mulch had a substantial impact on the number of leaves per plant on all observation dates (17 March, 29 March, and 10 April 2021). The main effects of both dose and mulch were found to be significant at the 5% level (Table 2), while their interaction remained non-significant (Figure 3). The maximum number of leaves was observed in plants treated with 100 ppm IAA under mulched conditions, whereas the minimum was recorded in the NAA control under non-mulched conditions.

Neck diameter per plant was significantly influenced by the dose and mulch on all three observation dates (17 March, 29 March, and 10 April 2021). The main effects of both dose and mulch were significant at the 5% level (Table 2). The interaction effect was non-significant on 17 March but became significant on 29 March and 10 April (Figure 4). The highest neck diameter was observed in plants treated with 100 ppm IAA under mulched conditions, while the lowest was recorded in the control under non-mulched conditions.

3. Discussion

The 100-ppm IAA treatment probably fostered the strongest growth because that level reliably promotes both cell division and elongation while staying below the threshold where excess hormone skews the plant's physiology. Concentrations of 200 to 300 ppm risk pushing auxin induction too far, potentially disrupting normal apical dominance or triggering feedback pathways that slow growth instead of speeding it. Such a dose-response pattern, where low to moderate auxin stimulates but very high levels reverse those gains, has been noted in other studies (Majda & Robert, 2018). One of the Auxin family's most advantageous PGRs,

Table 2. Impact of foliar hormonal application and mulching on the leaf length, leaf number and the neck diameter of onion crop.

	17 March 2021			29 March 2021			10 April 2021		
	Leaf length	Leaf number	Neck diameter	Leaf length	Leaf number	Neck diameter	Leaf length	Leaf number	Neck diameter
Factor A: Hormones									
100 PPM IAA	33.42 a	5.67 a	1.3 a	37.92 a	6.28 a	1.43 a	41.5 a	7.08a	1.52 a
200 PPM IAA	33.5 a	5.17 ab	1.3 a	31.25 c	5.92 ab	1.4 ab	39 a	7 a	1.5 ab
300 PPM IAA	29.5 b	4.83ab	1.27 a	27.92 d	5.83 ab	1.35 ab	38.33 ab	6.92 ab	1.49 ab
50 PPM NAA	31.08 ab	4.83 ab	1.14 ab	34.83 b	5.33 abc	1.25 bc8	35.58 b	6.17 bc	1.32 bc
100 PPM NAA	26.75 c	4.67 b	1.05 bc	32.92 bc	4.99 bc	1.12 cd	31.94 c	6.08 c	1.23 cd
150 PPM NAA	22.92 d	4.42 bc	0.93 cd	32.25 bc	4.92 bc	1.01 de	29.83 c	5.83 c	1.09 d
Control	23.08 d	3.75c	0.8 d	24.25 e	4. 25 c	0.9 e	26.5 d	4.83 d	1.08 d
S.E.	1.15	0.41	0.09	0.69	0.53	0.08	1.5	0.38	0.05
LSD Value	2.48**	0.89*	0.19**	1.49**	1.15*	0.18**	3.24**	0.83**	0.17**
Factor B: Mulching									
Mulched	31.33 a	5.45 a	1.31 a	34.93a	6.03 a	1.38 a	38.55a	6.88 a	1.5 a
Non-Mulched	25.88 b	4.07 b	0.91 b	28.38b	4.69 b	1.03 b	30.78b	5.67 b	1.15 b
Interaction (A*B)									
S.E.	0.62	0.22	0.04	1.82	0.29	0.05	0.8	0.20	0.05
LSD Value	1.33**	0.48**	0.11**	3.9.3**	0.61**	0.09**	1.8**	0.44**	0.17**

Where * means significant, ** means highly significant while 'ns' means non-significant at α =0.05

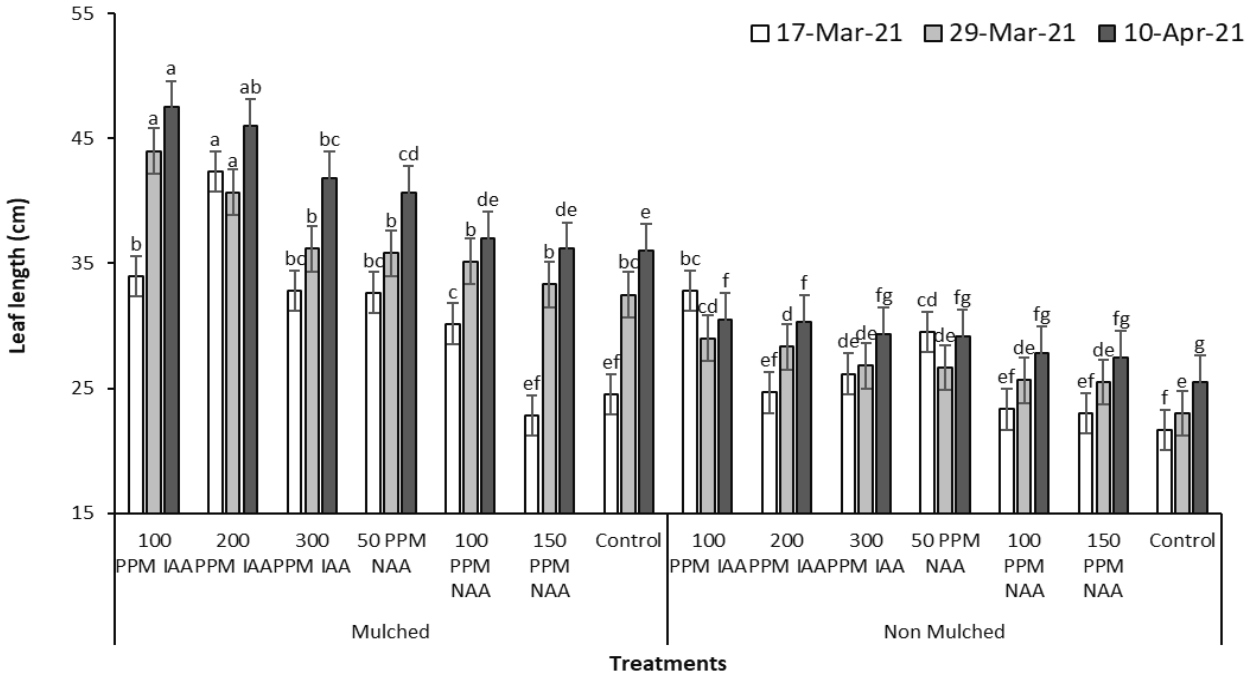

Figure 2. Interactive effect of foliar application of hormones and mulching over Onion leaf length

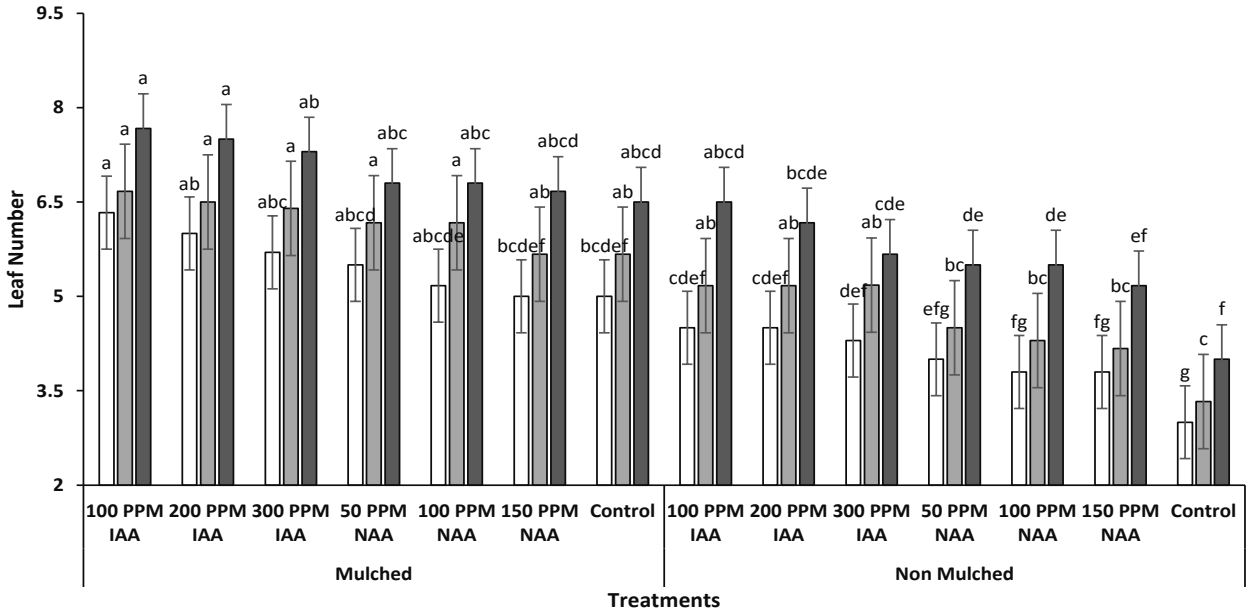

Figure 3. Interactive effect of foliar application of hormones and mulching over Onion leaf number per plant

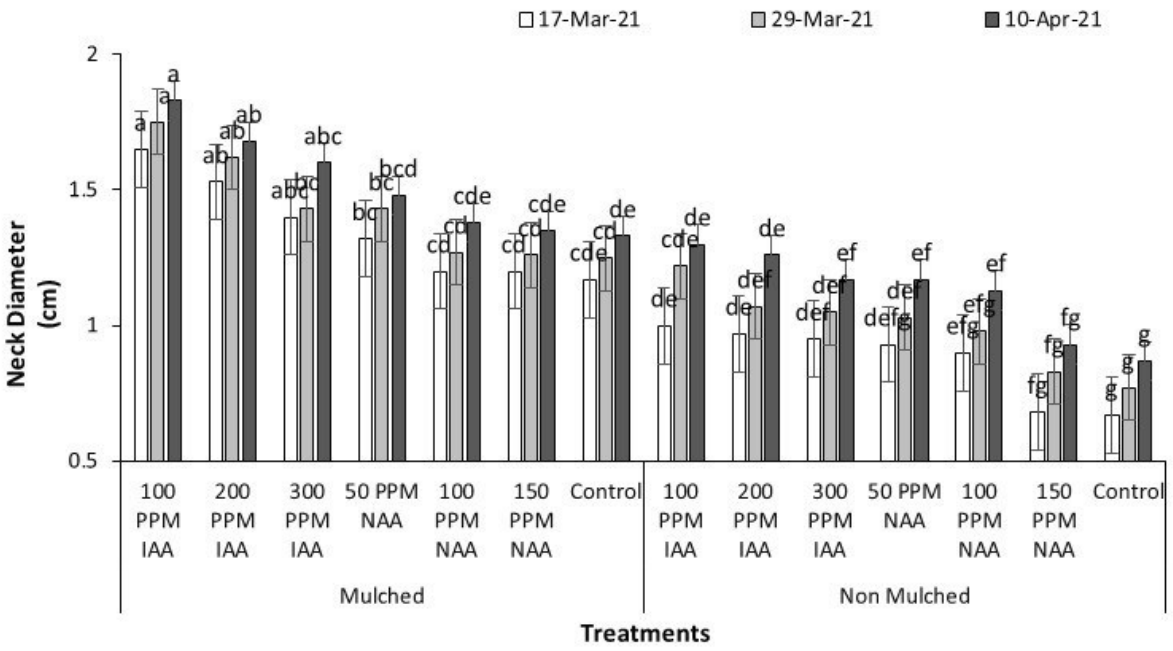

Figure 4. Interactive effects of foliar applications of hormones and mulching over Onion neck diameter

NAA, is essential for enhancing the product's quality, growth, and production. Bista *et al.* (2022) also observed similar results. The growth and development of onion bulbs are encouraged by the application of growth hormone. Similar findings were also reported by Ud-Deen & Kabir (2009) and Kumar *et al.* (2021).

PGRs alter and control a variety of plant growth and physiological processes. They also promote the translocation of photo-assimilates to produce related plant components because of improved source-sink IAA, which has a major impact on onion crops.

It also increases bulb yield, plant height, neck diameter and plant height per plant. 100ppm IAA is beneficial for the onion crop; it shows a significant effect. IAA may have a crucial role in cell growth and multiplication, adventitious root production, and apical dominance, which could explain the rise in onion morphological features (Majda & Robert, 2018; Shashikumar, 2015). The growth, yield, and quality of the product are all enhanced by NAA, one of the most advantageous PGRs in the Auxin family. The findings of Bista *et al.* (2022) also reported a significant increase in onion growth and bulb development with moderate auxin application, similar to the 100 ppm IAA response in this study. Relationships reported by Ud-Deen & Kabir (2009) also revealed similar outcomes, which raised agricultural output overall. Because of this, PGRs are recognized as one of the fastest ways to boost output (Rahman, 2011). Mulched plants showed significant improvement in leaf length, no. of leaves, neck diameter, and their rate of increase as compared to non-mulched. Likewise, Abba & Shanono (2023) found that black polythene mulching significantly improved biomass accumulation in onion, which supports our results where mulched plants consistently outperformed non-mulched ones. Similarly, Anisuzzaman *et al.* (2009) reported that mulched onions maintained better growth and seed production compared to non-mulched plants.

In contrast to earlier reports recommending higher concentrations of indole-3-acetic acid (IAA) or naphthalene-acetic acid (NAA), the present investigation found that 100 parts per million (ppm) of IAA produced the strongest response under the climatic and soil conditions of Burewala. Such a discrepancy is likely attributable to variations in environment, soil texture, cultivar, or the scheduling of foliar applications. These elements can change a plants sensitivity to externally supplied hormones, highlighting the importance of tailoring treatment guidelines to local circumstances.

4. Conclusion

Keeping in view the results of the experiment, it can be

concluded that indole-3-acetic acid (IAA) significantly enhanced the vegetative growth of onion, particularly at 100 ppm, where a notable increase in leaf length and leaf number per plant was observed. Similarly, mulching with black polythene proved effective in improving crop biomass compared to non-mulched conditions. These practices therefore represent cost-effective strategies for enhancing onion growth, especially in semi-arid regions. Although yield data such as bulb weight were not directly recorded in this study, the observed improvements in vegetative traits including neck diameter, leaf length, and number of leaves suggest a strong potential for higher bulb yield. To strengthen these findings, future research should incorporate yield-related parameters and explore higher or alternative concentrations of IAA for more comprehensive recommendations.

5. Funding

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6. Acknowledgment

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7. Conflict of Interest

The authors declare no conflict of interest.

8. Authors' Contribution

Sofia Sultana conducted the experimental research and data analysis. Salman Zahoor was responsible for manuscript formatting and literature review. Areeba Kashaf contributed to data collection and assisted in the review of relevant literature. Rana Binyamin critically reviewed the paper.

9. SDGs Addressed

This research supports SDG 2 (Zero Hunger) by improving onion growth and yield through sustainable practices, and SDG 12 (Responsible Consumption and Production) by enhancing resource efficiency with mulching. It also aligns with SDG 13 (Climate Action) by promoting practices that conserve soil moisture and reduce input needs.

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