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Impact of Plant Growth Regulators on Growth and Yield of Potato (*Solanum tuberosum* L.)

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ABSTRACT

Potato (*Solanum tuberosum* L.) is highly responsive to plant growth regulators (PGRs) that influence physiological and morphological processes throughout its life cycle. The present investigation was undertaken to determine the effect of exogenous application of indole-3-acetic acid (IAA), gibberellic acid (GA_3) and kinetin on growth and yield attributes of potato cv. Diamond under field conditions. The experiment was laid out in a randomized complete block design with ten treatments comprising different concentrations of GA_3, NAA and kinetin along with an untreated control. PGRs were applied at critical growth stages such as sprouting, vegetative development and tuber initiation. Results revealed that 100% GA_3 markedly improved vegetative performance, evidenced by maximum plant height (62.41 cm), leaf production (57.8 leaves plant^{-1}) and enhanced tuber characteristics including length (7.2 cm), diameter and marketable yield. NAA and kinetin treatments also promoted growth, though their influence remained slightly inferior to GA_3. The improved productivity associated with GA_3 application can be attributed to enhanced cell elongation, photosynthate translocation and tuber expansion. Therefore, foliar use of GA_3 at recommended concentration may serve as an effective agronomic strategy for augmenting yield of potato under Punjab conditions.

Keywords: Auxins, Cytokinins, Gibberellins, PGR, Potato.

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important Solanaceous vegetable crops. It has a Chromosome number 2n = 4x = 48. The origin of this crop is traced back to southern Peru and north western Bolivia. The potato is a starchy, tuberous crop derived from the perennial nightshade *Solanum tuberosum.* In many contexts, the term potato refers to the edible tuber, through it can also denote the plant itself. Common or colloquial terms include "tater" and "spud". Potatoes were introduced to Europe in the latter half of the 16th century by the Spanish. Today, they are a staple food in many regions of the world and a vital part of much of the global food supply. Wild potato species are found throughout the Americas, ranging from the United States to southern Chile. The potato was initially believed to have been independently domesticated in multiple locations, but genetic testing of a wide variety of cultivars and wild species and a single origin for potatoes (Spooner *et al,* 2005). The impact of bio-stimulants and growth regulators on the chemical composition of potato tubers has been multidirectional. The term "plant hormones" is are also used to refer to Phyto-hormones, which play a vital role in regulating plant growth. These hormones are small molecules derived from essential metabolic processes. Plant growth regulators are synthetic in nature, while plant hormones are naturally occurring. They play a significant role in the growth of plants (Kaur *et al,* 2018).

Plant growth regulators are a diverse group of endogenous and synthetic compounds that play a crucial role in regulating plant growth and development. Their influence extends to processes such as cell division, elongation, and differentiation, which impact various physiological aspects of plant life. PGRs include auxins, gibberellins, cytokinins, abscisic acid, and ethylene, each contributing to specific aspects (Rademacher, 2015). Manipulating these regulators offers opportunity to customize crop responses and potentially enhance productivity under different environmental conditions. Despite the known impact of PGRs on crop production, their specific effect on potato growth dynamics remains an area of ongoing research (Roberts, 2012). Understanding how PGRs affect key stages of potato development, from sprouting to tuber formation, holds potential for

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refining cultivation practices and improving yield. Moreover, studying the biochemical and physiological responses of potatoes to PGR applications is essential for promoting sustainable agricultural practices. The main objective of this study is to systematically examine the influence of PGRs on the growth and yield of potatoes.

MATERIALS AND METHODS

Experimental Site

The research was conducted at the Campus for Research and Advanced Studies, Dhablan, G.S.S.D.G.S. Khalsa College, Patiala which is situated at a latitude at 30°19 North, 76°24 East at an altitude of 250 meter above the mean sea level. It is situated in south eastern direction of Punjab and North West India. The experimental plot has uniform fertility and favorable climatic conditions are suitable for potato cultivation. The plots were prepared following standard agricultural practices, ensure consistency in soil texture, fertility, and drainage.

Potato Variety and Planting

A widely cultivated potato variety known as Diamond was selected for the experiment due to its adaptability and market appeal. Seeds was obtained from a trusted source to maintain genetic uniformity. Planting was carried out in rows with consistent spacing in accordance with recommended guidelines.

Plant Growth Regulators (PGRs)

Three commonly used PGRs were selected for the experiment: auxin (indole-3-acetic acid), gibberellin (gibberellic acid), and cytokinin (kinetin). These PGRs were sourced in pure form from reliable suppliers, ensuring the high quality and accurate concentration level.

Experimental Design

A randomized complete block design was implemented to minimize spatial variability. Experimental plots were organized into blocks, with each block assigned to a specific treatment group corresponding to one of the selected PGRs. Control plots without PGR application were included for baseline comparison.

Treatment Details

The experiment consisted of ten treatments combinations involving different concentrations of three plant growth regulators - Gibberellic acid (GA_3), Naphthalene acetic acid (NAA), and Cytokinin—along with an untreated control. The treatments were designed to study the effect of varying PGR levels on the growth and yield performance of potato (*Solanum tuberosum* L.). GA_3, NAA, and Cytokinin were applied at three concentration levels: 100%, 75%, and 50% of their recommended doses, corresponding to 30, 22.5, and 15 ppm for GA_3; 20, 15, and 10 ppm for NAA and 10, 7.5, and 5 ppm for Cytokinin, respectively. The control plot (T_1) received no PGR treatment. Thus, the ten treatments were as follows: T_1 – Control, T_2 – GA_3 at 100% (30 ppm), T_3 – NAA at 100% (20 ppm), T_4 – Cytokinin at 100% (10 ppm), T_5 – GA_3 at 75% (22.5 ppm), T_6 – NAA at 75% (15 ppm), T_7 – Cytokinin at 75% (7.5 ppm), T_8 – GA_3 at 50% (15 ppm), T_9– NAA at 50% (10 ppm) and T_{10} – Cytokinin at 50% (5 ppm). These treatments were selected based on standard recommendations and previous research findings to assess their comparative influence on the morphological and yield attributes of potato.

Method of Application

Plant growth regulators were freshly prepared for each treatment by dissolving the respective PGRs (GA_3, NAA, and Cytokinin) in a small quantity of ethanol and then diluting with distilled water to achieve the desired concentration. Each treatment solution was applied as a foliar spray using a hand-operated knapsack sprayer equipped with a fine mist nozzle to ensure even distribution over the foliage. The sprays were administered during early morning hours under calm conditions to minimize evaporation losses and maximize absorption efficiency. Equal volumes of each solution were applied to maintain uniformity across treatments.

Stages of Application

Foliar applications were performed at two critical stages of potato crop growth; 1st applied at 20 days after sowing (DAS) during the active sprouting stage when plants had established initial vegetative growth, whereas, 2nd applied 15 days after first spray (35 DAS) during the tuber initiation stage, a crucial period for cell division, elongation, and assimilate translocation toward developing tubers. This schedule ensured that the PGRs influenced both vegetative and reproductive growth phases effectively.

Data Recording and Observations

Observations were taken from five randomly

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Table 1. Impact of plant growth regulators on plant height (cm) of potato

Treatment	Plant height (cm)			
	20 DAS	40 DAS	60 DAS	At Harvest
T_1 Control	8.20	21.50	31.50	41.40
T_2 100% GA_3	9.60	27.24	44.86	62.41
T_3 100% NAA	9.20	26.14	43.23	61.71
T_4 100% Cytokinin	9.10	25.83	42.20	60.49
T_5 75% GA_3	8.70	23.60	37.10	57.80
T_6 75% NAA	8.80	23.20	36.10	54.90
T_7 75% Cytokinin	8.50	22.60	35.23	52.50
T_8 50% GA_3	8.70	23.20	35.70	47.40
T_9 50% NAA	8.60	22.40	34.80	47.10
T_{10} 50% Cytokinin	8.40	21.80	33.80	45.0
SE(m) ±	0.35	0.52	0.78	1.97
CD (0.05)	N.S.	1.23	1.70	2.26

Table 2. Impact of plant growth regulators on number of leaves/plant of potato

Treatment	Number of leaves plant			
	20 DAS	40 DAS	60 DAS	At Harvest
T_1 Control	8.9	22.7	35.9	48.9
T_2 100% GA_3	10.5	27.5	41.4	57.8
T_3 100% NAA	9.8	24.1	40.2	56.5
T_4 100% Cytokinin	10.2	26.4	39.8	55.5
T_5 75% GA_3	10.1	25.8	39.1	55.2
T_6 75% NAA	9.9	24.7	38.6	54.1
T_7 75% Cytokinin	9.7	23.4	37.5	53.5
T_8 50% GA_3	9.5	24.5	36.9	52.2
T_9 50% NAA	9.3	25.3	36.2	51.6
T_{10} 50% Cytokinin	9.1	23.2	36.7	50.8
SE(m) ±	0.25	0.42	0.91	1.06
CD (0.05)	N.S.	1.10	1.87	2.21

selected plants in each plot from all replications. Data were recorded at 20, 40 and 60 days after sowing and at harvest for key parameters related to growth and yield.

The recorded parameters included:

- Growth attributes: days to emergence, plant height (cm), and number of leaves per plant.
- Yield attributes: tuber length (cm), tuber diameter (cm), number of tubers per plant, average tuber weight (g), and total yield per plot (kg).

Standard agronomic and biometric methods were employed for all measurements. The data collected from the experiment were analysed statistically using Analysis of Variance (ANOVA). Treatment means were compared using the Critical Difference (CD) test at a 5% level of probability to determine statistical significance.

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PGR Application Protocol

PGRs were applied at key growth stages, including germination, vegetative growth, and tuberization, to capture critical points in the potato life cycle. Application rates were determined based on prior research and manufacturer recommendations to ensure optimal concentrations for each growth stage. Efforts were made to apply PGRs uniformly across all treatment plots.

RESULTS AND DISCUSSION

Growth Attributes

Key growth parameters such as days to plant emergence and emergence percentage at 20 days after planting and plant height were assessed. The data were subjected to statistically analysed and the results are presented in Table 1. At 20 days after sowing (DAS), the highest plant height was recorded in treatment T_2, where 100% GA_3 was applied, achieving 9.60 cm, followed by T_3 (100% NAA) and T_4 (100% Cytokinin), with heights of 9.20 cm and 9.00 cm, respectively. The control (T_1), which received no plant growth regulators, showed the minimum height of 8.20 cm. This trend continued as the crop matured. At 40 DAS, T_2 maintained the lead with 27.24 cm, while T_3 and T_4 reached 26.14 cm and 25.83 cm, respectively. The control lagged at 21.50 cm. By 60 DAS, T_2 plants exhibited a significant increase, attaining a height of 44.86 cm, compared to 43.23 cm in T_3 and 42.20 cm in T_4. Treatments with reduced hormone concentrations (50–75%) consistently showed lower plant heights, highlighting a clear dose-dependent response. At harvest, the tallest plants were again observed in T_2 (62.41 cm), followed by T_3 (61.71 cm) and T_4 (60.49 cm), whereas the control remained the shortest at 41.40 cm. These results emphasize that the application of 100% GA_3 significantly enhanced vegetative growth, particularly plant height, through its influence on cell elongation and division. Treatments with full doses of NAA and Cytokinin also contributed positively, though to a slightly lesser extent. The data clearly indicate that both the type and concentration of plant growth regulators are critical in maximizing vegetative growth attributes such as plant height in potato.

Yield Attributes

The analysis of yield attributes demonstrated a marked variation in tuber length among the different plant growth regulator treatments. The application of 100% gibberellic acid (GA_3) in T_2 resulted in the maximum tuber length of 7.2 cm, which was significantly higher compared to all other treatments. This pronounced elongation effect can be attributed to the ability of GA_3 to stimulate both cell elongation and division, thereby enhancing tuber development and contributing to overall yield improvement. Treatments with 100% NAA (T_3) and 100% Cytokinin (T_4) also showed considerable enhancement in tuber length, measuring 6.7 cm and 6.5 cm respectively, though their effect was comparatively lower than GA_3, possibly due to their primary role in root induction (NAA) and cell division (Cytokinin) rather than elongation. In contrast, the control treatment (T_1), which did not receive any exogenous hormonal application, recorded the minimum tuber length of 4.6 cm. This reduction highlights the limitation of relying solely on endogenous hormonal activity for tuber growth. Moreover, treatments with reduced concentrations of hormones, such as T_{10} (50% Cytokinin: 5.2 cm) and T_9 (50% NAA: 5.6 cm), exhibited lower tuber lengths compared to their full-dose counterparts, indicating a dose-dependent enhancement in tuber elongation and size. The superior performance of T_2 (100% GA_3) throughout the study suggests that gibberellic acid, when applied at an optimal concentration, effectively stimulates tuber elongation, thereby directly influencing yield parameters. These findings are in strong agreement with the studies of (Paikra *et al,* 2020), who reported significant tuber size enhancement with GA_3 application at 100 ppm, and (Singh *et al,* 2023), where gibberellin-treated potato plants exhibited increased tuber size and number under field conditions. The present results reaffirm that gibberellic acid is a crucial growth regulator in promoting tuber development, and its full-dose application is highly effective in maximizing yield potential.

CONCLUSION

The present investigation clearly demonstrated that the application of plant growth regulators significantly enhances both vegetative growth and yield attributes in potato. Among all treatments, the foliar application of 100% GA_3 (T_2) consistently exhibited superior performance across key parameters, including plant height, leaf number, leaf size, tuber length, tuber diameter, and total yield per hectare. The pronounced effect of GA_3 can be attributed to its role in stimulating cell elongation, division, and efficient assimilate partitioning toward developing tubers. Treatments with 100% NAA and Cytokinin also showed positive responses but remained slightly inferior to GA_3. Conversely, the control (T_1) and lower hormone concentration

treatments displayed restricted growth and yield, highlighting the dose-dependent efficacy of PGRs. Therefore, the application of GA_3 at the recommended concentration proves to be an effective strategy for enhancing vegetative vigour and maximizing tuber yield and growth in potato cultivation.

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