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RESEARCH COMMUNICTION

Response of plant growth regulators on development of shoot, root and mini tuber production in apical cuttings of potato (*Solanum tuberosum* L.)

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Abstract

A field experiment was conducted to assess the effects of plant growth regulators on the growth and yield of apical cuttings of potato (*Solanum tuberosum* L.). The study comprised thirteen treatments, including indole-3-acetic acid (IAA), indole-3-butyric acid (IBA) and 1-naphthaleneacetic acid (NAA) applied at 500, 750, 1000 and 1500 ppm, along with a control. Treatments were arranged in a Completely Randomized Design (CRD) with three replications. The experiment was carried out from March to July 2024 at the Instructional cum Experimental Farm, Department of Horticulture, SAS, Medziphema Campus, Nagaland University. Growth and yield parameters were recorded and analysed statistically using Analysis of Variance (ANOVA). Treatment T8 (IBA 1500 ppm) exhibited superior performance, producing the highest root parameters, including the number of primary roots (12.89), secondary roots (25.67), fresh root weight (0.018 g), dry root weight (0.014 g) and longest root length (7.97 cm). It also recorded the highest shoot growth, with shoot length (16.43 cm), diameter (7.00 mm), fresh weight (0.623 g) and dry weight (0.060 g). T8 showed the highest survival percentage (89.5 %), leaf area (1.78 cm^2) and tuber yield per plant (110.30 g). However, T7 (IBA 1000 ppm) produced the highest number of mini tubers (8.78). The control (T13) recorded the lowest values for all traits. The study highlights IBA at 1500 ppm as optimal for growth and yield, while IBA at 1000 ppm is best for mini tuber production, aiding in enhanced potato productivity.

Keywords: apical cuttings; growth parameters; mini tuber; plant growth regulators; potato

Introduction

Potato (*Solanum tuberosum* L.), a member of the Solanaceae family, is one of the most important food crops globally, ranking fourth after rice, wheat and maize (1). Originating in the high Andes of South America, the potato's adaptability across diverse climates and soils has contributed to its global expansion (2). Its nutritional value, high dry matter content and substantial carbohydrate and protein levels make it a critical component of food security (3). Additionally, the crop provides essential vitamins and minerals such as vitamin C, vitamin B6, potassium and manganese, contributing to a well-rounded diet (1). India has emerged as a major contributor to global potato production, accounting for approximately 14.93 % of the world's output, with 60.14 million tonnes harvested from an area of 2.33 million hectares during 2022-2023. However, despite this expansion, the Indian potato sector faces several challenges, particularly in seed production and distribution.

The limited seed replacement rate of 10 %, high transportation costs and seed deterioration during transit have negatively affected crop productivity (4). These limitations are exacerbated in regions like the North-East of India, where inadequate access to quality planting material and insufficient storage facilities result in low yields (5). Innovative approaches to seed production, such as the use of apical rooted cuttings (ARC), offer a promising solution to these challenges. ARC provides a low-cost, efficient method of producing high-quality seed tubers with a short multiplication cycle, making it particularly suitable for smallholder farmers (6). The integration of plant growth regulators (PGRs) with ARC has shown potential to further enhance rooting and tuber yields, offering significant advantages in addressing seed shortages (7). This study investigates the impact of higher PGR concentrations on ARC productivity in potato, expanding on earlier findings that highlight PGR efficacy in enhancing seed tuber production. This study investigates the impact of higher PGR concentrations on ARC productivity in potato, expanding on earlier findings that highlight PGR efficacy in enhancing seed tuber production (8). The study will provide valuable insights into the integration of PGRs with ARC, supporting efforts to improve seed quality, increase yields and enhance the sustainability of potato cultivation, particularly in resource-limited regions.

Materials and methods

The present investigation was carried out at Instructional cum Experimental Farm, Department of Horticulture, SAS, Medziphema Campus, Nagaland University, Nagaland during 2023-24. The experimental site is located at 20°45′43″ N latitude and 93°53′04″ E longitude, at an elevation of 305 m above mean sea level and falls under a sub-tropical climate. A field experiment was conducted to evaluate the response of different concentrations of plant growth regulators on apical cuttings of potato (*Solanum tuberosum* L.) *cv.* Kufri Himalini. Thirteen treatments of IAA, IBA and NAA at concentrations of 500, 750, 1000 and 1500 ppm, respectively, along with a control were applied in a Completely Randomized Design (CRD) with three replications. The stock solutions of PGRs were prepared fresh before use at the required concentrations using distilled water. Freshly collected apical cuttings (two-node segments) of potato were dipped in the respective PGR solutions for 10 min. Immediately after treatment, cuttings were planted in portrays filled with rooting medium consisting of cocopeat and vermicompost in a 2:1 ratio. Rooting was carried out under controlled nursery conditions and after root initiation, cuttings were transplanted into grow bags. Each grow bag measured 50 × 28 × 28 cm and was filled with a potting mixture of vermicompost, cocopeat and soil in a 1:2:1 proportion. After 40 days of transplanting, foliar application of NPK 19:19:19 was done. Each treatment plot consisted of ten grow bags, each planted with a single rooted cutting. Adequate irrigation was provided through hand watering to maintain optimal moisture levels and standard plant protection measures were undertaken as per recommendations. Growth observations, including shoot and root parameters, were recorded at the time of transplanting and during subsequent growth stages. Micro tuber parameters were recorded at harvest. Data for various parameters were statistically analyzed using analysis of variance (ANOVA) as outlined by Panse and Sukhatme (9).

Results and Discussion

The effects of different concentrations of plant growth regulators (PGRs) on various root, shoot and tuber parameters of potato (*Solanum tuberosum* L.) were significant. The findings indicated that higher concentrations of indole-3-butyric acid (IBA) enhanced root and shoot development as well as tuber yield.

Root parameters

The data of the different root parameters are presented in Table 1 and Fig. 1. The maximum number of primary roots at the time of transplanting was observed in T8 (IBA 1500 ppm) with 12.89 roots, which significantly was significantly higher than the control (T13) with 6.00 primary roots. Similar experiments on apical-rooted cuttings were conducted (10), who reported that two-node apical cuttings of Kufri Lima exhibited the highest number of roots per plant. Naturally occurring or externally applied auxins are essential

Table 1. Response of different plant growth regulators on root parameters of apical cuttings of potato.

Treatment	Number of primary roots	Number of secondary roots	Length of longest root (cm)	Fresh weight of roots (g)	Dry weight of root (g)
T_1 (IAA 500 ppm)	7.78	15.78	4.74	0.011	0.007
T_2 (IAA 750 ppm)	9.22	16.67	5.36	0.014	0.011
T_3 (IAA 1000 ppm)	9.56	17.89	6.07	0.014	0.011
T_4 (IAA 1500 ppm)	11.00	18.56	6.69	0.016	0.013
T_5 (IBA 500 ppm)	8.00	16.22	4.86	0.011	0.009
T_6 (IBA 750 ppm)	9.44	17.11	5.43	0.014	0.011
T_7 (IBA 1000 ppm)	11.78	21.55	7.24	0.017	0.013
T_8 (IBA 1500 ppm)	12.89	25.67	7.97	0.018	0.014
T_9 (NNA 500 ppm)	7.44	12.22	4.71	0.009	0.006
T_{10} (NNA 750 ppm)	8.55	16.22	5.27	0.012	0.009
T_{11} (NNA 1000 ppm)	9.45	17.22	5.47	0.014	0.011
T_{12} (NNA 1500 ppm)	10.11	18.56	6.11	0.015	0.011
T_{13} (Control)	6.00	11.33	4.38	0.009	0.006
Sem (±)	1.117	1.61	0.356	0.001	0.001
C.D. @5 %	3.264	4.72	1.042	0.003	0.003

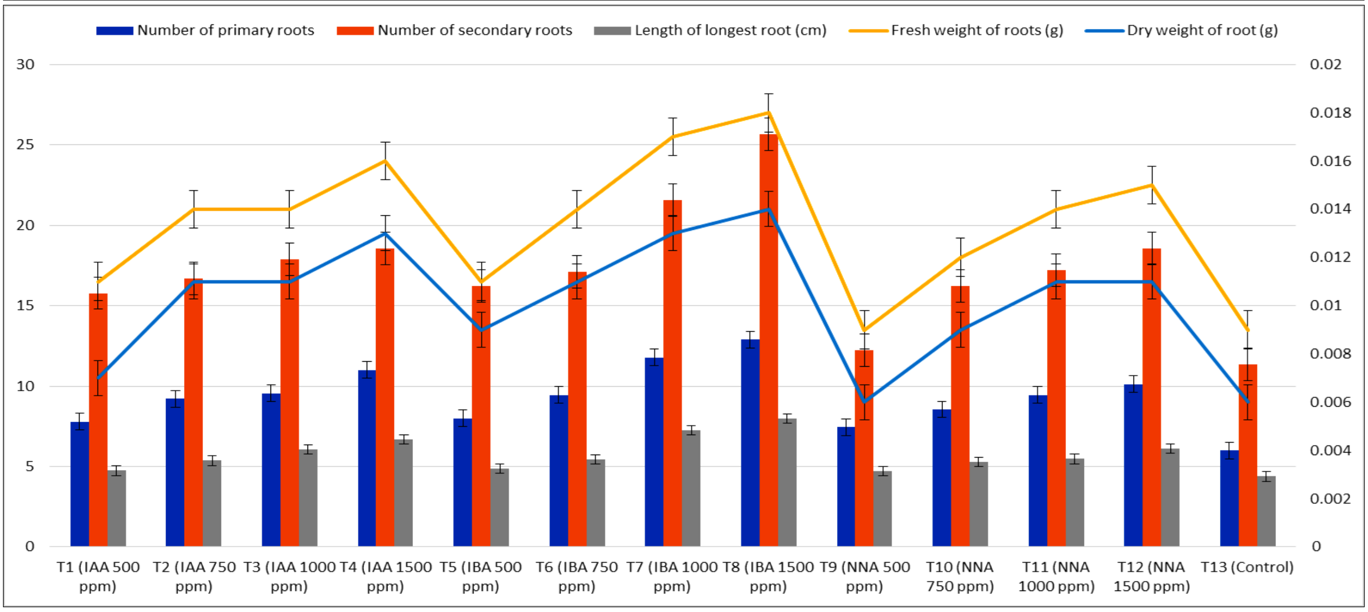

Fig. 1. Response of different plant growth regulators on root parameters of apical cuttings of potato.

for initiating root formation in cuttings (11). Similarly, T8 (IBA 1500 ppm) exhibited the highest number of secondary roots at 25.67, while the lowest count was recorded in T13 (Control) with 11.33 secondary roots. The application of IBA increases root formation and enhanced overall growth of the plant (12, 13).

The longest root length was also achieved in T8 (IBA 1500 ppm) at 7.97 cm, statistically at par with T7 (IBA 1000 ppm), while the shortest root length was noted in T13 (Control) at 4.38 cm. These results suggest that the optimal dose of IBA (1500 ppm) promotes longer root lengths, likely due to increased assimilation and translocation of auxin compounds within the cuttings. Additionally, root elongation across various plant species is known to be stimulated by auxins IBA at 2 mL produced maximum root length in the Kuroda variety of potato and effectively promote root proliferation in different potato varieties under tissue culture (14).

Fresh root weight was highest in T8 (IBA 1500 ppm) with 0.018 g, statistically at par with T7 (IBA 1000 ppm) and T4 (IAA 1500 ppm), while the lowest fresh root weight was observed in T13 (Control) with 0.009 g. Dry root weight followed a similar trend, with T8 (IBA 1500 ppm) recording the highest value (0.014 g), statistically at par with T7(IBA 1000 ppm) and T4 (IAA 1500 ppm) and the lowest dry root weight in T13 (Control) at 0.006 g. Similar findings were reported by an earlier study, which observed significantly higher values for root fresh weight and dry weight with a combination treatment of 1 mg/L IBA and 0.25 mg/L NAA.

Shoot parameters

The data of the different shoot parameters are indicated in Table 2 and Fig. 2. Treatment T8 (IBA 1500 ppm) exhibited the maximum shoot length of 16.63 cm, which was statistically at par with T7 (IBA 1000 ppm). The shortest shoot length was recorded in T13 (Control) at 8.06 cm. These results suggest that the increased shoot length observed with optimal IBA 1500 ppm treatment may be attributed to enhanced root growth, which improves the absorption and translocation of nutrients from the soil and enhances plant metabolic processes, ultimately leading to longer shoots. Treatment of potato cultivar Burren cuttings with 6000 ppm IBA produced longer stem lengths (17.87 cm) compared to 6000 ppm IAA (15.74 cm), consistent with earlier findings (16, 17).

The shoot diameter was largest in T8 (IBA 1500 ppm) at 7 mm, while T13 (Control) had the smallest shoot diameter of 3 mm. These results suggest that the increased shoot diameter observed with the optimal IBA 1500 ppm treatment may be attributed to improved root growth, which enhances nutrient absorption and translocation from the soil and facilitates better metabolic processes in the plant. The fresh weight of the shoots was also significantly higher in T8 (IBA 1500 ppm) with 0.623 g, statistically at par with T7 (IBA 1000 ppm), compared to the lowest value recorded in T13

Table 2. Response of different plant growth regulators on shoot parameters of apical cuttings of potato.

Treatment	Shoot length (cm)	Shoot diameter (mm)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Shoot root ratio	Number of leaves per shoot	Leaf area (cm^2)	Survival percentage
T1 (IAA 500 ppm)	10.80	3.00	0.237	0.022	3.29	5.89	1.26	75.0
T2 (IAA 750 ppm)	13.03	3.00	0.360	0.034	3.54	6.56	1.45	79.7
T3 (IAA 1000 ppm)	14.05	4.00	0.423	0.040	3.94	6.78	1.53	83.3
T4 (IAA 1500 ppm)	14.87	5.00	0.493	0.047	4.38	7.33	1.60	83.3
T5 (IBA 500 ppm)	11.54	3.00	0.260	0.024	3.45	6.33	1.34	75.0
T6 (IBA 750 ppm)	13.20	3.00	0.370	0.036	3.58	6.67	1.47	81.0
T7 (IBA 1000 ppm)	15.71	6.00	0.580	0.055	4.44	7.33	1.73	87.4
T8 (IBA 1500 ppm)	16.43	7.00	0.623	0.060	4.46	7.44	1.78	89.5
T9 (NNA 500 ppm)	9.99	3.00	0.223	0.020	2.82	5.78	1.24	75.0
T10 (NNA 750 ppm)	12.06	4.00	0.317	0.029	3.45	6.55	1.37	77.0
T11 (NNA 1000 ppm)	13.58	4.00	0.383	0.036	3.74	6.78	1.51	83.3
T12 (NNA 1500 ppm)	14.14	6.00	0.457	0.043	4.22	7.00	1.54	83.3
T13 (Control)	8.06	3.00	0.187	0..016	1.98	5.66	1.11	72.6
Sem (±)	0.51	0.08	0.043	0.04	0.662	1.032	1.173	0.555
C.D. @5 %	1.50	0.24	0.126	0.012	NS	3.015	NS	NS

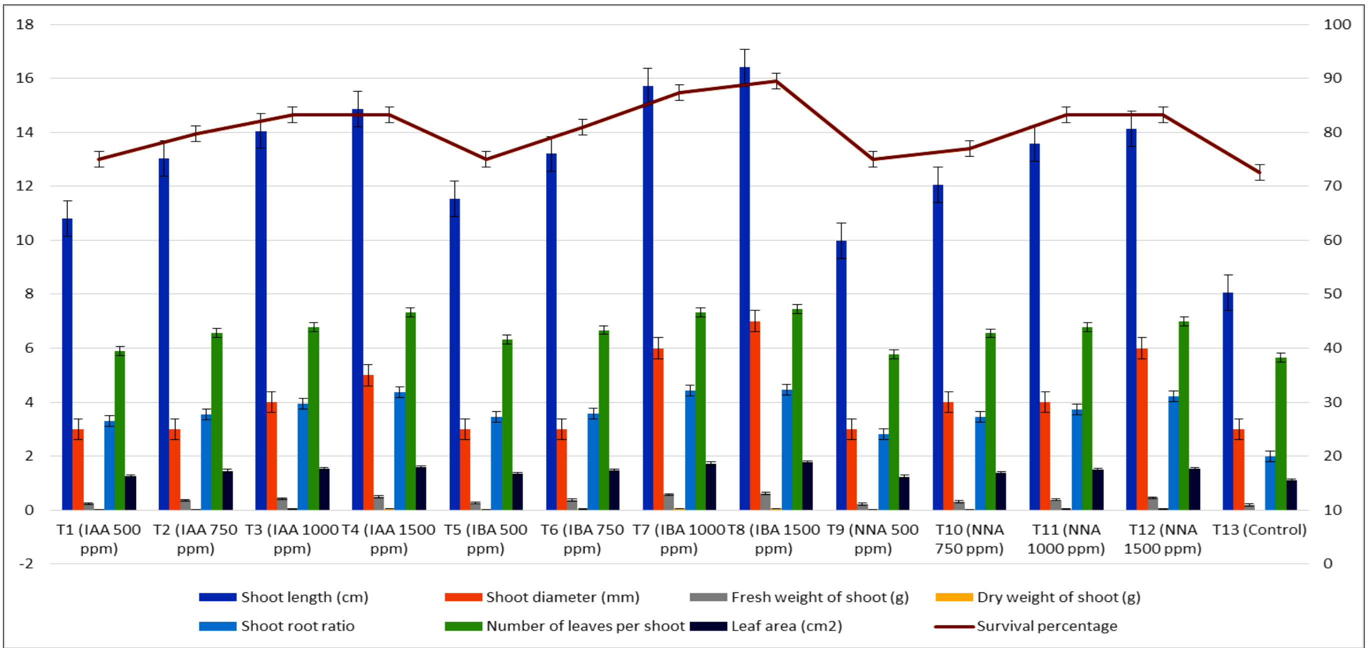

Fig. 2. Response of different plant growth regulators on shoot parameters of apical cuttings of potato.

(Control) with 0.009 g. Similarly, the dry weight of the shoots was highest in T8 (IBA 1500 ppm) at 0.060 g, statistically at par with T7 (IBA 1000 ppm), while T13 (Control) recorded the lowest dry weight at 0.016 g. This effectiveness is likely due to their promotion of maximum shoot length, internodal length and nutrient uptake and accumulation in plants. Specific concentrations of IAA promote multiple shoots and root regeneration and increase optimal shoot numbers in potatoes (18). Similarly, IBA 1000 ppm resulted in a maximum fresh weight of shoots (182.00 g/plant), which was found statistically at par with IBA 1500 ppm (8, 19).

Stem cuttings of potato *cv.* Burren treated with 6000 ppm IBA produced the maximum whole plant fresh weight (289.38 g) after 55 days compared to treatments with IAA 6000 ppm and others (17). Although the shoot-root ratio was non-significant, T8 (IBA 1500 ppm) recorded the highest shoot-root ratio of 4.46, while the lowest ratio was observed in T13 (Control) at 1.98. The increased shoot to root ratio can be associated with greater levels of shoot-dry matter and root-dry matter.

The number of leaves per cutting was highest in T8 (IBA 1500 ppm) with 7.44 leaves, statistically at par with T7 (IBA 1000 ppm), while T13 (Control) had the lowest leaf count at 5.66 leaves per cutting. These findings align with the Kufri Lalima treated with IBA 1000 ppm exhibited the highest number of compound leaves per plant (8). In addition to this, superior growth characteristics and a high number of compound leaves per plant (22.12) in ARC of Kufri Himalini under field conditions (20). This current research aligns closely with the findings, that increased leaf production may be attributed to vigorous rooting induced by growth regulators, enabling cuttings to absorb more nutrients and thereby promoting leaf growth (20). Average leaf area during transplanting was found to be non-significant, with the highest average leaf area recorded in T8 (IBA 1500 ppm) at 1.78 cm^2 and the lowest in T13 (Control) at 1.11 cm^2. Similar work shown that Kufri Jyoti ARC produced maximum leaf length (9.16 cm) at 75 days after planting (20).

The survival percentage of rooted cuttings was non-significant across treatments, with T8 (IBA 1500 ppm) recording the highest survival rate at 89.50 %, while T13 (Control) exhibited the lowest survival rate at 72.64 %. These factors likely contributed to enhanced shoot and root parameters, facilitating improved nutrient and water uptake and thereby enhancing survival rates. The rooting hormone K-IBA enhanced root initiation and development resulting in high survival rates of 99.33 % (21). Apical stem cuttings treated with 1 ppm Indole Acetic Acid (IAA) exhibited the highest survival rates, which aligns with earlier findings (22).

Tuber parameters

The data of the different tuber parameters are indicated in Table 3 and Fig. 3. The number of mini tubers per plant was maximized in T7 (IBA 1000 ppm) with 8.78 tubers, statistically at par with T4 (IAA 1500 ppm), while the minimum number of tubers was observed in T13 (Control) at 5.00 tubers. which may be due to limited development of the rooting system and inefficient absorption of water and nutrients, which hindered mini-tuber formation (23). The findings clearly show

Table 3. Response of different plant growth regulators on tuber parameters of apical rooted cuttings of potato.

Treatment	Number of mini tubers per plant	Weight of tuber (g)	Size of tuber (mm)	Tuber yield per plant (g)
T_1 (IAA 500 ppm)	4.38	4.00	9.00	17.52
T_2 (IAA 750 ppm)	6.11	5.50	11.00	33.61
T_3 (IAA 1000 ppm)	5.87	8.00	15.00	46.96
T_4 (IAA 1500 ppm)	8.78	9.00	17.00	79.02
T_5 (IBA 500 ppm)	4.07	4.50	9.00	18.32
T_6 (IBA 750 ppm)	6.00	6.00	14.00	36.00
T_7 (IBA 1000 ppm)	8.78	11.29	17.50	99.10
T_8 (IBA 1500 ppm)	7.50	14.70	19.00	110.30
T_9 (NNA 500 ppm)	4.36	3.67	8.90	16.00
T_{10} (NNA 750 ppm)	6.56	5.00	10.00	32.80
T_{11} (NNA 1000 ppm)	5.67	8.00	14.00	45.36
T_{12} (NNA 1500 ppm)	6.67	9.00	16.00	60.03
T_{13} (Control)	5.00	3.16	5.00	15.80
Sem (±)	0.11	0.10	0.21	0.91
C.D. @5 %	0.34	0.49	0.61	2.66

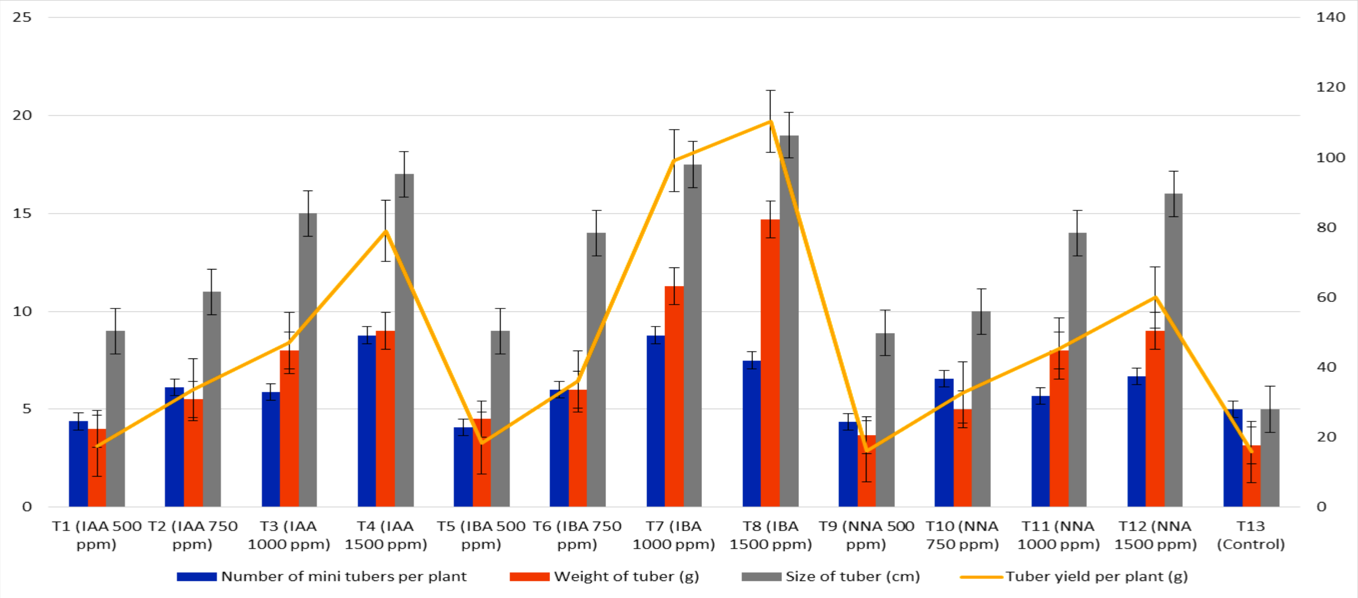

Fig. 3. Response of different plant growth regulators on tuber parameters of apical rooted cuttings of potato.

that the number of mini tubers per plant correlates with the use of IBA at 1000 and 1500 ppm, likely due to increased biomass accumulation, leading to higher fresh and dry weights and ultimately resulting in greater mini tubers yields. The rooting hormone K-IBA resulted in the highest number of tubers (12.00) compared to other hormones (21). Similar results were also reported in the previous study (24), where they recorded that Belete variety treated with 6000 ppm IBA produced the highest tuber yield (8.6 tubers/plant). The highest tuber weight was recorded in T8 (IBA 1500 ppm) at 14.70 g, whereas T13 (Control) had the lowest tuber weight at 3.16 g. Shoot tip cuttings of the Belete variety treated with 6000 ppm IBA produced the maximum tuber weight of 136.08 g, consistent with earlier findings (24). Tuber size followed a similar trend, with T8 (IBA 1500 ppm) recording the largest tuber size at 19.00 mm and T13 (Control) exhibiting the smallest tubers at 5.00 mm.

The tuber yield per plant was highest in T8 (IBA 1500 ppm) with 110.30 g, while T13 (Control) recorded the lowest yield of 15.80 g. (25) stated that mini tubers typically range in size from 5 to 25 mm. However, larger mini tubers are often prevalent in many potato seed production systems. IBA at 300 ppm resulted in the highest tuber yield (142.97 g) and suggested that utilizing apical stem cuttings could be a cost-effective method for potato growers, potentially increasing mini tuber yield and facilitating mass propagation in seed potato production (7). These results suggest that higher concentrations of IBA significantly enhance root and shoot growth, as well as tuber yield, offering a promising approach to improving potato propagation and productivity.

Conclusion

Based on the findings of the experiment conducted, T8 (IBA 1500 ppm) was found to be the most effective hormone among all the treatments for root and shoot parameters in apical cuttings of potatoes. T8 (IBA 1500 ppm) at higher concentration recorded the highest number of primary and secondary roots, maximum root length, maximum fresh and dry weight of the roots at the time of transplanting. Additionally, shoot parameters were also found to be highest when IBA at 1500 ppm was applied. Among the treatments studied, T8 (IBA 1500 ppm) was found to be the most effective hormone, recording the highest survival percentage of rooted cuttings, maximum tuber weight, size and yield per plant while T7 (IBA 1000 ppm) recorded the maximum number of mini tubers per plant.

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Authors' contributions

NLK carried out the research work and drafted the manuscript. SJ and CSM assisted in writing the manuscript and conducting the sequence alignment. SPK, CC, AS and M contributed to writing, reviewing and correction of manuscript. AK performed the statistical analysis and assisted in formatting the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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