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Potato (*Solanum tuberosum* L.) Microplants and Minitubers Effected by the Combination of Gibberellic Acid (GA_3) and Indole 3 Acetic Acid (IAA)

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Abstract: The purpose of this study, to find out the effect of GA_3 and IAA on potato micro plants *in vitro* and further performance in net house and in field. This study was carried out between 2014-2015 in the Central Potato Research Institute Modipuram, Meerut. In this study used different concentrations of GA_3 and IAA in combinations. For this experiment used 3 node stems cutting of potato variety Kufri Bahar and Kufri Surya with MS media supplemented with different concentrations and combinations of GA_3+IAA (0.05 mg GA_3/L+0.005 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA /L, 0.2 mg GA_3/L+0.01 mg IAA /L, 0.1 mg GA_3/L+0.02 mg IAA /L, 0.2 GA_3 mg/L+0.02 mg IAA /L and 0.4 mgGA_3/L+0.04 mg IAA/L) for microplant culture. Application of GA_3+IAA at 0.4 mg/L+0.04 mg/L significantly increased length of shoot, number of nodes, internode length, number of leaves, length of root and fresh weight of shoot per plant *in vitro*. Similarly, the application of GA_3+IAA at 0.4 mg/L+0.04 mg/L also increased the growth and yield parameters of potato variety Kufri Bahar and Kufri Surya in net house and in field. Potato quality and quantity can therefore be improved through application of 0.4 mgGA_3/L+0.04 mg IAA/L.

Keywords: GA_3, IAA, Microplants, Minitubers, In-Vitro, Field, Kufri Bahar, Kufri Surya

1. Introduction

In terms of area under cultivation and production, India comes in second place behind China. During 2020-21, world's potato production has increased from 354.8 million tons to 359.07 million tons.

Now a days purchasers demands top quality potato seed for good health. High productivity good shape and high-quality potato seed is the first essential provision to get rich potato yield.

Most of the Indian farmers sow potato in the rabi season, during October to November. During 2020-21, potato cultivation in India was 22.48 lakh ha and production was 542.3 lakh tons, while the same was 20.51 lakh ha and 485.62 lakh tons during 2019-20. Depending on costs and availability, India's yearly domestic consumption ranges from 32 to 35 million tonnes. The largest producing states in India are Gujarat, West Bengal, Bihar, Punjab, and Uttar Pradesh.

The vegetable is grown as an annual crop and comes from the nightshade family Solanaceae [24]. Potato is a crucial food crop that rank among the top crops produced globally [21]. This crop is propagated vegetatively by node, internode or stem culture and tuber sprouts. In many tropical and temperate regions, this crop is also regarded as a staple food. Plantlets or microplants that have a high rate of rapid multiplication in seed tubers form minitubers [7]. The process of tuberization begins by cell division and radical expansion of the cells, leading to swelling and eventual shape of the tubers. The initiation and degree of tuber development are controlled by a variety of environmental factors and hormones. Factors that affect photosynthetic production, such as light intensity, age, or the number of leaves, also influence the degree of tuberization. Photoperiod and temperature also modulate tuberization.

In order to change the characteristics of the number of tubers and the duration of in vitro plantlet creation, plant growth regulators are used in the production of potatoes [19].

In India, it is grown across estimated to be 53.11 million tonnes, against production of 48.56 million tonnes in 2019-

20 Farm sector news [3]. The top states for large-scale potato production include Uttar Pradesh, West Bengal, Bihar, Madhya Pradesh, Gujarat, Punjab, Assam, Haryana, Jharkhand, Chhattisgarh, Karnataka, and Maharashtra. With a 31.26 percent production share, Uttar Pradesh leads all other states in the production of potatoes, followed by West Bengal, Bihar, Gujarat, and Madhya Pradesh with respective shares of 23.29 percent, 13.22 percent, 7.43 percent, and 6.20 percent. (Ministry for Agriculture and Farmer Welfare, 2019-20).

With production of 10455.30, 7482.30, and 1720.20 thousand tonnes, respectively, West Bengal and Bihar are the two states in India that produce the most potatoes.

It produced almost 13.1 MT of potato, thus contributing nearly 28.6% of total potato production in the country (Directorate of Economics and Statistics 2016).

The aim of study is that, the potato quality, quantity and yielding capacity can stimulate with the help of growth hormone alone or in combination. So that, auxin and GA3 should be investigated for boosting the yield in tuber and store root crops, in our opinion, in light of the available research.

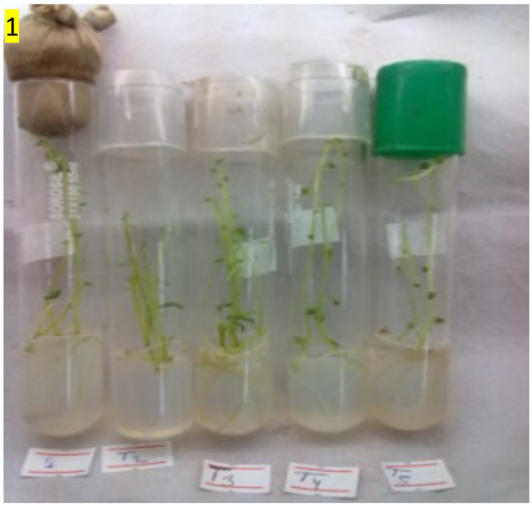

Figure 1. *Microplant of Kufri bahar.*

Figure 2. *Microplant of Kufri surya.*

Figure 3. *Harvesting of Kufri bahar.*

Figure 4. *Harvesting of Kufri surya.*

Figure 5. *Kufri bahar microplants transfer in the plastic tray.*

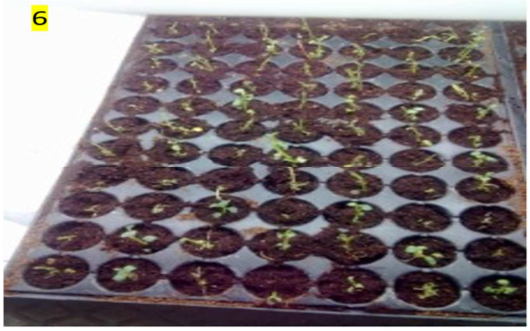

Figure 6. *Kufri surya microplants transfer in the plastic tray.*

Figure 7. *Kufri bahar microplants transfer in the net-house.*

Figure 8. *Kufri surya microplants transfer in the net-house.*

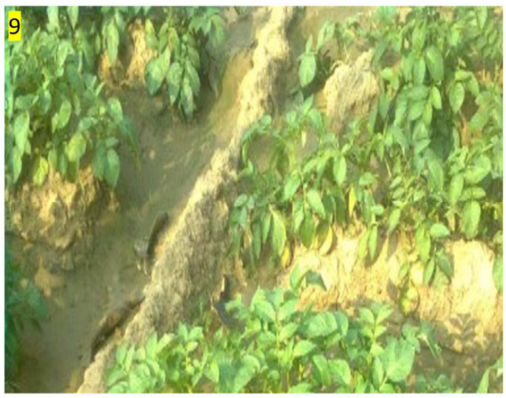

Figure 9. *Kufri bahar microplants in the net-house.*

Figure 10. *Kufri surya microplants in the net-house.*

Figure 11. *Haulm cutting and harvesting of minitubers in nethouse.*

Figure 12. *Potato Minitubers of Kufri Bahar.*

Figure 13. *Potato minitubers of Kufri Surya.*

Figure 14. *Potato Shape Index measure by Vernier Caliper.*

2. Material and Methods

The investigations, lab and field experiments were planned and conducted during autumn season of 2012-13, 2013-14 and 2014-15 at Central Potato Research Institute Campus, Modipuram, Meerut (UP). The site is situated at 29° 05' 19" N latitude, 77° 41' 50" E longitude, and 237 metres above mean sea level in a semi-arid and sub-tropical environment. The Central Potato Research Institute in Shimla provided verified virus-free microplants of the potato (*Solanum tuberosum* L.). Nodal cuttings of both cultivars of potatoes were cultivated for microplant multiplication in test tubes (25150 mm) containing 15 ml of solidified (0.8 percent agar) Supplemental nutrition (SN) medium [14], the calcium pantothenate (2 mg/l) and growth hormones GA_3 and IAA in combinations concentration (0.05mg/L+0.005 mg/L, 0.1 mg/L+0.01 mg/L, 0.2 mg/L+0.01 mg/L, 0.1 mg/L+0.02 mg/L, 0.2 mg/L+0.02 mg/L and 0.4 mg/L+0.04 mg/L) were added. Before autoclaving at 121°C for 20 minutes, the medium's pH was adjusted to 5.8. Cultures were incubated at 25±1°C under 16 h photoperiod (fluorescent, 100 µmole/m /s) (Figures 1 and 2). After 21 days, the shoot length, number of nodes, number of leaves, internode length, root length and shoot fresh weight were measured. Five replications of the experiment were used in the Completely Randomized Block Design (C. R. B. D.) layout. IRRISTAT software was used for data analysis. After 21 days, the roots of the microplants were gently washed to remove the agar medium. The root zone of mass micro propagated plants from culture tube was dipped in ordinary tap water to wash out adhering liquid medium (Figures 3 and 4). These were then planted in plastic trays with compost mixture of farmyard manure, sand and soil (1:1:1) and maintained at 20°C under high humidity under shade (Figures 5 and 6). After 7 days the plants were transferred to glass house conditions under shade for a week. Thereafter microplants were transplanted under net house with 1.5 m×2m = 3 m^2 plot size. The net house's soil had a sandy loam texture, a pH that was nearly neutral, rich in available phosphorus (51.2 kg/ha), medium in available potassium (160.4 kg/ha), and low in organic carbon (0.47 percent) (7.5). The planting depth was at 3-4 cm and planting geometry of 30 cm (row to row) ×10 cm (plant to plant). At the time of planting root promoting hormone 'Arodix-1' was applied at the lower end of the cutting for better survival (Figures 7 and 8). In total, fertilizer applied consisted of 100 kg N, 53 kg P_2O_5 and 67 kg K_2O per hectare, as calcium ammonium nitrate, diammonium phosphate and muriate of potash, respectively. Full doses of P and K were applied just before transplantation of *in vitro* microplants while N was split in three equal applications. A light irrigation was given with the help of a shower just after transplanting of *in vitro* microplants. Two- or three-times light irrigations were given daily with the help of a shower for a week and after that need-based irrigation were given. Earthing up was done 30 days after planting (Figures 9 and 10). Manual weeding was done in the plot and all the recommended measures for a seed potato crop were followed. Haulms of the crop were pulled at 90 days after transplanting while harvesting was carried out manually, 15 days after haulm pulling (Figure 11). Five replications of the experiment were used in a Split Plot Design. The growth parameters were recorded on five randomly selected plants at peak growth stage (75 days after planting), while yield parameters were recorded in the net plot at harvesting minitubers (Figures 12, 13 and 14). IRRISTAT software was used for data analysis.

Table 1. *Effect of GA3+IAA on shoot length, number of nodes, and internode length of varieties Kufri Bahar (V1) and Kufri Surya (V2) microplants at 21 days after inoculation in vitro.*

Treatments GA3+IAA	Length of shoot per microplant (cm)						Number of nodes per microplant						Internode length per microplant (cm)					
	1st year		2nd year		Mean		1st year		2nd year		Mean		1st year		2nd year		Mean	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
0.05mg/L+0.005 mg/L	6.49	6.72	6.59	6.74	6.54	6.73	6.02	5.68	6.08	5.70	6.05	5.69	1.07	1.06	1.05	1.06	1.06	1.06
0.1 mg/L+0.01 mg/L	6.63	7.14	6.77	7.11	6.70	7.12	6.52	6.30	6.40	6.44	6.46	6.37	1.08	1.10	1.06	1.10	1.07	1.10
0.2 mg/L+0.01 mg/L	7.13	7.58	7.04	7.54	7.08	7.56	6.66	6.48	6.64	6.54	6.65	6.51	1.10	1.10	1.11	1.12	1.10	1.11
0.1 mg/L+0.02 mg/L	7.82	7.90	7.97	7.91	7.90	7.91	6.96	6.98	6.96	6.90	6.96	6.94	1.10	1.12	1.12	1.12	1.11	1.12
0.2 mg/L+0.02 mg/L	8.12	8.10	8.17	8.03	8.14	8.06	7.20	7.30	7.32	7.20	7.26	7.25	1.11	1.14	1.13	1.13	1.12	1.13
0.4 mg/L+0.04 mg/L	9.30	9.41	8.92	9.08	9.11	9.24	7.80	7.98	7.82	7.84	7.81	7.91	1.18	1.14	1.20	1.15	1.19	1.14
Control	5.86	5.94	5.92	5.98	5.89	5.96	5.60	5.54	5.58	5.50	5.59	5.52	1.03	1.01	1.04	1.07	1.03	1.04
S Em ±	0.24	0.15	0.24	0.14	0.15	0.81	0.19	0.28	0.13	0.22	0.13	0.22	0.03	0.02	0.02	0.02	0.02	0.01
CD (P=0.05%)	0.71	0.46	0.70	0.41	0.44	0.23	0.56	0.83	0.40	0.66	0.37	0.64	NS	0.06	0.08	NS	0.07	0.03
CV	14.7	13.57	13.2	12.36	13.9	12.95	10.17	12.28	10.48	11.52	10.31	11.89	3.86	3.95	4.74	2.71	4.35	3.11

3. Result and Discussion

3.1. Shoot Length and Number of Nodes

The data presented in Table 1 revealed that there was significant variation over control with respect to shoot length and number of nodes. The shoot length and number of nodes after 21 days of inoculation showed increasing trend with increasing GA3+ IAA concentration in both the varieties under study. The maximum shoot length and number of nodes were recorded (9.11cm, 7.81) with 0.4 mg GA_3/L+0.04 mg IAA/L treatments in Kufri Bahar but, his was comparable to other treatments and the control in the Kufri Bahar variety. In Kufri Surya maximum shoot length and number of nodes per microplant (9.24cm, 7.91) were recorded with 0.4 mg GA_3/L+0.04 mg IAA/L and it was at par with remaining treatments and control. The minimum shoot length and number of nodes were observed in control. The shoot length

studies are co-related with Kumar et al. [11] has reported that maximum shoot length was found at GA and IAA concentration. Phytohormones can change the growth and development of potato include number of nodes [15].

3.2. Internode Length and Number of Leaves

Examining the results in Table 1 also showed that the internode length per microplant was influenced by the varied levels of GA3+IAA. Significantly maximum internode length (1.19 cm and 1.14 cm) was recorded in 0.4 mg GA_3/L+0.04 mg IAA/L in Kufri Bahar and Kufri Surya, respectively. It was at par with 0.1 mg GA_3/L+0.02 mg IAA/L, 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control in Kufri Bahar and 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control in Kufri Surya. Minimum internode length in both the varieties was recorded in control. After 21 days of sub-culturing [20], GA3 (0.58 M) and NAA (0.1 M) significantly increased the shoot length, number of leaves, number of nodes, and internode length.

The information in Table 2 showed that during both research years, the concentrations of GA3 and IAA grew together with the number of leaves in both kinds. Significantly maximum number of leaves (7.95) was recorded with 0.4 mg GA_3/L+0.04 mg IAA/L in Kufri Bahar. With 0.4 mg GA3/L+0.04 mg IAA/L, Kufri Surya recorded the highest number of leaves (8.09) per microplant. The result was at par with other treatments and control in Kufri Bahar and Kufri Surya. Minimum number of leaves in both the varieties under study was recorded under control. This result is supported by Khalid, A. F. Aftab [8] but exogenously.

Table 2. *Effect of GA3+IAA on number of leaves, root length and weight of shoot of varieties Kufri Bahar (V1) and Kufri Surya (V2) microplants at 21 days after inoculation in vitro.*

Treatments GA3+IAA	Number of leaves per microplant						Length of root per microplant (cm)						Fresh weight of shoot per microplant (cm)					
	1st year		2nd year		Mean		1st year		2nd year		Mean		1st year		2nd year		Mean	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
0.05mg/L+0.005 mg/L	6.18	5.82	6.26	5.94	6.22	5.88	5.37	5.45	5.41	5.35	5.39	5.40	309	350	312	351	310	350
0.1 mg/L+0.01 mg/L	6.66	6.48	6.54	6.62	6.60	6.55	5.73	6.19	5.81	6.26	5.77	6.22	325	385	326	383	325	384
0.2 mg/L+0.01 mg/L	6.84	6.64	6.82	6.74	6.83	6.69	6.32	6.46	6.27	6.46	6.29	6.46	354	390	355	392	354	391
0.1 mg/L+0.02 mg/L	7.14	7.14	7.24	7.08	7.19	7.11	6.50	6.80	6.52	6.79	6.51	6.79	404	434	409	435	406	434
0.2 mg/L+0.02 mg/L	7.40	7.46	7.54	7.38	7.47	7.42	7.24	7.19	7.26	7.25	7.25	7.22	446	481	449	481	447	481
0.4 mg/L+0.04 mg/L	7.94	8.12	7.96	8.07	7.95	8.09	7.54	7.69	7.44	7.75	7.49	7.72	494	494	492	493	493	494
Control	5.80	5.68	5.74	5.54	5.77	5.61	4.39	5.02	4.48	5.07	4.43	5.04	172	172	173	173	172	173
S Em ±	0.18	0.29	0.13	0.21	0.12	0.21	0.12	0.09	0.10	0.10	0.08	0.07	2.09	1.83	2.77	1.65	1.77	1.35
CD (P=0.05%)	0.54	0.84	0.39	0.61	0.34	0.62	0.36	0.28	0.29	0.29	0.24	0.20	6.1	5.32	8.04	4.8	5.15	3.93
CV	9.82	12.02	10.3	11.69	10.1	11.81	16.42	13.59	15.61	13.92	16.03	13.77	27.2	25.9	27.1	25.8	27.2	25.8

Table 3. *Effect of GA3+IAA treated in vitro microplant grown in net house (G-0) and in field in respect to growth parameters.*

Treatments GA3+IAA	Number of shoot per plant in net house			Number of shoot per plant in field			Length of shoot per plant (cm) in net house			Length of shoot per plant (cm) in field			Length of root per plant (cm) in net house			Length of root per plant (cm) in field		
	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean
0.05mg/L+0.005 mg/L	3.41	3.38	3.39	6.05	6.01	6.03	40.10	39.70	39.90	46.8	48.1	47.4	18	18	18	20	19.7	19.9
0.1 mg/L+0.01 mg/L	3.82	3.80	3.81	6.08	6.17	6.12	44.60	44.30	44.40	53.2	52.9	53.1	18	19	19	21	21.6	21.3
0.2 mg/L+0.01 mg/L	4.20	4.13	4.16	6.32	6.37	6.34	47.40	46.20	46.80	61	60.2	60.6	19	19	19	24.6	24	24.3
0.1 mg/L+0.02 mg/L	4.46	4.40	4.43	6.94	6.88	6.91	51.30	51.30	51.30	62.2	61.4	61.8	19	19	19	25	25.2	25.1
0.2 mg/L+0.02 mg/L	4.75	4.73	4.74	7.39	7.34	7.36	55.60	54.70	55.10	64.6	65.7	65.1	20	20	20	26.5	26.8	26.6
0.4 mg/L+0.04 mg/L	4.87	4.88	4.87	9.64	9.48	9.56	56.20	56.80	56.50	72.1	70.5	71.3	20	21	20	26.9	27.2	27.1
Control	3.10	3.33	3.21	5.23	5.41	5.32	30.80	32.40	31.60	34.7	35.7	35.2	18	18	18	18.4	18.5	18.4
S Em ±	0.61	0.63	0.47	1.11	1	0.84	1.96	2.21	1.72	6.31	5.97	4.84	2.99	2.77	2.12	1.61	1.41	1.12
CD (P=0.05%)	NS	NS	NS	3.15	2.86	2.4	5.59	6.29	4.90	17.9	16.9	13.7	NS	NS	NS	4.6	4.02	3.2
CV	15.21	13.99	14.6	19.4	18.08	18.75	17.99	17.17	17.56	20.57	19.37	19.6	4.07	4.22	4.06	13.42	13.62	13.51

3.3. Root Length and Fresh Weight of Shoot

Significant variations were found among the varieties in respect of length of root per microplant. During GA3+ IAA treatments, the highest length of root per microplant (7.49 cm) was recorded with 0.4 mg GA_3/L+0.04 mg IAA/L in Kufri Bahar (Table 2). However, it was at par with 0.2 mg GA_3/L+0.02 mg IAA/L 0.1 mg GA_3/L+0.02 mg IAA/L, 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control. In Kufri Surya the maximum length of root per microplant (7.72 cm) was recorded with 0.4 mg GA_3/L+0.04 mg IAA/L and it was at par with 0.1 mg GA_3/L+0.02 mg IAA/L, 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control. Minimum length of root was recorded under control in both the varieties under study.

Significantly maximum fresh weight of shoot (493 mg) was recorded with 0.4 mg GA_3/L+0.04 mg IAA/L in Kufri Bahar. The maximum fresh weight of the shoot (494 mg) with 0.4 mg GA3/L+0.04 mg IAA/L was also recorded in Kufri Surya. The

result was at par with 0.2 mg GA_3/L+0.02 mg IAA/L, 0.1 mg GA_3/L+0.02 mg IAA/L, 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control. Minimum fresh weight of shoot in both the varieties under study was recorded under control. The findings agreed with the research presented by El-Banna et al. [2]. Kumlay [12] recorded that the longest shoot and root obtained in cv. Caspar by using the concentration 0.25 mg L^{-1} GA_3 +1 mg L^{-1} IAA.

3.4. Number of Shoots

The information in Table 3 showed that there was a considerable variance in the number of shoots compared to the control. Number of shoots increased with increasing concentration of GA_3+IAA. Maximum shoot number (4.87) and (9.56) were recorded in 0.4 mg GA_3/L+0.04 mg IAA/L. However, there was no significant difference in net house and in field. The minimum number of shoot (3.21) and (5.32) was observed in control. In vitro-grown potatoes' root and shoot development was positively impacted by GA3 [23, 8].

3.5. Shoot Length

Shoot length per plant increased with the increasing concentration of GA_3+IAA and control treatment showed the least shoot length. Significantly maximum shoot length (56.2 cm) and (56.8 cm) were recorded at 0.4 mg GA_3/L+0.04 mg IAA/L and this was at par with 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control in the 1st year and 2nd year of investigation in net house. In field significantly maximum shoot length (71.3 cm) was recorded at 0.4 mg GA_3/L+0.04 mg IAA/L and at par with 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control. Again, the significantly minimum shoot length (30.8 cm, 32.4 cm and 35.2 cm) was found in control in both the years of study in net house and in the mean of field (Table 3). *In vitro* applied GA3+IAA was more effective in increasing the shoot length linearly at all stages of treatments in net house and in field. Our findings are comparable with those of research by Ghimire [5] and Faten et al. [4], which found that the shoot length grew linearly with increasing growth promoter doses at all growth stages. The favorable effects of raising the level of growth promoters on shoot length were also noted by Birbal et al. [1] and Zhang et al. [23]. According to Zhang et al. [23], potato cultivar Zihubai's shoot length was favorably impacted by GA3 and IAA.

3.6. Root Length

The perusal of the data presented in Table 3 also revealed that different levels of GA_3+IAA significantly influenced the root length per plant. Significantly maximum mean root length (20.4 cm and 27.1 cm) was recorded at 0.4 mg GA_3/L+0.04 mg IAA/L in net house and in field. However, it was not significant in net house but in field it was at par with 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control. Minimum mean root length (18.1cm and 18.4 cm) was recorded in control as shown in Table 3. Hoque, et al. [6] showed potato explants produced better results for root length on 1.0 mg/l IAA+0.25 mg/l GA_3. Hoque, et al. [6] also showed potato explants produced better results for root length on 1.0mg L−1 IAA + 0.25mg L−1 GA3 (7.38 cm).

Table 4. *Effect of GA3 +IAA treated in vitro microplant grown in net house (G-0) and in field in respect to yield parameters.*

Treatments GA3+IAA	Number of stolons per plant in net house			Number of stolons per plant in field			Number of minitubers per plant in net house			Number of minitubers per plant in field		
	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean
0.05mg/L+0.005 mg/L	4.72	4.56	4.64	8.62	8.54	8.58	4.21	3.95	4.08	7.04	7.08	7.06
0.1 mg/L+0.01 mg/L	5.14	5.22	5.18	8.82	8.66	8.74	4.58	4.67	4.62	8.52	8.51	8.51
0.2 mg/L+0.01 mg/L	5.94	5.74	5.84	9.12	9.12	9.12	5.54	5.37	5.45	8.94	8.89	8.91
0.1 mg/L+0.02 mg/L	6.03	6.04	6.03	9.68	9.63	9.65	5.88	5.75	5.81	9.38	9.39	9.37
0.2 mg/L+0.02 mg/L	6.45	6.38	6.41	10	10.2	10.1	6.27	6.18	6.22	9.76	9.99	9.86
0.4 mg/L+0.04 mg/L	8.62	8.54	8.58	11.2	11.4	11.3	8.19	8.23	8.21	10.5	10.6	10.5
Control	4.66	4.49	4.57	6.07	6.12	6.09	3.84	3.87	3.85	5.6	5.49	5.54
S Em ±	0.58	0.61	0.50	1.51	1.46	1.3	0.59	0.61	0.50	1.41	1.41	1.13
CD (P=0.05%)	1.65	1.74	1.43	4.3	4.17	3.71	1.70	1.76	1.44	4.01	4.02	3.24
CV	21.32	21.87	21.59	16.16	16.71	16.44	24.99	25.76	25.38	18.31	19.05	18.6

Table 5. *Effect of GA3 +IAA treated in vitro microplant grown in net house (G-0) and in field in respect to growth and yield parameters.*

Treatments GA3+IAA	Potato Shape Index in net house			Potato Shape Index in field			Fresh weight of minitubers per plant (g) in net house			Fresh weight of minitubers per plant (g) in field		
	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean
0.05mg/L+0.005 mg/L	164	164	164	166	168	167	141	142	142	176	173	175
0.1 mg/L+0.01 mg/L	167	168	167	166	169	168	153	153	153	183	185	184
0.2 mg/L+0.01 mg/L	174	174	174	203	208	206	162	160	161	200	200	200
0.1 mg/L+0.02 mg/L	178	177	178	238	245	242	170	171	171	207	222	215
0.2 mg/L+0.02 mg/L	220	215	217	255	245	250	175	175	175	233	240	236
0.4 mg/L+0.04 mg/L	237	243	240	274	269	272	185	185	185	256	255	255
Control	163	162	162	165	163	164	127	129	128	129	128	129
S Em ±	14.20	18.80	12.90	24.3	25.2	22.2	4.03	5.57	3.47	14.2	18.6	14.4
CD (P=0.05%)	40.5	53.70	36.90	69.3	72.5	63.2	11.4	15.8	9.86	40.6	52.9	41.1
CV	14.83	15.32	15.07	20.43	19.42	19.91	11.75	11.38	11.54	19.26	19.99	19.42

3.7. Number of Stolons

The data presented in Table 4 indicate that the number of stolons increased with the increasing concentration of GA_3+IAA. Significantly maximum stolons number (8.58 and 11.3) was recorded in 0.4 mg GA_3/L+0.04 mg IAA/L treatments in net house and in field. However, it was at par with 0.2 mg GA_3/L+0.02 mg IAA/L, 0.1 mg GA_3/L+0.02 mg IAA/L, 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control in net house and significantly differ from control in field. The minimum number of stolons (4.57) was recorded in control. Rahdari et al. [17] observed that auxins improve the root quality and number of branches in *Cordyline terminalis*. Indole-3-acetic acid stimulate stolon formation in LDs, both in the presence or absence of GA3 [22].

Xu et al. [22] used an in vitro tuberization system to show that the addition of IAA to a tuber-inducing medium accelerated tuber initiation while the addition of IAA and GA under non-inductive conditions slowed stolon growth.

3.8. Number of Minitubers

The data presented in Table 5 indicate that number of minitubers increased with increasing concentration of GA_3+IAA. Significantly maximum minitubers number (8.21 and 10.5) was recorded in 0.4 mg GA_3/L+0.04 mg IAA/L in net house and in field. However, it was at par with 0.2 mg GA_3/L+0.02 mg IAA/L, 0.1 mg GA_3/L+0.02 mg IAA/L, 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control in net house while, in field it was significantly differ from 0.05 mg GA_3/L+0.005 mg IAA/L and control. Minimum minitubers number found in both the years was recorded in control in net house and in field. IAA delay the leaf senescence and enhance the chlorophyll content that may favour the tuberization process. IAA applied *in vitro* was more effective in increasing the number of minitubers linearly in all stages of treatments in net house. This might be because auxin levels rise sharply in the stolon just before tuberization and then stay reasonably high during subsequent tuber growth, indicating an auxin-promoting function in tuber formation [18]. Auxin stimulate the potato tuber initiation and growth [9].

3.9. Potato Shape Index (PSI)

The highest potato shape index (240 PSI and 272 PSI) was recorded in 0.4 mg GA_3/L+0.04 mg IAA/L treatments. However, it was at par with 0.1 mg GA_3/L+0.02 mg IAA/L, 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control in net house and 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control in field. The lowest potato shape index (162 PSI and 164 PSI) was recorded in control in net house and in field (Table 4). The potato shape index indicates potato was oval in shape. The combined application of GA_3+IAA increased the shape of minitubers compared to control. Our findings are in agreement with the studies carried by Kumar et al. [10]. Kumar et al. [10] observed that the application of GA_3 and IAA increased the value of potato shape index significantly over the control.

3.10. Fresh Weight of Minitubers

Different concentration of GA_3+IAA influences fresh weight of minitubers. GA_3+IAA at 0.4 mg GA_3/L+0.04 mg IAA/L gave maximum minitubers fresh weight (185g & 255g) whereas it was at par with 0.2 mg GA_3/L+0.02 mg IAA/L, 0.1 mg GA_3/L+0.02 mg IAA/L, 0.2 mg GA_3/L+0.01 mg IAA/L, 0.1 mg GA_3/L+0.01 mg IAA/L and 0.05 mg GA_3/L+0.005 mg IAA/L and control in net house and in field. The minimum fresh weight of minitubers was found in control (128g) as shown in Table 5. Utilizing plant growth regulators in the field and *in vitro* improved the quality and output of many goods, according to several researchers Lim et al. [13] and Otroshy, [16].

4. Conclusion and Future Aspects

GA_3 and IAA had great effect on microplants and minitubers production and a significant result was observed in all of trails. Future research is therefore necessary to functionally characterize the auxin signalling elements in these crops so that they can be used to increase storage root yields. The role of auxin and GA3 should be investigated for boosting the yield in tuber and store root crops, in our opinion, in light of the available research. Auxin and GA3 may also play a function in the inhibition of stolon elongation and subsequent stimulation of the potato tuber formation process. For this element to be validated in potato growth as well as storage root development of tuber and storage root crops, respectively, more research is required.

Declaration

The author declare that they have no competing interests.

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