INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 25, No. 1, p. 236-241, 2024

RESEARCH PAPER OPEN ACCESS

Effects of gibberellic acid on potato (*Solanum tuberosum* L.) growth and development during off-season cultivation

Suresh Bharali[1], Narayan Sarkar*[2] Nijam Gayary[3], Dipak Konwar[4], Gunajit Kalita[5]

[1]*Department of Botany, Tihu College, Tihu, Assam, India*

[2]*Department of Botany, Gauhati University, Guwahati, Assam, India*

[3]*Rain Forest research institute, Jorhat, Assam, India*

[4]*Department of Botany, Pub Kamrup College, Baihata, Assam, India*

[5]*Deparmentt of Botany, Nalbari College, Nalbari, Assam, India*

Key words: Gibberellic acid, Germination rate, Plant growth regulators, Dormancy, Photosynthetically efficient

http://dx.doi.org/10.12692/ijb/25.1.236-241 Article published on July 09, 2024

Abstract

Solanum tuberosum L. (potato) is a crop in temperate regions, exhibiting exceptional food productivity and adaptability. Plant hormones can be used to increase the yields. Gibberellic Acid 4+7(GA4+7) is a plant growth regulator which can increase germination rate of some seeds and induce leaves. In this study, Potato tubers were treated with different concentration of GA4+7 solution and another set of tubers were treated with distilled water(controlled).The different growth parameters such as number of sprouts, Length of seedlings, number of leaves and Chlorophyll content was observed after 15, 22, 29 and 36 days. The result showed that the number of sprouts of potato tubers was increased with the increasing concentration. The lengths of the potato seedling of GA4+7 treated tubers were more than the seedlings of the controlled tubers. Also, the GA4+7 treated seedlings produced more leaves and more chlorophyll content in leaves than the controlled seedlings. This result suggests that GA4+7 can induce germination of potato tubers and break the dormancy. It can enhance seedling growth by producing photosynthetically efficient leaves and finally the tuber growth takes place and ultimately the yield of potato tuber increases.

* **Corresponding Author:** Narayan Sarkar ✉ sarkarnarayn8@gmail.com

Introduction

Potato (*Solanum tuberosum* L.) is a vital crop in temperate regions, renowned for its high food productivity and adaptability. As a leading starchy tuber crop, it plays a crucial role in food security. The virtues of potato, including its high yield potential, short growth cycle, and ease of processing, render it an ideal candidate for cultivation. In India Potato production thrives in Gangetic plains, where over 80% of this this tuber crops are grown from October to March. However, there is a dormant phase typically spanning from January to September that potato tubers experience and is indistinguishable from tuber initiation and enlargement. There are many mechanisms in common with the regulatory systems in the dormancy of tubers especially the system which seems to involve balance between inhibitory and stimulatory growth regulators. We can expect that onset of the suspended state whether it is true dormancy or a quiescent state, involves a closing down the synthetic capabilities of the plants.

Plant hormone Gibberellins have been shown to play a decisive role in all phases of plant growth. Its effects on various physiological processes, including seed germination, seedling growth, and chlorophyll development, have been extensively studied. GA3 has also been shown to increase yields and improve fruit quality in crops such as potatoes, sugarcane, and chilli (Holmes and Lang, 1978; Moore, 1980; Balraji *et al.*, 2002). GA4 and GA7 are also reported to enhance the crop productivity on different crops. GA_4 and GA_7 differ from GA_3 in the presence or absence of hydroxyl at the junction of rings C and D and there is also difference in regard to the presence or absence of double bond ring A. Dennis and Nitsch (1966) positively identified GA_4 and GA_7 in immature endosperm of apple. Originally GA_4 and GA_7 were isolated from *Gibberella fujikuroi* mycelial filtrate (Takahashi *et al.,* 1955). Poggi Pellegrin and Bulard (1976) found that GA4 was ten times more active than GA3 in promoting germination, hence physiologically more active. Moreover, GA_{4+7} proved to be highly stimulatory at high day time temperature alternating with night temperature of 20 to 25 °C (Palevtich and Thomas, 1974).

Recent studies have also shown that GA_4 and GA_7 have different effects on plant growth and development. GA_4 has been shown to promote seed germination, seedling growth, and stem elongation (Yamaguchi *et al.*, 2020; Li *et al.*, 2022). On the other hand, GA7 has been shown to inhibit seed germination and promote root growth (Liu *et al.*, 2020; Zhang *et al.*, 2022). GA4 and GA7 have also been shown to interact with other plant hormones, such as auxin and cytokinin, to regulate plant growth and development (Chen *et al.*, 2020; Wang *et al.*, 2022). In addition, GA_{4+7} have been shown to be involved in plant responses to environmental stresses, such as drought and high temperatures (Kumar *et al.*, 2020; Singh *et al.*, 2022). Overall, the literature suggests that GA_{4+7} play important roles in plant growth and development, and that they interact with other plant hormones and environmental factors to regulate plant response.

The aim of this study was to contribute to the existing body of knowledge by investigating the effects of GA_{4+7} on potato growth and development during off season, with potential applications in optimizing crop yields and food security.

Materials and methods

Preparation of gibberellic acid solution

A GA_{4+7} stock solution was prepared by dissolving 1.0 gm in absolute alcohol and making up to 1000 ml with distilled water. This gives 1000ppm solution. From this the solution of 10, 50, 100, 250 and 500 ppm were prepared.

Collection and sterilization of potato tubers

Fresh, healthy potato tubers (*S. tuberosum* L.) were collected and were treated with Dithane M45 (0.5%) for surface sterilization.

Treatment of potato tubers

The Potato tubers were then placed in GA_{4+7} concentrations and another set was placed in distilled water (control) for 24 hours. The tubers were then transferred to the soil and moistened occasionally.

Calculation of number of sprouts, length of seedlings and leaf number and measurement of chlorophyll content

The different developmental parameters such as number of sprouts, shoot length, number of leaves, and chlorophyll contents of leaves were observed after 15, 22, 29 and 36 days. Measurements were taken at 7-day intervals, and mean values were used to draw action-curves and results were analyzed statistically. Chlorophyll content was measured following the Arnon (1949) method. The chlorophyll content of potato leaves was extracted and analysed after 40 days of treatment. The optical density of the extract was measured with a B and L Spectronic 20 at the wave length of 644 mμ, 652 mμ and 663 mμ. The concentration of chlorophyll-a, chlorophyll-b and total chlorophyll in mg/g of tissue was calculated by the formulae.

Chlorophyll-a mg/g tissue = $\frac{[12.7(D663) - 2.69(D644)] \times V}{1000 \times W}$

Chlorophyll-b mg/g tissue = $\frac{[22.9(D644) - 4.68(D633)] \times V}{1000 \times W}$

Total chlorophyll mg/g tissue = $\frac{D.652 \times 1000}{34.5} \times \frac{V}{1000 \times W}$

Where, D represents optical density,

V, final volume of chlorophyll extract in 85 per cent acetone

W, the fresh weight in gm of the tissue extracted

Results

Effect of GA_{4+7} on sprouting of tubers

GA_{4+7} stimulated sprouting in potato tubers, breaking dormancy. The effect increased with concentration (10-1000 ppm) and time (15-36 days). The optimal concentration was 1000 ppm, resulting in 6.0 sprouts per tuber after 36 days, compared to 1.0 in the control. The number of sprouts on each tuber treated with 10, 50, 100, 250, 500 and 1000 ppm of $GA_{4+7}$was counted after 15 days and the same repeated after 22 29 and 36 days and the mean value of triplicate are recorded (Table 1). From the data action- curves were drawn (Fig. 1) and analysis of variance is done at 1% significance level of probability (Table 2). For each concentration, the number of sprouts increases from 15 days to 36 days. The statistical analysis showed that the effect of GA on germination of potato was inhibitory.

Table 1. Number of sprouts on tubers treated with GA_{4+7}

Conc. of GA_{4+7}	Time in days				Total for conc.	Mean
	15	22	29	36		
0	0.1	0.3	0.7	1.0	2.1	0.5
10	1.4	2.4	3.0	3.5	10.3	2.5
50	2.3	3.0	3.5	4.0	12.8	3.2
100	2.4	3.2	3.9	4.2	13.7	3.4
250	2.9	3.4	4.2	4.6	15.1	3.7
500	3.1	3.9	4.9	5.4	17.3	4.3
1000	3.9	4.5	5.4	6.0	19.8	4.9
Total for time	16.1	20.7	25.8	28.7		
Mean	2.30	2.95	3.65	4.1		

CD for GA_{4+7} (n=12)

At 5% level of probability = 0.41,

At 1% level of probability = 0.57

CD for time (n=21)

At 5% level of probability = 0.29

At 1% level of probability = 0.40

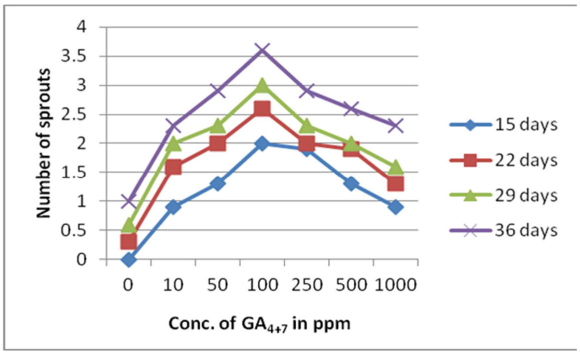

Fig. 1. Action-curves on number of sprouts treated with GA4+7

Table 2. Analysis of variance of sprouting

Source of variance	SS	DF	MSS	F-Value
GA_{4+7}	47.46	7-1=6	7.91	131.83**
Time	13.3	4-1=3	4.43	73.83**
Error	1.24	3x6=18	0.06	
Total	62	84		

**Significance at 1% level of probability

Length of the plants

The sprouted tubers gradually started sending off their shoots. The length of the shoots was recorded after 15, 22, 29 and 36 days of sprouting of tubers. The means were calculated out and presented in table (Table 3). The collected data were subjected to statistical analysis and the analysis of variance is presented in table (Table 4). From the means action-curves were drawn (Fig 2). The length of the seedlings increases from 15 days to 36 days for all the concentrations. The effect of GA on seedling length was stimulatory. Statistical analysis showed that the effect was significant.

Table 3. Length of plants (cm) emerged from GA4+7 treated tubers

Conc. of GA_{4+7} (ppm)	Time in days 15	22	29	36	Total for conc.	Mean
0	0.0	0.2	0.5	0.7	1.4	0.35
10	0.6	1.1	2.0	2.8	6.5	1.6
50	0.8	1.2	2.4	3.1	7.5	1.8
100	1.1	1.5	2.8	3.5	8.9	2.2
250	1.4	2.0	3.1	4.1	10.6	2.6
500	2.5	3.2	4.2	5.5	15.4	3.8
1000	3.5	5.2	6.2	7.6	22.5	5.6
Total for time	9.9	14.4	21.2	27.3		
Mean	1.41	2.05	3.02	3.9		

CD for GA_{4+7} (n=12)

At 5% level of probability = 0.61

At 5% level of probability = 0.61

CD for time (n=21)

At 5% level of probability = 0.53

At 1% level of probability = 0.38

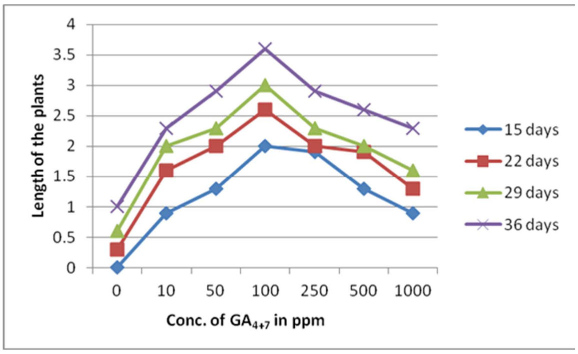

Fig. 2. Action-curves on length of the plants with GA4+7

Table 4. Analysis of variance of plant length

Source of variance	SS	DF	MSS	F-Value
GA_{4+7}	69.57	7-1=6	11.59	61.02**
Time	25.01	4-1=3	8.33	43.84**
Error	3.58	3x6=18	0.19	
Total	98.16	84-1=83		

**Significance at 1% level of probability

Numbers of leaves

Number of leaves emerged from tubers treated with GA_{4+7} was recorded after second, third, fourth and fifth week of treatment and means were calculated out (Table 5). The obtained data were used for statistical analysis and the analysis of variance is represented in a table (Table 7). After fifth week of treatment at the optimal concentration of 500 ppm the mean number of leaves was 19.2 against 8.2 at control. From the table it was found that $GA_{4+7}$was highly significant promontory effect on the number of leaves per plant.

Table 5. Mean number of leaves on plants emerged from GA4+7 treated tubers

Conc. of GA_{4+7} (in ppm)	Time in days 15	22	29	36	Total for Conc.	Mean
0	1.0	2.8	6.0	8.2	18	4.5
10	2.0	3.0	7.0	8.6	20.6	5.1
50	2.2	4.6	10.6	12.1	29.5	7.3
100	2.6	6.6	12.0	14.3	35.5	8.8
250	3.0	7.2	14.2	17.0	41.4	10.3
500	3.2	9.4	17.4	19.2	49.2	12.3
1000	3.0	8.0	16.2	17.2	44.4	11.1
Total for time	17.0	41.6	83.4	96.6		
Mean	2.42	5.94	11.91	13.8		

CD for GA_{4+7} (n=12)

At 5% level of probability =1.24

CD for time (n=21)

At 5% level of probability = 0.88

Table 6. Analysis of variance

Source of variance	SS	DF	MSS	F-Value
GA_{4+7}	213	7-1=6	35.5	18.58**
Time	603.75	4-1=3	201.25	105.36**
Error	34.43	6x3=18	1.91	
Total	851.18	84-1=83		

**Significance at 1% level of probability

Table 7. Chlorophyll content (mg/g) of potato leaves

GA_{4+7} Conc. (ppm)	Chl-a ± SE (mg/g)	Chl-b ± SE (mg/g)	Total chl.± SE(a+b) (mg/g)
0	0.298 ± 0.004	0.461 ± 0.007	0.759 ± 0.011
10	0.367 ± 0.006	0.531 ± 0.008	0.898 ± 0.014
50	0.401 ± 0.006	0.565 ± 0.010	0.966 ± 0.016
100	0.433 ± 0.006	0.625 ± 0.009	1.058 ± 0.015
250	0.481 ± 0.004	0.677 ± 0.012	1.158 ± 0.016
500	0.509 ± 0.005	0.745 ± 0.005	1.254 ± 0.010
1000	0.429 ± 0.001	0.679 ± 0.003	1.108 ± 0.004

Chlorophyll contents

The chlorophyll content of the leaves increases from 15 days to 36 days for all the concentrations. The statistical analysis showed that the effect of GA on chlorophyll content of leaves was stimulatory and the effect was significant (Table 7).

Discussion

The results of this study demonstrate the highly stimulatory effect of GA4+7 on breaking dormancy of potato tubers, increasing sprout number, shoot length, leaf number, and chlorophyll content. The time effect was also found to be highly significant.

The statistical analysis revealed an efficient stimulatory effect of GA4+7 on breaking dormancy in potato tubers, with a dose-dependent increase in sprouting intensity from 10 to 1000 ppm. The optimal concentration of 1000 ppm GA4+7 induced a six-fold increase in mean sprout number compared to the control after 36 days, indicating a maximal response. This finding is in agreement with previous research demonstrating the efficacy of gibberellins in promoting seed germination and seedling growth (Dennis and Nitsch, 1966; Yamaguchi *et al.*, 2020), further supporting the role of GA4+7 in overcoming dormancy and enhancing sprouting in potato tubers.

The significant increase in shoot length and leaf number at 1000 ppm and 500 ppm GA4+7, respectively, suggests a promotory effect on cell elongation and cell division, leading to enhanced plant growth. This is in agreement with previous findings on the role of gibberellins in regulating cell growth and differentiation (Moore, 1980). Specifically, at the maximal concentration of 1000 ppm, the mean shoot length attained 7.6 cm after 36 days, whereas the control treatment exhibited a significantly truncated mean length of 0.7 cm. Statistical analysis of the data via analysis of variance revealed significant differences in shoot length among treatments. The mean values were subsequently used to construct action-curves, illustrating the dose-response relationship between GA4+7 concentration and shoot length.

The results of this study also demonstrate a highly significant promotory effect of GA4+7 on the number of leaves per plant in potato, consistent with previous research on the role of gibberellins in promoting leaf growth and development. The optimal concentration of 500 ppm GA_{4+7} resulted in a maximum mean value of 19.2 leaves per plant after five weeks of treatment. These findings support the potential use of GA_{4+7} as a plant growth regulator to enhance potato productivity.

The results demonstrate a significant increase in chlorophyll content of potato leaves in response to GA4+7 applications, with a maximum enhancement observed at 500 ppm. This finding is consistent with previous research on the role of gibberellins in regulating chlorophyll biosynthesis and photosynthetic activity (Chen *et al.*, 2020; Kumar *et al.*, 2020). The optimal concentration of 500 ppm GA4+7 resulted in a 71% increase in chlorophyll a content, 62% increase in chlorophyll b content, and 65% increase in total chlorophyll content, compared to the control. This enhanced chlorophyll content suggests improved photosynthetic activity, which can contribute to increased potato productivity. This is consistent with previous studies on the role of gibberellins in regulating chlorophyll content and photosynthesis (Chen *et al.*, 2020). The dose-dependent response of chlorophyll content to GA4+7 application suggests a hormonal regulation of chlorophyll biosynthesis. Gibberellins are known to regulate gene expression and enzyme activity involved in chlorophyll biosynthesis (Yamaguchi *et al.*, 2020). The findings of this study support the potential use of GA4+7 as a plant growth regulator to enhance potato productivity. Further research is needed to investigate the molecular mechanisms underlying the effects of GA4+7 on chlorophyll content and photosynthetic activity in potato. Additionally, field trials should be conducted to validate these findings and explore the practical applications of GA4+7 in potato cultivation

Conclusion

In conclusion, the study demonstrates that GA4+7 has a profound impact on potato tuber sprouting, shoot growth, leaf development, and chlorophyll content. The findings of this study have significant implications for potato cultivation, particularly in regions where potato is a staple crop. The use of GA4+7 as a plant growth regulator can potentially increase potato yields, improve tuber quality, and enhance food security.

Further research is needed to explore the molecular mechanisms underlying the effects of GA4+7 on potato growth and development. Additionally, field trials should be conducted to validate these findings and explore the practical applications of GA4+7 in potato cultivation. Overall, this study highlights the potential of GA4+7 as a valuable tool for improving potato productivity and contributes to the development of sustainable agricultural practices. Our study highlights the potential of GA4+7 to overcome the dormant phase of potato tubers, allowing for off-season cultivation.

References

Balraji S. 2002. Effect of gibberellic acid on growth and yield of chilli. Journal of Agricultural Science **139(3),** 271-276.

Chen J. 2020. Gibberellin and auxin interactions in plant growth and development. Journal of Plant Growth Regulation **39(2),** 531-545.

Holmes JC, Lang NS. 1978. The effect of gibberellic acid on tuber yield and stem number in potatoes. Potato Research **21(2),** 147-155.

Kumar P, Kumar V, Sharma R. 2020. Gibberellins: A review on their role in plant growth and development. Journal of Plant Growth Regulation **39(2),** 531-545.

Li X. 2022. Gibberellin A4 promotes seed germination and seedling growth in *Arabidopsis thaliana*. Plant Physiology and Biochemistry **171,** 110-118.

Liu Y. 2020. Gibberellin A7 inhibits seed germination and promotes root growth in rice. Plant Science **292,** 110-118.

Moore PH. 1980. Gibberellic acid-induced increase in sugarcane yield. Crop Science **20(3),** 367-370.

Palevitch D, Thomas TH. 1974. Gibberellin-induced germination of muskmelon seeds. Journal of Experimental Botany.

Poggi Pellegrin MF, Bulard C. 1976. Effect of gibberellic acid on germination of lettuce seeds. Physiologia Plantarum **38(2),** 127-132.

Singh R. 2022. Gibberellins and plant responses to environmental stresses. Journal of Plant Growth Regulation **41(1),** 1-13.

Wang Y. 2022. Gibberellin and cytokinin interactions in plant growth and development. Plant Physiology and Biochemistry **172,** 110-118.

Yamaguchi S. 2020. Gibberellin A4 promotes stem elongation in *Arabidopsis thaliana*. Plant Physiology **182(2),** 531-545.

Zhang Y. 2022. Gibberellin A7 promotes root growth and inhibits seed germination in maize. Plant Science **296,** 110-118.