Effect of Gibberellic Acid (GA_3) on Growth and Tuber Yield of Potato Under Aeroponic Conditions

Dhanorkar Shravani Shankarrao [1], Dr. Naveen Joshi [2]

[1,2] Department of Biotechnology, Mansarovar Global University, Sehore, M.P., India.

ABSTRACT

This study evaluated the effect of Gibberellic acid (GA_3) at 0.25 mg/L on the growth and tuber production of potato plants cultivated under aeroponic conditions. Tissue-cultured potato plantlets were acclimatized and grown in a controlled polyhouse environment using a standard hydroponic nutrient system. Growth parameters were assessed at 7, 15, 30, and 45 days and compared with untreated controls using statistical analysis ($P < 0.05$). No significant differences were observed at 7 days; however, from the 15th day onward, GA_3 treatment significantly enhanced shoot length, stem length, leaf length, and plant height. By the 45th day, a marked increase in leaf thickness and tuber number was recorded, with tuber yield nearly doubling compared to the control. The results indicate that GA_3 application effectively promotes vegetative growth and enhances tuber production in aeroponic potato cultivation, suggesting its potential for improving seed potato production systems.

Keywords: *Aeroponics; Gibberellic Acid (GA_3); Potato; Plant Growth; Tuber Yield.*

INTRODUCTION

This research investigates the influence of gibberellic acid (GA_3) supplementation within hydroponic nutrient solutions on key growth parameters of potato plants cultivated under aeroponic conditions, specifically focusing on alterations in leaf, stem, and root morphology, as well as the quantitative assessment of tuber formation. The application of gibberellic acid (GA_3) is known to influence various physiological processes in plants, including stem elongation and tuber initiation (Çalışkan et al., 2021). Specifically, exogenous applications of gibberellic acid have been observed to temporarily promote early leaf growth and dry matter production, yet in some instances, inhibit tuberization in potato plants (Bodlaender & Waart, 1989). This inhibitory effect often stems from gibberellin's role in promoting shoot growth over tuber development, thereby reallocating photosynthates towards canopy expansion (Hamdani et al., 2024). Conversely, optimizing gibberellin concentrations and application timing can be crucial for dormancy release and successful sprouting of potato tubers, impacting subsequent growth and yield (Prathama et al., 2023; Qayyum et al., 2025). Given that potato mini-tubers are often cultivated in aeroponic systems to mitigate challenges like high temperatures and soil-borne diseases (Filho et al., 2022; Lhokitasari et al., 2022), understanding the precise hormonal interactions, particularly with gibberellins, becomes critical for maximizing yield and quality in controlled environments (Saidi & Hajibarat, 2021). In recent time use of phytohormones such as gibberellins, anti-gibberellins, and cytokinins has shown promise in modulating tuberization and overall plant morphology in potato (Bharath & B, 2024). Hence it is necessary to study about its dose and application regime to optimize potato development under aeroponic conditions (Bharath & B, 2024). Since these plant growth regulators are costly its economic feasibility in large-scale aeroponic systems needs thorough evaluation to ensure cost-effectiveness while achieving desired physiological responses. In present scenario, use of phytophormone still not find to be economically viable in many commercial aeroponic setups, necessitating further research into optimized application strategies and cost-efficient synthesis methods. Present study aims to determine the optimal concentration of gibberellic acid in the nutrient solution for enhancing potato tuber yield and quality within an aeroponic system, focusing on its impact on physiological parameters and tuberization kinetics.

(Sumarni et al., 2022) This investigation will specifically assess the impact of varying gibberellic acid concentrations on leaf area index, internode elongation, root biomass, and the number and size distribution of tubers, thereby elucidating the dose-dependent physiological responses critical for aeroponic potato cultivation. As a success story use of aeroponics along with phyto hormone for potato production in aeroponics has already been demonstrated to substantially improve mini-tuber production, with optimal conditions potentially inducing greater stolon development due to enhanced humidity and darkness at the stem base (García-Segura et al., 2021; Sharma et al., 2020). In India, the aeroponics technique, despite its advantages, is still in its nascent stages and requires further refinement to enhance system efficacy (Sharma et al., 2023).

METHODOLOGY

Collection of Potato Plantlets

In the study healthy potato plantlets received from plant tissue conditioned and later on hardened in polyhouse till complete 30 days growth period.

Set Up of The Aeroponics Tower

In the study potato seed production along with overall plant growth under the influence of Gibberellic acid 3 (GA_3) once treated twice by 0.25mg/litre, was investigated. Here complete aeroponics set up been made as shown in Fig.1. Set up aeroponics made separate for control and GA_3 treated hydroponics nutrient.

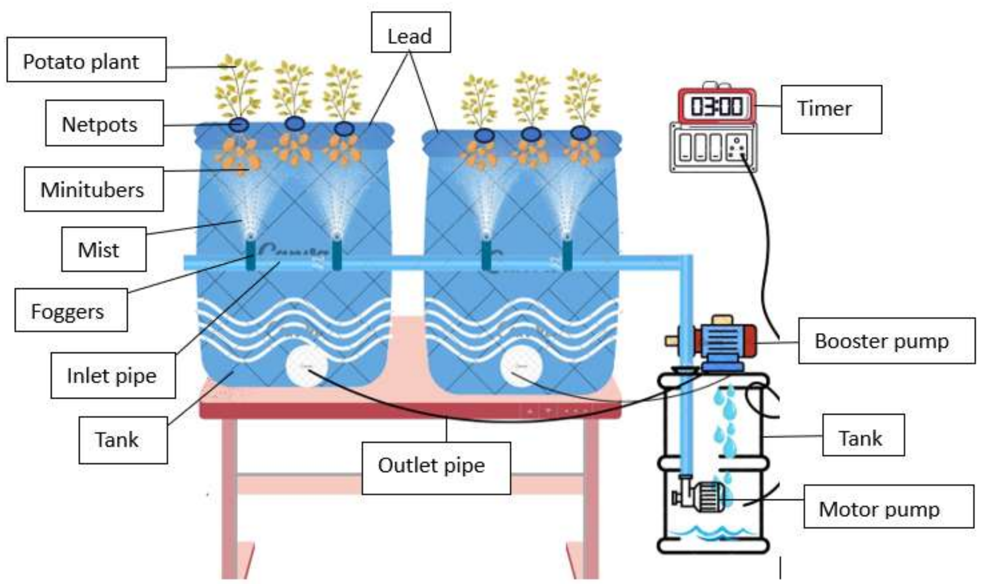

Fig.1: Aeroponics Setup View Made for The Potato Study

Nutrient and Polyhouse Set Up

The commercial grade leafy hydroponics nutrient used as solution A and solution B having elemental composition as Nitrate nitrogen (210ppm), Phosphorous (60ppm), Potassium (330ppm), Calcium (170mm), Magnesium (50ppm), Sulphur(65ppm), Iron (6.0ppm), Manganese(2.0ppm), Boron (0.3ppm), Copper (0.06ppm), Zinc (0.06ppm) and molybdenum (0.07ppm). The solutions added as 1:1 ratio and TDS level set between 500-1000 ppm as per plant stage.

The other regular maintenance of pH, nutrient level and plant management carried out as per protocol.

Green House Condition

The aeroponic set up maintained with green house and plantation study carried out in the winter season (November to January) with relative minimum and maximum temperature recorded to be 15°C to 30°C respectively. During study humidity maintained with 75%.

Data Recording and Statistics

The real effect of 0.25mg/lit. GA_3 on potato plant growth under aeroponics conditions was investigated along with control set. Here statistical changes in shoot length, root length, stem length, leaf length, number of leaves, number of shoots, number of stems, plant height, leaf thickness, stem thickness, shoot thickness, stolon length and number of tubers. The t- test was applied to record the statistical significant change ($P<0.05$) once control versus experimental data compared.

RESULT AND DISCUSSION

Effect of GA_3 on Potato Plant Growth (7th Day Analysis)

In the study plant tissue cultured potato plantlets once treated with 0.25mg/lit of GA_3 along with control under aeroponics condition its defined change by the 7th day was statistically analyzed. Here once comparative changes in potato shoot length, root length, stem length, leaf length, and number of leaves, number of shoots, and number of stems, plant height, leaf thickness and stem thickness recorded. Here no significant change ($P>0.05$) was recorded by the 0.25mg/lit GA3 till 7th day (Table 1 and Fig 2). However, subsequent measurements at later growth stages are necessary to determine the full impact of GA_3 on morphological parameters, as previous research indicates that such effects often manifest after extended periods (Kumari, 2023; Partap et al., 2020; Sharma et al., 2023). For instance, the application of various plant hormones, including gibberellic acid and anti-gibberellins, has been shown to significantly influence potato tuberization and growth when applied during the stolonization period (Bharath & B, 2024). Conversely, optimizing GA_3 concentration and exposure duration has been demonstrated to effectively break dormancy and enhance sprouting vigor in potato tubers, suggesting that the timing and methodology of GA_3 application are critical for eliciting a physiological response (Qayyum et al., 2025).

Table 1: Comparative Change in The Plant Parameters of *S. Tuberosum* Till 7th Day Upon GA_3 Treatment in Aeroponics

Parameters	Control	Experiment	P value	Significant
Shoot length	12±3.7	11±4.7	0.5965	No
Root length	8.4±3.4	8.5±3.7	0.9545	No
Stem length	1.5±0.94	2.0±1.3	0.1236	No
Leaf length	1.7±0.96	2.1±0.85	0.0732	No
No of leaves	23±11	31±12	0.1005	No
No of shoots	1.3±4.5	1.3±4.9	0.6701	No
No of stems	7.3±2.7	9.8±5.3	0.1622	No
Plant height	21±5.5	20±6.6	0.7591	No
Leaf thickness	0.38±0.23	0.51±0.25	0.0191	No
Stem thickness	1.2±0.63	1.3±0.55	0.5313	No
Shoot thickness	3.6±0.61	3.9±1.1	0.4318	No

Control Plant on 7th Day | **Experimental Plant on 7th Day**

Fig. 2: No Significant Changes Recorded Upto Seventh Days with GA_3 Treatment with Potato Plants Under Aeroponics

15th Days Analysis

Under aeroponics condition added GA_3 as growth regulator found to be imparting some positive impact on potato plant growth. Here control versus experimental data of shoot length (cm) (17±3.7 vs 24±8.8 P <0.0241); stem length (cm) (2.2±0.82 vs 4.0±1.4 P< 0.0001); leaf length (cm) (2.7±0.86 vs 4.4±1.3 P< 0.0001); plant height (cm) (28±5.4 vs 37±9.5 P < 0.0092) respectively. While no significant change (P>0.05) recorded with root length, number of leaves, number of shoots, number of stems, leaf thickness and stem thickness (Table 2 and Fig.3). This suggests a differential sensitivity of various morphological attributes to GA_3 treatment at this specific time point, with aerial components exhibiting a more immediate response compared to subterranean structures or secondary growth parameters. Previous studies have similarly observed that exogenous applications of gibberellins often yield limited effects during early growth stages, attributable to complex hormonal balances within the plant (Eissa et al., 2025). However, other studies indicate that GA_3 treatments can significantly affect growth variables such as length and diameter in apical sprouts, particularly when considering interactions with immersion time and other growth regulators like 6-benzylaminopurine (Lizarazo-Peña et al., 2020).

Table 2: Comparative Change in The Plant Parameters of *S. Tuberosum* Till 15th Day Upon GA_3 Treatment in Aeroponics

Parameters	Control	Experiment	P value	Significant
Shoot length	17±3.7	24±8.8	0.0241	Yes
Root length	11±3.7	13±2.3	0.0825	No
Stem length	2.2±0.82	4.0±1.4	<0.0001	Yes
Leaf length	2.7±0.86	4.4±1.3	<0.0001	Yes
No of leaves	28±11	44±20	0.0301	No
No of shoots	1.3±0.45	1.4±0.51	0.4086	No
No of stems	12±3.8	11±3.7	0.3901	No
Plant height	28±5.4	37±9.5	0.0092	Yes
Leaf thickness	0.39±0.20	0.31±0.16	0.780	No
Stem thickness	0.99±0.53	0.82±0.33	0.0681	No
Shoot thickness	4.1±0.78	3.3±0.64	0.0109	Yes

Fig. 3 Control and Experimental Plant on 15th Day with Better Effect of GA_3 on Plant Growth for Several Parameters

30th Day Analysis

Here by the 30th days an increase in positive effect with several parameters remained as like as 15th day and here additional number of leaves found to be increasing in GA_3 set once compared to control. Here significant increase ($P<0.05$) recorded in control versus GA_3 values, since we recorded an increase in shoot length (cm) (25±4.5 vs 32±10 $P< 0.0386$); stem length (cm) (2.8±0.87 vs 3.8±1.1 $P< 0.0001$); leaf length (cm) (2.9±0.80 vs 4.2±1.2 $P< 0.0001$); number of leaves (38±14 vs 58±22 $P< 0.0124$); plant height (cm) (39±4.8 vs 47±11 $P< 0.0328$). Here once again no significant change ($P>0.05$) recorded with GA_3 treatment for parameters as root length, number of shoots, number of stems, leaf thickness, stem thickness and shoot thickness (Table 3 and Fig. 4) These findings indicate a continued trend of GA_3 primarily influencing longitudinal growth in aerial parts, while root development and thickening growth appear to be less responsive or require different hormonal signaling pathways. This differential response highlights the intricate regulatory mechanisms governing plant morphology, where specific growth regulators like GA_3 selectively modulate certain developmental processes while leaving others largely unaffected at particular stages. This selective modulation is consistent with findings where gibberellic acid significantly increased stem and internode length in various species, often without a proportional effect on stem diameter or root development (Li et al., 2022; Sardoei et al., 2024).

Table 3: Comparative Change in The Plant Parameters of *S. Tuberosum* Till 30th Day Upon GA_3 Treatment in Aeroponics

Parameters	Control	Experiment	P value	Significant
Shoot length	25±4.5	32±10	0.0386	Yes
Root length	14±3.4	15±2.1	0.4303	No
Stem length	2.8±0.87	3.8±1.1	<0.0001	Yes
Leaf length	2.9±0.80	4.2±1.2	<0.0001	Yes
No of leaves	38±14	58±22	0.0124	Yes
No of shoots	1.3±0.45	1.3±0.49	0.6701	No
No of stems	17±3.2	14±6.5	0.2437	No
Plant height	39±4.8	47±11	0.0328	Yes
Leaf thickness	0.46±0.23	0.55±0.18	0.0601	No
Stem thickness	1.2±0.53	1.2±0.59	0.6004	No
Shoot thickness	4.3±0.77	4.2±1.3	0.7460	No

Fig.4: Control and Experimental Plant on 30th Day with Better Effect of GA_3 on Plant Growth for Several Parameters

45th Day Analysis (Complete Analysis)

By the 45th day effect of GA_3 found to be most promising and as expected GA_3 continued to improve plant overall quality by modulating growth parameters of plant as same as 30th day recorded data. In addition an improvement on a positive side recorded with leaf thickness which was not evidenced earlier and the most expected increase in number of tubers found to be realised by GA_3 treatment in a significant manner ($P<0.05$) which showcased the success of GA_3 in aeroponics for potato plant growth in every dimension. Here positive and significant increase ($P<0.05$) recorded for control versus GA_3 sets as :- shoot length (cm) (25±4.4 vs 33±9.8 P< 0.0248); stem length (3.0±0.85 vs 3.9±1.1 P< 0.0001); Leaf length (3.1±0.77 vs 4.4±1.1 P< 0.0001); number of leaves (39±13 vs 61±22 P<0.0061); leaf thickness (0.50±0.15 vs 0.60±0.16 P<0.0065); and lastly number of tubers (4.0±1.4 vs 9.3±4.5 P<0.0168), respectively (Table 4 and Fig. 5 and Fig. 6.) Notably, prior research has corroborated that gibberellic acid plays a crucial role in potato tuberization, directly impacting the number of nodes, which subsequently influences tuber formation (Bharath & B, 2024). Further, GA_3 application at concentrations such as 300 ppm has been observed to significantly enhance plant spread and height in other tuber-bearing plants, suggesting a broader physiological impact beyond just tuber number (Chaudhary & Bahadur, 2024). The present investigation thus aligns with studies demonstrating GA_3's dose-dependent efficacy in promoting potato growth and yield attributes, where varying concentrations can optimize specific parameters like plant height and shoot number (Paikra et al., 2020). However, it is also important to consider that higher concentrations of GA_3 have been shown to potentially decrease marketable tuber rates and even lead to deformed or elongated tubers (Çalışkan et al., 2021), suggesting a delicate balance for optimal agricultural outcomes. This nuanced response of potato morphology to GA_3 application underscores the necessity for precise concentration and timing optimization to achieve desired horticultural goals, particularly in controlled environments like aeroponics (Bodlaender & Waart, 1989). The observed enhancements in plant height, number of leaves, and tuber count corroborate findings where gibberellic acid (GA_3) directly influences cell division and elongation, consequently promoting internode extension and overall shoot growth (Çalışkan et al., 2021). Moreover, the regulatory role of GA_3 extends to the complex process of tuber initiation, a physiological event modulated by both light spectrum and hormonal concentrations (Sumarni et al., 2022). These findings are consistent with earlier reports that GA_3 promotes dormancy break by triggering a cascade of physiological, biochemical, and molecular changes, including enhanced enzyme activity, activation of DNA/RNA synthesis, and increased mobilization of stored carbohydrates (Qayyum et al., 2025).

Table 4: Comparative Change in The Plant Parameters of *S. Tuberosum* Till 45th Day Upon GA_3 Treatment in Aeroponics

Parameters	Control	Experiment	P value	Significant
Shoot length	25±4.4	33±9.8	0.0248	Yes
Root length	15±3.3	16±2.0	0.4722	No
Stem length	3.0±0.85	3.9±1.1	0.0001	Yes
Leaf length	3.1±0.77	4.4±1.1	0.0001	Yes
No of leaves	39±13	61±22	0.0061	Yes
No of shoots	1.3±0.45	1.3±0.49	0.6701	No
No of stems	17±3.1	16±6.3	0.5966	No
Plant height	48±14	48±11	0.9860	No
Leaf thickness	0.50±0.15	0.60±0.16	0.0065	Yes
Stem thickness	1.2±0.46	1.2±0.60	0.9891	No
Shoot thickness	4.3±0.77	4.2±1.3	0.8019	No
Stolon length	5.3±1.5	7.4±2.9	0.0758	No
No of tubers	4.0±1.4	9.3±4.5	0.0168	Yes

Fig. 5: The Overall Growth of *The S. Tubersoum* Plant Once Treated with GA_3 Along with Control Set Till 45th Day Post Treatment

Tuber Formation in Control Set Upon 45th Day

Fig. 6: Tuber Formation in GA_3 Set Upon 45th Day

CONCLUSION

The application of Gibberellic acid (GA_3) at 0.25 mg/L significantly improved the growth and yield of potato plants under aeroponic conditions. While no early effects were observed at 7 days, significant enhancements in vegetative parameters such as shoot length, stem length, leaf length, and plant height were recorded from the 15th day onwards. By the 45th day, GA_3 treatment also led to a notable increase in leaf thickness and tuber production. Overall, GA_3 proved effective in enhancing both plant growth and productivity, indicating its potential for improving aeroponic potato seed production systems.

REFERENCES

1. Bharath, S. R., & B, M. R. (2024). Effect of Varied Levels of Gibberellin, Anti-Gibberellin and Cytokinin on Growth and Tuberization in Potato. *Madras Agricultural Journal*, *111*. https://doi.org/10.29321/maj.10.000ma9
2. Bodlaender, K. B. A., & Waart, M. van de. (1989). Influence of gibberellic acid (GA_3) applied to the crop on growth, yield and tuber size distribution of seed potatoes. *NJAS - Wageningen Journal of Life Sciences*, *37*(3), 185. https://doi.org/10.18174/njas.v37i3.16630
3. Çalışkan, S., Hashemi, M., AKKAMIŞ, M., Aytekin, R. İ., & Bedir, M. (2021). Effect of gibberellic acid on growth, tuber yield and quality in potatoes (Solanum tuberosum L.). *Turkish Journal Of Field Crops*, *26*(2), 136. https://doi.org/10.17557/tjfc.1033429
4. Chaudhary, H., & Bahadur, V. (2024). Effect of different plant growth regulators on growth, flowering and quality of tuberose (Polianthes tuberosa L.) cv. GKTC-4 under Prayagraj agro-climatic conditions. *International Journal of Advanced Biochemistry Research*, *8*(6), 278. https://doi.org/10.33545/26174693.2024.v8.i6d.1319
5. Eissa, R. A., Mugwanya, M., Kimera, F., & Sewilam, H. (2025). Effects of benzylaminopurine and gibberellic acid on growth, yield, and nutrient composition of greenhouse cultivated yellow cherry tomatoes. *Scientific Reports*, *15*(1), 39556. https://doi.org/10.1038/s41598-025-27667-6
6. Filho, J. B. da S., Fontes, P. C. R., Ferreira, J., Cecon, P. R., & Crutchfield, E. (2022). Optimal Nutrient Solution and Dose for the Yield of Nuclear Seed Potatoes under Aeroponics. *Agronomy*, *12*(11), 2820. https://doi.org/10.3390/agronomy12112820
7. García-Segura, D. R., Valdéz-Aguilar, L. A., Ramírez, H., Zermeño-González, A., & Cadena-Zapata, M. (2021). Producción de mini tubérculos de papa en aeroponía en comparación con suelo y polvo de coco. *Terra Latinoamericana*, *39*. https://doi.org/10.28940/terra.v39i0.902
8. Hamdani, J. S., Budiarto, R., & Ramadani, S. F. (2024). Retardant Improve Seed Tuber Yield of G0 Potato (Solanum tuberosum cv. Medians). *Asian Journal of Plant Sciences*, *23*(1), 118. https://doi.org/10.3923/ajps.2024.118.122
9. Kumari, M. (2023). Gibberellic acid (ga3) alone and in combination with indole 3 butyric acid (iba) modulation during in vitro propagation of potato (solanum tuberosum l.) MICROPLANTS. *PLANT ARCHIVES*, *23*, 122. https://doi.org/10.51470/plantarchives.2023.v23.no1.021
10. Lhokitasari, R. F., Hayati, M., & Rahmawati, M. (2022). Growth and production of potato mini tubers (Solanum tuberosum L.) in the aeroponic system by root zone treatment and concentration of leaf-fertilizer. *IOP Conference Series Earth and Environmental Science*, *951*(1), 12037. https://doi.org/10.1088/1755-1315/951/1/012037
11. Li, L., Wang, J., Chen, J., Zh, W., Qaseem, M. F., Li, H., & Wu, A. (2022). Physiological and Transcriptomic Responses of Growth in Neolamarckia cadamba Stimulated by Exogenous Gibberellins. *International Journal of Molecular Sciences*, *23*(19), 11842. https://doi.org/10.3390/ijms231911842

12. Lizarazo-Peña, P., Fornaguera-Espinoza, F., López, C. E. Ñ., Gutierrez, N. A. C., & Fonseca, L. P. M. (2020). Effect of gibberellic acid-3 and 6-benzylaminopurine on dormancy and sprouting of potato (Solanum tuberosum L.) tubers cv. Diacol Capiro. *Agronomía Colombiana*, *38*(2), 178. https://doi.org/10.15446/agron.colomb.v38n2.82231
13. Paikra, S., Kumar, V., & Sharma, P. K. (2020). Studies on the effect of plant growth regulators and their application methods on growth, yield and quality attributes of potato (Solanum tuberosum L.) variety Kufri Pukhraj under agro-climatic conditions of Chhattisgarh plains. *International Journal of Chemical Studies*, *8*(2), 2714. https://doi.org/10.22271/chemi.2020.v8.i2ap.9160
14. Partap, M., Kumar, P., Kumar, A., Joshi, R., Kumar, D., & Warghat, A. R. (2020). Effect of Elicitors on Morpho-Physiological Performance and Metabolites Enrichment in Valeriana jatamansi Cultivated Under Aeroponic Conditions. *Frontiers in Plant Science*, *11*. https://doi.org/10.3389/fpls.2020.01263
15. Prathama, M., Rosliani, R., & Pangestuti, R. (2023). Study of Growth and Yield of Potato Plants (Solanum tuberosum L.) under Several Gibberellin Application during The Dry Season. *BIO Web of Conferences*, *69*, 1016. https://doi.org/10.1051/bioconf/20236901016
16. Qayyum, M. M., Shahzad, U., Jahan, M. S., El-Beltagi, H. S., Ghuffar, S., Qasim, M., Mehmood, N., Anwaar, S., Qureshi, H., Anwar, T., Rebouh, N. Y., Shah, M. A., & Muminov, M. M. (2025). Optimizing gibberellic acid concentration and exposure time for effective dormancy breaking and sprouting enhancement in potato. *Scientific Reports*, *15*(1), 28966. https://doi.org/10.1038/s41598-025-13219-5
17. Saidi, A., & Hajibarat, Z. (2021). Phytohormones: plant switchers in developmental and growth stages in potato [Review of *Phytohormones: plant switchers in developmental and growth stages in potato*]. *Journal of Genetic Engineering and Biotechnology*, *19*(1), 89. Elsevier BV. https://doi.org/10.1186/s43141-021-00192-5
18. Sardoei, A. S., Tahmasebi, M., Bovand, F., & Ghorbanpour, M. (2024). Exogenously applied gibberellic acid and benzylamine modulate growth and chemical constituents of dwarf schefflera: a stepwise regression analysis. *Scientific Reports*, *14*(1). https://doi.org/10.1038/s41598-024-57985-0
19. Sharma, A. K., Buckseth, T., & Singh, R. K. (2020). Standardization of planting geometry for aeroponic mini-tuber production in potato (Solanum tuberosum). *The Indian Journal of Agricultural Sciences*, *90*(11), 2096. https://doi.org/10.56093/ijas.v90i11.108566
20. Sharma, A. K., Buckseth, T., & Singh, R. K. (2023). Effect of planting periods on production potential of potato (Solanum tuberosum) varieties under aeroponics. *The Indian Journal of Agricultural Sciences*, *93*(3). https://doi.org/10.56093/ijas.v93i3.122747
21. Sumarni, E., Soesanto, L., Purnomo, W. H., & Priswanto, P. (2022). The Effect of Light Distance on Aeroponic Potato Seed Production in The Tropical High Land. *Jurnal Teknik Pertanian Lampung (Journal of Agricultural Engineering)*, *11*(1), 99. https://doi.org/10.23960/jtep-l.v11i1.99-109