Malaysian Applied Biology
https://doi.org/10.55230/mabjournal.v55i2.3555

Research Article

Growth and Production Comparison of Red and Granola Potato (*Solanum tuberosum*) Microtubers as Influenced by Light Treatment and Different Sucrose Concentrations

Diky Setya Diningrat[1]*, Adelia Febriyossa[1], Selvia Dewi Pohan[1], Heppy Setya Prima[1], Larasati Arum Utami[1], Eka Dodi Suryanto[2], Bagoes Maulana[2], Ayu Nirmala Sari[3], Asmin[4]

1. Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, 20221, Indonesia
2. Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Medan, 20221, Indonesia
3. Department of Biology, Faculty of Sciences and Technology, Universitas Islam Negeri Ar-Raniry Banda Aceh, Indonesia
4. Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, 20221, Indonesia

*Corresponding author: dikysd@unimed.ac.id

ABSTRACT

Microtuber production through tissue culture offers an effective solution for producing high-quality, disease-free potato seed tubers. This study investigates the effects of light treatment and sucrose concentration on microtuber production in red and Granola potato varieties. The research was conducted at the Tissue Culture Laboratory of PT. G10 Agrotechnology in Medan, North Sumatra. The treatments applied were lighting regulation (bright with 1000 lux LED lighting for 24 hr vs. total darkness (0 lux, culture bottles wrapped with aluminum foil) in the incubation room and different sucrose concentrations (80, 100 & 120 g/L) added to the MS (Murashige & Skoog) basic medium. This research used a Completely Randomized Design method with 5 replications. Data were analyzed using ANOVA. Results showed that bright light treatment and 80 g/L sucrose concentration provided the best results for Granola and red potato plantlet growth from 14 to 70 days after planting. For the number, weight, and diameter of microtubers, the combination of dark light treatment and 120 g/L sucrose concentration produced the highest average values for both Granola and red potatoes. Overall, the growth and production of Granola potatoes were higher than those of red potatoes in every parameter. The results of this research can be used as a reference for producing red potato and Granola microtubers through tissue culture.

Key words: Granola, light treatment, microtubers, red potato, sucrose

INTRODUCTION

The demand for potatoes, particularly Granola and red varieties, continues to increase for both fresh consumption and processed products, creating significant opportunities to enhance potato production in Indonesia (Bueno da Silva *et al*., 2024). However, productivity remains constrained by major cultivation challenges, notably the limited availability of high-quality seed tubers and persistent pest and disease pressures (Taylor *et al*., 2021; Sadawarti *et al*., 2023). The shortage of certified potato seeds forces farmers to rely on farmer-saved seed tubers, which are prone to degeneration and disease accumulation, while climate anomalies further exacerbate yield instability by affecting plant growth (Saptana *et al*., 2022).

The limited supply of quality potato seeds is largely attributed to slow propagation rates and the high risk of seed-borne diseases that significantly reduce yield potential (Tessema *et al*., 2023). In vitro culture techniques offer an effective solution for producing disease-free planting materials, particularly through meristem tip culture, which enables rapid multiplication under controlled and aseptic conditions (Sawicka *et al*., 2021; Bettoni *et al*., 2022). Among in vitro approaches, microtuber production is especially advantageous due to its short production cycle and suitability for seed systems, although its success is strongly influenced by environmental conditions and growth regulators, including carbohydrate sources such as sucrose and tuberization-related compounds (Paul *et al*., 2022; Mohamed & Girgis, 2023; Sharde *et al*., 2024; Vishal *et al*., 2025). Despite extensive research on microtuber production, optimization of light conditions and sucrose concentrations remains a critical knowledge gap, particularly for red and Granola potato varieties. Previous studies have examined individual factors, but the interactive effects of lighting and sucrose concentration on these specific varieties have not been systematically investigated. Therefore, this research aims to determine the optimal combination of light exposure (bright vs. dark conditions) and sucrose concentration (80, 100 & 120 g/L) for maximizing growth and microtuber production in red and Granola potato varieties through in vitro culture, providing valuable insights for improving seed potato production systems. The two potato varieties studied differ in key morphological characteristics. Red potato is characterized by red-violet flowers, red skin color, dark yellow flesh, and long-oval tuber shape, while Granola potato features blue-violet flowers, yellow skin and flesh, and shortened-oval tuber shape.

Article History
Accepted: 11 March 2026
First version online: 30 June 2026
Cite This Article:
Diningrat, D.S., Febriyossa, A., Poha, S.D., Prima, H.S., Utami, L.A., Suryanto, E.D., Maulana, B., Sari, A.N. & Asmin. 2026. Growth and production comparison of red and granola potato (*Solanum tuberosum*) microtubers as influenced by light treatment and different sucrose concentrations. Malaysian Applied Biology, 55(2): 34-40. https://doi.org/10.55230/mabjournal.v55i2.3555

MATERIALS AND METHODS

Materials

The research was carried out from March to August 2024 at the Tissue Culture Laboratory of PT. Ganesha 10 Agrotechnology. Materials used in this research included: 4-month-old red potato and Granola plantlets, and Murashige and Skoog (MS) media for growing media. The shoot explants were obtained from the potato plantlets that had been grown previously in the Tissue Culture Laboratory of PT. Ganesha 10 Agrotechnology. The research stages included media preparation, equipment and material preparation (potato explants), explant planting, incubation, observation, and analysis (Warnita *et al*., 2021; Mohamed & Girgis, 2023).

Equipment and material preparation

Equipment and material preparation were carried out by preparing the tools and materials used. Equipment preparation included sterilizing tools using an autoclave at a temperature of 121°C. Material preparation involved preparing explants and other materials (Sembiring *et al*., 2021).

Media preparation

Media preparation was carried out using MS medium with the addition of agar for planting explants and different sucrose modifications, including 80, 100, and 120 g/L. The pH was adjusted to 5.8; if pH<5.8, a few drops of 1 N NaOH were added, and if pH>6, a few drops of 1 N HCl were added. Subsequently, the media was heated until boiling. Before pouring into bottles, 25 mL of solution was poured into each bottle, then covered with plastic and secured with rubber bands. The media were then sterilized in an autoclave at 121°C. Afterward, the media was stored in the incubation room (Sembiring *et al*., 2021; Astarini *et al*., 2021).

Explant transplanting

The potato shoot explants were removed from the bottles using tweezers by cutting them into a size of about 0.2 - 0.5 cm. Thereafter, the cutting explants were transplanted to the new medium according to the treatments, with 6 shoot explants cultivated in each bottle. (Astarini *et al*., 2021).

Incubation

The culture bottles containing planted explants were placed on incubation racks and arranged according to the existing treatment design. The culture incubation room temperature was maintained at 25 ± 2°C with humidity around 70% and light intensity of 1000 lux for 24 hr each day (Sembiring *et al*., 2021; Astarini *et al*., 2021).

Experimental design and data analysis

The experimental design used was a two-factor Completely Randomized Design (CRD) (Warnita *et al*., 2021). The first factor was lighting, and the second factor was sucrose concentration, with details in Table 1:

Table 1. The light intensity and the concentration of sucrose that were applied in the experiment

Light	Sucrose	Treatment	
		Light treatment	Sucrose concentration (g/L)
P1	S1	Dark	80
	S2	Dark	100
	S3	Dark	120
P2	S1	Bright	80
	S2	Bright	100
	S3	Bright	120

Note: P = light treatment, S = sucrose treatment

All treatments were incubated at a temperature of 25 ± 2°C. Treatments were repeated 5 times, and each replication consisted of 6 explants. The results of this research were followed by a two-way factorial analysis of variance (ANOVA). Before ANOVA, data were tested for normality using the Shapiro-Wilk test and homogeneity of variance using Levene's test to ensure assumptions were met. When significant differences were detected ($p<0.05$), multiple comparisons were performed using Tukey's Honestly Significant Difference (HSD) post-hoc test. All statistical analyses were conducted using SPSS version 25.0 software with a significance level of α = 5% (Warnita *et al*., 2021; Sembiring *et al*., 2021; Astarini *et al*., 2021).

RESULTS

Plant height

Plant height was measured at 14, 28, 42, 56, and 70 days after planting. Table 2 and Figure 1 demonstrate that lighting treatments and sucrose concentrations applied to potato cultures, for both Granola and Red potato varieties, exhibited significant effects on plantlet height at 14 and 70 days after planting across both cultivars. However, observations conducted at 28, 42, and 56 days after planting revealed no statistically significant treatment effects on plant height for either Granola or Red potato varieties.

Table 2. Effect of sucrose concentration and lighting on mean plant height (cm) at 14, 28, 42, 56, and 70 days after planting (DAP)

Treatment	Mean plant height (cm)									
	14 DAP		28 DAP		42 DAP		56 DAP		70 DAP	
	G	M	G	M	G	M	G	M	G	M
P1S1	1.91^{bc}	1.72^{bc}	3.87	3.76	5.53	5.44	6.59	6.49	7.85^{c}	7.76^{c}
P1S2	0.82^{ab}	0.75^{ab}	2.11	2.03	2.83	2.76	3.95	3.86	4.87^{ab}	4.78^{ab}
P1S3	0.61^{a}	0.53^{a}	1.29	1.18	1.75	1.66	2.21	2.15	2.78^{a}	2.69^{a}
P2S1	6.83^{f}	6.74^{f}	8.95	8.84	9.65	9.55	10.25	10.13	10.57^{e}	10.57^{e}
P2S2	3.32^{de}	3.21^{de}	6.64	6.55	8.51	8.41	9.38	9.27	9.83^{cde}	9.83^{cde}
P2S3	2.67^{cd}	2.55^{cd}	5.49	5.36	7.13	7.05	7.81	7.74	8.15^{cd}	8.15^{cd}

Note: G: Granola Potato; M: Red Potato. Values followed by different letters within the same column indicate significantly different effects according to HSD analysis at α=5%. Values without letters indicate no significant differences based on ANOVA at α=5%

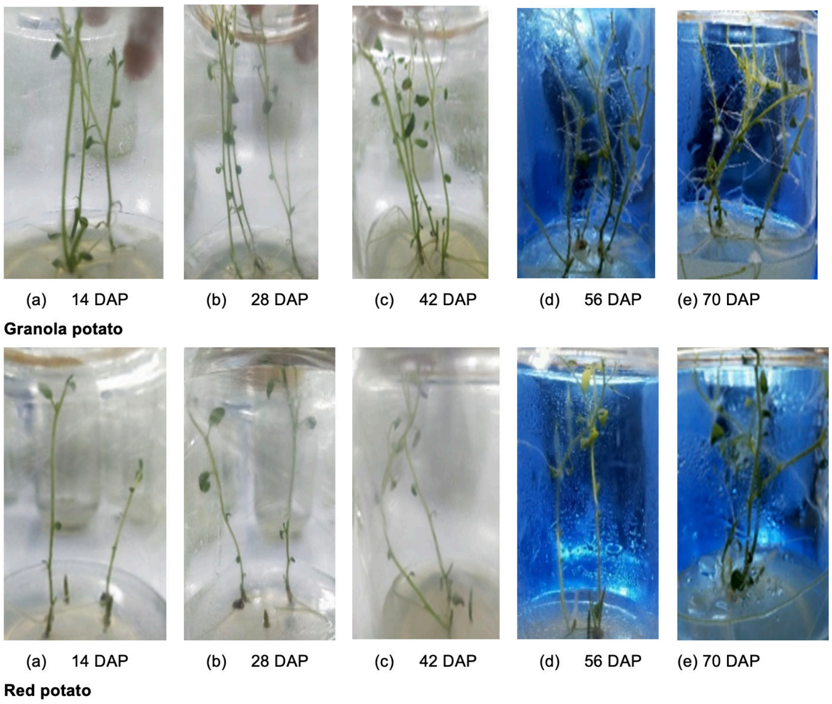

Fig. 1. Plant height increment at 14, 28, 42, 56, and 70 days after planting in granola and red potato cultures

Potato microtuber quantity

Analysis of potato microtuber quantity data is presented in Table 3. The results indicate that the highest mean microtuber count was observed in treatments combining dark conditions with 120 g/L sucrose concentration (P1S3), yielding 9 microtubers in Granola potato and 7 microtubers in red potato cultivars. However, statistical analysis revealed no significant effects of the lighting and sucrose concentration treatment combinations on mean microtuber production across both cultivars.

Table 3. Effect of sucrose concentration and lighting on the mean number of potato microtubers at 70 days after planting

Treatment	Mean number of potato microtubers	
	Granola	Red
P1S1	6	5
P1S2	6	6
P1S3	9	7
P2S1	7	5
P2S2	7	4
P2S3	6	5

Values followed by different letters within the same column indicate significantly different effects according to HSD analysis at α=5%. Values without letters indicate no significant differences based on ANOVA at α=5%

Potato microtuber weight

Observational data regarding the mean potato microtuber weight are presented in Table 4. The combination treatment of dark conditions and 120 g/L sucrose concentration (P1S3) exhibited the highest mean microtuber weight values, specifically 12 g for Granola potato and 8.5 g for red potato. Conversely, the combination treatment of dark conditions and 80 g/L sucrose concentration demonstrated the lowest values at 6 g for both Granola and Red potato varieties.

Table 4. Effect of sucrose concentration and lighting on mean potato microtuber weight (g) at 70 days after planting

Treatment	Mean potato microtuber weight (g)	
	Granola	Red
P1S1	7.3	6.8
P1S2	7.2	7.4
P1S3	12.0	8.5
P2S1	8.6	6.9
P2S2	8.2	6
P2S3	6.0	6.4

Values followed by different letters within the same column indicate significantly different effects according to HSD analysis at α=5%. Values without letters indicate no significant differences based on ANOVA at α=5%

Potato microtuber diameter

Observational results regarding potato microtuber diameter are presented in Table 5. Table 5 demonstrates that the combination treatment of dark conditions and 120 g/L sucrose concentration (P1S3) produced the largest mean microtuber diameter, measuring 0.95 cm for Granola potato and 0.85 cm for red potato. Conversely, the combination treatment of light conditions and 120 g/L sucrose concentration (P2S3) exhibited the smallest mean microtuber diameter values, specifically 0.55 cm for Granola and 0.58 cm for red potato.

Table 5. Effect of sucrose concentration and lighting on mean potato microtuber diameter (cm) at 70 days after planting

Treatment	Mean potato microtuber diameter (cm)	
	Granola	Red
P1S1	0.70	0.65
P1S2	0.73	0.72
P1S3	0.95	0.85
P2S1	0.84	0.64
P2S2	0.78	0.55
P2S3	0.55	0.58

alues followed by different letters within the same column indicate significantly different effects according to HSD analysis at α=5%. Values without letters indicate no significant differences based on ANOVA at α=5%

DISCUSSION

The growth patterns of Red and Granola potato microtubers were relatively similar, though Granola potato consistently demonstrated higher values across all measured characteristics. Detailed morphological characteristics of both varieties used in this study are presented in Figures 2 and 3 to provide a complete characterization of the experimental materials.

Meanwhile, from the research data obtained, it can be concluded that the growth patterns of Red and Granola potato microtubers are relatively similar. However, for the measured characteristics, the granola potato consistently demonstrated higher values than the red potato. Regarding plant height observations, the treatment combination that generally yielded the highest results was bright light conditions with 80 g/L sucrose concentration in the basal medium (P2S1). This is evident in Table 2 data, which indicates that the P2S1 treatment combination produced greater height development compared to other treatment combinations. These differences in plant height may be influenced by the sucrose concentration present in the medium (Astarini *et al*., 2021; Diningrat *et al*., 2024). Appropriate sucrose concentrations can stimulate plantlet growth processes, whereas excessively high concentrations may inhibit growth (Zeid *et al*., 2022; Singh *et al*., 2023).

The addition of sucrose concentration in tissue culture basal media serves as a carbon source (Melyan *et al*., 2025). Appropriate sucrose concentration facilitates plant assimilation processes and converts starch substances into energy sources for growth (Long *et al*., 2024). Higher sucrose concentrations in basal media result in decreased shoot numbers, internode length, node quantity, and overall plant height (Singh *et al*., 2023; Long *et al*., 2024). This phenomenon is attributed to sucrose's influence on the osmotic pressure of the medium, which affects the absorption of other essential nutrients by the plant (Long *et al*., 2024; Melyan *et al*., 2025).

The sucrose concentration and light exposure influence plant development (Dogramaci *et al*., 2024). Decreased light intensity can result in excessive etiolation or shoot elongation due to the presence of gibberellin in plants (El-Yazied *et al*., 2022; Dogramaci *et al*., 2024). Additionally, the intensity, quality, and duration of light exposure affect potato (Solanum tuberosum) microtuber production (El-Yazied *et al*., 2022; Dogramaci *et al*., 2024; Melyan *et al*., 2025). Conversely, dark periods influence the total carbohydrates utilized for respiration in these plants (Singh *et al*., 2023; Dogramaci *et al*., 2024).

Results indicate that the combination of light exposure and sucrose concentration in potato tissue culture basal media did not increase microtuber production. Sucrose, as a carbohydrate source for plants, is essential for photosynthesis maintenance and energy provision (Astarini *et al*., 2021; Singh *et al*., 2023; Long *et al*., 2024). However, the addition of inappropriate sucrose concentrations to tissue culture media adversely affects potato microtuber formation (Singh *et al*., 2023; Long *et al*., 2024).

The excessively high sucrose levels can increase the risk of abnormal organ formation in potato plantlets (Zeid *et al*., 2022). Furthermore, inappropriate sucrose concentrations may enhance nodule or shoot growth, consequently decreasing potato microtuber formation (Warnita *et al*., 2021; Singh *et al*., 2023). Organized in vitro plant tissue growth generally does not experience light-induced inhibition; rather, light is often required for optimal results (Diningrat *et al*., 2024; El-Yazied *et al*., 2022). Under optimal light conditions, in vitro plants utilize light for morphogenesis processes (El-Yazied *et al*., 2022; Dogramaci *et al*., 2024). However, under light-deficient conditions, plants reduce carbohydrate utilization, resulting in carbohydrate accumulation and subsequent microtuber formation in potato plants (Valencia-Lozano *et al*., 2022; Di *et al*., 2024).

Analysis of variance yielded non-significant differences for microtuber quantity and microtuber weight variables, indicating that the combination of light/dark exposure treatments and varying sucrose concentrations in potato tissue culture basal media did not significantly impact microtuber production in this study. Several factors may explain these non-significant results. First, the culture duration of 70 days may have been insufficient for microtuber maturation, as some studies suggest longer incubation periods enhance microtuber development. Second, the explant size and physiological state could have influenced the uniformity of responses across treatments. Third, genotype-specific responses to environmental conditions may require cultivar-specific optimization protocols. These findings highlight the complexity of microtuber induction and suggest that future research should investigate extended culture durations, additional sucrose concentration ranges, and the molecular mechanisms underlying variety-specific responses to light and carbohydrate availability.

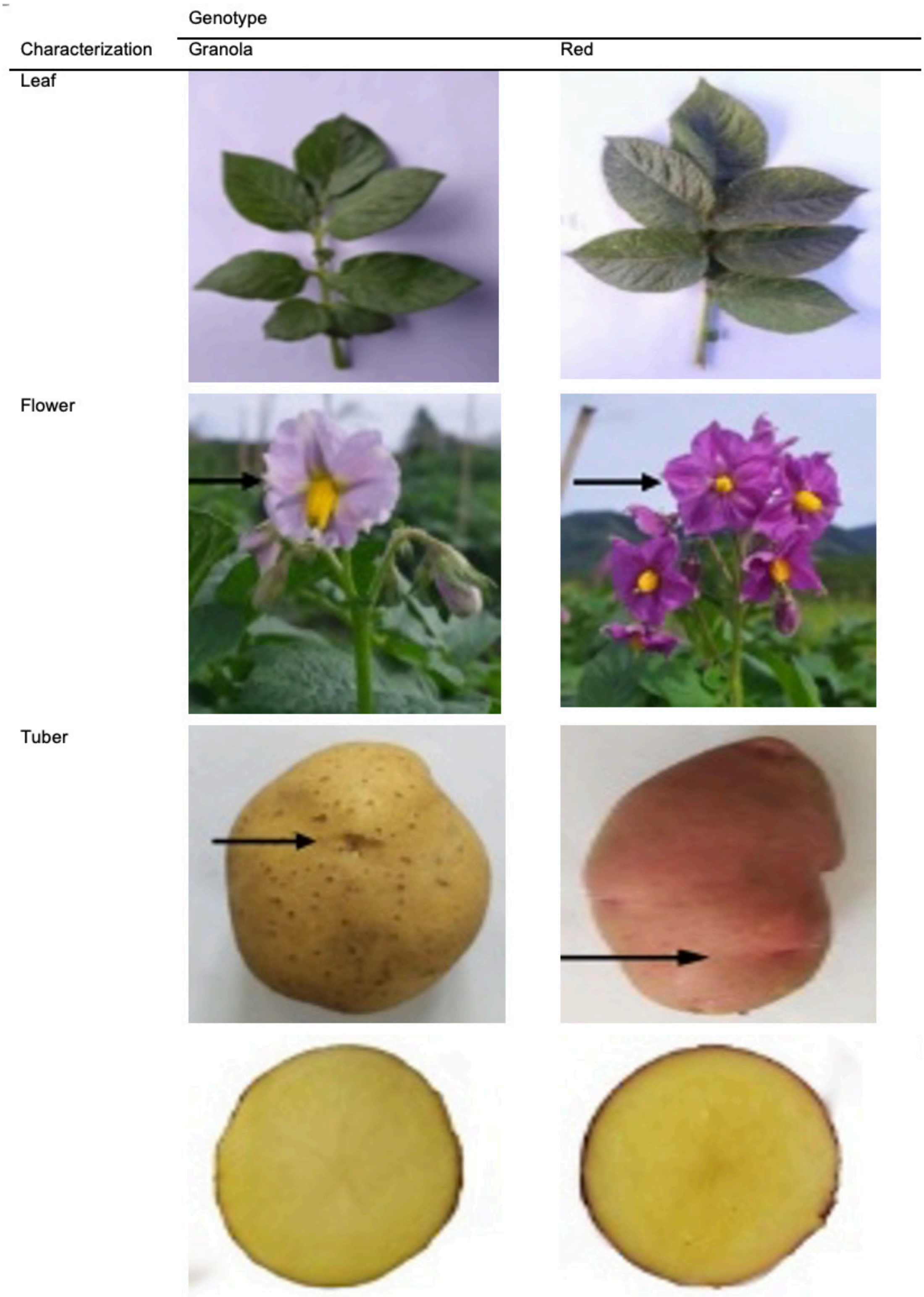

Fig. 2. Comparative morphological characteristics of granola and red potato varieties

Fig. 3. Comparative morphological characteristics of plantlet granola and red potato varieties

The mean diameter values of potato microtubers showed no significant differences according to the analysis of variance; however, the observational values revealed different mean values. Varying sucrose concentrations substantially influence potato microtuber formation in tissue culture, as microtubers represent food reserves in in vitro potato plants. Potato microtubers form when energy requirements derived from sucrose exceed photosynthesis rates, causing excess sucrose to stimulate starch synthesis and microtuber formation (Dogramaci *et al*., 2024; Melyan *et al*., 2025).

CONCLUSION

The results demonstrate that light exposure and sucrose concentration significantly affected plant height but not microtuber characteristics. Future research should investigate longer culture durations, additional sucrose concentrations, and the molecular mechanisms underlying genotype-specific responses to optimize microtuber production. A sucrose concentration of 80 g/L under bright light conditions provided the best results for potato plantlet growth from 14 to 70 days after planting. Observational data indicated no significant differences in microtuber quantity, weight, and diameter based on analysis of variance. However, the mean values obtained showed varying results. For microtuber quantity, weight, and diameter observations, the combination of dark light exposure and 120 g/L sucrose concentration yielded the highest mean values.

ACKNOWLEDGEMENTS

This research was funded by LPPM Universitas Negeri Medan through the Innovation Applied Product Research scheme, and RIKUB DPPM Kemendikbudristek was conducted in collaboration with PT. G10 Agrotechnology Medan.

ETHICAL STATEMENT

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Astarini, I.A., Febryanti, N.L.P.K. & Miller Jr, J.C. 2021. Influence of media composition and genotype on potato (*Solanum tuberosum* L.) microtuberization. Jurnal Hortikultura Indonesia, 12(1): 51–58. https://doi.org/10.29244/jhi.12.1.51-58

Bettoni, J.C., Mathew, L., Pathirana, R., Wiedow, C., Hunter, D.A., McLachlan, A., Khan, S., Tang, J. & Nadarajan, J. 2022. Eradication of Potato Virus S, Potato Virus A, and Potato Virus M from infected *in vitro*-grown potato shoots using in vitro therapies. Frontiers in Plant Science, 13: 878733. https://doi.org/10.3389/fpls.2022.878733

Bueno da Silva, M., Wiese-Klinkenberg, A., Usadel, B. & Genzel, F. 2024. Potato berries as a valuable source of compounds potentially applicable in crop protection and pharmaceutical sectors: A review. Journal of Agricultural and Food Chemistry, 72(28): 15449–15462. https://doi.org/10.1021/acs.jafc.4c03071

Di, X., Wang, Q., Zhang, F., Feng, H., Wang, X. & Cai, C. 2024. Advances in the modulation of potato tuber dormancy and sprouting. International Journal of Molecular Sciences, 25(10): 5078. https://doi.org/10.3390/ijms25105078

Diningrat, D.S., Febriyossa, A., Suryanto, E.D., Maulana, B., Sari, A.N., Nainggolan, T.B., Hasibuan, A.A.U. & Rambe, K.U. 2024. Design of artificial intelligence for evaluation of in vitro potato (*Solanum tuberosum*) microtuber growth from tissue culture based on digital imagery. Journal of Physics: Conference Series, 2908(1): 12001. https://doi.org/10.1088/1742-6596/2908/1/012001

Dogramaci, M., Dobry, E.P., Fortini, E.A., Sarkar, D., Eshel, D. & Campbell, M.A. 2024. Physiological and molecular mechanisms associated with potato tuber dormancy. Journal of Experimental Botany, 75(19): 6093–6109. https://doi.org/10.1093/jxb/erae182

El-Yazied, A.A., Ibrahim, M.F.M., Ibrahim, M.A.R., Nasef, I.N., Al-Qahtani, S.M., Al-Harbi, N.A., Alzuaibr, F.M., Alaklabi, A., Dessoky, E.S. & Alabdallah, N.M. 2022. Melatonin mitigates drought induced oxidative stress in potato plants through modulation of osmolytes, sugar metabolism, ABA homeostasis and antioxidant enzymes. Plants, 11(9): 1151. https://doi.org/10.3390/plants11091151

Kumar, R., Tiwari, R.K., Sundaresha, S., Kaundal, P. & Raigond, B. 2022. Potato viruses and their management. In: Sustainable Management of Potato Pests and Diseases. Springer, pp. 309–335. https://doi.org/10.1007/978-981-16-7695-6_12

Long, J., Yu, F., Wu, Y., Xu, Z. & Liu, X. 2024. Regulation of different lights on energy acquisitions, microtuber formation, and growth of *in vitro*-grown *Solanum tuberosum* L. Agronomy, 14(6): 1232. https://doi.org/10.3390/agronomy14061232

Melyan, G.H., Martirosyan, Y.T., Sahakyan, A.J., Sayadyan, H.Y., Melikyan, A.S., Barseghyan, A.H., Vardanyan, A.S., Martirosyan, H.S., Harutyunyan, M.G. & Mkrtchyan, A.L. 2025. Influence of nutrient medium components on in vitro tuberization of *Solanum tuberosum* L. and subsequent minituber production in aeroponic and greenhouse conditions. Life, 15(2): 241. https://doi.org/10.3390/life15020241

Mohamed, A.E.-S. & Girgis, N.D. 2023. Factors affecting in vitro tuberization of potato. Bulletin of the National Research Centre, 47(1): 80. https://doi.org/10.1186/s42269-023-01056-3

Paul, V., Buckseth, T., Singh, R.K., Ravichandran, G., Lal, M.K., Singh, B. & Tiwari, J.K. 2022. Alternative methods of seed potato (*Solanum tuberosum*) production: Indian perspective — a review. Current Horticulture, 10(2): 3–11. http://dx.doi.org/10.5958/2455-7560.2022.00019.X

Sadawarti, M.J., Singh, S.P., Buckseth, T., Devi, S., Singh, R.K., Kumar, V., Katare, S., Singh, B., Khambalkar, P.A. & Samadhiya, R.K. 2023. Elements affecting seed potato quality in India — a review. International Journal of Bio-Resource and Stress Management, 14(12): 1592–1607. http://dx.doi.org/10.23910/1.2023.4952a

Saptana, Sayekti, A.L., Perwita, A.D., Sayaka, B., Gunawan, E., Sukmaya, S.G., Hayati, N.Q., Yusuf, Sumaryanto & Yufdy, M.P. 2022. Analysis of competitive and comparative advantages of potato production in Indonesia. PLoS ONE, 17(2): e0263633. https://doi.org/10.1371/journal.pone.0263633

Sawicka, B., Umachandran, K. & Pszczółkowski, P. 2021. Innovative potato production technology and its influence on quality of tubers. International Conference on Emerging Technology and Interdisciplinary Sciences, pp. 174–195. https://doi.org/10.57040/icetis.vi.16

Sembiring, R., Hayati, M. & Kesumawti, E. 2021. Potato tuber (*Solanum tuberosum* L.) formation due to the application of different concentrations of coconut water in in-vitro. IOP Conference Series: Earth and Environmental Science, 711(1): 12021. https://doi.org/10.1088/1755-1315/711/1/012021

Sharde, R., Tripathi, M.K., Bhatt, D., Tiwari, S., Sharma, M., Tomar, Y.S. & Tripathi, N. 2024. Influence of plant growth regulators on *in vitro* morphogenesis in sprout culture of potato (*Solanum tuberosum* L.). Potato Research, 67(2): 399–420. https://doi.org/10.1007/s11540-023-09640-w

Singh, P., Arif, Y., Siddiqui, H., Upadhyaya, C.P., Pichtel, J. & Hayat, S. 2023. Critical factors responsible for potato tuberization. The Botanical Review, 89(4): 421–437. https://doi.org/10.1007/s12229-023-09289-7

Taylor, A.S. & Dawson, P. 2021. Major constraints to potato production in Indonesia: A review. American Journal of Potato Research, 98(3): 171–186. https://doi.org/10.1007/s12230-021-09831-6

Tessema, L. & Tesfaye, M. 2023. Understanding and managing seed degeneration in potato: Implications for potato resilient seed system and food security. A review. CABI Reviews, 2023. https://doi.org/10.1079/cabireviews.2023.0049

Valencia-Lozano, E., Herrera-Isidrón, L., Flores-López, J.A., Recoder-Meléndez, O.S., Barraza, A. & Cabrera-Ponce, J.L. 2022. *Solanum tuberosum* microtuber development under darkness unveiled through RNAseq transcriptomic analysis. International Journal of Molecular Sciences, 23(22): 13835. https://doi.org/10.3390/ijms232213835

Vishal, Mali, S., Dutta, M., Choudhary, A. & Zinta, G. 2025. Potato microtuberization: Its regulation and applications. Critical Reviews in Biotechnology, 1–24. https://doi.org/10.1080/07388551.2025.2490957

Warnita, W., Mayerni, R., Kristina, N. & Nadila, N.E. 2021. Induction of potatoes (*Solanum tuberosum* L.) micro tuber at some coumarin concentrations and incubation temperatures. Plant Cell Biotechnology and Molecular Biology, 22(33&34): 1–12.

Zeid, I.M.A., Soliman, H.I.A. & Metwali, E.M.R. 2022. In vitro evaluation of some high yield potato (*Solanum tuberosum* L.) cultivars under imposition of salinity at the cellular and organ levels. Saudi Journal of Biological Sciences, 29(4): 2541–2551. https://doi.org/10.1016/j.sjbs.2021.12.040