



Effects of Media and Plant Growth Regulators on Mini-Tuber Yield of Granola Cultivar of Potato in Aeroponics System

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Abstract

Potato is a perennial plant (*Solanum tuberosum* L.) in the nightshade family, which is one of the most developed and competitive vegetable crops compared to other vegetables. Furthermore, its production could not meet the increasing demand, which led to very intensive research and development programs. This research aims to examine the effect of nutrients and growth regulators on the yield of mini-tuber in the aeroponic system and to determine the best type of nutrient, as well as the type and concentration of plant growth regulators to increase mini-tubers yield in an aeroponics system. This experiment has been carried out experimentally using a split-split plot design. The main plots were the types of nutrient media, which consisted of Grow More-modified nutrient and AB-Mix nutrient. The sub-plots were the types of plant growth regulator (PGR), which consisted of BAP and GA₃, while the sub-sub-plot were the concentrations of PGR, which consisted of 0; 5; 10; 15; 20 and 25 µM. Each combination of treatments was repeated three times. The results showed that the use of media type, PGR and PGR concentration affected the formation and yield of Granola cultivar of potato mini-tubers. Knols grown in AB-Mix nutrient medium supplemented with 20 µM GA₃ resulted in the best mini-tuber formation, as shown by the average number of mini-tubers of 8.33, the total weight of mini-tubers of 21.38 g and the average mini-tuber diameter of 13.05 mm.

Keywords: AB-mix; BAP; GA₃; grow more; precision agriculture

Pengaruh Jenis Media dan Zat Pengatur Tumbuh Tumbuhan pada Hasil Umbi Mini Kentang Kultivar Granola Secara Aeroponik

Abstrak

Kentang merupakan salah satu tanaman sayuran yang paling berkembang karena memiliki daya saing tinggi dibandingkan sayuran lain. Kentang merupakan salah satu komoditas yang mendapat prioritas dalam program penelitian dan pengembangan. Penelitian ini bertujuan untuk mempelajari pengaruh nutrisi dan zat pengatur tumbuh terhadap hasil umbi mini kentang kultivar Granola. Penelitian ini merupakan penelitian eksperimental dengan Rancangan Petak-petak Terpisah dengan tiga ulangan. Petak utama adalah jenis nutrisi yang terdiri dari nutrisi Grow More-dimodifikasi dan AB-Mix. Anak petak adalah jenis zat pengatur tumbuh (ZPT) yang terdiri dari BAP dan GA₃, sedangkan anak-anak petak adalah konsentrasi ZPT yang terdiri dari 0, 5, 10, 15, 20, dan 25 µM. Penelitian ini menunjukkan bahwa penggunaan jenis media tanam, serta jenis dan konsentrasi ZPT yang digunakan dapat mempengaruhi pembentukan serta produksi umbi mini kentang kultivar Granola. Knol yang

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ditumbuhkan pada media AB-Mix dengan penambahan 20 μ M GA₃ menghasilkan umbi mini kentang Granola terbaik, sebagaimana ditunjukkan dengan rata-rata jumlah umbi mini sebesar 8,33 umbi, berat total umbi mini sebesar 21,38 g dan rata-rata diameter mencapai 13,05 mm.

Kata kunci: AB-mix; BAP; GA₃; grow more; pertanian presisi

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most developed vegetable crops due to its high competitiveness compared to others (Hidayat, 2016). Furthermore, it is an essential food commodity in Indonesia that is needed throughout the year. The high demand results in the need for the production of larger quantities and high-quality potatoes. Subsequently, the production of potatoes in Indonesia has increased from 1,219,270 tons in 2015 to 1,314,657 tons in 2019 (Statistics Indonesia, 2020). However, this production could not meet the constantly increasing market demand for potatoes. The Granola cultivar of potato is one of the most cultivated cultivars in Indonesia, which has high productivity and long harvest time. Research and development programs have been prioritized to increase potato production in Indonesia (Karjadi, 2014).

Potato production in developing countries is hampered by constraints such as poor soil fertility, pest and diseases, as well as an inadequate supply of high-quality tuber seeds. The majority of farmers either recycle their own seeds or get them from informal sources, which leads to a degeneration of the seed and the accumulation of tuber-borne diseases and therefore lowers the yields (Muthoni et al., 2013). A good tuber is one of the most important factors in increasing potato productivity (Wulandari et al., 2014; Nuraini et al., 2016). In order to alleviate the problem of the lack of good quality seeds, strategies for rapid propagation have been carried out, such as tissue culture in conjunction with hydroponics and aeroponics (Muthoni et al., 2013). The use of an aeroponics system for mini-tuber production offers several benefits which include: 1) optimization of root aeration, resulting in better yield compared to classic hydroponics system; 2) regardless of the season, the plants can be grown all year round, resulting in higher yields; 3) intensive production can be performed in a limited area, which has resulted in gaining more yield and more effective; 4) no loss of fertility,

therefore no plant rotation is needed; 5) tuber can be harvested safely at any time and in any size, which enables the control of the mini-tuber size (Otazu, 2010; Mbiyu et al., 2012). Sumarni et al. (2013) also added that the use of aeroponic techniques on potato tuber seed production can improve the quality of tuber seed produced.

Aeroponics is a cultivation system that can increase the quality and yield of the product and is very efficient in the use of soil, water and nutrients, therefore it is incorporated into precision agriculture. Precision agriculture can be interpreted as a precise and accurate agricultural model, which includes the application of nutrients, pesticides, water sources, planning and control that are carried out precisely and accurately (Cambouris et al., 2014; Schimmelpfennig, 2016; Neforawati et al., 2019; Shafi et al., 2019). Compared to conventional techniques, the aeroponic systems can initiate potato tubers faster (Dianawati et al., 2013). The production of potatoes in an aeroponic system is influenced by several factors, including potato genotype, Plant Growth Regulator (PGR), light, temperature, humidity, media and planting techniques (Sonnewald and Sonnewald, 2014; Fadhil et al., 2015). The application of PGR in aeroponic systems can induce the formation of stolons that later develop into tubers.

The types of PGR that can be used to stimulate plant growth and productivity including 6-Benzylaminopurine (BAP), which stimulates shoot growth (Feng et al., 2012; Munarti and Kurniasih, 2014) and Gibberellic acid (GA₃) that stimulates stems and leaf area growth (Karjadi, 2014). The growth of axillary shoots is the beginning of the formation of the mini-tuber. These shoots can develop into stolons and mini-tubers if the conditions are suitable for the formation of tuber (Chiipanthenga et al., 2012; Pratama et al., 2014). The GA₃ can induce mini-tuber formation because it stimulates the differentiation and morphogenesis, especially the formation of shoots, which is very important in the formation of mini-tuber (Karjadi and Waluyo, 2017). This research aims to examine

the effect of nutrients and growth regulators on the production of mini-tubers in the aeroponic system and to determine the best type of nutrient as well as the type and concentration of plant growth regulators to increase the yield of mini-tuber in the aeroponics system.

MATERIALS AND METHODS

This research has been conducted at the Kledung Horticultural Seed Garden, Temanggung Regency, Central Java Province of Indonesia. Furthermore, it was carried out experimentally using a split-split plot design. The main plots were the types of nutrient media consisting of Grow More-modified nutrient and AB-Mix nutrient. The sub-plot was the types of PGR which consisted of BAP and GA₃, while the sub-sub-plot was the concentration of PGR, which consisted of 0, 5, 10, 15, 20 and 25 µM. Each treatment combination was replicated three times.

Aeroponics system

The aeroponics system, which includes cubical size, plant material (A certified-G1-tuber-seed-derived plantlets (knol) of Granola cultivar), planting techniques, planting density (75 plants m⁻²) and plant maintenance were carried out according to procedures described by Sugiyono et al. (2021). The knol and planting density of 75 plants m⁻² were used in this research because they showed the best results in the previous study (Sugiyono et al., 2021).

Data collection and analysis

The variable observed was the yield of Granola cultivar potato mini-tuber. The parameters measured include the total number of mini-tubers, mini-tuber total weight, average weight per mini-tuber and mini-tuber average diameter. The data were collected and subsequently analyzed using an analysis of variance (ANOVA), followed by the Honestly Significance Difference (HSD) Test, with a confidence level of 95% when a significant difference between treatments was observed.

RESULTS AND DISCUSSION

The development of potato tuber consists of two aspects: morphological development and biochemical changes that lead to the formation and storage of carbohydrates. During morphological development, the formation of the tuber consists of two sequential processes, namely the formation of the stolon and

the formation of the tuber at its tip. The lateral shoot can result in a stolon due to the changes in cell division and cell elongation. It is generally accepted that the longitudinal growth of the stolon stopped shortly before the swelling of the stolon tip. The cells inside the pit and the cortex enlarge and begin to divide lengthwise, resulting in the swelling of the stolon tip. Then the random cell division and enlargement occur mainly in the perimedullary zone until the specified tuber size is reached (Momena et al., 2014; Tierno et al., 2014; Rykaczewska, 2016).

The results of the HSD test on the effect of nutrients on mini-tuber formation showed that only the total weight of the mini-tubers is controlled by the nutrients used. Table 1 shows that AB-mix resulted in a significantly heavier average mini-tubers total weight. According to Tiwari et al. (2020), the use of media with low N concentrations can accelerate mini-tuber induction. An nitrogen deficiency in the media has a role in shortening the vegetative phase and accelerating the generative phase in such a way that the formation of mini-tubers will be formed more quickly (Buckseth et al., 2016). AB-Mix is a commercially available hydroponics solution that is rich in both macronutrients, especially potassium (40%), phosphorus (23%), nitrogen (14%) and micronutrients. Plant growth on the AB-mix medium can be seen in Figure 1. In contrast, Grow More is a commercially available leaf-manure that contains slightly lower macro and micronutrient content. It seems that the AB-Mix nutrient is sufficient to support the growth and the formation of mini-tubers of Granola cultivar of potato, due to its higher nutrients content compare to that of Grow More medium. This finding was consistent with the finding previously reported by Sugiyono et al. (2021).

Further HSD analysis (Table 2) showed that the interaction between nutrients and PGRs controlled the average mini-tuber weight of Granola cultivar of potato in the aeroponics system. It was also discovered that the knol planted on AB-Mix nutrient treated with GA₃ produced a significantly heavier average of mini-tuber weight. The GA₃ application aims to improve internode elongation and stimulate tuber enlargement due to the longitudinal growth of the stolon. The GA₃ can accelerate the formation of stolons which later develop into shoots or tubers (Salem and Hassanein, 2017).

Table 1. The effect of different nutrients on total-mini tuber weight of Granola cultivar of potato in aeroponics system

Nutrient	Total mini-tuber weight
Grow More-modified Nutrient	5.56 ^b
AB-mix	8.41 ^a

Note: Numbers followed by different letters show significantly different in HSD (≤ 0.05)

Table 2. The effect of interaction between nutrients and PGRs on the average mini-tuber weight of Granola cultivar of potato in aeroponics system

Type of nutrient	PGR type	Average mini-tuber weight
Grow More-modified Nutrient	BAP	1.67 ^{ab}
	GA ₃	1.32 ^b
AB-mix nutrient	BAP	1.39 ^b
	GA ₃	2.29 ^a

Note: Numbers followed by different letters show significantly different in HSD (≤ 0.05)



a.



b.

Figure 1. The appearance of potato cultivar Granola in an aeroponics system, a) the condition of the potato cultivar Granola crop in an aeroponic system, b) mini-tubers generated in an aeroponic system

Furthermore, the results of the HSD test on the effect of PGR concentration on the mini-tuber formation of Granola cultivar of potato in aeroponics system (Table 3) showed that PGR at a concentration of 0 μM produced the highest average number of tuber (8.58 tubers plant⁻¹) and the highest average tuber weight (9.85 g plant⁻¹) or 514.8 tubers m⁻². These results also indicated

that the knols planted on the media without growth regulator produced the highest number of tubers, which led to the heaviest total tuber weight. This also indicated that Grow More-modified nutrient and AB-Mix medium are capable of inducing stolon formation and growth and therefore accelerating the induction of the mini-tubers.

Table 3. The effect of different concentrations of PGR on the total number and total weight of mini-tubers of Granola cultivar of potato in aeroponics system

The concentration of PGR (μM)	Number of mini-tuber	Total mini-tuber weight
0	8.58 ^a	9.85 ^a
5	3.42 ^b	6.54 ^{bc}
10	5.17 ^b	5.90 ^{bc}
15	4.75 ^b	5.88 ^{bc}
20	4.67 ^b	8.85 ^{ab}
25	3.50 ^b	4.90 ^c

Note: Numbers followed by different letters show significantly different in HSD (≤ 0.05)

Looking at the influence of the interaction between nutrient type and PGR concentration mini-tubers average diameter, the results of the HSD test (Table 4) showed that AB-mix nutrients without the addition of PGR resulted in the largest average tuber diameter (12.19 mm). AB-mix media is a hydroponic solution with high macronutrients, especially

potassium, phosphorus, nitrogen and micro-nutrients. This high nutrient content could have been sufficient to stimulate the production of mini-tubers. Sugiyono et al. (2021) reported that the use of AB-Mix medium was very effective for the formation of mini-tubers as indicated in the number of average weight and diameter.

Table 4. The effect of interaction between nutrients and concentrations of PGR on the average mini-tuber diameter of Granola cultivar of potato in an aeroponics system

Type of nutrient	The concentration of PGR (μM)	Average mini-tuber diameter
Grow More-modified nutrient	0	8.76 ^e
	5	10.98 ^{abcd}
	10	9.42 ^{de}
	15	9.71 ^{cde}
	20	10.85 ^{abcde}
	25	11.70 ^{abc}
AB-mix nutrient	0	12.19 ^a
	5	11.90 ^{ab}
	10	11.07 ^{abcd}
	15	10.25 ^{abcde}
	20	11.36 ^{abcd}
	25	9.97 ^{bcd}

Note: Numbers followed by different letters show significantly different in HSD (≤ 0.05)

In addition, the results of the HSD test on the effect of the interaction between PGR type and concentration on total mini-tubers weight (Table 5) showed that the use of GA₃ at a concentration of 20 μM resulted in the heaviest mini-tuber (12.91 g). This finding indicated that GA₃ at a concentration of 20 μM

can increase both the source strength and sink capacity in the formation of potato mini-tubers. Gibberellin increases cellular proliferation, which improves the development of the lateral organs and mini-tubers growth (Kumlay, 2014; Sonnewald and Sonnewald, 2014; Wang et al., 2018).

Table 5. The effect of interaction between PGRs and concentrations on the total mini-tuber weight of Granola cultivar of potato in an aeroponics system

Type of PGR	The concentration of PGR (μM)	Total mini-tuber weight
BAP	0 μM	9.25 ^{abc}
	5 μM	5.52 ^c
	10 μM	6.02 ^{bc}
	15 μM	6.94 ^{bc}
	20 μM	4.80 ^c
	25 μM	5.18 ^c
GA ₃	0 μM	10.46 ^{ab}
	5 μM	7.57 ^{bc}
	10 μM	5.77 ^{bc}
	15 μM	4.81 ^c
	20 μM	12.91 ^a
	25 μM	4.61 ^c

Note: Numbers followed by different letters show significantly different in HSD (≤ 0.05)

The results of the HSD test on the effect of the interaction between the type of nutrients, type of PGRs and PGR concentration on the formation of mini-tubers of Granola cultivar of potato in aeroponics system (Table 6) showed that the knols grown in Grow More-modified nutrient medium at 0 μM GA₃ resulted in the highest total number of mini-tubers (Figure 2), although it was not significantly different with that of the knol grown in AB-Mix medium supplemented with 20 μM GA₃. Gibberellin was reported to be more effective in inducing the growth of potato shoots

than its ability to induce tuber formation. Other PGRs, such as auxin, are believed to be more effective in inducing the formation of potato tuber (Famarzi et al., 2012; Roumeliotis et al., 2012). Table 6 also showed that the knols grown in AB-Mix nutrient medium supplemented with GA₃ 20 μM resulted in the highest total mini-tuber weight (21.38 g plant⁻¹). These results showed that AB-Mix and GA₃ nutrients at a concentration of 20 μM can produce the highest source strength and sink capacity to form potato mini-tubers in aeroponic systems.

Table 6. Effect of interactions among nutrients, PGRs and concentrations on mini-tuber formation of Granola cultivar of potato in an aeroponics system

The type of nutrient	Type of PGR	The concentration of PGR (μM)	Total number of mini-tuber	Total mini-tuber weight	Average mini-tuber diameter
Grow More-modified nutrient	BAP	0	5.67 ^{bcd}	6.00 ^{bcd}	9.56 ^{cdef}
		5	4.67 ^{bcd}	5.94 ^{bcd}	10.38 ^{bcdef}
		10	9.33 ^{ab}	4.76 ^d	7.51 ^f
		15	5.00 ^{bcd}	7.88 ^{bcd}	10.42 ^{bcdef}
		20	3.33 ^{cd}	5.71 ^{bcd}	10.97 ^{abcde}
		25	2.67 ^d	7.16 ^{bcd}	13.83 ^a
	GA ₃	0	12.67 ^a	8.31 ^{bcd}	7.96 ^{ef}
		5	2.67 ^d	5.37 ^{cd}	11.58 ^{abcd}
		10	2.33 ^d	4.00 ^d	11.33 ^{abcd}
		15	4.33 ^{bcd}	3.62 ^d	9.00 ^{def}
		20	3.00 ^d	4.44 ^d	10.72 ^{bcde}
		25	4.67 ^{bcd}	3.55 ^d	9.57 ^{cdef}
AB-mix nutrient	BAP	0	9.33 ^{ab}	12.50 ^{bc}	12.26 ^{abc}
		5	3.33 ^{cd}	5.10 ^d	11.80 ^{abcd}
		10	4.33 ^{bcd}	7.28 ^{bcd}	11.27 ^{abcd}
		15	6.00 ^{bcd}	6.00 ^{bcd}	9.94 ^{bcdef}
		20	4.00 ^{cd}	3.89 ^d	9.68 ^{cdef}
		25	2.67 ^d	3.20 ^d	9.22 ^{cdef}
	GA ₃	0	6.67 ^{bcd}	12.61 ^b	12.11 ^{abcd}
		5	3.00 ^d	9.76 ^{bcd}	12.00 ^{abcd}
		10	4.67 ^{bcd}	7.55 ^{bcd}	10.88 ^{abcde}
		15	3.67 ^{cd}	6.00 ^{bcd}	10.56 ^{bcdef}
		20	8.33 ^{abc}	21.38 ^a	13.05 ^{ab}
		25	4.00 ^{cd}	5.67 ^{bcd}	10.73 ^{bcde}

Note: Numbers followed by different letters show significantly different in HSD (≤ 0.05)

Table 6 also showed that the knols grown in Grow More-modified nutrient medium supplemented with 25 μM BAP resulted in the largest average mini-tuber diameter (13.83 mm mini-tuber⁻¹) and was not significantly different from that of the knol grown in AB-Mix medium supplemented with 20 μM GA₃. These results indicated that the Grow More-modified nutrient supplemented with 25 μM

BAP can produce the highest source strength that would convert sufficient photosynthate to be translocated into mini-tubers and therefore having the largest diameter of the mini-tubers. Aksenova et al. (2012) showed that the inflows of cytokinin from the roots situated close to the stolons regulate the sinking ability of the tubers. Examining the number of mini-tubers formed, total weight and diameter, it can be seen that

the knols has grown in AB-Mix medium supplemented with 20 μM GA₃ resulted in the best formation of the mini-tuber. This treatment

yielded up to 8.33 tubers plant⁻¹ with the total mini-tuber weight of 21.38 g plant⁻¹ and an average diameter of 13.05 mm mini-tuber⁻¹.



a.



b.

Figure 2. The appearance of Granola cultivar potato tubers in an aeroponic system: a) Treatment of Grow More media with GA₃ 0 μM . b) treatment of Grow More media with GA₃ 10 μM

Due to modifications in cell division and extension, the lateral buds grow to form stolons. Cells in the pit and cortex expand and divide the extension lengthwise in the direction of the development of the tuber, therefore producing an end swelling of the stolon. The tuber morphology obtained appeared to be oval and not round. This indicates a longer longitudinal growth, although the tubers have formed. However, the addition of BAP or GA₃ treatment seems to cause this longitudinal growth to continue at a faster rate than the growth rate of tuber enlargement, resulting in an oblong tuber morphology (Aksenova et al., 2012; Kianmehr et al., 2012; Roumeliotis et al., 2012).

CONCLUSION

This research showed that the use of the media type, the concentration of PGRs and PGR affects the formation and yield of Granola potato cultivar mini-tubers. The knols has grown in AB-Mix medium supplemented with 20 μM GA₃ resulted in the best mini-tubers formation, as shown on the average number of mini-tubers of 8.33, the total weight of minitubers of 21.38 g and the average mini-tuber diameter of 13.05 mm.

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