The Effect of Plant Material, Nutrient and Planting Density on Mini Tuber Production of Granola Potato Cultivar in Aeroponics System

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Abstract

Potato is an important food crop in both developed and developing countries and it is the fourth most important food crop after wheat, maize, and rice. Potato production in Indonesia has decreased from year to year, which may have been caused by low tuber seed quality. The objective this research was to determine the effect of plant materials, types of nutrients, and planting density on mini tuber formation of Granola cultivar of potato. This research has been carried out experimentally using a Split-split Plot Design. The research results showed that *knol*s planted on AB-mix nutrient at a planting density of 75 plants/m2 resulted in the best mini tuber production of Granola cultivar of potato in aeroponics system. With the existence of potato seed production through aeroponic techniques, the availability of high quality potato tuber seed can be increased, which in turn will increase national potato production to meet the ever increasing demand of potato.

Keywords: Granola, Aeroponic, Nutrient, Mini Tuber

Introduction

Potato is the fourth most important food crop after wheat, maize, and rice (Alva et al., 2011; Devaux et al., 2014; Muthoni et al., 2010). The demand for potato in Indonesia continues to increase in line with population growth, but its production has not able to meet that increasing market demand. Potato production in Indonesia has increased from 1,219,270 tonnes (2015) to 1,284,780 tonnes (in 2018), but this production was lower than that of in 2014, which was 1,347,815 tonnes (Statistics Indonesia, 2018). Indonesian potato production is hindered by the difficulty in providing high quality seeds in the right quantity and cultivar (Waluyo & Karyadi, 2013), unfavourable climates, and problems caused by pests and diseases (Agustina et al., 2019; Fahim et al., 2013; Samiyarsih et al., 2018). Granola is one of the yellow potato cultivars

which is widely cultivated in Indonesia. This superior cultivar has an average harvest time of 90 days, with productivity reaching 30-40 tons per hectare, and more resistant to diseases.

In vitro propagation method is one of the most suitable alternative methods for producing micro tuber seed because large numbers of clones can be produced in a short time at a lower cost (Badoni & Chauhan, 2010). Micro tubers can be produced at any time of the year, are easy to store and transport (Nistor et al., 2010), and improve the quality of seed tubers (Donnelly et al., 2003). In vitro propagation can produce shoots, plantlets, or micro tubers which can subsequently be used for tuber seed production, breeding programs, and germplasm conservation. These shoots, plantlets, or micro tubers can also be used to produce mini tubers in a greenhouse via aeroponics system.

The use of aeroponic techniques for mini tubers production offers several advantages compared to other methods because this technique can optimize the aeration of the roots, is independent of the season, yields more tuber seed and is more effective, does not lose fertility, and is easy to harvest. The aeroponics success of potatoes is influenced by several factors, including cultivar, water, plant material, aeroponic systems, media, and aeroponic spacing/planting density (Chiipanthenga et al., 2012; Faramarzi et al., 2012; Farran & Mingo-Castel, 2006; Khodadadi et al., 2011; Mbiyu et al., 2012; Otazu, 2010; Tsoka, O., 2012). Optimation of tuber seed production is widely possible due to the fact that:1) different cultivars may need different nutrient formulation or concentration; 2) planting materials play a very important role on tuber formation; 3) Each cultivars needs different planting space or density; and 4) the important of plant growth regulators on potato mini tuber formation (Chiipanthenga et al., 2012; Mbiyu et al., 2012; Otazu, 2010; Tsoka, O., 2012).

Methods

This research has been conducted in Kledung Horticultural Seed Garden, Temanggung, Central Java Provinces, Indonesia. This research aimed to study the effect of plant material, types of nutrients, and spacing on the formation mini tubers of Granola cultivar of potato in aeroponic systems. This research has been carried out experimentaly using a Split-split Plot Design. The material used was Granola cultivar produced by Kledung Horticultural Seed Garden. The main plot was the type of plant material, which consisted of in vitro-derived plantlet (and hereafter is called plantlet) and certified-G1-tuber-seed-derived plantlets (and hereafter called *knol*). The subplot was nutrition media which consisted of Farran nutrition; Otazu nutrition; and AB-commercial mix. The sub-sub-plot was the planting density which

consisted of 50 plants/m^2; 75 plants/m^2; and 100 plants/m^2; Each treatment combination was repeated 3 times to obtain 54 experimental units.

The variable observed was the production of mini tubers, with parameters measured including total number, total weight, average weight, and average diameter of mini tuber. The data obtained were analysed using an analysis of variance (ANOVA), followed by an Honestly Significant Difference (HSD) test at 95% level of confidence.

Results and Discussion

The research results showed that mini tuber formation of Granola cultivar of potato on aeroponics system was controlled by the planting material, nutrition medium, and the planting density applied. The results showed that the growth of Granola cultivar potato in this aeroponic system was quite good (Figure 1) and produced 2-21 mini tubers/plant, with an average of 5 tubers/plant (300 tubers/m^2). Bag et al. (2015) reported that the number of mini tubers produced reached 38.12 micro tubers/plant on the Kufri Himalini cultivar potato. Meanwhile, Rykaczewska (2016) reported that the average micro tuber production of Ametyst and Typhoon cultivars was 32.5 and 36.0 micro tubers/plant, respectively.

Figure 1. The appearance of potato cultivar Granola in an aeroponics system

Potato tuber formation consists of two aspects: tuber morphological development and biochemical changes which results in the formation and storage of carbohydrate in the tuber. Morphological development of tuber consists of two processes i.e., stolon development and tuber formation on the stolon tip. It is generally agreed that stolon longitudinal growth ceased after stolon tip thickening has been started. The lateral shoot will give rise a stolon due to the changes on cell division and cell elongation. Just before tuber formation, stolon elongation ceased, the cells inside the pith and cortex enlarge and start to divide longitudinally, which resulted in the swelling of stolon tip. When the tuber reaches 0.8 cm in diameter the

longitudinal cell division stops, but random cell division and enlargement subsequently occur especially in the *perimedullar* zone until the designated tuber size is reached (Xu et al., 1998).

The total number of mini tubers, total mini tuber weight, average mini tuber weight, and average mini tuber diameter were controlled by either planting materials, nutrients, planting density, interactions between factors, or interactions among factors tested. HSD test results on the influence of planting materials on all parameters measured (Table 1) showed that *knol* produced significantly better total number of mini tubers, total mini tuber weight, and average mini tuber weight than those of plantlet. No significant difference was found on the average mini tuber diameter produced, although *knol* still produced larger mini tuber diameter.

The growth and mini tuber production of Granola cultivar of potato originated from tuber seed (*knol*) under aeroponic system was better than that of plantlets. It is suggested that plantlet produced from tuber seed have better morphological dan anatomical structures and physically stronger than that of in vitro derived-plantlet. The morphological dan anatomical structures of in vitro-derived plantlets usually have not fully developed which resulted in both plant vulnerability and slower growth especially in the early stage of plant development during or just after acclimatization in the field. A good acclimatisation process is therefore needed (Otazu, 2010). This finding was contradictory with that of reported by Otazú, (2010) and Jelodutar & Hassanpanah (2012), who found that in vitro-derived plantlets produced best mini tuber formation.

Table 1. The effect of different planting materials on mini tuber formation of Granola cultivar of potato in aeroponics system

Type of planting material	Total mini tuber number	Total mini tuber weight	Average mini tuber weight	Average mini tuber diameter
Plantet	1,87[b]	0,79[b]	0,44[b]	0,96
Knol	2,13[a]	1,73[a]	0,76[a]	1,06

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

The results of HSD test on the effect of nutrient formulation on mini tuber formation (Table 2) showed that AB-mix media resulted in significantly better total number of mini tubers, total mini tuber weight, average mini tuber weight, and average mini tuber diameter than those of Farran and Otazu nutrient formulations. This result indicated that Farran dan Otazu nutrient have not been able to stimulate better mini tubers formation as reported by Farran & Mingo-Castel (2006) and Otazu (2010). However, these results were consistent with previous experiment reported by Sugiyono *et al.* (2015) and Prayoga *et al.* (2015), that Farran and Otazu

media formulations showed no difference with modified Hoagland and Grow More in producing mini tubers in aeroponics system. Sugiyono *et al.* (2015) and Prayoga et al. (2015) suggested that Grow More-modified medium could substitute Farran and Otazu media.

Table 2. The effect nutrient formulations on mini tuber formation of Granola cultivar of potato in aeroponics system

Nutrient	Total mini tuber number	Total mini tuber weight	Average mini tuber weight	Average mini tuber diameter
Farran	2,10[b]	1,06[b]	0,57[b]	1,05[a]
Otazu	1,33[c]	0,60[c]	0,47[b]	0,88[b]
AB-Mix	2,57[a]	2,12[a]	0,76[a]	1,10[a]

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

HSD test result also showed that planting density at 75 plants/m^2 resulted in significantly higher total number and total weight of mini tubers than that of 50 plants/m^2 planting density, although in term of total number of mini tubers formed, it was not significantly different with 100 plants/m^2 planting density (Table 3). Planting density at 50 plants/m^2 tended to produced heavier and bigger mini tuber than those of 75 and 100 plants/m^2 planting densities, although no significant difference was observed. In term of the number of mini tubers formed, this finding was quite similar with the number of mini tuber reported by Sugiyono et al. (2015) and Prayoga et al. (2015), who applied 60 plants/m^2 planting density. Those findings also indicated that planting density at 60-100 plants/m^2 in aeroponics system resulted in no nutrient competition among Granola cultivar of potato. In other words, at 60-100 plants/m^2 planting density, nutrient supply was not a limiting factor for plant growth and mini tuber formation of Granola cultivar of potato under aeroponics system. It also strongly indicated that nutrient and growth conditions determine growth and mini tuber formation of Granola cultivar of potato under aeroponics system.

Table 3. The effect of planting densities on mini tuber formation of Granola cultivar of potato in aeroponics system

Nutrient	Total mini tuber number	Total mini tuber weight	Average mini tuber weight	Average mini tuber diameter
50 Plants/m^2	1,43^b	0,93^b	0,65	1,08
75 Plants/m^2	2,33^a	1,68^a	0,64	1,02
100 Plants/m^2	2,23^a	1,17^b	0,51	0,93

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

Further analysis results on the effect of interaction between planting materials and nutrients (Table 4) showed that *knol* planted on AB-mix nutrient produced the highest results, and significantly difference with those of other treatment combinations except on the average of mini tuber weight. HSD test results on the effect of the interaction between planting materials and planting densities on mini tuber formation of Granola cultivar of potato in aeroponics system (Table 5) showed that *knol* planted at 75 plants/m^2 resulted in significantly better total number of mini tubers, total mini tuber weight, average mini tuber weight, and average mini tuber diameter than those of other interaction between planting material and planting density. The largest average tuber diameter was obtained at *knol* planted at looser spacing i.e., 50 plants/m2, although it was not significantly different with that of 75 plants/m^2 planting density.

Table 4. The effect of the interaction between planting materials and nutrients on mini tuber formation of Granola cultivar of potato in aeroponics system

Planting material	Nutrient	Total mini tuber number	Total mini tuber weight	Average mini tuber weight	Average mini tuber diameter
Plantet	Farran	2,33 ^{b}	0,71 ^{cd}	0,35 ^{ns}	0,98 ^{bc}
	Otazu	1,33 ^{c}	0,47 ^{d}	0,37 ^{ns}	0,94 ^{bc}
	AB-mix	1,93 ^{bc}	1,17 ^{bc}	0,60 ^{ns}	0,53 ^{bc}
Knol	Farran	1,86 ^{bc}	1,39 ^{b}	0,79 ^{ns}	1,11 ^{ab}
	Otazu	1,33 ^{c}	0,72 ^{cd}	0,56 ^{ns}	0,82 ^{c}
	AB-mix	3,20 ^{a}	3,05 ^{a}	0,91 ^{ns}	1,25 ^{a}

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

Faramarzi et al. (2012) stated that the number, tuber weight and plant height were influenced by the cultivar, planting density and the interaction between those two factors. Similar results were also reported by Khodadadi et al. (2011), which showed that the Savalan cultivar

produced the largest number of mini tubers among the cultivars tested. This result indicated that the formation of mini tubers was controlled by planting density and cultivars planted.

Table 5. The effect of the interaction between planting materials and planting densities on mini tuber formation of Granola cultivar of potato in aeroponics system

Planting material	Planting density (plant/m^2)	Total mini tuber number	Total mini tuber weight	Average mini tuber weight	Average mini tuber diameter
Plantet	50	1,33 ^{c}	0,60 ^{b}	0,49 ^{c}	0,98 ^{ab}
	75	2,06 ^{ab}	0,75 ^{b}	0,37 ^{c}	0,91 ^{ab}
	100	2,20 ^{ab}	1,00 ^{b}	0,46 ^{c}	0,98 ^{ab}
Knol	50	1,53 ^{bc}	1,25 ^{b}	0,81 ^{ab}	1,18 ^{a}
	75	2,60 ^{a}	2,60 ^{a}	0,90 ^{a}	1,13 ^{ab}
	100	2,27 ^{a}	1,32 ^{b}	0,55 ^{bc}	0,87 ^{b}

Note: Numbers followed by different letters show significant difference in HSD ($\leq$0.05)

The HSD test results on the effect of the interaction between nutrients and planting densities (Table 6) also showed that Granola cultivar of potato planted on AB-mix nutrient at planting density of 75 plants/m^2 also resulted in significantly higher number of mini tubers, heavier total mini tuber weight and average mini tuber than those of other treatment interactions. The largest average mini tuber diameter was obtained from plants cultivated in Farran medium at 50 plants/m^2 planting density, although no significant difference was observed compared to that of produced by plants grown on AB-Mix nutrient at 75 plants/m^2 planting density. HSD test results on the interaction between planting materials and nutrients, nutrients and planting densities, and planting materials and planting densities, strongly indicated that *knol* grown on AB-mix nutrient at 75 plants/m^2 planting density could be the best conditions to obtain better mini tuber formation of Granola cultivar of potato in aeroponics system.

Table 6. The effect of the interaction between nutrients and planting densities on mini tuber formation of Granola cultivar of potato in aeroponics system

Nutrient	Planting density (plant/m^2)	Total mini tuber number	Total mini tuber weight	Average mini tuber weight	Average mini tuber diameter
Farran	50	1,40 ^{cd}	1,02 ^{c}	0,78 ^{a}	1,29 ^{a}
	75	2,20 ^{bc}	1,21 ^{bc}	0,56 ^{ab}	1,00 ^{ab}
	100	2,70 ^{ab}	0,93 ^{c}	0,37 ^{b}	0,83 ^{b}
Otazu	50	1,10 ^{d}	0,55 ^{c}	0,52 ^{ab}	0,90 ^{b}
	75	1,60 ^{cd}	0,71 ^{c}	0,49 ^{ab}	0,90 ^{b}
	100	1,30 ^{cd}	0,52 ^{c}	0,38 ^{b}	0,84 ^{b}
AB-mix	50	1,80 ^{bcd}	1,20 ^{bc}	0,64 ^{ab}	1,04 ^{ab}
	75	3,20 ^{a}	3,09 ^{a}	0,85 ^{a}	1,16 ^{ab}
	100	2,70 ^{ab}	2,04 ^{b}	0,76 ^{a}	1,10 ^{ab}

Note: Numbers followed by different letters show significant difference in HSD ($\leq$0.05)

Results of the HSD test on the effect of the interaction among planting materials, nutrients and planting densities on mini tuber formation of Granola cultivar of potato in aeroponics system (Table 7) reconfirmed the results of two factors interaction that *knol* grown on AB-Mix nutrient at 75 plants/m^2 planting density resulted in the highest total number and weight of mini tubers, which was significantly different with those of other treatment interactions. Although the number of mini tubers formed by *knol*s grown on AB-Mix nutrient at 75 plants/m^2 planting density was not significantly different with *knol*s grown on AB-Mix nutrient at 100 plants/m^2 planting density. This results also showed that three factors interactions produced much better mini tuber formation compared to individual factors and two-factor interactions.

Table 7. The effect of the interaction among planting materials, nutrients and planting densities on mini tuber formation of Granola cultivar of potato in aeroponics system

Planting material	Nutrient	Planting density (plant/m^2)	Number of tuber per plant	Total weight of tuber
Plantlet	Farran	50	1,40 ^{d}	0,61 ^{c}
		75	2,40 ^{bcd}	0,63 ^{c}
		100	3,20 ^{ab}	0,90 ^{bc}
	Otazu	50	1,20 ^{d}	0,50 ^{c}
		75	1,80 ^{bcd}	0,55 ^{c}
		100	1,00 ^{d}	0,36 ^{c}
	AB-mix	50	1,40 ^{d}	0,69 ^{c}
		75	2,00 ^{bcd}	1,07 ^{bc}
		100	2,40 ^{bcd}	1,75 ^{bc}
Knol	Farran	50	1,40 ^{d}	1,44 ^{bc}
		75	2,00 ^{bcd}	1,79 ^{bc}
		100	2,20 ^{bcd}	0,95 ^{bc}
	Otazu	50	1,00 ^{d}	0,60 ^{c}
		75	1,40 ^{d}	0,88 ^{bc}
		100	1,60 ^{cd}	0,68 ^{c}
	AB-mix	50	2,20 ^{bcd}	1,70 ^{bc}
		75	4,40 ^{a}	5,12 ^{a}
		100	3,00 ^{abc}	2,34 ^{b}

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

Conclusion

The formation of Granola cultivar potato tubers in an aeroponic system is influenced by the plant material, nutrition, and the planting density used. Knol planted on AB-mix nutrient at a planting density of 75 plants/m2 resulted in the best mini tuber production of Granola cultivar of potato in aeroponics system.

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