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Research Article

Seed tuber production of potato from stem cuttings, planting densities, and paclobutrazol concentrations

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ABSTRACT

Rapid multiplication of potato seed using cuttings is a pivotal strategy for ensuring seed availability. This study aimed to elucidate the interactive effects of node number, paclobutrazol concentration, and planting density on seed potato and cutting productions. The study consisted of two experiments. The first experiment evaluated two genotypes (Granola and PKHT-6) with one or two nodes per cutting. The second experiment investigated planting density (one, three, or five plants per polybag) and paclobutrazol concentration (0, 15, 30, and 45 mg L^{-1}). Notably, node number did not significantly influence cutting success, despite genotype-specific and interactive effects on vegetative parameters like plant height, stem diameter, leaf number, and root length. Planting density had no statistically significant impact on all vegetative parameters but demonstrably affected all production parameters. Conversely, paclobutrazol concentration significantly affected all vegetative parameters and influenced all production parameters except tuber weight per plant. From the results of this research, the use of single cutting is more recommended because it will obtain more plant material compared to two-node cuttings. Thus, in a more global context of potato development, this has the potential to increase the production of potato seeds from cuttings twice as much as the current seed production. The use of three plants/polybags is more recommended since it will produce more tuber but not different with five plants, and the use of paclobutrazol 15 mg L^{-1} is also recommended to increase the number of tubers. In this way, the production costs of G0 potato seeds can be reduced so that the availability of G0 potato seeds will be more guaranteed and affordable.

Keywords: Granola; PKHT-6; rapid multiplication; tuber production

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important horticulture crop from economic and food security perspectives. In Indonesia, the harvested area exceeds 63,114 thousand hectares, and a monthly harvest surpasses 5.47 thousand hectares (BPS, 2020). However, potato production tends to decline. Compared to 2019, yields in 2020 decreased by 31.88 thousand tons equal to 2.42% decline (BPS, 2020). This decrease in production can be attributed, to the widespread use of low-quality and uncertified potato seeds.

Research by Alveno et al. (2022) demonstrates a significant decline in yields from the first (G1) to the second generation (G2). To increase potato productivity, increasing the availability of high-quality seed derived from superior cultivars is needed. Rapid multiplication of initial generation (G0) potato seed tubers and cuttings from both *in vitro* and its cuttings is a promising strategy for producing adequate seeds for farmers, like in *Amorphophallus muelleri* Blume (Putri et al., 2023).

Propagation of certified potato seeds can be done by tissue culture to eliminate pathogens, and then plantlets are acclimatized and induced to form shoots as cutting material ready for planting. Technology for potato seed from cutting is well-established (Kasutjianingati et al., 2018; Nikmatullah et al., 2018). Potato derived from plantlet cuttings produce higher plant height than those from micro tubers (Kasutjianingati et al, 2018). In mulberry, Sudomo et al. (2007) stated that the treatment of the number of buds significantly affected the percentage of viability and vegetative growth of stem cuttings. Moreover, Sudomo et al. (2007) mentioned that the smaller the number of buds, the smaller the ability to sprout and produce roots, while many shoots for cuttings give relatively poor results. Nikmatullah et al. (2018) mentioned that apical stem cutting supplemented with 1 ppm IAA produces the highest number of potato seeds. Putri et al. (2023) noted that dipping leaf cutting on a combination of 2-4 mg L^{-1} NAA+15 mg L^{-1} BA stimulates optimum for shoot growing and tuber yield in *Amorphophallus*.

To alleviate poor growth, the application of paclobutrazol is hypothesized to increase tuber production. Paclobutrazol is a retardant that inhibits cell elongation in the sub-apical meristem, reducing the rate of stem elongation without affecting leaf growth and development (Tumewu et al., 2012). Foliar spray paclobutrazol can inhibit gibberellin synthesis (Azima et al., 2017). According to Hamdani et al. (2021), applying paclobutrazol with a frequency of three times increases the chlorophyll content in potato. In addition, plants given paclobutrazol can be protected from environmental stress (Xia et al., 2018).

Optimizing plant density within a defined area represents a fundamental strategy for maximizing crop yields. By regulating planting density, plants can effectively utilize their surrounding environment for growth and resource acquisition. This issue has been addressed by Nikmatullah et al. (2018) where three nodes produced the highest survival rate than two and five nodes. However, Wiroatmodjo (1995) noted that planting density significantly impacts rhizome size, particularly at high population densities (5 plants/pot); in such cases, the resulting rhizomes tend to be smaller compared to those produced under lower densities (1 plant/pot) implies the importance of optimal planting density. This study aimed to elucidate the interactive effects of node number, paclobutrazol concentration, and planting density on seed potato and cutting productions.

MATERIALS AND METHODS

The experiment was conducted at PT. Horti Agro Makro, Cilame Village, Garut Regency, West Java from August 2022 to August 2023. Two experiments were conducted, i.e., (1) Growth of potato cuttings from different genotypes and node numbers, and (2) Growth and production of mini potato tubers (G0) from different densities of cutting treated with paclobutrazol.

Experiment 1: Cutting performance from two genotypes and node numbers

The plant material used potato plantlets from invitro production which were acclimatized for three weeks. The plantlets were about two months old. The acclimatized plantlets were then cut according to the treatment and then planted in sterile media in a mixture of cocopeat and husks. The experiment was conducted in a controlled greenhouse.

The experiment was arranged using a factorial completely randomized design consisting of two factors: genotype and number of nodes. The first factor was Granola and PKHT-6 genotypes, and the second factor was the number of nodes which consisted of one node and two nodes. The node was counted from the apical bud.

The experiment used five replicates to obtain 20 experimental units. Each experimental unit consisted of 10 cuttings in every 5 pots. Variables observed included root length, plant height, stem diameter, leaf numbers, and transplanting success.

Maintenance was done by keeping the planting medium moist and applying foliar fertilizer (Gandasil A® 5 g L^{-1}). Observations were made at two weeks after planting.

Experiment 2: Growth and production of cutting density and paclobutrazol treatments

The planting material used rooted cuttings of the PKHT-6 genotype, about 4 weeks after planting of cutting. The seedlings of single bud were transplanted into polybags size 35 cm x 35 cm containing mixed media of cocopeat and sterile husk. The experiment was arranged using a randomized complete block design consisting of two factors, i.e., plant density and paclobutrazol concentration, with three replications.

The first factor was plant density of 1, 3, and 5 plants per polybag. The second factor was the paclobutrazol concentration of 0, 15, 30, and 45 mg L^{-1}. Paclobutrazol was applied through foliar application about 100 mL per pot at one time at second week after transplanting. Two weeks after planting was considered after seedling established. Maintenance was carried out based on SOP for potato seed production (Decree of the Minister of Agriculture of the Republic of Indonesia Number: 20/Kpts/SR.130/IV/2014).

Observations were made starting from two weeks after planting until harvest (12 weeks after planting). The variables observed were the branch numbers, plant height, and leaf numbers. At the end of the experiment, tuber numbers and tuber weight were observed.

RESULTS AND DISCUSSION

Experiment 1: Cutting performance from two genotypes and node numbers

Based on the analysis of genotype variance, the number of nodes and their interactions affected some of the observed variables (Table 1). Root length, stem diameter, and leaf numbers were influenced by genotype. Node number affected almost all variables observed. The interaction between genotype and node numbers had no significant effect on the variables of root length, stem diameter, and success of transplanting, but it had a very significant effect on the leaf numbers and had a significant effect on plant height. According to Wulandari et al. (2014), plant production is primarily determined in the vegetative growth phase, the better plant growth, the bigger tubers will be produced. It is important to note that other factors such as nutrient availability and environmental conditions also contribute significantly to final tuber size. Further research should investigate the underlying mechanisms governing genotype x node number interactions and their impact on resource allocation and tuber formation.

Table 1. Summary of ANOVA of shoot cutting from different potato genotypes and node numbers.

Parameter	Genotype (V)	Node number (N)	V*N
Plant height	ns	**	*
Stem diameter	**	**	ns
Leaf number	**	**	**
Root length	**	**	ns
Transplant success	ns	ns	ns

Note: *=significant, **=highly significant, ns=not significant at 5% level

The number of nodes did not affect plant height and leaf number for the Granola genotype (Table 2). This is probably due to low carbohydrate resources in the stem (Suci & Heddy, 2018). Lommen (2015) reported that around 85–92% of the photosynthetic results of potato plants from cuttings were translocated for tuber development.

The stem diameter of PKHT-6 was bigger than that of Granola (Table 3). This finding is in line with Neni et al. (2018), who stated that PKHT-6 produced the largest stem diameter compared to other genotypes. Two-node cuttings exhibited significantly higher root length and stem diameter compared to one-node cuttings ($p < 0.05$) (Table 3). Santoso et al. (2009) noted the importance of cutting size in ensuring sufficient reserves for seedling growth and development. Interestingly, the final transplant success remained unaffected by genotype, node number, or their interaction ($p > 0.05$) (Table 1). However, further analysis of individual components like rooting and leaf development might reveal genotype-specific responses. Although single-node cuttings offer the potential for accelerated seed production and cost reduction, further research is crucial to optimize cutting practices based on genotype, desired seedling vigor, and potential yield trade-offs.

Table 2. Plant height and leaf number of shoot cutting from different potato genotypes and node number.

Genotypes	Single node	Two nodes
	Plant height (cm)	
Granola	3.62bc	3.85b
PKHT-6	3.47c	4.60a
	Leaf number	
Granola	4.4b	4.4b
PKHT-6	4.5b	5.8a

Note: Numbers in the same column and variable followed by the same letter are not significantly different at LSD test 5%.

Table 3. Root length, stem diameter, and transplant success of shoot cutting from different potato genotypes and node number.

Treatment	Root length (cm)	Stem diameter (cm)	Transplant success (%)
Genotypes			
Granola	1.66b	0.68b	100
PKHT-6	3.89a	0.88a	100
Node number			
Single node	2.23b	0.67b	100
Two nodes	3.32a	0.90a	100

Note: Numbers in the same column followed by the same letter for each treatment are not significantly different at LSD test 5%

Experiment 2: Growth and production of cutting density and paclobutrazol treatments

The number of plants per polybag did not affect all vegetative growth parameters, and conversely, the paclobutrazol concentration significantly affected all vegetative parameters (Table 4). Plants that can grow well in the vegetative phase will also provide good production in the generative phase (Aprilyanto et al., 2016). As for production, the number of plants per polybag had a significant effect on all production variables, while the concentration of paclobutrazol was significant for all production variables except tuber weight (Table 4).

Table 4. Summary of ANOVA of plant density and paclobutrazol concentration treatments.

Variables	Plant number per polybag (D)	Paclobutrazol concentration (C)	D*C
Branch number			
Week 8	ns	**	ns
Week 10	ns	**	ns
Plant height			
Week 8	ns	**	ns
Week 10	ns	**	ns
Leaf number			
Week 8	ns	**	ns
Week 10	ns	**	ns
Tuber number/plant	**	**	**
Tuber weight/plant	**	**	**
Tuber number/polybag	**	**	ns
Tuber total weight/polybag	**	**	ns
Tuber weight	*	ns	ns

Note: *=significant, **=highly significant, ns=not significant at 5% level.

In general, paclobutrazol treatment had a significant effect on the number of branches (Figure 1A). The 15 mg L^{-1} paclobutrazol treatment had no significant effect as compared to the 30 and 45 mg L^{-1} at 6, 8, and 10 weeks after transplanting (WAP), but significantly stimulated number of branching than control. Increasing the concentration up to 45 mg L^{-1} had no significant effect on number of branches. The finding is contrary to Bhattarai (2017), where spraying paclobutrazol increases the branches of potato.

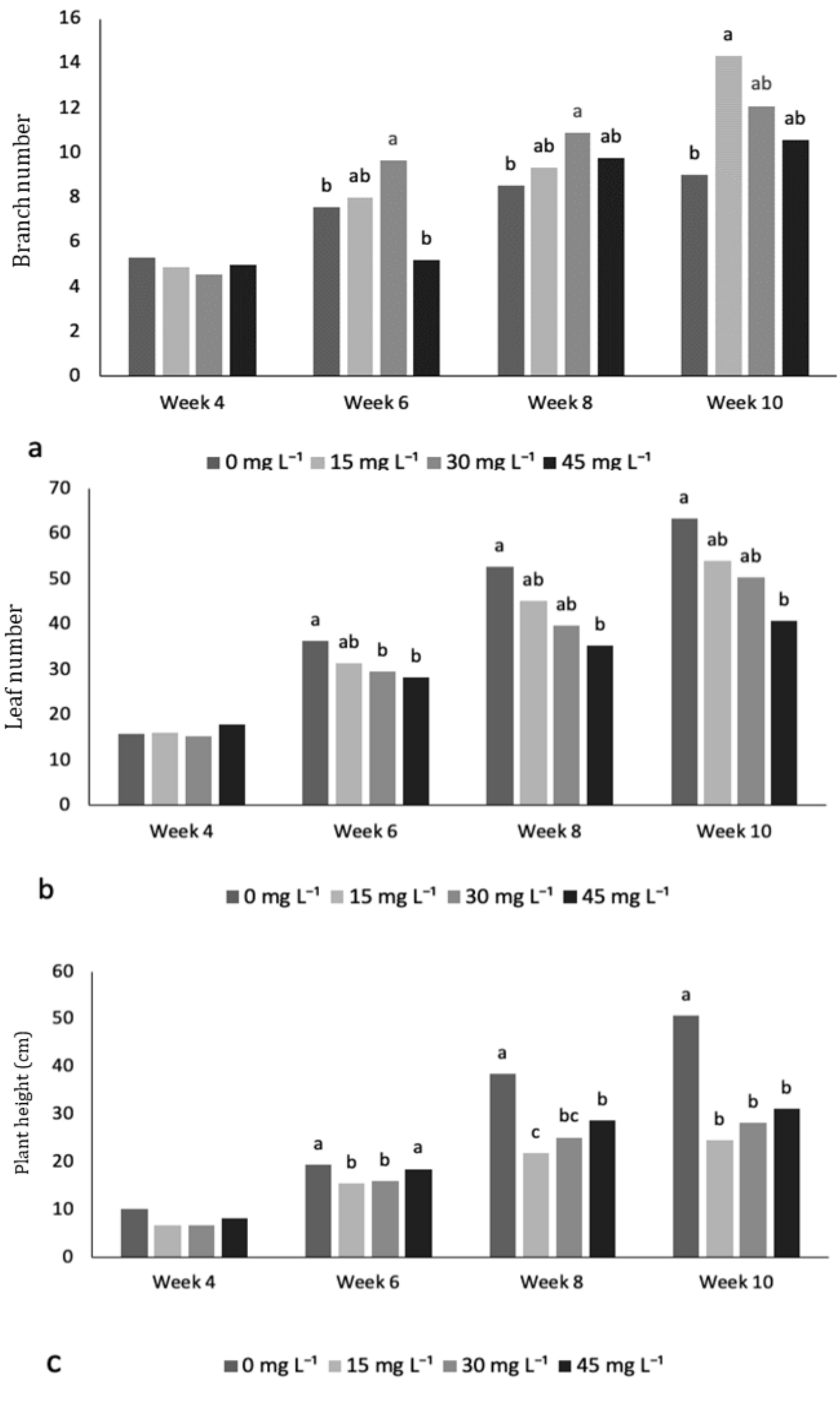

Figure 1. Effects of paclobutrazol on branch number (a), leaf number (b), and plant height (c) at the age of 4-10 WAP of potato. Numbers followed by the same letter are not significantly different at LSD test 5%.

Paclobutrazol at a concentration of 15 to 45 mg L^{-1} decreased the number of leaves and plant height (Figure 1B and Figure 1C). Higher paclobutrazol concentration stimulates shorter plants. Figure 1A shows that 15 ml L^{-1} of paclobutrazol stimulates potato branching. According to Aulia et al. (2014) farmers desire potatoes with higher branching due to higher tuber production.

There was a significant interaction between plant density in certain conditions and paclobutrazol concentration on the number of tubers per plant and tuber weight per plant (Table 5). One plant cutting per polybag with the addition of paclobutrazol spraying produced the highest number of tubers per plant and tuber weight per plant. Kianmehr et al. (2012) stated that the size of potato tuber is significantly affected by paclobutrazol application. Planting three and five plants per polybag followed by spraying paclobutrazol showed a tendency to produce less the number of tubers per plant. It is likely that higher plant density increases competition for light, water, nutrients, and space as stated by Fathiyah et al. (2017) and Fatchullah (2017) leading to low production by each plant. This is also consistent with the results of our current study where the weight per tuber for the treatment of one plant per polybag was significantly higher than three or five plants per polybag (Table 6). The application of paclobutrazol was able to increase the number of tubers and the total tuber weight per polybag (Table 6). The increase in total tuber weight per polybag was caused more by the number of tubers produced and not by tuber size.

Table 5. Number and weight of tubers per plant from different plant numbers per polybag and paclobutrazol concentration.

Plant density	Paclobutrazol concentration			
	0 mg L^{-1}	15 mg L^{-1}	30 mg L^{-1}	45 mg L^{-1}
	Number of tubers per plant			
One plant/polybag	5.7b	9.7a	9.7a	10.7a
Three plants/polybag	2.4cd	4.3bc	4.1bc	2.1d
Five plants/polybag	1.5d	2.6cd	2.8cd	2.5cd
	Tuber weight per plant (g)			
One plant/polybag	141.8b	238.6a	237.1a	251.3a
Three plants/polybag	53.1d	87.4c	53.1d	53.1d
Five plants/polybag	34.6d	52.9d	55.2d	52.1d

Note: Numbers in the same column and variable followed by the same letter are not significantly different at LSD test 5%.

Table 6. Tuber number and weight per polybag from different plant number per polybag and paclobutrazol concentration.

Treatment	Tuber number/polybag	Tuber total weight/polybag (g)	Average tuber weight (g)
Plant density			
One plant/polybag	8.9b	217.20b	24.97a
Three plants/polybag	10.8a	231.49ab	21.83b
Five plants/polybag	10.9a	243.60a	21.34b
Paclobutrazol concentration			
0 mg L^{-1}	6.9b	158.98b	-
15 mg L^{-1}	11.9a	255.14a	-
30 mg L^{-1}	12.0a	263.07a	-
45 mg L^{-1}	10.0a	246.86a	-

Note: Numbers in the same column and factor followed by the same letter are not significantly different at LSD test 5%.

CONCLUSIONS

Two-node cutting had higher plant height, root length, and stem diameter of the plant as compared to single-node cutting. Plant height and leaf number of seedlings derived from apical cutting were affected by genotype x node number interaction. The number of plants per polybag did not affect vegetative variables but affected tuber variables. On the other hand, paclobutrazol concentration affected all variables except individual tuber weight. It is recommended to use cutting of two nodes followed by three plants/polybags and supplemented with paclobutrazol 15 mg L^{-1} for rapid propagation of evaluated genotypes.

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