Performance and Yield of Potato (Solanum tuberosum L.) Granola Variety from Five Generations in Toba, North Sumatra

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Abstract. Potato is one of the major horticulture crop in Indonesia, but potato productivity in Indonesia is still relatively low compared to several European countries such as Belgium and Netherlands. One of the major problem was the availability of Generation 4 tuber as potato extension seed, which then forced farmer to use lower quality seed. This study aims to determine the effect of using different seed generations on potato performance and production. The study was carried out in Aek Natolu Jaya village, Lumban Julu sub-district, Toba Regency, North Sumatra from November to March 2020, using potato seed from five generation. The results showed that G0, G1, and G2 had the same performance and was the best performance based on the height and diameter of the stem and had the best yield and started to decrease in the G3 and G4 treatments. The highest number of tubers harvested was found on G0 and G1 treatments. G0, G1, and G2 has higher yield and also produced better tuber grades than G3 and G4. G2 has high yield and the only generation produced Grade A tubers, which indicates that G2 is more suitable to be used as extension seed.

Keywords: Grade · Seed · Tropics · Tuber · Yield

1 Introduction

Potato is the fourth major food crop after wheat, rice and corn. In Indonesia, potato is an important crop, and even though currently potato is still mainly considered as vegetable, potato have great potential as a source of carbohydrates to support food diversification programs in Indonesia. Among potato variety, Granola is the most popular variety in Indonesia. According to Ridwan et al. [1], around 90% of Indonesian farmers is planting this variety. According to Kusmana [2], Indonesian farmers prefers this variety because of its high production, short lifespan, and the adaptability to various conditions.

Granola variety is considered a high yielding variety, with potential productivity under optimum conditions reaching 26.5 tons ha^{-1}. Potato productivity in Indonesia is still relatively low compared to several European countries such as Belgium which can reach an average of 44.3 tons ha^{-1} and Netherlands 42.5 tons ha^{-1} [3], while on average Indonesia can only produce 19.27 ton ha^{-1}.

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Low productivity of potato plants, especially in Indonesia, is caused by several factor, namely low availability of quality seed, conventional cultivation techniques, topographic factors, and the tropical climate of Indonesia is an optimum place for the proliferation of potato plant pests and diseases. Low availability of quality seed are the main concern when trying to increase potato production in Indonesia.

The current potato seed system in Indonesia consists of five classes of seeds, namely G0, G1, G2, G3, and G4 [4]. G0 was the foundation seed, G3 seed is the source seed, while G4 seed was extension seed, which is then used by farmers to produce tubers for consumption. So far, farmers are having a hard time accessing G4 as extension seed. Producing G4 takes a long time and most of the time they are not readily available. The production of G4 begins with acclimatizing potato plantlets, then these plantlets produce mini tubers, namely the G0. G0 is then planted and produces G1, and so on until we get G4 [5]. Because G4 is not readily available, farmer are forced to use potato tubers from higher generation as seed. Meanwhile, the higher the generation of potato used as a seed, the higher chance it has lower quality [4].

Based on this, it is necessary to conduct further research on the effect of using different seed generations on potato performance and yield in the field. This study aims to determine the effect of using different seed generations on potato performance and yield.

2 Methodology

This study was conducted in Aek Natolu Jaya village, Lumban Julu sub-district, Toba district, North Sumatra from November to March 2020. Plant materials used in this study were potato seeds of the Granola variety in the form of tubers from 5 generations, namely G0, G1 G2, G3, and G4 with each tuber weight average of 9.5 g; 45 g; 32 g; 34 g; 40 g. Other materials used in the study were manure, dolomite, urea, SP-36, KCl, NPK 15-15-15, insecticides, and fungicides. The tools used in this study consisted of a hoe, marker, ruler/meter, scales, stationery, and documentation tools.

Design used in this study was Single Factor Completely Randomized Group Design with three replications. The factors observed were 5 generations of Granola potato varieties as seed, namely G0, G1, G2, G3, and G4 with average tuber weight of 9.5 g; 45 g; 32 g; 34 g and 40 g and repeated three times so that there were 15 experimental units. Each experimental unit consisted of 30 plants with a spacing of 80 cm $\times$ 30 cm and a bed size of 900 cm $\times$ 60 cm with a trench width of 20 cm. The number of sample plants observed was 10 plants in each experimental unit.

Data obtained during this study were analyzed to determine the effect of the treatment using the F test at a significant level of $\alpha = 5\%$. The further test used was Duncan Multiple Range Test (DMRT) at a significant level of $\alpha = 5\%$. The whole process of data analysis using Microsoft Office Excel and SAS software.

3 Results

3.1 Potato Growth Performance

The results of analysis of variance showed that generation had a significant effect on plant height, number of shoots and stem diameter at 5 WAP (Week After Planting) and

a highly significant effect at 9 WAP at the level of α = 5%. Generation also had a significant effect on other observed variables, namely the percentage of living plants, number of leaves and number of branches at the age of 9 WAP but had no significant effect at the age of 5 WAP. The results of the analysis of variance in the blocks did not show a significant effect on the quantitative variables of growth percentage, number of branches, and number of shoots at the age of 5 WAP but showed a significant effect on the variables of plant height, number of leaves, and stem diameter and at the age of 9 WAP in all blocks does not show a significant effect on quantitative variables.

Analysis of variance showed that the generation had a significant effect at the level of =5% on all post-harvest variables, while the block did not show a significant effect. The results of analysis of variance are presented in Table 1 and Table 2.

Table 1. Analysis of variance on post-harvest variables experimental observations

	Age (WAP)					
	Influence of Generation		Plot		Coefficient of Variance (%)	
	5 WAP	9 WAP	5 WAP	9 WAP	5 WAP	9 WAP
Growth percentage	ns	**	ns	ns	4.11	3.25
Plant height	**	**	*	ns	9.10	5.77
Number of leaves	ns	**	**	ns	8.44	9.35
Number of branches	ns	**	ns	ns	6.34	4.30
Number of shoot	*	**	ns	ns	13.52	12.82
Stem diameter	**	*	**	ns	8.10	8.75

Note: ns: not significant, CC: Pearson Correlation of Coefficient
* = significantly different at α = 5%, * = significantly different at α = 1%, ns = not significantly difference; # = number

Table 2. Analysis of variance for post-harvest variables

Variables	Generation	Blok	Coefficient of Variance
# of tubers	**	ns	16.66
Weight per plant	**	ns	21.13
Tuber weight per plot	**	ns	17.26
Yield per ha	**	ns	17.27
# of A grade tuber	**	ns	9.44^{t}
# of B grade tuber	*	ns	24.94
# of C grade tuber	ns	ns	9.28
# of D grade tuber	**	ns	14.33

* ns = not significantly difference; # = number

Table 3. Percentage of living potato plants

Generation	Age, WAP			
	3	5	7	9
G0	38.89b	93.33ab	93.33ab	93.33a
G1	98.89a	96.67a	95.56a	94.45a
G2	18.89c	86.67b	86.67c	86.67b
G3	88.89a	88.89b	86.67c	82.22b
G4	90.00a	90.00ab	87.78bc	82.22b

Note: Numbers followed by the same letter in the same column shows that they are not significantly different from the DMRT test at the level of 5%.

3.2 Percentage of Living Plants

Percentage of living plants is the ratio of the number of plants that live in the experimental field to the population planted. At the age of 3 WAP, G0 and G2 treatments had the lowest percentage of living plants, which was still below 50%, while at 5 WAP all plants had grown but not all seed grew because there are seeds that were attacked by earthworms. Generation significantly affected the percentage of living plants (Table 3). According to Utami et al. [6], it took longer for small tuber seeds to shoot out into soil surface because of the use of beddings and it requires more energy to do so, while small tuber seed doesn't have much energy stored compared to the larger tuber seeds.

G0 and G1 had the percentage of living plants at 7 and 9 WAP. Treatment with the lowest percentage at 7 and 9 WAP were G2, G3, and G4. There was a decrease in the survival rate at the age of 5 WAP to 9 WAP in treatments G1, G3, and G4 due to several plants that died from disease, namely bacterial wilt and *fusarium* wilt.

3.3 Plant Height

Plant height was positively correlated with both number of leaves and the number of branches, at 5 WAP and 9 WAP. Taller plants was observed to have more branching than shorter plants. Potato stems grow upright, about 30–90 cm above the soil surface [7]. The average plants heights at the age of 3, 5, 7 and 9 WAP was observed to be significantly different between generations. From Table 4, it can be seen at 3 WAP, the height of G0, G1, G2, G3 and G4 was not significantly different, but at 5 WAP, G1, G3, and G4 had better performance compared to G0 and G2. At the age of 7 WAP, it showed that the G1 treatment had the highest height among other treatments, which was 52.58 cm but at the age of 9 WAP, G0 and G2 caught up with G1 and were the better performance compared to G3 and G4.

Plant height of G0 and G2 was lower at the beginning of the vegetative period at 5 WAP. This could be due to tuber size used for seeds, which, on average, were only 9.5 g and 32 g. According to Mulyono et al. [4], smaller tubers have lower food reserves so that the ability to support the initial growth process will also be lower than larger tubers which contain more food reserves. At the age of 7 WAP, the height growth of G0 and

Table 4. Average potato plant height (cm)

Generation	Age (WAP)			
	3	5	7	9
G0	5.39a	22.38b	41.22b	53.55a
G1	5.26a	31.01a	52.58a	56.50a
G2	4.39a	22.63b	44.33b	53.09a
G3	5.61a	27.84a	40.20b	44.96b
G4	4.43a	26.86ab	43.75b	46.19b

Note: Numbers followed by the same letter in the same column shows that they are not significantly different from the DMRT test at the level of 5%.

G2 plants ware equivalent to that of the G1 plants, which were higher than the G3 and G4 treatments. According to Mulyono et al. [4] at the age of 5 WAP, the G0 treatment already had sufficient roots and leaves to support the growth process.

Based on the height, International Union for the Protection of New Varieties of Plants [8] classified potato plants into five levels, namely very short (<44.0 cm), short (44.1–49.9 cm), medium (50.0–54.9 cm), tall (55.0–59.9 cm), and very tall (>60.0 cm). Based on observation at 9 WAP, treatments G3 and G4 were classified as short; G0 and G2 were classified as medium; and G1 was classified as high. Average height of potato can be seen in detail the plants from all treatments in Table 4.

3.4 Number of Shoot

Number of shoots formed showed a significant difference between generations from 3 WAP to 9 WAP. G1 had the highest number of shoots at the age of 3 WAP (Table 5). At the age of 5 WAP to 9 WAP, the highest number of shoots were G1, G3, and G4. The higher number of shoots formed in G1, G4, and G3 treatments was due to the larger size of the tubers used as seeds compared to G0 and G2. This is as stated by Arifin [9], which states that plants grew from larger tubers will have higher height, number of shoots, number of leaves, number of tubers, and fresh weight of tubers. Average number of shoots per plant can be seen in Table 5.

3.5 Number of Leaf and Branches

Leaves are the main photosynthetic organs in plants because photosynthesis takes place in the leaves. The more leaves that can carry out the photosynthesis process, the more photosynthates it can produce [10]. Potato leaves are compound leaves, and according to the composition, potato leaves are categorized as imparipinnate leaf. Imparipinnate leaf is a type of leaf that have paired lateral leaflets and have terminal leaf at the apex. The number of leaves was significantly different from the age of 3 to 9 WAP except at the age of 5 WAP, where all generation were not significantly different (Table 6). At 3 WAP, treatments G0, G1, G2, and G3 had the same number of leaves and were the

Table 5. Number of shoot per plant

Generation	Age (WAP)			
	3	5	7	9
G0	2.63bc	2.63b	2.65b	2.69b
G1	4.27a	4.29a	4.33a	4.37a
G2	2.38bc	2.43b	2.60b	2.67b
G3	3.37b	3.53a	3.56a	3.60a
G4	3.40b	3.65a	3.69a	3.70a

Note: Numbers followed by the same letter in the same column shows that they are not significantly different from the DMRT test at the level of 5%.

Table 6. Average number of potato leaf

Generation	Age (WAP)			
	3	5	7	9
G0	6.12ab	52.87a	116.30ab	161.00a
G1	5.87ab	61.03a	120.00a	137.67b
G2	8.55a	54.60a	119.00a	137.00b
G3	6.53ab	59.80a	86.03c	135.67c
G4	4.73b	62.17a	97.63bc	91.97c

Note: Numbers followed by the same letter in the same column shows that they are not significantly different from the DMRT test at the level of 5%.

highest number of leaves, while G4 was the lowest and at 7 WAP G3 and G4 had the same number of leaves and the same number of leaves. the lowest. At WAP the number of leaves in G0 treatment was higher than other treatments.

Branches are extensions of stem that serve as a place for leaves to grow, which then form the crown of the plant. The number of branches between treatments did not show significant differences starting from the age of 3–5 WAP (Table 7), but at the age of 7–9 WAP, all treatments had shown significant differences. The number of branches G0, G1, and G2 at 7 WAP had the number of branches that was not significantly different and was the best number of branches, while the highest number of branches at the age of 9 WAP was in G0 treatment. Number of branches was positively correlated with the number of leaves at the age of 5 and 9 WAP. The number of branches was also positively correlated with stem diameter at 9 WAP. The number of branches is directly correlated to the number of leaves, namely the more branches, the more leaves. In Tables 7 and 8 it can be seen in detail the average number of leaves and the average number of branches of potato plants from all treatments.

Table 7. Number of branches

Generation	Age, (WAP)			
	3	5	7	9
G0	4.14a	9.30a	13.17ab	16.75a
G1	4.37a	9.60a	13.47ab	14.23bc
G2	4.39a	9.47a	13.86a	15.20b
G3	4.24a	9.47a	11.83b	12.31d
G4	3.44a	10.30a	13.12ab	13.82c

Note: Numbers followed by the same letter in the same column shows that they are not significantly different from the DMRT test at the level of 5%.

3.6 Stem Diameter

Stem diameter has a positive correlation with the number of leaves. Larger stem means it can support more leaves. According to Farid et al. [11], the size of the stem diameter will affect the growth and production of potato plants. Larger stem diameter will promote better growth and production.

At 3 WAP, G0 has the lowest stem diameter, while treatments G1, G2, G3, and G4 had diameters that were not significantly different and were the best stem diameters (Table 6). At 5 WAP, the diameter of the G0 treatment was equivalent to that of G3 and G4, but not higher than that of G1 and G2, but at the age of 7 WAP and 9 WAP the stem diameter of G0 treatment was equivalent to that of G1 and G2, and is the best stem diameter. Stem diameter in G0 treatment was low at the beginning of the vegetative period at the age of 3 and 5 WAP, this could be due to the tuber weight for seed which was 9.50 g which was lower than G1, G2, G3, and G4 treatments. According to Mulyono et al. [4] that smaller tubers have lower food reserves so that the ability to support the initial growth process will also be lower than larger tubers which contain more food reserves. At the age of 5 WAP, the stem diameter performance in G0 treatment was equivalent to that of plants from G1 and G2 treatments and was higher than G3 and G4 treatments. According to Mulyono et al. [4] at the age of 5 WAP, the G0 treatment already had sufficient roots and leaves to support the growth process. Based on Table 9, the diameter of the treatment rods G3 and G4 is the lowest diameter. According to Farid et al. [12], that potato seeds produced from generation to generation resulted in declining of genetic quality. In Table 9, it can be seen in detail the average stem diameter of potato plants from all treatments.

3.7 Harvest Time

Harvest was carried out when plants from each treatments were ready to be harvested. Potato plants are ready to be harvested when their leaves and stems has started to turn yellow and dried up, which causes the plant to fall. Potato plants are ready to be harvested after entering the tuber ripening phase, where the leaf veins turned yellow and then fall off, photosynthesis decreased, tuber growth slows down and the leaf veins eventually die

Table 8. Stem diameter (cm)

Generations	Age (WAP)			
	3	5	7	9
G0	0.29c	0.82b	1.04a	1.23a
G1	0.42ab	1.01a	1.19a	1.20a
G2	0.46a	0.97a	1.12a	1.24a
G3	0.39ab	0.76b	0.79b	0.94b
G4	0.44a	0.78b	0.84b	1.00b

Note: Numbers followed by the same letter in the same column shows that they are not significantly different from the DMRT test at the level of 5%.

Table 9. Harvest time

Generation	Harvest time (days after planting)
G0	100
G1	93
G2	93
G3	93
G4	93

[13]. Granola variety should be able to be harvested at the age of 85 days after planting [14].

Harvesting was carried out simultaneously at 93 days after planting, except for G0 treatment (Table 9). At age of 93 days, plants of G0 treatment were still not ready to be harvested. Most of the stems were still green and the number of dry leaves had not reached 80%. It was then harvested a week later, at 100 days after planting. Harvest was carried out simultaneously at the age of 93 days because most potato plants had shown ready-to-harvest characteristics and also considering the risk of bad weather that could lead to fungi attack.

At the age of 93 days each treatment had different conditions, such as in treatments G3 and G4, almost all of the leaves have turned yellow and dry; and the stems have fallen. The stems fell down because the stems had dried up or were attacked by *Phytoptohra infestans*. This is different from G1 and G2 treatment. G1 and G2 were harvested when the leaves and stems had turned yellow but had not completely dried, since green stems were still found. But they had to be harvested immediately due to weather conditions that risked of fungal development and were likely to attack and damage tubers. In Table 9, it can be seen in detail the observation of harvest time.

3.8 Yield

Number of tubers of treatment G0 and G1 were not significantly different and was the largest number of tubers (Table 10). Based on this, G0 and G1 are suitable as seed sources because according to Mulyono [4] G0 and G1 are seed generation that are capable of producing more small-sized tubers (grades C and D) for subsequent seed needs. Therefore, they are used as source seeds. It can be seen in Table 10 that G0 and G1 has the highest number of tubers, while G2, G3, and G4 had number of tubers that are not significantly different and were the lowest number of tubers. In Table 10, it can be seen that treatments G0, G1 and G2 had the same average tuber weight, tuber weight per plot and yield per ha and had the best average tuber weight, tuber weight per plot and yield. According to Afifah [15], potato productivity is largely determined by the quality of the seeds, and the class of seeds used. Cultivating potato using higher seed class can increase yield. This is in accordance with the results of this study, which showed that the yield of G0, G1, and G2 was the best, while the lowest yield was found in the G3 and G4 treatments. The number of tubers and the weight of tubers planted can affect yield.

Table 10. Number of tubers per plant, tuber weight per plant, tuber weight per plot, and yield per ha

Generation	Number of tubers per plant	Tuber weight per plant (kg)	Tuber weight per plot (kg)	Yield per ha (ton ha^{-1})
G0	17.33a	1.16a	28.07a	38.98a
G1	16.36a	1.23a	28.87a	40.09a
G2	11.34b	1.14a	23.78a	33.02a
G3	12.07b	0.61b	14.20b	19.72b
G4	9.02b	0.60b	10.00b	13.89b

Note: Numbers followed by the same letter in the same column shows that they are not significantly different from the DMRT test at the level of 5%.

Table 11. Percentage of potato quality grade between treatments

Generation	Potato quality grade percentage (%)			
	A	B	C	D
G0	0.00b	26.31ab	29.17a	44.53b
G1	0.00b	27.67a	33.57a	38.77bc
G2	2.05a	34.28a	32.70a	30.93c
G3	0.00b	15.84c	28.33a	57.33a
G4	0.00b	14.36c	33.40a	50.77ab

Note: Numbers followed by the same letter in the same column shows that they are not significantly different from the DMRT test at the level of 5%.

Different seed generation has produced varied number of tubers and potato tuber quality grades. All of them varied significantly, except for tuber grade C, which was not statistically different across treatments. As shown in Table 11, grade A tubers were only found in G2 treatment, this shows that G2 is more suitable to be used as extension seed, while G3 and G4 is no longer suitable, because there has been a decrease in yield (Table 10). This is in accordance with Utami [6], that stated, G2 is a multiplication of G1 which is designated as extension seed.

G0, G1, and G2 produced grade B tubers which were not significantly different and were the best percentage of grade B tuber. When compared to grade D tubers (small), all treatment had significant variation. G3 and G4 produced the highest number of grade D tubers, which was more than 50% of the total number of tubers. G3 and G4 also produced the lowest number of grade B (large) tuber. This can be caused by the decline of seed quality. Just as Directorate of Horticultural Seeds [5] stated that the low percentage of grade A in the G4 treatment was caused by lower quality of the seeds when compared to the seeds of the class above it (G0, G1, and G2) and not because of the weight of the seeds used in G4, because when compared based on seed weight, G4 seeds used in this study had the second highest weight after G1.

4 Conclusion

Generation had a significant effect on potato performance which included percentage of living plant, plant height, number of shoots, number of leaves, number of branches and stem diameter. Treatment G0, G1, and G2 had the same performance and was the best performance based on plant height and stem diameter and started to decrease in G3 and G4 treatments. Generational treatment also significantly affected potato yields, including tuber weight per plant, number of tubers per plant, yield, tuber weight per plot, and percent number of tubers. Treatments G0 and G1 had the highest number of tubers planted. The best yield was found in the G0, G1, and G2 treatments and a decrease in yield occurred in the G3 and G4 generations. G0, G1, and G2 treatments also produced better tuber grades than G3 and G4. G2 has high yield and the only generation produced Grade A tubers, which indicates that G2 is more suitable to be used as extension seed.

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