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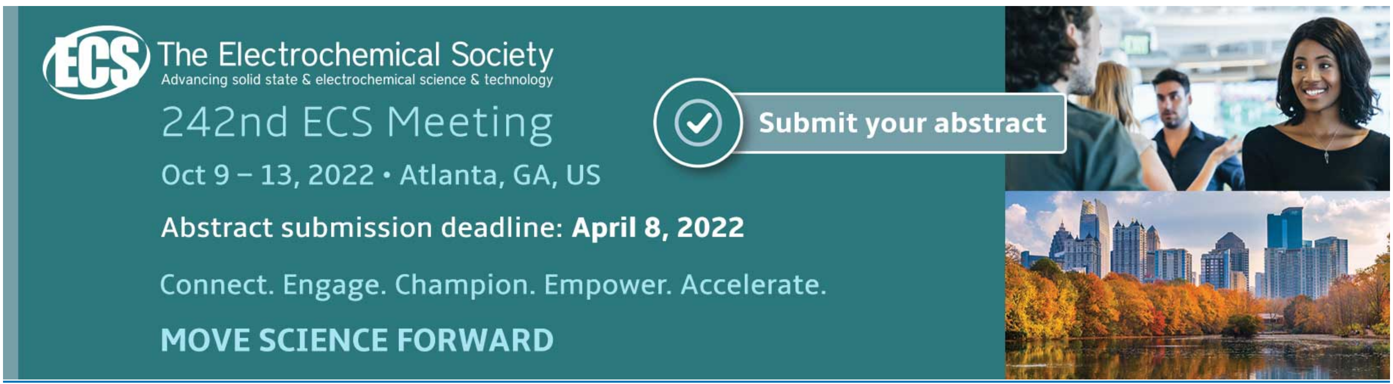

Effect of selection methods on seed potato quality in the following season

N Gunadi[1]*, A Pronk[2], A A Kartasih[1], L Prabaningrum[1], T K Moekasan[1] and H Hengsdijk[2]

[1]Indonesian Vegetable Research Institute (IVEGRI), Lembang, Indonesia
[2]Wageningen University and Research (WUR), Wageningen, The Netherlands

*E-mail: nkgunadi@gmail.com

Abstract. Most potato farmers in Indonesia select the small tubers at harvest for planting in the following season, the so-called farmers' practice (FP). This propagation method is cheap, but the small tubers may come from less healthy plants, which increases the build-up of diseases with accelerated yield decreases over the seasons. Alternatively, farmers may identify healthy plants within the growing season and select those for propagation, the so-called positive plant selection method (PPSM). An experiment was carried out to evaluate the effects of PPSM compared to FP on yields in the following season in the two main potato growing areas of West Java, i.e., Pangalengan and Garut. Generations G2 and G3 of cv. Granola and one generation of the imported cv. Atlantic were used. Selected seeds using PPSM and FP were planted in the second season in a randomized complete block design. Results show that yields of seeds selected through PPSM were significantly higher compared to seeds selected through FP, over both locations, on average, 7.4, 5.5 and 1.2 ton ha^{-1} for Granola G2 and G3, and the Atlantic, respectively. These yield increases represent an increase in the gross revenue of 30.8 to 51.8 million IDR ha^{-1} for Granola and 1.9 to 7.8 million IDR ha^{-1} for Atlantic at a farm gate price of 7,000 and 6,500 IDR kg^{-1}, respectively. This study confirms that PPSM is superior to FP and improves the quality of the farms saved seeds.

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the most important crops in the world. In terms of production and economic value potato ranks fourth after rice, wheat and maize. In terms of energy and protein production per hectare and per unit of time, potato ranks first, significantly more than cereals, pulses and cassava [1]. Recently, the interest in potato production increases especially in emerging economics, including Indonesia. Indonesia has become the largest potato producer in Southeast Asia and only second after China among the priorities countries at the International Potato Center (CIP) in East Asia, South East Asia and the Pacific [2, 3]. At present, the area with potato in Indonesia is between 60,000 to 70,000 ha with a total annual production of about 1.2 million tons. Potato has been a priority crop in the strategic plans of the Indonesian Agency for Agricultural Research Development (IAARD) in the last 30 years because of its potential as alternative carbohydrate source, and for food diversification and export markets.

In general, potatoes in Indonesia are grown in the highland areas above 1,000 m above sea level (asl.) with moderate cool temperatures. It is understood that the potato is originally come from the cool tropical highlands of the Andes of South America [4] and therefore in order to adapt with its original climate condition, the potatoes are grown in the highland areas. The main potato variety in Indonesia since the 1980's is Granola, which covers 80 to 85% of the potato area. The moderate resistance to potato leaf role virus (PLRV) and potato virus Y (PVY) of Granola have contributed to its success in Indonesia and other tropical countries [2].

Potato is a vegetatively propagated crop. With each generation (G) seeds degenerate due to pests, diseases and loss of growth vigor. Fresh potato seeds, meaning young generations (G0 or G1), from rapid multiplication or other propagation techniques, are grown under protective conditions to prevent degeneration and when older (G2, G3, etc.). However, in other emerging economies such as in Indonesia, potato seed is the most expensive component of potato production, and potato profitability depends on the quality of seed [5, 6, 7]. Seed accounts for 30-40% of the total costs of potato production [8, 9, 10]. The high quality seed is relatively expensive which is considered to be too costly by most farmers, especially as purchased seeds frequently fail on the expected quality. A common practice of potato farmers is to save potato seed tubers from their own crops. Small tubers are usually selected and saved for seeds for the planting the following season. This results in an increased build-up of diseases and yields decrease over the seasons. When their own seed stock has degenerated, farmers will buy seed tubers from other farmers or traders with origin and or quality. The degeneration of seed potatoes depends on the seed selection and also on the variety grown. Varieties differ in levels of resistance to virus infections and virus particle multiplication within the plant [11].

One method to slow down the degeneration is through the positive selection. This method was suggested by the International Potato Centre (CIP) as a possible option for maintaining the vigour of smallholders seed potato [12]. In this method, the best potato plants in the field are marked before crop senescence and used for seed in the following season/planting. This method increased average yields in farmer-managed trials by 34%, corresponding to a 284 € increase in profit per hectare at an additional production cost of only 6 € /ha [13].

The objective of the present research was to determine the effect of plant selection in the previous season on the seed potato quality improvement in the subsequent season. The present experiments show potato farmers the importance of plant selection for obtaining good quality seeds in the following planting season. Farmers in Indonesia need to adopt the positive plant selection technique to maintain good quality seeds by reducing the speed of degeneration of their own farm saved seed.

2. Materials and methods

The experiments to determine the effect of plant selection in the previous season on the seed potato quality improvement in the subsequent season were carried out in two planting seasons. In the first planting season seed potatoes were selected through the positive plant selection method (PPSM) and farmers practice (FP) in the highlands of Cikajang (1350 m asl.), Garut, West Java as at that altitude disease pressure is low. In the second planting season the effects of the plant selection method was evaluated through effects on yield and performance. This evaluation was done in two locations i.e. Margamekar (1300 m asl.), Pangalengan, West Java and in Cikajang (1350 m asl), Garut, West Java. The dominant potato variety in Pangalengan is the table variety Granola produced for the fresh market where in Garut the dominant variety is Atlantic produced for processing.

2.1. First planting season

Two generations (G2 and G3) of certified cv. Granola and one imported seed of cv. Atlantic were grown in the first season using two methods to obtain seed tubers for planting in the subsequent season. Therefore, six combination treatments were involved in the experiment. To obtain the seed tubers, the potatoes were grown during the rainy season 2015/2016, planted on 16 November 2015 and harvested on 2 March 2016. Field plots were prepared by making furrows spaced 75 cm apart. Plant spacing within the row was 30 cm. The plot size was 13 x 12.5 m, with sixteen rows and 50 plants per row. Therefore the total number of potato plants was 800 per plot. Two seed tuber selection methods were employed:

2.1.1. Positive plant selection method (PPSM). During the growing season, infected plants were selected and removed from the plots and healthy looking plants were positively selected by putting the stick next to each plant. The selection process was carried out three times, i.e. at 7, 9 and 12 weeks after planting. At harvest, tubers from the healthy plants indicated by the stick were graded and again selected for infected and defect tubers before placing in storage. In storage, the selected seeds were quality screened again at one, two and three months after harvest. At all times, the PPSM selected seeds were stored separately from other seeds to prevent mixing.

2.1.2. Farmer practice (FP). During the growing season, farmers selected infected plants and put the bamboo stick next to it. The infected plants were not removed. The selection practice was mostly done two times during the growing season i.e. at 9 and/or 12 weeks after planting. At harvest the selected plants were harvested after the non-selected plants. The 'good appearing' tubers from the selected infected plants were still stored as seeds. In storage, the screening was similar to PPSM.

2.2. The subsequent planting season
The experimental plots to evaluate the effect of the selection methods of seeds on growth and yield were planted in Pangalengan and Garut, West Java on 15 June and 16 June 2016, respectively, and harvested on October 5 and October 6, 2016 respectively, 112 days after planting. One week before harvest, the haulm of the crops were killed using a herbicide. The experiment consisted of six treatments i.e. G2.PPSM (Granola generation 2 positive plant selection method), G2.FP (Granola generation 2 farmer practice), G3.PPSM (Granola generation 3 positive plant selection method), G3.FP (Granola generation 3 farmer practice), Atl.PPSM (Imported Atlantic positive plant selection method) and Atl.FP (Imported Atlantic farmer practice). The treatments were layout using a randomized complete block design and each treatment was replicated three times. Each experimental plot consisted of 12 rows and 12 plants per row yielding 144 plants per plot. The planting distance was 75 x 30 cm and therefore the experimental plot size was 9.0 x 3.6 m = 32.4 m^2. Soil tillage, fertilisation and crop protection were uniformly carried out according recommended practices in all plots.

Harvest was done on 7.5 m x 3.0 m = 22.5 m^2, consisted of 10 rows and 10 plants per row. At harvest, tuber fresh weight per plot, per plant and the number of tubers per plant were determined. Additionally, the percentage of tubers in three weight classes was determined, 0-50 g, 50-100 g and > 100 g. The marketable yield was determined as the percentage of tuber > 50 g. All observed variables were analysed by the analysis of variance using the MSTATC statistical program. The treatment means were compared using Least Significant Difference (LSD) at 5% probability level. The two locations for yield evaluation were analysed separately.

3. Results and discussion
The results of the effect of plant selection method on growth and yields of potatoes in the subsequent season were as follow:

3.1. The first planting season
The number of diseased plants, either being removed in the PPSM plots or identified by the bamboo stick in the FP plots, varied between the different seed sources (Table 1). Removal or identification of diseased plants in the PPSM plots was started earlier than that in the FP plots. Leaving diseased plants in the field in the FP treatment increases the risk of spreading infections to healthy neighbouring plants and thus decreasing the seed quality of the entire plot. The total number of diseased plants in Atlantic was higher than of both generations of Granola in PPSM plots as well as FP plots. This indicated that the seed of Atlantic was more degenerated than of Granola. Remarkably, the expected difference in seed quality between Granola G2 and G3 was not observed in the number of selected plants. Although

the number of removed plants between Granola G2 and G3 was comparable, the number of healthy selected plants from Granola G3 was slightly higher than of Granola G2 where the opposite was expected. This result supports farmers' complaints about the variability of certified seed quality of different generations.

Table 1. The number of identified diseased plants (removed or indicated by a bamboo stick) at different selection times, the total number of diseased plants and the number of selected plants by selection method and seed source

		Weeks after planting			Total # diseased plants	# of selected plants
Selection method	Seed source	7	9	12		
PPSM	G2	8	7	7	22	628
	G3	8	9	4	21	654
	Atlantic	18	33	27	78	485
FP	G2	-*	14	7	21	666
	G3	-	7	20	27	671
	Atlantic	-	57	38	95	562

* not determined

3.2. The subsequent planting season

3.2.1. Pangalengan, West Java. The effect of seed source (SS) and selection method (SM) on tuber yield components in the subsequent season in Pangalengan is presented in Table 2. There was no significant interaction between SS and SM and therefore only the main factors are discussed. Tuber yield (ton ha^{-1}) varied between 10.6 and 36.3 tons ha^{-1} which is lower as well as higher as the average yields of around 20 to 25 tons ha^{-1} in West Java [14]. Tuber yield components differed significantly between SS and Granola G3 had the highest yield components followed by Granola G2 and the lowest yield components were found for Atlantic. The higher yield components of Granola G3 compared to those of Granola G2, may presumably be associated to the different quality of the seeds used in the first planting season (Table 1). Although both Granola G2 and G3 used in the first planting season were certified and quality of G2 was expected to be better than G3, the results of both the first and subsequent planting season indicated that the quality of Granola G2, the younger generation, was lower than that of Granola G3, the older generation. Gunadi et al. [15] also found that in Indonesia seed quality was not always related to generation due to various reasons. Subsequently, farmers who invest in expensive seeds (younger generation seeds) may not always get the quality seeds they pay for.

Table 2. Effect of seed source (SS) and selection method (SM) and their interaction on tuber yield components in the subsequent season, Pangalengan, October 2016

Treatment	Tuber yield (kg $plot^{-1}$)	Tuber yield (g $plant^{-1}$)	Tuber number (# $plant^{-1}$)	Tuber yield (ton ha^{-1})
Seed source (SS):				
G2	77.19	844.7	8.6	27.4
G3	98.29	1002.7	11.0	34.9
Atlantic	30.14	363.7	3.8	10.7
Selection method (SM):				
PPSM	69.68	748.9	8.5	24.8
FP	67.40	725.2	7.1	23.9
SS x PPSM:				
G2.PPSM	86.07	922.9	8.7	30.6
G2.FP	68.31	766.5	8.6	24.3
G3.PPSM	102.09	1038.3	12.8	36.3

G3.FP	94.48	967	9.2	33.6
Atl.PPSM	31.79	370.7	3.9	11.3
Atl.FP	28.5	356.8	3.6	10.1
Mean	68.54	737.1	7.8	24.4
LSD (5%) SS	***	***	***	**
SM	*	*	*	*
SS x SM	ns	ns	ns	ns
CV (%)	9.4	8.6	11.4	9.3

Note: LSD = Least Significance Different; CV = Coefficient of Variation; *** = significant at 0.1%; ** = significant at 1%; * = significant at 5%; ns = not significant

In Pangalengan, SM had a significant effect on all tuber yield components but no interaction was found (Table 2). The PPSM seeds had higher yield components compared to FP seeds. The latter is in agreement with previous research [12, 13, 16]. Figure 1 shows that tuber yield of PPSM seeds was increased compared to tuber yield of FP seeds by 26, 8 and 12% for Granola G2, Granola G3 and Atlantic, respectively. Visual observations in the field indicated that the higher yields of PPSM seeds compared to FP seeds were mainly due to healthier and more vigorous potato plants [17].

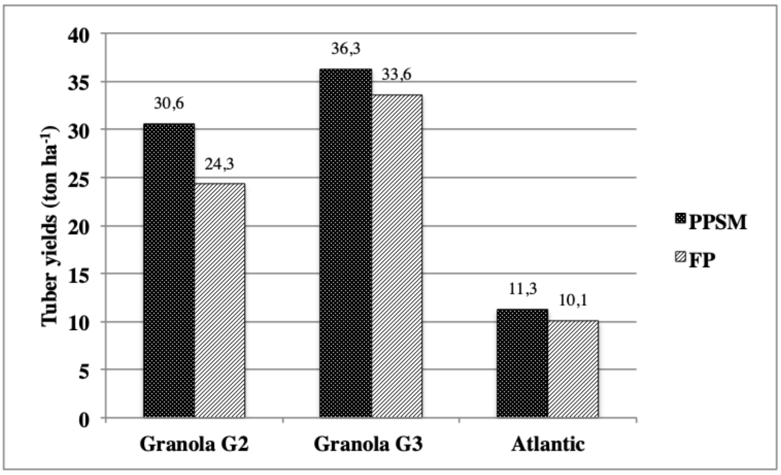

Figure 1. Tuber yields of PPSM and FP seeds of three seed sources in Pangalengan,

The percentage of tuber by weight in each class category at harvest in Pangalengan is presented in Table 3. No effects were found for SS whereas an effect was found for SM on the % tubers < 50 g and the % of marketable yield. PPMS seeds had higher marketable yields and FP had a higher % tubers < 50 g, that is more small tubers. This shows that with PPSM seeds perform better in the subsequent planting season than FP seeds.

Table 3. Effect of seed source (SS) and selection method (SM) and their interaction on the percentage of tubers based on weight in each class category in the subsequent season, Pangalengan, October 2016

Treatment	% tubers > 100 g	% tubers 50-100 g	% tubers < 50 g	% marketable tubers
SS:				
G2	57.9	24.5	17.5	82.5
G3	54.1	26.1	19.7	80.2
Atlantic	58.6	25.1	16.2	83.7

SM:				
PPSM	59.8	25.5	14.6	85.3
FP	53.9	25.0	21.0	79.0
SS x PPSM:				
G2.PPSM	63.3	23.2	13.5	86.4
G2.FP	52.5	26	21.4	78.5
G3.PPSM	56.1	28.9	14.9	85
G3.FP	52.1	23.3	24.5	75.4
Atl.PPSM	60.0	24.5	15.5	84.5
Atl.FP	57.2	25.8	17	82.9
Mean	56.8	25.3	17.8	82.2
LSD (5%) SS	ns	ns	ns	ns
PPSM	ns	ns	*	*
SS x PPSM	ns	ns	ns	ns
CV (%)	15.5	27.0	18.6	4.0

Note: LSD = Least Significance Different; CV = Coefficient of Variation; *** = significant at 0.1%; ** = significant at 1%; * = significant at 5%; ns = not significant

3.2.2. Garut, West Java. The effect of SS and SM on tuber yield components in the subsequent season in Cikajang, Garut is presented in Table 4. There was no significant interaction between SS and SM and therefore only the main factors are discussed. The tuber yield (ton ha^{-1}) varied between 13.5 and 27.6 ton ha^{-1} and was somewhat higher at the low end and lower at the high end compared to yields in Pangalengan. Results were similar as in Pangalengan: tuber yield components differed significantly between SS and Granola G3 had the highest yield components followed by Granola G2 and the lowest yield components were found for Atlantic. Again, the higher yield components of Granola G3 compared to those of Granola G2, may be related to the different quality of the seeds used in the first planting season. The results confirm those found in Pangalengan on the seed quality of certified Granola G2 and G3: Granola G3 performed better than Granola G2 thus indicating a lower quality of Granola G2 compared to Granola G3.

Table 4. Effect of seed source (SS) and selection method (SM) and their interaction on tuber yield components in the subsequent season, Cikajang, Garut, October 2016

Treatment	Tuber yield (kg $plot^{-1}$)	Tuber yield (g $plant^{-1}$)	Tuber number (# $plant^{-1}$)	Tuber yield (ton ha^{-1})
SS:				
G2	70.0	753.9	8.1	24.9
G3	77.6	783.1	9.5	27.6
Atlantic	38.2	456.7	4.3	13.6
SM:				
PPSM	65.3	696.7	7.6	23.2
FP	58.5	631.8	7.0	20.8
SS x SM:				
G2.PPSM	76.3	798.1	8.3	27.1
G2.FP	63.7	707.7	7.8	22.6
G3.PPSM	81.6	820.9	10.1	29

G3.FP	73.5	745.3	8.9	26.1
Atl. PPSM	37.9	471.1	4.4	13.6
Atl.FP	38.4	442.4	4.2	13.5
Mean	61.9	664.3	7.3	22
LSD (5%) SS	***	***	***	***
SM	*	*	ns	*
SS x SM	ns	ns	ns	ns
CV (%)	10.8	7.2	8.3	10.7

Note: LSD = Least Significance Different; CV = Coefficient of Variation; *** = significant at 0.1%; ** = significant at 1%; * = significant at 5%; ns = not significant

As in Pangalengan, SM had a significant effect on all yield components except tuber number/plant and again no interaction was found. The PPSM seeds had higher tuber yields per plot, per plant and per ha compared to FP seeds (Table 4). Figure 2 shows that tuber yield of PPSM seeds was increased for Granola G2 and G3 but not significant compared to FP with 20 and 11% respectively, where no differences were found for Atlantic. As in Pangalengan, the visual observations in the field indicated that the higher yields of PPSM seeds compared to FP seeds were mainly due to healthier and more vigorous potato plants.

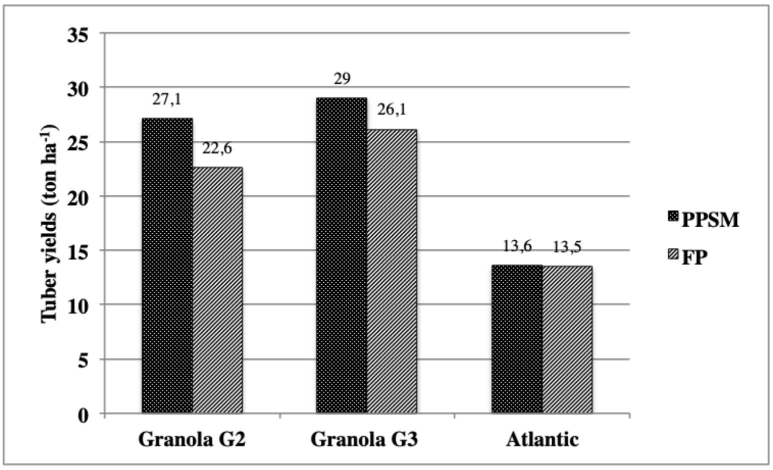

Figure 2. Tuber yields of PPSM and FP seeds of three sources in Cikajang, Garut.

The percentage of tubers by weight in each class category at harvest in Garut is presented in Table 5. SS had an effect on % of tubers > 100 g and on % of tuber < 50 g. Where Granola G3 had the highest yields (Table 4), tubers were smaller as the percentage of tubers > 100 g was significantly lower than those of G2 and Atlantic but more tubers per plant were found. Atlantic had the lowest percentage of small tubers (< 50 g) indicating that all tubers had grown into marketable tubers and confirmed by the higher percentage of marketable tubers compared to Granola. As in Pangalengan, PPSM seeds had higher percentage of marketable yield and FP had a higher percentage of tubers < 50 g that is more small tubers. In agreement with the results for Pangalengan, PPSM seeds performed better in the subsequent season than FP seeds.

Table 5. Effect of seed source (SS) and selection method (SM) and their interaction on the percentage of tubers based on weight in each class category in the subsequent season, Cikajang, Garut, October 2016

Treatment		% tubers > 100 g	% tubers 50-100 g	% tubers < 50 g	% marketable tubers
SS:					
G2		53.5	32.8	13.7	86.3
G3		42.0	40.3	17.7	82.3
Atlantic		54.3	38.8	6.9	93.1
SM:					
PPSM		52.3	36.6	11.1	88.9
FP		47.6	38	14.4	85.6
SS x SM:					
G2.PPSM		52.9	34.6	12.4	87.5
G2.FP		54.1	30.9	14.9	85.1
G3.PPSM		46.3	39.1	14.6	85.4
G3.FP		37.8	41.4	20.8	79.2
Atl. PPSM		57.8	35.8	6.3	93.7
Atl.FP		50.8	41.7	7.4	92.5
Mean		49.9	37.3	12.7	87.2
LSD (5%)	SS	*	ns	***	***
	SM	ns	ns	*	*
	SS x SM	ns	ns	ns	ns
CV (%)		15.8	18.3	21	3.1

Note: LSD = Least Significance Different; CV = Coefficient of Variation; *** = significant at 0.1%; ** = significant at 1%; * = significant at 5%; ns = not significant

The number of removed plants in the first planting season was higher in the younger generation of Granola (G2) than in the older generation (G3), showing a common problem with certified seeds and indicating a lower quality of the younger generation than of the older generation. This is, according to the certification protocol, not possible [6], but in practice as well as in research is often found [15]. This result supports farmers' complaints on the quality of the seed certification. However, it is difficult to track down where and where this problem with certified seed quality comes from and how it could be improved. The number of plants removed from Atlantic in the first planting season showed that the imported seed was more degenerated than the Granola seed, which is expected as imported

Atlantic is usual certified G4 seed. The positive selected seeds planted in Pangalengan and Garut in the subsequent season were all from the same SM and treated equally: all seeds were stored in the farmer's storage in Cikajang, Garut and one week before planting in the second season, part of the stored seeds were transported to Pangalengan. However, yields of Granola G3 and Atlantic seem to differ between Pangalengan and Garut, where yields of Granola G2 seem comparable.

There are no obvious reasons for these differences, but they may be associated with the differences in cultivation practices between the regions. In the area where farmers are used to cultivate Granola, i.e. Pangalengan, yields of the same seeds were higher than in Garut. The opposite was true for Atlantic, in the area where farmers are used to cultivate Atlantic, i.e. Garut, yields of the same seeds were higher than in Pangalengan. This trend on yields of Granola and Atlantic, that is high yields of Granola in Pangalengan and of Atlantic in Garut and low yields of Granola in Garut and Atlantic in Pangalengan, has been found before [8, 9, 10].

The higher yields of Granola in Pangalengan in general, is most probably associated with the easiness to access to good quality seeds of Granola in Pangalengan as relatively many potato seed growers are present in the region. In contrast, farmers in Garut have relatively easier to access to the imported Atlantic seeds of lower quality (G4) than to Granola seeds as the source of Atlantic seeds is located in Garut area. As Granola is a table variety and Atlantic a processing variety, it may also be that cultivation practices are locally tuned to the variety to maximise yields. Differences in cultivation practices between the regions are found [8, 9, 10] and may be variety specific.

PPSM resulted in higher tuber yield components compared to FP. This result was found for both varieties, Atlantic and Granola, and for both generations of Granola, G2 and G3, and for both regions, Garut and Pangalengan. However, the yield increase of Atlantic was smaller than of Granola G2 and G3, 1.2, 5.5 and 7.4 ton ha^{-1} marketable yield in Pangalengan and 0.1, 2.9 and 4.5 tons ha^{-1} in Garut, respectively. Although these yield increases may seem small, they represent an increase in the gross revenue of 5.9 to 36.8 million IDR ha^{-1} for Granola and 0.5 to 21.2 million IDR ha^{-1} for Atlantic at an farm gate prices of 5,000 and 4,700 IDR kg^{-1}, respectively.

With average gross revenues in Pangalengan of 70 million IDR ha^{-1} for Atlantic to 126 million IDR ha^{-1} for Granola and in Garut of 110 million IDR ha^{-1} for Atlantic to 122 million IDR ha^{-1} for Granola, the maximum increase of the gross revenue is 29%. In addition to the increase in gross revenue, benefits of PSSM extend to a decrease in the costs of farm saved seeds. Seed is the largest cost component in potato production in Indonesia [8, 9, 10]: on average about one third of the total production costs. Commonly, farmers invest in good quality seeds and practice farm saved seed techniques for several planting seasons thereafter.

After the ban on the seed potato import in 2003, farmers have experienced that the period the seed could be saved in this way decreased resulting in higher costs for farmers. Before the import ban, farmers renewed their seed stock every 5 to 7 planting seasons depending on the crop performance. Because high quality imported seeds are not any longer available, recently farmers need to renew their seed stock after only two planting seasons as the seeds are degenerated fast, resulting in poor crop yields. As the quality of the locally produced certified seed potatoes is questionable, maintaining the quality of the own seed stock is key to reduce production costs. When farmers are able to increase the use of own farmer saved seeds with one or two planting seasons as a result of PPSM, farmers reduce production costs and increase yields.

4. Conclusions

PPSM is feasible to be used by potato farmers in Indonesia to improve the quality of the farm saved seed. The additional effort that farmers have to make to perform PPSM is rewarded with an increased marketable yield and associated higher gross revenues, while production costs (for seeds) most likely are reduced.

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