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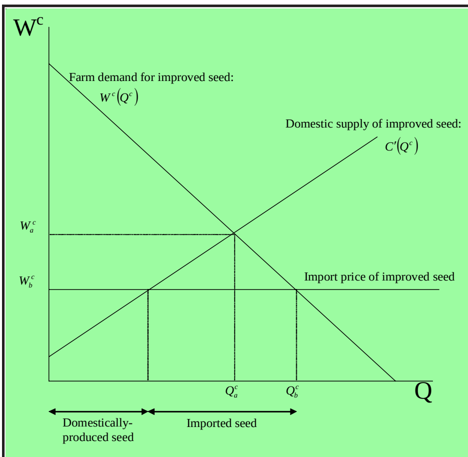
Supply and Demand for Quality Potato Seed in Indonesia:

Farmers' Perspectives and Policy Options



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ABSTRACT

Seed is the most costly component of potato production, and potato profitability often depends on access to quality seed. Since potato is reproduced clonally, diseases such as viruses tend to build up over time. As a result, yield often declines as farmers save tubers from one harvest for use as seed in the next season.

Interviews with key informants of the potato sector and a formal survey of 180 potato farmers provided users' perspectives on the supply and demand of quality potato seed in Indonesia. The survey showed that farmers are aware of the value of quality seed and recognize that using it can significantly increase yield over several production seasons. Farmers have developed several strategies for managing potato seed: they sort out damaged seed during storage; they select varieties with virus resistance; and they periodically renew seed from reputable sources. However, few farmers practice the "seed plot technique" in which the seed plot is different from the ware crop. Instead, farmers usually select the smallest tubers from their harvest for use as seed for the next crop.

Several sources of quality seed are available in Indonesia, including imported seed, locally grown certified seed, and private-sector seed produced from tissue culture and other rapid multiplication techniques that eliminate seed-borne diseases. So far, imported seed appears to be the most economical and reliable source of quality seed. Publicly certified seed is heavily subsidized, while private-sector seed from tissue culture has not been profitable for most companies. However, seed is marketed through an 'informal' farmer seed system. Seed in the informal system is less expensive but of uncertain quality.

Policy makers wishing to improve access to quality potato seed in Indonesia face trade-offs between alternative strategies. One option is to have a relatively liberal policy toward seed imports. Imports provide farmers with a reliable source of high quality, although expensive, seed. Policies to promote competition among importers may help reduce the prices and increase the supply of imported seed. However, the drawbacks of increased reliance on seed imports include the loss of foreign exchange, a greater likelihood of inadvertent introduction of an exotic seed-borne pest or disease, and limiting varietal choice by farmers to foreign-bred varieties. A second option is to promote public and private efforts to supply locally grown quality seed to farmers. The recent experience of Indonesia suggests, however, that this option has not yet been proven to be financially or technically sustainable. Without continued subsidies, locally grown certified seed cannot compete with imported seed of the same variety. Restricting

imports of seed would help the public system financially, but only at the cost of lowering the overall supply and raising the cost of quality seed to farmers. A third option is to enhance the informal seed system itself, through technical training to farmers and seed growers. Reserving certain land areas for potato seed production, and training farmers in seed plot techniques can enhance the quality and supply of seed. General support for potato breeding and crop improvement will also increase the demand for improved seed and other production inputs.

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1

INTRODUCTION

One of the major constraints facing potato (*Solanum tuberosum*) production in the humid tropics is a lack of low-cost, quality seed. Seed alone accounts for 10-20% of the value of potato production. Further, since farmers usually plant potato tubers saved from their previous harvest, diseases build up over time to reduce yield. For these reasons, seed is the most costly input for potato farmers and having a good supply of quality seed is a critical factor in potato productivity and profitability.

Despite its importance, the optimal seed strategy for potato development in tropical countries is not very clear. Some countries have relied heavily on imports of certified seed from temperate countries to satisfy local needs. However, imported seed remains expensive for farmers and restricts farmers' choice of varieties to those available from seed-exporting countries. Other countries, often with foreign technical and financial assistance, have sought to replicate certified seed systems of industrialized countries to supply potato seed. Many of these projects, unfortunately, have not had a good track record of sustainability after the project support ended (Crissman, 1990). Further, the certification standards used by formal seed systems in industrialized countries in temperate regions may not be appropriate for developing countries in tropical environments (Tripp, 1997). Others argue that considerable success can be achieved by introducing step-wise improvements into informal, farmer-based seed systems (Thiele, 1999) or by abandoning clonal seed altogether and adopting botanic seed, known as "True Potato Seed" or TPS (Almekinders, Chilver, and Renia, 1996; Simmonds, 1997).

This study examined the supply and demand for quality potato seed in Indonesia, where several efforts to supply higher quality potato seed at lower cost to farmers have been underway over the past several years. Though not a traditional staple food in Southeast Asia, potatoes are becoming an important agricultural commodity in the region (Fuglie *et al.*, 2002). In the region's humid tropical highlands, potatoes can be produced year-round. They are grown primarily on small farms, most of which are less than 2 ha, using labor- and input-intensive production methods, and sold as a cash crop. In Indonesia, annual potato production grew from around 120,000 *t* in 1970 to nearly 1 million *t* by 2000, a growth rate unequaled in any other country of the world over this period.

To supply the growing demand for potatoes in Indonesia, both the private and public sectors made considerable investments in improving the availability and quality of potato seed. One source of improved seed has been imports. Since the 1970s, Indonesia has provided a modest market for international seed companies. These companies import certified seed, mostly from Europe, that meet local phytosanitary regulations. Another source is private seed and tissue culture companies. In the 1990s, a number of private companies began producing disease-free potato seed in Indonesia by using tissue culture and rapid multiplication techniques as alternatives to imported seed. A third source is a government-run seed certification scheme. With financial and technical assistance from the Government of Japan, a formal potato seed certification system was established in West Java in the 1990s. A fourth source of potato seed, investigated by the International Center (CIP) and the Indonesian Vegetable Research Institute (IVEGRI) in the 1980s and 1990s, is TPS. TPS is an alternative to clonal seed tubers.[1] Finally, farmers themselves have developed an 'informal' seed system to supply and renovate their potato seed stocks. With these multiple potato seed sources, Indonesia is a good laboratory for examining the supply and demand for improved seed in tropical potato production.

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[1]On-farm and economic evaluations of TPS in Indonesia and elsewhere in Asia are reported in Chilver *et al*. (1999) and Fuglie (2001). TPS was popular with farmers when first introduced in the early 1980s; but with the improvements in clonal seed quality by the 1990s, TPS ceased to be economically viable in most of Indonesia. Thus, this paper does not examine TPS as a seed alternative.

The specific objectives of this study are to:

a. Examine existing seed programs and sources of seed supply, analyzing the strengths and weaknesses of the existing seed potato systems;
b. Describe the market for potato seed, including seed marketing channels and seed prices;
c. Determine farmers' practices of potato production and potato seed management;
d. Investigate farmers' perceptions of seed quality from various sources and their willingness-to-pay for quality potato seed; and,
e. Recommend policies to improve seed quality and availability in Indonesia.

2

METHODOLOGY

2.1 Model of a potato seed market

The conceptual model used for examining the market for potato seed builds from a model of seed prices developed by Crissman and Hibon (1996). In their model, farmers' own seed, which has been saved from previous generations of the farmer's crop, gradually loses quality through the build up of viruses and other seed-borne diseases. Eventually, yield from farmers' seed stabilizes at a low level, say y^f. Disease-free or certified seed provides a higher yield, y_1^c, in the first year it is used by a farmer; and somewhat lower yield, y_2^c, in the second season its progeny is used, and so on. But as a farmer saves this for use in subsequent generations, it eventually degenerates and its productivity falls, until yield again stabilizes at the same yield as farmers' seed, y^f. The rate of degeneration is variety-specific, depending on a variety's resistance to viruses and other diseases, as well as on the seed management practices of the farmer. Some varieties with durable resistance to viruses may provide a reasonable yield for farmers when used repeatedly for years or even decades. In fact, virus-resistant varieties can sometimes substitute for a seed multiplication system in countries that lack technical and institutional capacity to produce quality, disease-free seed (Walker, 1994).

In our model, a farmer chooses between buying quality seed versus using farm seed in order to maximize net returns or profits. Since quality seed may outyield farm seed for several generations of use, the model treats seed as a capital input that depreciates over time rather than as a variable input used in a single season.

The gross benefits to the farmer from using quality seed is given by the present value of the increase in yield obtained over several generations of use. Assume that after T seasons, the improved seed no longer has a yield advantage over farm seed. Then the present value of the yield benefit from improved seed is:

(Eq 1) $$\text{Seed Benefits} = \sum_{t=1}^{T} e^{-r\lambda(t)} P_t \left(y_t^c - y^f\right)$$

where *t=1,2,...T* is the number of crop generations (seasons) the quality seed or its progeny is used; *e* is the exponential function; *r* is the (monthly) discount rate; and P_t is the market price of potato at generation *t*. The time between crops is given by $\lambda(t) = tg+(t-1)d$, where *g* is the number of months a crop is in the field (between planting and harvest), and *d* is the number of months seed is stored between crops (to break seed dormancy and/or wait for the appropriate environmental conditions).[2] Future benefits are discounted to reflect the fact that benefits in the present or near future are worth more to the farmer today than benefits in the distant future. The difference in crop yield between certified seed and farm seed $\left(y_t^c - y^f\right)$ is highest in the first season of use *(t=1)*; but it falls in subsequent generations of use *(t=2,…T)* as diseases and other factors build up in the saved seed.

Now, consider the change in costs associated with using improved seed. This includes the (presumably higher) price paid for the improved seed times any change in seeding rate and changes in the use of other inputs. The present value of the change in costs is:

(Eq 2)

$$\text{Seed Costs} = \left(W^c q_0^c - W^f q^f\right) + \sum_{t=1}^{T} e^{-r\lambda(t)} \left[W^f \left(q_t^c - q^f\right) + \sum_{i=1}^{N} W_i \left(x_{ti}^c - x_i^f\right) \right]$$

where W^c is the market price of quality seed and W^f is the price or opportunity cost of the farmer's seed. The seeding rate for improved seed is q_t^c and q^f for the farmer's seed. We assume that once improved seed has been used, in subsequent generations, its market value is the same as the farmer's own seed, even if it still continues to outyield farm-grown seed. While a farmer may know that quality seed has only been used for one or two seasons and still provides superior yield, it may not be possible for him to prove this to other farmers and therefore sell it at a price above that of regular farmers'

[2] λ(t) is simply an accounting formula to keep track of the time between planting and harvesting in environments where multiple cropping is possible, for the purpose of calculating present value. For example, suppose that the potato-growing season is four months and there are four months fallow between crops (so that three harvests are obtained every two years). Then λ(1) = 4*1+0=4 months, λ(2) = 4*2-4=12 months, and λ(3) = 4*3+4*2=20 months. λ(1) is the time between the purchase of the certified seed and the harvest of the first crop. λ(2) is the time between the purchase of the certified seed and the harvest of the second crop. λ(3) is the time to the harvest of the third crop, etc.

seed. The inability to assure the quality of seed is one of the principal reasons for having a public-sector certification system in which regulators verify the age and quality of seed tubers produced by bona fide seed producers. A farmer may also change use of other inputs (by using more fertilizers and chemical pesticides on the improved seed, for example): x_{it}^{c} is the amount of input *i* used in season *t* with improved seed; x_i^f is the amount of the input used with the farmer's own seed; W_i is the price of the input. However, input costs between seed and ware potatoes may not vary. For example, farmers may not grow a separate seed crop but simply sort tubers by size at harvest, selling the larger-sized tubers in the market and saving the smaller tubers as seed for the next crop.

Under a profit-maximization rule, a farmer can be expected to adopt quality seed so long as the present value of benefits of seed use exceeds the additional costs, or so long as equation 1 gives a result greater than equation 2. To simplify the model, let's assume that the market price of potatoes remains constant over time[3] and the quantities of inputs are the same whether a farmer uses quality seed or farm seed. Let the seeding rate used for either improved seed or farm seed be the same and given by *q*. Then the profitability π of improved seed is then:

(Eq 3) $$\pi = \sum_{t=1}^{T} e^{-r\lambda(t)} P \left(\Delta y_t^c\right) - q\left(W^c - W^f\right)$$

where $\Delta y_t^c = y_t^c - y^f$

For a population of farmers each growing potatoes on small parcels of land, the performance of improved seed might not vary much across their parcel. But we might expect the benefits of improved seed to vary significantly between farms and across potato-farming communities, depending on differences in soil quality, cropping history, weather patterns, time discount rates, prices received and paid, and the management practices of the farmer. Some farmers may

[3] It is the expected future price of potatoes that enters the calculation of (expected) net profits. We assume that a farmer's expectations are based on his/her experience with potato prices. This could be taken as an average price from recent years, or if there are sharp seasonal price trends, an average of seasonal prices. However, since seed prices tend to vary proportionally with ware prices, the effects of price variation can be taken into account by 'normalizing' seed prices on the price of ware potato, which we do later in the model.

not find the improved seed to be profitable at all, and continue to use only farm seed, while other farmers find that improved seed yields high positive returns. At the level of the market (aggregating over all potato farmers), we can specify the yield advantage of improved seed as a function of the quantity of improved seed that is adopted, where the first farm to adopt is the one where the yield (and profit) advantage is highest; and the second farm to adopt is the one where the yield advantage is next highest, and so on. Then, at the margin, the yield difference between improved and farm seed falls as more and more farmers adopt improved seed. Let ΔY_t^c be the aggregate increase in yield achieved by all farmers who adopt improved seed; and let $\Delta Y_t^c\left(Q^c\right)$ be the aggregate "yield improvement function" from farmer adoption of improved seed, where $Q^c = \sum q^c$ is the total amount of improved seed purchased by farmers.[4] The positive but declining yield improvement as more farmers adopt implies that $\Delta Y_t^{c'}\left(Q^c\right) \geq 0$ and $\Delta Y_t^{c''}\left(Q^c\right) < 0$ (i.e., the yield improvement earned by adopting farmers is positive; but the level of improvement falls as more farmers adopt it).

With these notations and assumptions, the aggregate farm demand for improved seed can be derived. Equation 3 for the aggregate net return from seed to all farmers who adopt it is rewritten as:

$$\text{(Eq 4)} \quad \Pi\left(Q^c\right) = \sum_{t=1}^{T} e^{-r\lambda(t)} P \, \Delta Y_t^c\left(Q^c\right) - Q^c\left(W^c - W^f\right)$$

For farmers adopting improved seed, the first-order necessary condition for profit-maximization is:

$$\text{(Eq 5)} \quad \Pi'\left(Q^c\right) = \sum_{t=1}^{T} e^{-r\lambda(t)} P \, \Delta Y_t^{c'}\left(Q^c\right) - \left(W^c - W^f\right) = 0.$$

In other words, for the marginal adopter, the change in benefits just equals the change in costs of improved seed.

[4] Small letters (q, x, y, π) are used to represent input levels, yield, and profit by individual farmers. Capital letters (Q, X, Y, Π) are used to present aggregate input, yield, and profit by all farmers who adopt improved seed.

It is convenient to normalize prices on the ware potato price P by letting $\hat{W}^c = W^c/P$ and $\hat{W}^f = W^f/P$. Solving equation 5 gives the inverse farm demand function of improved seed (i.e., the market price of improved seed as a function of quantity demanded):

$$\text{(Eq 6)} \qquad \hat{W}^c\left(Q^c\right) = \hat{W}^f + \sum_{t=1}^{T} e^{-r\lambda(t)} \Delta Y_t^{c'}\left(Q^c\right).$$

Equation 6 has a simple interpretation. The unit value of improved seed to a farmer is equal to the price of farm seed plus the present discounted value of the increase in yield that the quality seed gives over the farm seed. At the level of the market, the price of improved seed is equal to the price of farm seed plus the present value of the marginal increase in yield from adoption of improved seed. The 'marginal increase in yield' is the yield increase obtained from the last farmer to adopt improved seed (i.e., the farmer earning the least amount of yield increase among all those who have adopted, but who still finds it profitable to adopt). Note that at this market price, some farmers could earn large positive returns from adoption, while other farmers (those at the margin) would just barely break even from adoption. Further, under our assumption of declining marginal benefits from adoption (i.e., that $\Delta Y_t^{c''}\left(Q^c\right) < 0$), farm demand for seed falls as the price of improved seed rises. Finally, the amount of improved seed that passed through market channels (purchased by farmers) in any one year is only a fraction of the total seed used by farmers that year. The fact that farmers keep tubers from the crop of improved seed for an average of T years before renewing their seed stock implies that only 1/T share of total seed needs will be supplied by the market in any one season.

The model can be used further to determine the optimal number of seasons a farmer should keep seed before buying a fresh batch of improved seed. This can be done by comparing, in season 2 and in subsequent seasons, the present value of net benefits from continuing to use the progeny of improved seed or replacing it with newly purchased improved seed each season. The optimal number of seasons to keep seed will be influenced by the price of improved seed.

To complete the model of the seed market, we need to specify the supply function for improved seed. If imports of certified seed are allowed and the importing country is a relatively small importer, then the import price specifies a perfect elastic source of supply of improved seed. Domestic seed producers of disease-free or certified seed face a cost function for seed production given by $C(Q_D^c)$ where $C'(Q_D^c) > 0$. These costs include the costs of all land, labor, materials, and fees for seed certification used in seed production. The marginal cost of producing disease-free or certified seed is assumed to increase as more is produced. The marginal cost function $C''(Q_D^c)$ specifies the supply function for domestically produced quality seed.

The equilibrium market price for improved seed can now be solved. If imports are not allowed, domestic seed producers must then provide all improved seed. In Figure 1, the equilibrium price and quantity of improved seed supplied in the absence of imports is given by the intersection of the farm-derived demand for seed ($W^c(Q^c)$) given in equation 6 and the supply (marginal cost) function of domestic seed producers ($C'(Q_D^c)$). This results in a supply of improved seed of Q_a^c sold at price W_a^c. If imports are allowed, then according to the market structure in Figure 1, the resulting supply of improved seed will be Q_b^c selling at price W_b^c. Seed is supplied by the most efficient domestic seed producers and from imports. However, it is possible that imports could supply all of the market for improved seed if no domestic producer could provide quality seed at or below the import price. Also, if the import price were above W_a^c, domestic producers would be able to supply all the improved seed, even in the absence of trade restrictions. If a tariff was imposed on imported seed, then the local price of imported seed would rise to $(1+\tau)W_b^c$ (not shown in the Figure), where τ is the rate of an ad-valorem tariff. This would reduce seed imports, increase domestic seed production, and raise the market price of improved seed to farmers.

An illustration may help to explain the seed market model described above. Suppose a country allows imports of certified seed and that the domestic normalized price of imported seed is 5.0 (i.e., imported seed sells at five times the price of ware potatoes), the normalized price of farm seed is 1.5. Some improved seeds are imported and some are supplied domestically. If farmers perceive imported and domestically produced certified seeds to be of

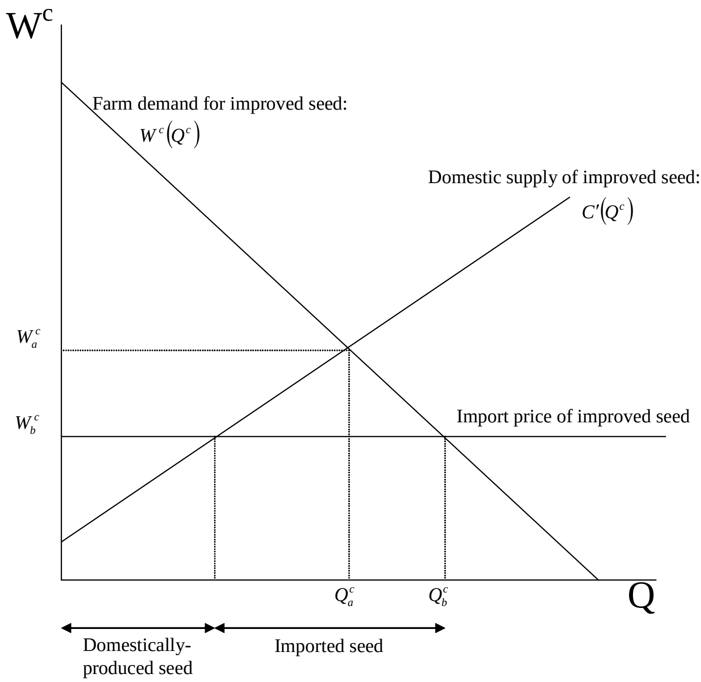

Figure 1. Model of the market for improved potato seed

approximately the same quality, they would be willing to pay the same price for each. Suppose a potato season lasts four months, saved seed is stored for four months to break dormancy, and potatoes can be grown year-round. Assume that the time discount rate for a typical farmer is 1%/month and the seeding rate is 1 t/ha. Let's assume that on average, a farmer who purchases improved seed obtains a 30% increase in yield in the first year of use, or an additional 3 t/ha over the average yield from farm seed of 10 t/ha. Keeping a portion of the harvest of the improved seed for a second season provides an average yield of 12 t/ha; and for a third season, yield is 11 t/ha. By the fourth season, the yield from the improved seed and the farm seed are the same. The net return per hectare of improved seed (from equation 5) is:

$$\begin{aligned}\pi &= \left(e^{-4\%}(13-10) + e^{-12\%}(12-10) + e^{-20\%}(11-10)\right) - (5.0 - 1.5) \\ &= (5.47) - (3.5) = 1.97\end{aligned}$$

In other words, improved seed used over three seasons increases farm yield by 6 *t*/ha over the yield of farm seed. In present value terms, this is worth 5.47 tons of ware potatoes to the farmer today. The additional cost of using 1 ton of the use of improved seed instead of farm seed is equivalent to 3.5 tons of ware potatoes. Thus, the net return from improved seed for this farmer for ware potatoes is 1.97 *t*/ha. But recall that for the marginal farmer, the net returns will be near zero at the market equilibrium price of improved seed; the increased yield from improved seed will just pay for the added cost of the seed. For farmers who get better-than-average yield benefits from improved seed, net benefits will be higher.

The conceptual model described provides a framework for examining the economic performance of alternative sources of potato seed. By comparing the yield performance and production management of different seed sources over generations, conclusions can be drawn on the value of that seed to farmers. Since yield degeneration rates are variety-specific, we can also use the model to examine the farm value of improved seed from different varieties, as well as how it may affect varietal preferences.

2.2 Survey of key informants and potato growers

Information and data on seed prices, yield from different sources of seed (controlled by age of seed), and the market for potato seed in Indonesia is generally sparse and is not readily available. Since the seed market within Indonesia is largely in the hands of private traders, they may be reluctant to divulge much information about their businesses and markets. Therefore, to obtain data on potato seed systems in Indonesia, two main survey instruments were used. First, key informant interviews were conducted. Key informants include managers of the public certified-seed system in West Java, private seed producers, seed traders, and other persons knowledgeable of the potato seed situation in Indonesia. Second, a formal survey of a random sample of 182 farmers from the five most important potato production areas in Indonesia was conducted. The survey was carried out between October 2001 and May 2002, covering the previous crop year. In each production area, the survey team visited the principal potato-growing districts in the province and obtained a list of the main potato-growing villages in the district. Four villages were randomly selected from this list. Then, from a list provided by village leaders, 10 farmers were randomly selected for interviews. Thus, 40 farmers were interviewed in each of the provinces of West Java, Central Java, East Java, and North Sumatra. In West Sumatra, which has substantially less potato area than the other provinces, only two villages (and 20 farmers) were selected for the survey. Table 1 shows the five provinces covered by the survey. Together, these provinces accounted for about 95% of Indonesia's total potato production.

The questionnaire elicited data on the characteristics of the farm household and the livelihood system, costs of production for potato and other vegetables, farmers' choice of variety, and potato seed management practices. In addition, farmers were asked to estimate the expected yield from potato seed from up to five different sources (own seed, seed bought through the informal farmer-based seed system, formal certified seed, seed from private companies that used tissue culture and rapid multiplication methods to eliminate seed-borne diseases, and imported seed). They were asked to estimate the yield from this seed in the first season it was used and for up to three subsequent generations, for each variety and seed source that they had previously tried. These farmer perspectives on seed quality provide the basis for the economic assessment of improved seed presented in this paper.

Table 1. General background of the potato growing areas included in the survey

	West Java	Central Java	East Java	North Sumatra	West Sumatra *	Indonesia
Annual potato area harvested (1999-2001 average ha)	25,548	10,591	7,330	14,530	3,899	68,819
Potato yield reported in government statistics (1999-2001 average kg/ha harvested)	16,960	12,234	10,324	13,953	13,914	13,868
Potato growing districts included in survey	Bandung	Wonosobo Banjarnegar a	Kotabatu Malang Pasaruan	Tanakaro	Solok Kerinci [a]	
Sub-districts included in the survey	Pangalengan	Batur Kejajar	Bumiaji Pujon Tosari	Merek Barusjahe Tigapanah	Lembah-gumanti Kayuaro [a]	
No. of farmers interviewed	42	42	40	40	18	182

* The West Sumatra sample also includes 3 farms from Kerinci district in Jambi province just across the border from West Sumatra. For the purpose of this study, these farms are considered part of the West Sumatra sample.

Source: Area planted and yield of potatoes in provinces are from Badan Pusat Statistik. Other information from authors' survey.

3

POTATO PRODUCTION IN INDONESIA'S TROPICAL HIGHLANDS

Potatoes were introduced in the highlands of Indonesia sometime in the 17th or 18th century; but it did not become an important commodity until crop protection chemicals became available in the 1970s (Hefner, 1990). After that, potato production and area in Indonesia expanded rapidly, reaching 1 million *t* harvested from about 70,000 ha annually by the mid-1990s. In this highland vegetable production system, year-round rainfed production is possible, and 2-3 crops of short-duration vegetables are often grown. Potato, the most important crop in this system, is typically rotated with cabbage or another vegetable during the year.

Results of the farm survey show that small farms dominate highland vegetable production in Indonesia (Table 2). The average size of a potato farm is about 1 ha of cropland, with few farms over 2 ha. Many potato farms are rented, especially in West Java. Generally, the land market is well developed in the highland vegetable production areas and cash rent predominates. About 60% of the area planted to potatoes in West Java was on rented land in 2000, more than double the percentage in other provinces surveyed.

In all provinces except West Java, the sample of potato growers included landless households who were able to rent land to grow potatoes. About 6% of the potato growers owned no cropland of their own, while about half used their own land and the rest used both owned and rented land to grow crops. The average area of cropland owned per household was 1.16 ha with an additional net rental area (area rented minus area rented out) of 0.34 ha for total land operated of 1.60 ha.

State-owned land is probably the most important source of rented cropland. Public forestland and state-owned tea and coffee plantations rent land to farmers after tree clearing and replanting of tree seedlings. Farmers raise vegetables in the rows between the seedlings for a few years until the tree canopy develops and limits crop growth. Part of the rental payment is in kind as farmers are required to provide care for the seedlings while they grow crops between them.

Table 2. Farm size and tenure status of potato farmers in Indonesia

	West Java	Central Java	East Java	North Sumatra	West Sumatra	Indonesia [a]
Average farm size (ha owned) [b]	1.48 (2.12) [b]	1.10	1.11	0.90	1.17	1.16 (1.30) [b]
Maximum farm size (ha owned)	27.00	5.10	4.00	4.00	3.00	27.00
Average farm land operated (ha) [b]	2.22 (5.19) [b]	1.53	1.46	1.19	1.63	1.60 (2.29) [b]
Average cropping intensity [c] (ha harvested/ha operated)	1.61	2.12	1.06	1.25	2.23	n.a.
Tenure status 1 (% of potato cropland rented)	59%	28%	24%	24%	28%	40%
Tenure status 2 Farmers who only use own land (%)	36%	50%	63%	60%	67%	49%
Farmers who only farm rented land (%)	0%	12%	13%	13%	6%	7%
Farmers who own and rent land (%)	64%	38%	25%	28%	28%	44%

[a] The national average reported here is a weighted average from the five provinces (weighted by potato area in the province).

[b] In West Java, there was one very large farm (27 hectares owned with more than 100 hectares operated) that was a clear outlier from the rest of the sample. The average farm size reported for West Java and Indonesia excludes this observation. The averages with this observation included are shown in parentheses.

[c] Includes area planted to annuals and perennials.

Source: Authors' survey.

Potato-farming households are relatively prosperous with diverse sources of income. Average per capita income in 2000 from all sources was Rp 6.6 million, or about US$ 736 at the market rate of exchange. Agriculture contributed three-fourths of total household income, and potato contributed nearly half of agricultural income (Table 3).

By far, the most important variety grown in Indonesia at the time of our survey was Granola (Table 4). Granola is a variety released in Germany in the late 1970s and introduced into Southeast Asia in the early 1980s. It proved popular in the tropical highlands due to its short-growing season (harvested 90-100 days after planting), high yield, resistance to viruses, and acceptance by consumers. It quickly came to dominate potato production in Indonesia and the Philippines. In 2000, it was grown on 91% of the potato area in Indonesia. However,

Table 3. Household composition and income of potato farmers in Indonesia

	West Java	Central Java	East Java	North Sumatra	West Sumatra	Indonesia [a]
Average family size (persons/household)	4.1	4.0	4.7	4.6	6.1	4.4
Average education of household head (years of schooling)	7.5	10.0	6.8	8.8	8.7	8.2
Average years of experience growing potatoes	20.3	11.2	17.4	11.6	11.5	15.8
Average household income (million Rp/year)	30.7	37.2	26.2	30.9	38.7	31.9
Average per capita income (million Rp/year)	7.5	9.4	5.6	6.7	6.4	6.6
Share of income from agriculture (%)	66%	73%	87%	83%	82%	75%
Share of income from potatoes (%)	35%	62%	33%	18%	32%	35%

[a] The national average reported here is a weighted average from the five provinces (weighted by potato area in the province).

Source: Authors' survey.

Table 4. Potato farm area and varieties planted in 2000

	West Java	Central Java	East Java	North Sumatra	West Sumatra	Indonesia
Average potato area harvested per farm (ha/year)	1.34	1.87	0.46	0.46	0.47	0.96
<u>Potato varieties</u>						
Area planted to Granola (%)	87.1	97.8	76.6	95.2	100.0	91.4
Area planted to processing varieties * (%)	12.9	0.0	0.0	4.8	0.0	5.6
Area planted to other varieties ^ (%)	0.0	2.2	23.4	0.0	0.0	3.0

* These include Atlantic, Columbus, Hetra, and Panda.

^ Other varieties consist mainly of Ritex, a farmer-selected variety popular in East Java.

Source: Authors' survey.

Granola is unsuited for processing due to its high sugar and low dry matter content.

To meet the growing local demand for processed potato products, several new varieties have been introduced. In 2000, about 6% of potato area was sown to processing varieties (Columbus, Atlantic, and Panda). The rest of the potato area is planted to an assortment of other varieties, including a popular farmer selection in East Java known as Ritex.

The average levels of inputs, yields, and costs of production for each province are given in Table 5. Potato uses inputs intensively, but pays high returns. The survey confirmed that seed is the most costly input for potato growers, accounting for about 19% of the gross value of crop yield. The average seeding rate was 1.13 *t*/ha. More than 400 kg of chemical fertilizer nutrients and 8 tons of animal manure were applied per hectare per crop (total nutrients applied per year may be 2-3 times these levels given the extensive use of multiple cropping). Potatoes also require heavy use of chemical pesticides. About two-thirds of pesticide costs are for fungicides and one-third for insecticides. Granola is very susceptible to late blight (*Phytophthora infestans),* a devastating fungal disease that thrives in the cool humid conditions found in Indonesia's tropical highlands. Farmers may spray pesticides on their potato crop 20-30 times during a single season. Principal insect pests are the potato tuber moth (*Phthorimaea operculella* Zeller) and leaf miner fly (*Liriomyza huidobrensis*). Recently, the potato cyst nematode (*Globodera rostochiensis*) has appeared in some parts of the country.

About 40% of the gross value of production reported in Table 5 was economic profit, after subtracting the cost of purchased and farm-supplied inputs, including land, labor, seed, fertilizers, pesticides, and other inputs. Although potato does have a reputation for being a lucrative crop in Indonesia, this level of profitability seems high. If true, then the incentives to further expand potato area would be high, although potato area in Indonesia peaked in the mid-1990s and has remained relatively stable since then at about 70,000 ha annually. It seems likely that the cost of land reported in Table 5, which is based on the average cash rent paid for rented vegetable cropland reported by farmers in the survey, does not fully account for the opportunity cost of farmers' own land. Land cost accounted for only about 2% of the total value of crop yield. Normally, we might expect the factor share of land to be at least 10% in developing countries (Hayami and Ruttan, 1985). What might explain the apparent undervaluation of land costs is the fact that public lands were the most important source of rented land for vegetable

Table 5. Cost of potato production per hectare per season in 2000

	West Java	Central Java	East Java	North Sumatra	West Sumatra	All Indonesia
Input Quantity (per ha)						
Total labor (days) [a]	450	192	381	164	251	286
Male labor	326	152	289	108	152	206
Female labor	124	40	92	56	99	80
Seed (kg)	1,347	1,304	1,296	888	1,818	1,129
Manure (kg)	12,292	6,481	7,557	7,058	3,886	8,076
Chemical fertilizers (kg nutrients)	443	427	469	544	408	418
N	139	211	216	119	85	137
P_2O_5	183	174	206	246	233	182
K_2O	121	43	48	178	90	99
No. of fungicide applications per crop *	20	24	n.a.	14	n.a.	n.a.
No. of insecticide applications per crop *	10	10	n.a.	8	n.a.	n.a.
Input Cost ('000 Rp/ha)						
Land	557	492	1,551	591	572	572
Labor	3,789	2,712	3,815	2,691	3,565	2,983
Manure	3,122	1,408	870	920	519	1,676
Seed	8,099	4,689	4,777	2,994	6,656	5,212
Total chemical fertilizer	1,943	2,238	1,947	2,556	1,822	1,908
Total pesticide	5,517	5,469	3,546	2,488	2,042	3,885
Other inputs	64	0	417	95	0	91
Total farm-supplied inputs[a]	7,468	4,612	6,236	4,202	4,674	6,183
Total non-farm inputs[b]	15,623	12,396	10,686	8,134	10,520	11,159
Total inputs	23,091	17,008	16,921	12,336	15,195	17,342
Output						
Average yield (kg/ha)	19,473	13,459	13,406	13,814	17,292	14,625
Stn. Dev. of yield (kg/ha)	17,379	5,980	6,578	5,162	8,919	9,668
Economic Returns ('000 Rp/ha)						
Gross value of yield	38,707	27,708	29,797	20,650	37,669	28,301
Net income [c]	31,238	23,096	23,561	12,261	32,995	22,119
Economic profit [d]	15,615	10,700	12,875	4,127	22,475	10,960
Cost of production (Rp/kg)						
Price received for potatoes	1,988	2,059	2,223	1,495	2,178	1,935
Cost of production [e]	802	921	797	589	608	763
Economic cost of production [f]	1,186	1,264	1,262	1,196	879	1,186

[a] Includes both family and hired labor. For hired labor, a typical work day is 6 hours.
[a] Farm-supplied inputs include land (rented or owned), labor (family or hired), and manure (own-farm produced or purchased).
[b] Non-farm inputs include potato seed (whether purchased or farm-saved seed), chemical fertilizers, pesticides, and others.
[c] Net income is defined as the gross value of production minus the cost of market inputs.
[d] Economic profit is defined as the gross value of production minus the cost of all inputs.
[e] Cost of production is defined as (cost of non-farm inputs)/yield.
[f] Economic cost of production is defined as (cost of all inputs)/yield.

Source: Authors' survey; except data on number of pesticide applications per crop, which are drawn from a farm management survey conducted in 1998-99 (van der Fliert *et al*., 1999).

production. It is possible that the state agencies did not base their cash rents on the market opportunity cost of cropland in the highland regions, but on other factors. For example, rental agreements for this land typically require not only payment of a cash rent, but also that tenants provide care for tree seedlings as part of forestry and plantation replanting schedules.

Potato production in the small highland farms is labor-intensive, requiring an average of more than 280 days of labor per hectare per season. Most potato farms, even relatively small ones, make extensive use of hired labor. In the highland vegetable communities, one does not find evidence of *ijon, tebasan,* or other traditional institutional arrangements regulating marketing and owner-worker relations like those described in Hayami and Kikuchi (1981).

Agricultural laborers are usually employed on a cash wage basis either as casual workers during peak periods, or as permanent workers (Hefner, 1990). Further, farmers harvest and sell the produce themselves, rather than sell the standing crop to a trader as is commonly practiced with rice and other staple food crops (Hayami and Kawagoi, 1993; Bottema and Altemeier, 1996). In this study, 180 out of 182 farmers surveyed harvested the crop themselves. Four percent sold their crop to processing companies with whom they had contracts, and one farmer in the sample was obliged to sell to a trader from whom he had obtained credit. The others reported that they were free to negotiate sale o f their harvest with any trader. Marketing arrangements for upland vegetable crops appear to be competitive with rapid price transmission between urban and rural markets (Hayami and Kawagoe, 1993).

The expansion of highland vegetable production in the 1970s and 1980s helped transform poor subsistence communities into relatively prosperous commercial ones even in the face of significant population growth (Hefner, 1990). The predominantly small-farm structure and extensive use of hired labor meant that these economic gains were shared even by households with limited or no land holdings. However, this agricultural transformation also entailed a significant environmental cost. High levels of soil erosion and pesticide use are endemic in the intensive mountain vegetable production system. While the long-run impact of erosion on the productivity of the deep, upland soils may be small, off-site impacts are likely to be high (Barbier, 1990). The significant off-site share of erosion impacts implies that market incentives alone are probably insufficient to induce farmers to invest adequately in conservation measures. So, while potato cultivation has significantly improved the livelihood of mountain-farming families, the long-run sustainability of current production practices remains an issue.

4

SOURCES OF IMPROVED POTATO SEED IN INDONESIA

After two decades of rapid growth, by the late 1990s, area planted to potatoes in Indonesia had stabilized at around 70,000 ha/year. Assuming an average seeding rate of 1.5 *t*/ha, this implies a need for about 105,000 tons of potato seed annually. Several competing sources of potato seed supply this critical input to Indonesia's farmers. One important source is seed saved from the previous harvest or purchased from other farmers (the informal seed system). In addition, at least three sources of 'improved' or 'quality' seed are available. First are imports of certified seed of foreign-bred varieties. A second source of improved seed is from a newly established public-sector certified seed system located in West Java. Finally, a third source of improved seed is disease-free plantlets or mini tubers supplied by private companies with tissue culture facilities.

4.1 Imports of certified potato seed

Indonesia has operated a relatively liberal policy toward the importation of potato seed. Some countries, such as China, severely restrict the importation of potato seed on phytosanitary grounds (to prevent the unintended importation of foreign, seed-borne pests and diseases). Indonesia, Thailand, and Vietnam allow importation of seed so long as it is certified by a reputable agency as being free of specified pests and diseases. Indonesia previously maintained a 60% tariff on imported potato seed but removed the tariff in 1998.

Table 6 shows the quantity and value of imports of fresh potatoes by Indonesia from 1994 to 2002. Seed potatoes account for almost half of potato imports. Imports were exceptionally high in 1999 when they exceeded 6,000 tons. This was a period of rapid expansion in potato planting in Indonesia following the lowering of import tariffs and a more than tripling of the market price for potatoes between 1997 and 1998. The major potato seed supplying countries include the Netherlands, Australia, Germany, and the UK. On average, potato seed imports were about 1,600 *t*/year. This represents only about 1.5% of the total annual seed requirement.

Table 6. Indonesian imports of ware and seed potatoes, 1994-2002

Year	Quantity (tons) Total	Ware	Seed	Value ('000 US$) Total	Ware	Seed	Unit Price (US$/ton) Ware	Seed
1994	1,198	332	866	1,037	164	873	494	1,008
1995	1,093	308	785	1,236	420	816	1,363	1,040
1996	2,104	894	1,210	1,427	439	988	491	817
1997	2,934	2,035	899	2,365	1,503	862	739	959
1998	1,045	682	363	607	342	264	502	728
1999	9,294	3,176	6,117	2,899	958	1,941	301	317
2000	5,824	4,569	1,255	2,112	1,437	676	314	538
2001	3,815	2,679	1,136	1,356	772	584	288	514
2002	3,772	2,336	1,436	1,555	747	808	320	563
Average	3,453	1,890	1,563	1,622	754	868	399	555

Source: BPS, Imports.

Potato imports consist principally of Granola, processing varieties, and a number of 'trial' varieties. Table 7 provides a breakdown of imports by variety for each year, from 1999 to 2002. At least 81 different varieties were imported into Indonesia during this period, although for most of these, only small 'trial' quantities were imported (Ministry of Agriculture, 2003). Granola made up 40% of total potato imports over these years. Production of this variety is destined primarily for the fresh market. Varieties used primarily for processing, which include Atlantic, Kennebec, Panda, and some others, made up about 50% of potato seed imports. Small quantities of "trial" varieties made up the remaining 10% of potato seed imports.

4.2 Development of a publicly certified potato seed system

The Government of Indonesia (GOI) has recognized that one of the most important aspects for increasing crop production and productivity is the supply of quality seed, as well as new varieties, and the use of improved agricultural practices. Agricultural policy in Indonesia has put emphasis on developing a dynamic and suitable seed industry that serves the needs of farmers throughout the country. Under the guidance of Crop Cultivation Law No. 12/1992 (*Undang-Undang* No. 12 *tahun* 1992 *tentang Sistem Budidaya Tanaman*) and Government Legislation No. 44/1995 (*Peraturan Pemerintah* No. 44 *tahun* 1995 *tentang Perbenihan Tanaman*), the Ministry of Agriculture formulated the General Strategy for the National Seed Industry Development. Some aspects emphasized in implementing the strategy

Table 7. Imports of potato seed by variety to Indonesia, 1999 to 2002

No.	Variety	Import volume (tons) 1999	2000	2001	2002*	County of Origin
1	Granola	1,784	1,093	708	204	Holland, Germany, Australia
2	Atlantic	937	150	467	327	Holland
3	Kennebec	1,096	229	155	-	UK, Australia
4	Panda	210	50	100	75	Poland
5	Hermest	257	15	35	-	Holland
6	Desire	156	35	1	8	Holland
7	Hertha	85	-	85	-	Holland
8	Diamani	85	-	25	-	Holland
9	Agria	75	-	25	-	Holland
10	Columbus	24	40	25	-	Holland
11	Santana	45	35	-	-	Holland
12	Russet Burbank	63	-	-	-	Holland
13	Timate	60	-	-	-	Holland
14	Simply Red	-	50	10	-	Holland
15	Maris Peper	-	50	5	-	Holland
16	Karlena	0	52	-	-	Holland
17	Aster	-	50	-	-	Holland
18	Reverina Russet	-	-	-	50	Holland
19	Mainchip	-	15	20	-	Holland
20	Chipeta	-	15	20	-	Holland
21	Escort	-	-	34	-	Holland
22	Felsina	-	-	2	30	Holland
23	Inovatore	-	-	-	30	UK
24	Graga	22	-	-	-	UK
25	Ajiba	19	-	3	-	UK
26	Suncrip	-	15	-	-	New Zealand
27	Mila	-	15	-	-	New Zealand
28	Luxor	-	2	5	-	Holland
29	Nadine	-	-	-	4	Holland
30	Liseta	3	-	-	-	Holland
31	Etc (51 Varieties)	6	78	40	4	Holland, Germany, UK, Australia New Zealand, Poland
	Total	4,928	1,989	1,764	732	

* through August 2002

Source: Directorate of Horticulture, Ministry of Agriculture, Jakarta, Indonesia.

are: (a) increased involvement of the private sector, (b) strengthened seed legislation/regulation, (c) prioritized commodity that has significant economic impacts, (d) strengthened seed control and quality systems, (e) strengthened breeding division/department, (f) improved market orientation, (g) improved information system, (h) improved networking and collaboration, and (i) improved human resources and seed facilities.

For potato, the GOI initiated a technical cooperation project with the Japanese International Cooperation Agency (JICA) in 1992 in West Java to develop a system for the multiplication and distribution of certified potato seed. The certified seed program is under the jurisdiction of the West Java provincial government, with support of national and provincial agricultural institutions.

In the publicly certified seed system, disease-free seed is produced under greenhouse conditions and then multiplied by seed growers for up to four generations. The West Java Seed Control and Certification Agency inspects the seed plots to certify that the seed meets disease tolerances (see the Appendix for a detailed description of the certified potato seed program in West Java). The system has produced G-4 certified seed since 1998, and production reached nearly 1,200 tons of G-4 in 2002 (Table 8). Prices for certified seed are set by the certification system according to the following rules: G-4 certified seed is priced at three times the current price of ware potatoes; G-3 seed is priced at 1.5 times the price of G-4 seed (4.5 times the ware potato price); and G-2 seed is priced at 1.5 times the price of G-3 seed (6.75 times the ware potato price). The prices do not necessarily reflect market supply and demand. So far, the value of seed sales has not been sufficient to cover actual seed production costs, and the system has required subsidies to operate.

Table 8. Production of certified seed in West Java, Indonesia, 1998-2003 (tons)

Year	Generation G-2	G-3	G-4	Total
1998	19.21	76.36	405.88	501.45
1999	25.65	170.37	393.24	589.25
2000	56.47	227.32	1,079.05	1,362.84
2001	48.17	271.56	330.50	650.24
2002	85.89	296.42	1,194.03	1,576.35
2003	40.23	280.63	475.38	796.24

Source: West Java Seed Control and Certification Agency

4.3 Private-sector seed supply from tissue culture

Between 1995 and 2000, about 10-15 private companies operated as competing sources of disease-free potato seed. These companies, located primarily in West Java, produced disease-free mini tubers in net houses. They used plantlets supplied from 4 to 6 sources that had tissue culture facilities, including at least three private companies, an agricultural university, and a public research center.

By 2002, only three potato seed companies continued to produce seed from tissue culture plantlets; only one company was producing plantlets. This plantlet-producing company in West Java started production in 1994; by 1998-1999, it was selling around 1,500 bottles/month at a price of Rp 3000/bottle. Each bottle contained 10 plantlets. However, by 2003, the company sold less than 150 bottles of potato plantlets the entire year (Personal communication with Director, *PT Dafa Teknoagro Mandiri*, 2003). The drastic decline in potato plantlet demand coincided with the reduction in the number of potato companies producing disease-free mini tubers in net houses. The reduction in demand for plantlets forced the company to employ its tissue culture facilities for other species, such as ornamentals, bananas, and orchids, in order to keep the business viable.

The expansion in demand for tissue culture plantlets up in the late 1990s was followed by the subsequent decline that can be attributed to a number of factors. The economic crisis that affected Indonesia in 1997-1998 had a strong impact on the agricultural sector. There was a drastic decline in the value of the local currency (the exchange rate devalued from around 2500 Rp/US$ in mid-1997 to around 8000 Rp/US$ by the end of 1998). This caused the price of traded goods, such as imported certified potato seed and ware potatoes for export, to increase significantly in terms of local currency. Between April 1997 and January 1999, the wholesale market price of ware potatoes in Jakarta rose from 920 Rp/kg to 3,560 Rp/kg. Even after discounting for inflation, the real price of potatoes increased by about 100% during this period. The rapid rise in potato prices created an incentive to expand potato production and increased the demand for seed. With the rising cost of imported seed, producers looked for other sources, including tissue-culture plantlets and mini tubers produced by local private-sector seed suppliers.

A rapid appraisal of private-sector seed producers by CIP in 2001-2002 identified a number of technical problems in tissue culture and net house management, including the lack of genetic purity, virus contamination in tissue culture for plantlets production, and inappropriate procedures for seed multiplication in net houses and fields (Jayasinghe, 2003). In many of the net houses, G0 seed multiplication lacked adequate measures to maintain seed quality. Many net houses were covered with transparent plastic sheeting that raised temperature and humidity within the net house, creating conditions favorable for late blight. Soil sterilization and raised seedbeds to prevent contamination were not regularly practiced, and none of the private sector net houses visited used the 'flush-out' system to keep materials free from contamination. For field multiplication, site selection was judged to be extremely poor, such that widespread contamination of seed plots with bacterial wilt, root-knot nematode, and other pests and diseases were commonly observed (Jayasinghe, 2003; Suri and Jayasinghe, 2003).

By April 2000, the real wholesale potato price fell back again to the early 1997 levels, and potato area harvested fell to under 60,000 ha in 2001 after exceeding 73,000 ha in 2000. The reduction in potato area reduced the overall demand for potato seed. Also, the technical problems described may have reduced farmers' confidence in seed from these private companies. The decline in demand plus the failure of some companies to maintain good seed multiplication practices were probably the major causes of the decline in locally-grown potato seed from the private sector after 2001.

5

THE INFORMAL SEED SYSTEM AND FARMERS' PERPECTIVES ON SEED QUALITY

Farmers' seed management refers to the procurement of seed for his or her crop. This includes not only saving part of the harvest for use as seed in subsequent planting, but also obtaining fresh seed from outside sources. The term "informal seed supply system" refers to the same, emphasizing that the farmers' seed production takes place outside the formal regulated seed production sector. Informal potato seed supply systems are dynamic and have continuous processes comprised of variety selection, variety adaptation, seed selection, processing, storage, and exchange by farmers (Thiele, 1999). In general, the traditional potato seed supply systems in Indonesia are characterized by farmers producing and preserving their own seeds for subsequent planting, and periodically exchanging with and/or purchasing seed from other farmers or traders.

5.1 Farmers' seed management

There is a tendency to assume that a farmer seed system refers only to the acquisition of seeds by farmers. Although this forms one of the most important aspects of local seed systems, much of the seed planted by farmers is in fact seed that farmers have kept from the previous harvest. A local seed system thus forms an integral part of the wider agricultural system, and depends largely on the capacity of local farmers to plant crops each season and successfully retain some of the output for planting in the following season. In cases where a farmer is unable to retain part of the harvested output, or where a farmer decides to plant a different seed variety, seed is generally acquired from within the local community or within the farmer's wider social network. It can be said that a farmer seed system broadly refers to the processes that farmers use to produce, obtain, maintain, develop, and distribute seed resources, both from one growing season to the next and in the long term. These processes can be examined from social and technical perspectives and in terms of the dynamic ways in which these two perspectives interact.

Table 9 describes sources of potato seed and the frequency of seed renewal practices by farmers in Indonesia. In any given season, farmers may use seed from multiple sources. From our farm survey, about 81% of potato farmers in Indonesia plant seed selected from their previous potato crop. Twenty-nine percent of farmers purchased at least some of their seed from other farmers. Nearly 9% purchased imported seed and 6% used minitubers purchased from private companies. Imported and private-sector seed were more important in West Java and West Sumatra compared with other regions. On average, farmers renewed at least a portion of their seed stock every fourth season, and 85% of the farmers purchased seed within seven seasons of continuous use.

Most farmers, especially smallholders, do not distinguish crop management practices for producing potato seed from those for table potatoes. Farmers carry out the same plant-to-plant and row-to-row distance, frequency and application of pesticides and other agronomic practices both, for seed crop and for table potato. Most farmers simply select the smaller tubers from the overall harvest to use as seed in the subsequent crop.

Harvested potatoes are graded and sorted by size and health. Seed and ware potatoes are selected and separated immediately after harvest. Healthy, small tubers (20-40 g) are selected for seed and stored. Many times, farmers leave the rotten and damaged tubers in the field because of lack of awareness that this practice may contribute to maintaining diseases in the field. The seed store could be any convenient space in the house. These sites offer cool and dark conditions, given the common type of house construction and climate in highland areas. Farmers typically inspect their seed stock 1-4 times during storage and discard any diseased tubers. Seed selection is an important means of reducing the incidence of seed-borne diseases such as bacterial wilt *(Ralstonia solanacearum)* (Sinung-Basuki, *et al.*, 1999).

Potato seed is often stored in bamboo baskets. The diameter of the bamboo basket is about 45 cm with 25 cm height. The capacity of each basket is about 26 kg or 900 tubers. Because of limited space, seed contained in the bamboo baskets are piled up 2 to 5 high. By using and piling up these bamboo baskets, farmers may store potato seed as many as 200-500 kg/m^2. However, farmers realize that the

Table 9. Farmers' potato seed management

	West Java	Central Java	East Java	North Sumatra	West Sumatra	Indonesia
Source of seed [a]						
Use own seed (%)	85.4	85.7	75.0	75.0	66.7	80.6
Buy from other farmers (%)	19.5	38.1	27.5	32.5	55.6	29.0
Buy imported seed (%)	14.6	7.1	2.5	0.0	16.7	8.6
Buy seed produced by private company (%)	9.8	0.0	7.5	0.0	11.1	5.6
Buy public certified seed (%)	0.0	0.0	0.0	0.0	0.0	0.0
Frequencies of seed renewal						
Average number of generations farmers retain own seed (seasons)	3.8	4.7	4.8	4.2	3.8	4.2
Farmers who replace seed every 1-3 generations (%)	37.5	26.2	54.0	52.5	50.0	41.8
Farmers who replace seed every 4-6 generations (%)	60.0	61.1	40.1	25.0	43.8	48.6
Farmers who keep seed 7 or more generations (%)	2.5	23.8	20.3	30.0	16.7	15.6

[a] Percentages sum to greater than 100% because some farmers used seed from more than once source.

use of bamboo baskets may make it more difficult to sort them during storage. Moreover, if sorting is delayed, diseases may spread more quickly and result in more losses from rotting tubers. Yet, despite the high seed quality risk, farmers keep using this practice because it allows them to optimize use of the limited space.

5.2 Marketing of potato seed in the informal system

In West Java, and even in Indonesia in general, farmers use seed from sources other than their own fields ("renovation") when they do not have enough of their own seed, or when crops are severely damaged by pests and/or diseases, significantly affecting yields. When new seed is purchased and the farmer has reason to believe that it will give a higher yield than seed from his previous crop, farmers often purchase a small quantity and multiply it one or two seasons, keeping all of the harvest for use as seed in subsequent plantings. Most farmers purchase new seed from friends, neighbors, seed growers, or seed traders. It is a common practice for small farmers to request their neighbors whose potato crops look healthy to reserve for them some of the harvest for use as seed.

Interviews during the field survey indicated that farmers are familiar with major potato pests and diseases, and they are mostly aware of disease transmission through degenerated seed. Since there is only one dominant potato variety in Indonesia, farmers understand that the low yield of their crops is basically due to poor health of the seed. For this reason, they prefer to use earlier generations of seed. However, the best seed available is often beyond the budget of most farmers, so that seed renovation is not done more frequently.

Seed traders and seed growers are the two important sources of potato seed in the informal seed system. Seed traders are those who trade not only seed but also ware potatoes. They usually buy and assemble seed or seed material from farmers and then store it for 3-4 months to break dormancy. Such seed is then sold as 'ready-to-plant'. During storage, sorting is conducted several times to get rid of diseased and rotten tubers. Losses during storage are typically around 20% of the original stock.

Seed growers are those who grow potatoes especially for seed and sell it as such to other farmers. Seed growers tend to be larger and more technically sophisticated than the average potato farmer. It should be noted that seed traders sometimes also produce a small volume of the seed. Hence, there seems to be no clear specialization between seed traders and seed growers, since both of them produce and sell the seed. Farmers usually base their choice on the reputation of the grower or trader, but the quality is not always guaranteed and informal seed is frequently diseased or infested by pests.

In West Java, the informal potato seed system has an interesting feature as a regionally and nationally recognized source of relatively good potato seed. Seed produced in Pangalengan District of West Java flows to other potato production centers in West Java such as Garut, Ciwidey, and Majalengka. Some of the seed also flows to other provinces, such as Central Java, East Java, and South Sulawesi. Within Java, the seed is usually delivered by truck, while for South Sulawesi, seed is shipped through the port at Surabaya, East Java. As previously noted, farmers in West Java tend to purchase imported seed more frequently as a source of seed renewal. This is particularly important for producers who multiply imported seed for a few seasons and then market it through the informal seed system to neighboring farmers or to farmers and traders in other regions of the country.

5.3 Seed prices and farmer perspectives on seed quality

The cost-of-production budgets described earlier show that seed is the single most costly input in potato production. Seed accounted for about 30% of total input costs and 18% of the gross value of output, on average (recall Table 5). Clearly, farmers are interested in sources of low-cost seed, but face a trade-off in terms of lower output, if the low-cost seed is also of low quality. Farmers' seed management practices reveal that they typically view seed purchases as a kind of capital investment to be made once every few seasons after their own saved seed has degenerated.

The surveys revealed that there is a wide variation in potato seed prices (even for the same variety) in Indonesia depending on the source (Table 10). 'Ready-to-plant' seed supplied by other farmers through the informal system was available for 3,000-4,000 Rp/kg in 2000-2001. Seed sold through the informal system varied according to the current market price of ware potatoes. A common rule of thumb used by seed sellers and traders to price seed sold through the informal seed system is to sell 'ready-to-plant' seed for 1.5-2.0 times the current ware potato price. Prices for imported seed ranged from 13,300 Rp/kg in West Java to 15,100 Rp/kg in West Sumatra. The price of imported seed was largely determined by prices in the exporting country, the exchange rate, and local transportation costs. In 2000-2001, imported seed were selling at 6-7 times the price of table potatoes, or 3-5 times the cost of seed supplied through the informal system. Disease-free mini tubers supplied by private companies were mainly available to potato growers in West Java. Private-sector companies charged about 10,000 Rp/kg for this seed, or about five times the ware potato price.

The fact that at least some farmers were willing to pay substantially more for imported and private-sector seed reflected their perception that this seed was of better quality than seed available in the informal system. The model described in the previous section showed that seed could have multiple prices in a market if it were

Table 10. Potato seed prices in 2000-2001, by source of seed

Source of seed	West Java	Central Java	East Java	North Sumatra	West Sumatra	All Indonesia
			(Rp/kg)			
Ware potato price at harvest	1,988	2,059	2,223	1,495	2,178	1,935
Seed supplied by other farmers and seed traders	4,056	3,329	3,362	3,058	4,045	3,498
Seed supplied by private companies using tissue culture	10,167					10,167
Imported seed	13,278	14,583	14,000		15,125	14,019
		(normalized price – seed potato price/ware potato price)				
Ware potato price at harvest	1.00	1.00	1.00	1.00	1.00	1.00
Seed supplied by other farmers and seed traders	2.04	1.62	1.51	2.05	1.86	1.81
Seed supplied by private companies using tissue culture	5.11					5.11
Imported seed	6.68	7.08	6.30		6.94	7.24

Source: Authors' survey.

not of the same quality. Seed perceived to be of higher quality and produce higher yield would be more expensive. In equilibrium (where supply equals demand for each quality of seed), the present value of the yield gains over successive generations of seed use should equal the increase in seed cost.

To judge farmers' perceptions of seed quality from different sources, farmers were asked in the survey to estimate the yield for specific varieties that they expected from seed supplied by the informal system; by private seed companies selling mini tubers derived from tissue culture; imported seed; and publicly certified seed. Moreover, farmers were asked to estimate the expected yield for each source of seed for up to four generations of seed use (i.e., assuming they keep a portion of the harvest for planting the next season). Farmers were usually able to provide reasonable estimates of the rate of yield degeneration over successive seasons if they had previous experience with seed from that source. Response rates varied depending on the source of seed. Most farmers in the survey were able to provide estimates of expected yield for four generations of use of informal seed and imported seed for the potato variety Granola. Estimates for private-sector seed and publicly certified seed were only provided by sample farmers in West Java, as these sources were not widely available in other provinces. Thus, out of the sample of 180 farmers, 158 responses on the yield of informal seed, 139 responses on the yield of imported seed, 21 responses on the yield of private-sector seed, and 10 responses on the yield of publicly certified seed were gathered.

For granola, farmers expected that seed from all sources would degenerate over time and give lower yield when saved for planting in subsequent seasons (Table 11). Further, the rate of yield decline was expected to accelerate in older seed. One exception is that the yield of imported seed was expected to increase slightly between the first and second generations of use before yield degeneration sets in. Farmers explained that imported seed was often physiologically old when first purchased and therefore did not yield optimally upon initial planting. It performed better in the second season when the tubers were of optimal physiological age for use as seed. In the third, fourth, and subsequent seasons, yield from the use of imported seed was also expected to decline.

Publicly certified seed provided the highest yield benefit of any source of seed, although its supply was small and only a few farmers in the sample had experience with this seed. Imported seed gave the next highest yield. Domestically produced disease-free mini tubers from private companies yielded below that of imported seed but above farmer-supplied seed.

Expected yields shown in Table 11 can be used to examine the economics of farmers' decisions regarding seed renewal. First, the discounted present value of the net benefits of purchased seed from each source of seed was calculated. This is the present value of the increases in yield over four generations of use minus the increase in seed cost from purchasing seed versus using one's own saved seed from the previous crop. Next, the benefit-cost ratio or the ratio of the present value of the increase in yield to the increase in seed cost was calculated. The net present value of purchased seed and the benefit-cost ratio are presented in Table 12 for various rates of nominal discount rates (2-5%/month).[6] Some farmers with low debts and good

[6] The nominal discount rate includes not only the time preference of farmers for current versus future earnings but also expectations about price inflation. At the time of our survey, inflation in Indonesia was about 1%/month. Therefore the real discount rate is probably about 1% less than the rates shown in Table 12. We would expect the real discount rate for most Indonesian potato farmers to be in the range of 1-3%/month.

Table 11. Expected yield and yield degeneration of potato seed from different sources

(Variety = Granola)

Seed source	No. of farmers responding	Expected yield from seed by generation Mean values (t/ha)			
		1st	2nd	3rd	4th
Publicly certified seed	10	23.6	22.9	22.1	n.a.
Imported seed	139	20.0	21.3	19.7	15.9
Seed supplied by private companies using tissue culture	21	19.0	18.3	17.6	12.1
Seed sold by other farmers and seed traders	158	17.5	16.2	14.5	12.1
Own saved seed	210	17.3	15.9	14.3	12.1

n.a. = not available.

Source: Authors' farm survey.

Table 12. Returns to use of purchased potato seed from different sources

Seed source	Net present value (Rupiah per ton of seed purchased) Nominal discount rate (% per month)				Benefit-cost ratio (Rp in add'l revenue per Rp of add'l seed cost) Nominal discount rate (% per month)			
	2%	3%	4%	5%	2%	3%	4%	5%
Publicly certified seed	26,882	23,338	20,291	17,665	3.99	3.59	3.25	2.96
Imported seed	13,915	10,430	7,555	5,172	1.99	1.74	1.54	1.37
Seed supplied by private companies using tissue culture	3,788	2,500	1,405	472	1.37	1.25	1.14	1.05
Seed sold by other farmers and seed traders	396	335	284	243	1.11	1.10	1.08	1.07

Benefits calculated over four generations of use based on expected yields given in Table 11.

Source: Authors' farm survey.

assets may find easier access to institutional credit and face a relatively low discount rate. Other farmers may have a higher discount rate. At a higher discount rate, the net benefits of purchased seed declines. At a low discount rate, the net present value of purchased seed for all sources is positive, although it is much higher for publicly certified seed and imported seed than for seed from private companies and seed traded by farmers. At a discount rate of 4%, farmer-traded seed is no longer profitable to use, and at a discount rate of 5%, private-sector seed net present value is also negative. But the net present value of imported seed and publicly certified seed remains positive even if the benefits in future seasons are heavily discounted. The higher yield in the first season of use is sufficient to pay for the higher cost of seed. At a 2% discount rate, publicly certified seed provides 4 Rp of yield benefit for every 1 Rp of additional seed cost; and imported seed, 2 Rp of yield benefit for each 1 Rp of additional cost. Even at a discount rate of 5%, benefits accumulated to nearly three times the additional cost of publicly certified seed and 1.33 times the additional cost of imported seed.

The high returns from investment in improved seed, especially from imported seed and publicly certified seed, suggest that these improved inputs might be underutilized in Indonesia. According to these expected gains, it would appear to be profitable for most farmers in Indonesia to use these sources of seed rather than own seed or farmer-traded seed. Few farmers in Indonesia currently have access to publicly certified seed, however, due to its limited supply. Also, the price charged for publicly certified seeds probably does not reflect its full cost of production due to subsidies provided though the technical assistance project (with JICA) that developed the capacity for this seed production. Imported seed continues to be the primary option for most farmers for obtaining quality potato seed. Improved education, more aggressive marketing, and perhaps greater competition in the market for imported seed may help more farmers in Indonesia benefit from improved seed and increase their returns from potato farming. Increased reliance on imported seed, however, will limit farmers' options on variety selection to foreign varieties; increase the risk of inadvertently introducing exotic seed-borne pests and diseases; and cost foreign exchange.

From the model presented in the previous section, it is possible to use the information in Table 11 to derive farmers' willingness-to-pay for purchased seed from different sources. The willingness-to-pay is simply the discounted present value of the increase in yield from using purchased seed instead of saving seed from one's own previous crop. It is the maximum amount farmers could afford to pay and still gain economically from purchasing the seed. The average willingness-to-pay calculated for various discount rates and actual prices paid for seed from each source of seed are given in Table 13. At a discount rate of 2% and 3%, the average willingness-to-pay for farmer-traded seed was within the range of actual prices reported by

Table 13. Market prices and estimated 'willingness-to-pay' for potato seed from different sources

Seed source	Market price (Rp/kg)	Willingness-to-pay for seed (Rp/kg) Nominal discount rate (% per month)			
		2%	3%	4%	5%
Publicly certified seed *	9,000	35,882	32,338	29,291	26,665
Imported seed	14,000	27,915	24,430	21,555	19,172
Seed supplied by private companies using tissue culture	10,200	13,988	12,700	11,605	10,672
Seed sold by other farmers and seed traders	3,500	3,896	3,835	3,784	3,743
Opportunity cost of own saved seed ^	n.a.	2,719	2,771	2,821	2,867

* The price of publicly certified seed is set at 4.5 times the price of ware potatoes. This price is not determined by market conditions but is the price set by the public seed system for G-3 certified seed.

^ The opportunity cost of own saved seed is determined by adding the cost of seed storage to the price of ware potatoes at the previous crop harvest so that saved seed is 'ready to plant'. Storage costs include interest, value of losses, labor and materials. Harvest price of ware potatoes assumed to be 2000 Rp/kg.

n.a. = not available.

Source: Authors' farm survey.

farmers for this seed source (3,500- 4,000 Rp/kg). In other words, the marginal value of farmer-traded seed appears to be close to the marginal cost of this seed as described by the model of the seed market in the previous section.

The estimated willingness-to-pay for private-sector seed, imported seed, and publicly certified seed are above the actual market price even at a high rate of discount. For these sources of seed, it appears that the marginal benefits exceed the marginal costs. As previously mentioned, the prices set for publicly certified seed probably do not reflect their full cost of production and so far are in very limited supply, so the price of this seed does not reflect a market equilibrium price. But the results suggest that the market for imported seed might also not be in equilibrium with marginal benefits (demand) greatly exceeding marginal costs (supply). One explanation might be that non-tariff barriers, such as quarantine regulations, are restricting imports of seed.

Another possibility is that the estimates of 'willingness-to-pay' for improved seed overstate the actual demand for improved seed in Indonesia due to biases in the sample or errors in the survey. For example, all of the farmers providing estimates of expected yield from imported seed are farmers who have at some time in the past tried this seed on their farms. These may be the farmers who are most likely to realize the benefits of improved seed, due to their knowledge of the crop or to the environmental conditions of their farm. Farmers who have not adopted improved seed (and therefore did not provide estimates of expected yield) may perceive fewer benefits from adoption. Therefore, the survey results may have overestimated the level of perceived benefits from improved seed for the population of potato farmers as a whole. Even with these caveats, the pattern of seed pricing and farmers' reported perceptions of seed quality are consistent with the model of the seed market presented in the previous section. Seed that is perceived to have higher quality (giving higher yield) commands a higher price in the market. The yield advantage lasting several generations of improved seed over farm seed explains why improved seed may be priced at 5-10 times that of farm seed or ware potatoes.

6

DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

Improving the quality and lowering the cost of potato seed is an important challenge for many developing countries wishing to increase the competitiveness and profitability of potato production. Potato seed is the single most costly input into production, accounting for nearly 20% of gross output. Most farmers in Indonesia rely on the informal system to obtain seed, saving a portion of their harvest as seed, and periodically purchasing seed tubers from other farmers or traders when their own seed stock has degenerated due to the build up of diseases.

In the informal system, the Pangalengan District in West Java is recognized nationally as a relatively good source of seed, and certain farmers in this region are known as reputable sources of good seed. These seed growers typically obtain their starting stocks by importing certified seed from abroad and then multiplying the imported seed for one or two generations before marketing to other farmers and traders through the informal seed system. One strategy farmers have developed to reduce the cost of seed is to grow the variety Granola. Because it possesses some resistance to viruses, it has a relatively slow rate of degeneration. Farmers can therefore reuse seed from their potato harvest for several seasons before purchasing fresh seed. Therefore, farmers view purchased seed as a capital input, enjoying its benefits over several seasons or years until it has depreciated.

Both the public and private sectors have recently made significant investments to increase the supply of quality potato seed and reduce reliance on seed imports. In the late 1990s, a number of private companies built tissue culture facilities and net houses to grow disease-free potato seed by using rapid multiplication techniques. This private-sector effort, however, did not prove to be financially or technically feasible, and most of these companies have since closed their potato seed businesses. For many companies, it proved too costly or infeasible to maintain adequate standards to assure quality seed production. At around the same time, the Indonesian government, with technical assistance from Japan, developed a system for the production, multiplication, and certification of quality potato seed. This system is now operating in West Java but so far the amount of certified seed supplied by this system is small and its price, heavily subsidized. It seems likely that in order for the publicly certified seed system to meet the seed needs of growers, government subsidies will be required or restrictions will have to be placed on the importation of certified seed.

The results of our survey of 182 potato farmers from five provinces of Indonesia showed that producers are well aware of the value of quality seed in potato production. Farmers generally recognized that imported or disease-free seed would significantly outyield own farm seed for several generations of use. The principal constraint to the wider use of quality seed was its high cost: imported seed costs 5-7 times higher than farm-saved seed or seed purchased through the informal system. Even at this high price, many farmers would likely benefit from increased use of quality seed. If a farmer faced a severe capital constraint (i.e., a high discount rate), however, the net benefit of quality seed is reduced since the value of future improvements in crop yield is heavily discounted.

Policy makers wishing to improve technology and inputs for potato production face trade-offs between alternative strategies. One option is to have a relative liberal policy toward seed imports, such as allowing importation of certified seed at low tariffs and without onerous quarantine regulations. Imports provide farmers with a reliable source of high quality, although expensive, seed. Policies to promote competition among importers may help reduce the prices and increase the supply of imported seed. Policies to promote greater competition among importers include: licensing more companies to import seed; encouraging more countries to supply the imported seed; and allowing foreign varieties to be marketed freely in Indonesia.[7] However, the drawbacks of increased reliance on seed imports include (i) the loss of foreign exchange, (ii) a greater likelihood of inadvertent introduction of an exotic seed-borne pest or disease, and (iii) restricting varietal choice by farmers to foreign-bred varieties, although this drawback could be overcome by contracting seed growers in exporting countries to produce seed for Indonesia.

[7] Current seed regulations in Indonesia require that a variety must be officially released by the government seed board in order for it to be legally sold to farmers. To register a variety requires several seasons and/or locations of yield trials and review and approval by the seed board.

A second option is to promote public and private efforts to supply locally grown quality seed to farmers. The recent experience of Indonesia suggests, however, that this option has not yet proven to be financially or technically sustainable. The efforts of private companies in Indonesia in the late 1990s to produce disease-free potato seed largely failed because standards could not be maintained at a reasonable cost. The publicly certified seed system that has been developed in West Java has produced a limited supply of disease-free seed but the system has so far been heavily subsidized. Without continued subsidies, it will be difficult for this system to compete with imported seed. Restricting imports of seed would help the public system financially, but only at the cost of lowering the overall supply and raising the cost of quality seed to farmers.

A third option is to work to enhance the informal seed system itself, through technical training of farmers and seed growers. It has been mentioned that a number of potato farmers in the Pangalengan District of West Java are reputed as good suppliers of seed through the informal system. One of the major constraints in seed production is finding a seed plot that has been free of potato and other *solanaceous* crops for several seasons so that it is clear of soil-borne diseases such as bacterial wilt. Since publicly owned land (especially tree and tea plantations) are an important source of rental land for potato growers, some of these areas could be designated and managed specifically for potato seed production. It is also possible to enhance the production of farmers' own saved seed through training. Currently, most farmers do not distinguish between their 'seed' crop and 'ware' crop, simply keeping the smaller sized tubers from the harvest as seed. Instead, farmers could be trained in 'seed plot techniques' to enhance the quality of their saved seed and reducing the rate of seed degeneration.

Policies to support the potato seed system cannot generally be isolated from support for potato breeding and crop improvement generally. The development of locally adapted, superior potato varieties will increase the demand for locally-grown seed, unless special arrangements are made to produce and import seed for these varieties. New varieties that have resistance to degenerative seed-borne diseases like viruses are likely to be popular with farmers because farmer-saved seed of these varieties can be used for a longer period.

Technologies that intensify crop production, like improved fertilizer and pesticide management, are also likely to increase the demand for clean seed, since disease-free seed is likely to respond more readily to yield-intensifying technologies. Finally, farm credit schemes that reduce the opportunity cost of capital (i.e., lower the discount rate faced by farmers) will increase the demand for improved seed and other production inputs.

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Appendix

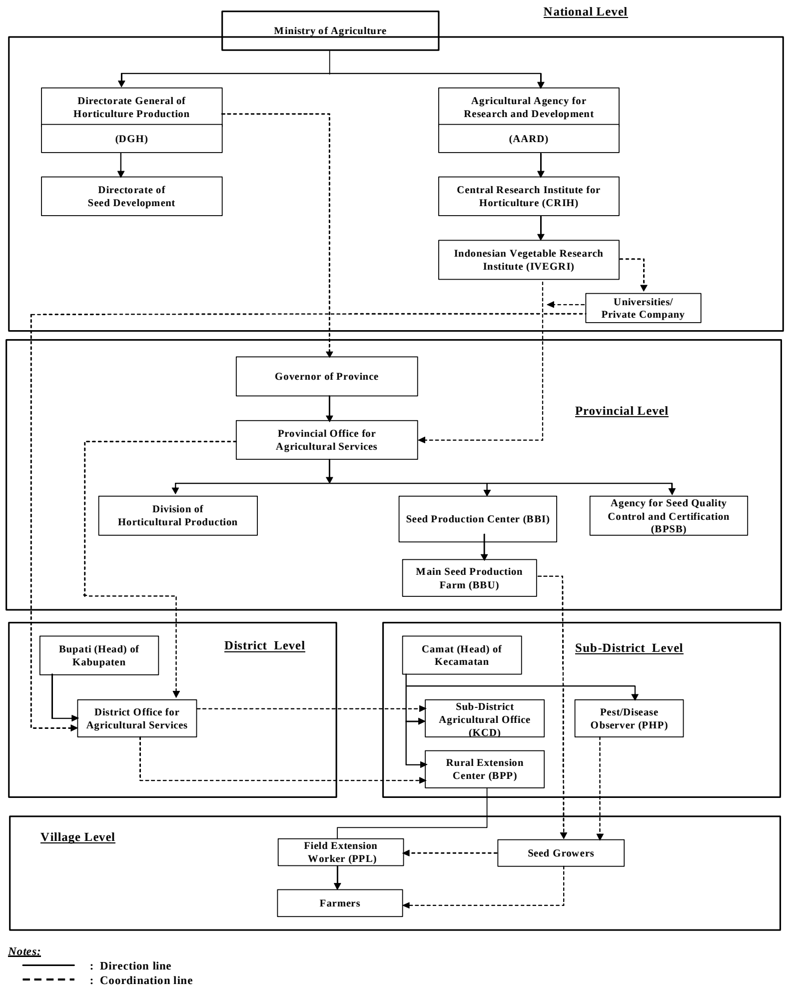
THE CERTIFIED SEED PRODUCTION SYSTEM IN INDONESIA

A dynamic potato seed industry requires a harmonious system combining basic and applied research, government supporting and regulatory activities, and commercial production and marketing. Each component of the system must function effectively for the industry as a whole to develop. Human resources with the necessary technical business and financial expertise are a pre-requisite. The GOI will ensure, especially for those functions under direct control of government that the various components of the industry operate effectively and constraints within the system are eliminated. The GOI recognizes the need to look at the seed industry in a holistic manner, rather than attempting to develop it on an *ad-hoc* basis. The policies related to the seed sector are directly related to its stage of development, and the institutional capacity to undertake the various activities. Thus, it is not static but evolutionary, changing in response to its developmental progress. Periodic reviews of the seed policies will be made to ensure that they continue to be appropriate and produce the desired effects.

Linkages among institutions in certified potato seed production

Some public institutions involved in the certified potato seed production system are the Indonesian Vegetable Research Institute – IVEGRI (Balai Penelitian Tanaman Sayuran), West Java Provincial Agricultural Office (Dinas Pertanian Tanaman Pangan Propinsi Jawa Barat) that is coordinating the Seed Production Center (Balai Benih Induk - BBI) and Main Seed Production Farm (Balai Benih Utama - BBU), Seed Growers and the West Java Agency for Seed Control and Certification (Balai Pengawasan dan Sertifikasi Benih Propinsi Jawa Barat). IVEGRI is responsible for performing breeding activities or genetic improvement, maintaining the purity of variety and initially supplying plantlets to BBI; BBI is in charge of supplying high quality nucleus seeds, multiplying the nucleus seeds, and producing foundation seeds by following these steps (stem cuttings -> G0 seeds -> G1 seeds -> G2 seeds); BBU is responsible for producing stock seeds G3 from foundation seeds G2 prepared by BBI, and supplying the stock seeds to seed growers; and Seed Growers are responsible for producing extension seed G4 from stock seed G3 supplied by BBU, and distributing them to potato farmers. Meanwhile, the West Java Agency for Seed Control and Certification is involved in controlling and certifying seeds to guarantee the availability of high quality potato seeds. The general organizational structure of the formal potato seed system in West Java is shown in the Figure.

Figure 2. The publicly certified potato seed system in Indonesia



At the national level, two institutions are closely related to back up the operation of this formal potato seed system. The Directorate General of Horticultural Production (DGHP) is mainly responsible for providing technical and administration services in horticultural development, while the Agency for Agricultural Research and Development (AARD) is responsible for generating and disseminating new technology. IVEGRI is a technical unit operating under AARD coordination.

Potato breeding

For many crop production systems in Indonesia, a major constraint for increasing production is the availability of quality seed. This is in addition to other constraints such as varieties; crop protection; storage and marketing, all important for the production of good seed. This is also true for potato. Most potato seed is produced, managed and distributed by farmers informally. Potatoes reproduce asexually and clonally; small tubers saved from one harvest become the seed for the next season. About 10-20% of total production is normally reserved for seed. Potato seed—unlike other seed—is costly, bulky and perishable. Diseases are transmitted within the seed tubers; yields gradually decline as seed degenerate and become more and more infected. Formal seed systems are designed to supply good quality seed with low disease content, and are produced in areas where disease pressure is low and healthy seed can be multiplied and sold to other farmers. Production of quality seed depends on a system of tissue-culture-based rapid multiplication under controlled net-house conditions with strict quality control. Institutional arrangements are typically complicated and require several government agencies to collaborate.

Selection of high-yielding varieties is carried out by research institutes to help introduce better varieties. Conventional breeding of potato is established at IVEGRI (and some universities, such as Bogor Agricultural University – Institut Pertanian Bogor - IPB) with the use of selected parental sources. This is very important, but, at present, is only done at the research centers, whose evaluation programs are limited and need to be enhanced. Without a proper evaluation procedure, improvements to existing varieties or testing of improved varieties for release cannot take place. This deprives farmers of access to good varieties and their improved economic returns. This area must be strengthened so as to ensure a mechanism to access, evaluate, recommend and release improved varieties. Indonesia has potato breeding/selection program involving crossing, selecting and testing of new varieties. The GOI through national agricultural research systems (NARS) carries out the responsibility for variety development. For potato, Indonesia depends to some extent on the supply of advanced breeding lines from CIP.

In general, variety release programs comprise the following steps: After genetic purity is attained and desired traits are fixed, the breeder enters the new variety in trials conducted at research centers. Good performers are then entered into national variety evaluation trials conducted for several seasons and years across the country. Depending on their performance, recommendations for release are made either for regional use or for national release if the variety has a good overall performance. The breeder, in association with the extension services, then conducts verification trials in farmers' fields, incorporating the new entry and tested against standard recommended varieties. A minimum number of on-farm locations stipulated by the national variety release committee, is needed for acceptance of the entry. Potato varieties that have been released by IVEGRI are Granola-Lembang, Atlantik-Malang, Merbabu 17, Amudra and Manohara.

Certified potato seed multiplication regulations

High quality seed potato mother plants, the basic material to be developed through the project, are being multiplied at the Indonesian Vegetable Research Institute (IVEGRI). The Central seed Farm (BBI) and the Main Seed Farm (BBU) were established in Pangalengan, West Java. The seed produced by the BBU (stock seed) will then be multiplied by seed growers (SG) to produce extension seed potato (ES). The following is a detailed description of potato seed multiplication in BBI Pangalengan, West Java:

(1) Production of G0 Seed Tubers

BBI at Pangalengan is responsible for producing G0, G1 and G2 seed tubers, and also distributing these seeds to other BBI's and BBU's. The G0 seed tubers are produced at screen house A and the G1 seed tubers are produced at screen house B, while the G2 seed tubers are produced in the isolated field.

<u>Screen House A</u>
The screen house A is an insect proof screen house with a roof of transparent fiber plastic, a wall of steel screen and a concrete floor. The size of screen house A is 253.5 m^2 (39.0 x 6.5 m^2) and it could accommodate 80 seedbeds. The seedbed is 168.5 cm length, 82.0 cm width and 16.0 cm height. This screen house is equipped with an irrigation system, fogger light reducer net, TL lamp, thermo meter and moisture meter.

<u>Sterilization</u>
Clean water is pumped by using the power sprayer to clean up the screen house and the seedbed. The screen house and seedbed are further sterilized with pesticides. The planting media consists of 1 part of subsoil and 1 part of manure (goats or cows). The media is steamed for three 3 hours to reach the temperature of 90-100°C and then kept at that temperature for one more hour, thus totalling four hours. It takes two days for cooling down, and the media is ready to use.

<u>Planting and harvesting of cuttings</u>
The fertilizer is applied to the media in the seedbed 3-7 days before planting. There are three different NPK combination used, i.e.: (i) 54 g Urea + 100 g SP 36 + 27 g KCL; (ii) 80 g Urea + 120 g SP 36 + 40 g KCL; (iii) 52 g Urea + 135 g SP 36 + 40 g KCL per seedbed. The

fertilizer is mixed and evenly broadcasted to the media in the seedbed. Mother plants (the source of cuttings) is derived from virus free plants or virus free sprout from G0 mini tubers (1-2 g/tubers). The cuttings could be harvested after the mother plants have six leaves. A cutting usually will have four leaves and the other two leaves are kept uncut in the mother plants. Cutting harvesting could be carried out 3 times in three weeks interval, for each mother plant. From one mother plant, a total of 10-12 cuttings could be harvested, thus the multiplication rate is of 10 to 12. Two lower leaves of the cutting should be trimmed before planting. The lower end of the cutting is dipped to Rootone F (a root growth inducer) and then planted by using 8 cm x 10 cm distance. There will be a total of 210 cuttings per seedbed. The cuttings are shaded for one week until they are rooted.

Producing G0 seed from G0 seed

G0 seed could be produced from in vitro plantlets and sprouts of G0 mini tubers. Another way of producing G0 seed could also be derived from G0 seed. The G0 is propagule derived from G0 tubers that weigh 5 g or less. The sprouted G0 tubers that has reached 0.5 cm long are stored in the diffuse light storage for a month. Sprouted tubers are then planted in seedbed with the same media and fertilizer as those used for growing cuttings. Fertilizers are spread along the rows that have 10 cm distance between each other. There are about sixteen rows in a seedbed. The planting distance is 10 cm in a row; thus, there will be approximately 160 G0 sprouted tubers per seedbed.

Lighting, watering, hilling and roguing

One month after planting, the plants are treated with light for 24 hours to accelerate the vegetative growth. Watering is carried out twice a week depending on the condition of the plants. The roguing technique is applied to virus-infected plants or undesirable plants daily.

Control of pests and diseases

The plants are usually sprayed with insecticides or fungicides once or twice a week to prevent pest and diseases. Different insecticides are used for different insects, i.e. *Curacron* 50 EC for potato tuber moth and aphids, Agrimex 18 EC and Trigard 75 WP for leaf miner fly, and Mesorul 50 WP for aphids and thrips. Fungicides such as Curzate 8/64 WP, Proplant 722 GL, Vandozeb 80 WP and Daconyl 500 F are used to control late blight and other potato diseases.

Virus Inspection

The inspection of PVX, PVY, PVS, and PLRV is conducted through visual method, using indicator plants and ELISA Tests. The indicator plants consist of *Compherena gobosa* and *Dature stramoinum* for PVX, *Nicotiana tabacum* for PVY, *Chenoposium amaranticola* for PVS, and *Physalis floridarea* for PLRV.

Harvesting and storage

Granola is an early cultivar so that it could be harvested at 100-115 days after planting. The haulm is removed 7-10 days before harvest to harden the skin of potato tubers. The harvested tubers are selected and graded before putting them in the plastic boxes. The harvest tuber is graded into 9 classes based on their weight, i.e. XL = 120 g, L-2 = 90-120 g, L-1 = 60-90 g, M = 30-60 g, S-2 = 20-30 g, S-1 = 10 g, SS-1 = 5-<10 g, SS-2 = 3-<5 g, and SS-3 = 1-<3 g. Potato seeds are washed with clean water, sun dried and treated with mixed pesticides before they are stored. The mixed insecticide and fungicide consist of Curacorn 500 EC 2cc/l and *Benlate* 0.25 g/lit. The seed tuber is dipped in a mixed solution of Curacron and Benlate for 15-20 seconds. Curacron is used for controlling potato tuber moth and Benlate is applied for controlling tuber dry rot. After dry, the seed tubers are treated with Mipcin 50 WP. The seed tubers are stored in a storage room that has good ventilation and lighting systems. The seed tubers sprout in 4-5 month. When the seed tubers have to be kept for a longer period (8-12 months), then they have to be stored in cool storage with a constant temperature of 3 °C.

(2) Production of G1 Seed Tubers

Screen House B

The G0 seed tubers from screen house A are multiplied to G1 seed tubers in screen house B. BBI Pangalengan has 14 units of screen house B for producing G1 seed tubers. Each screen house B is 39 m long and 13 m wide, then the total area is 507 m^2. In screen house B, the seeds are directly planted to the soil. Since there is no crop rotation in the screen house B, the soil should be sterilized every time before producing G1 seed tubers.

Soil sterilization and planting

Before starting the sterilization, the soil is watered until reaching the field capacity. The steam from steam boiler is flowed through the perforated pipes that are installed 20-30 cm below the soil surface. It needs 3-4 hours to complete the sterilization process with constant temperature ranging from 90 - 100^{o}C. An area of 2 x 20 m^2

needs 125-140 liters of kerosene; thus, one screen house uses about 1,500-1,700 liters of kerosene. Meanwhile, the sterilization of manure is carried out outside the screen house B (except for the Buto Ijo manure that could be sterilized together with soil in the screen). Planting distance between rows is 65 cm, while within row is 11.5-15.0 cm. There are 19 rows in one screen house B; thus, the total capacity is 5,000-6,000 plants. Before planting, manure and the fertilizer are evenly spread along the rows, covered with thin soil layer. The amount of manure applied is 50 g per seed, which is equivalent to 20 ton/ha. Fertilizers are applied as many as 900 g ZA, 1,350 g SP36 and 450 g KCl per row or equivalent to 400 kg ZA, 700 kg SP 36 and 200 kg KCl per ha. Soon after the seeds emerge, the first hilling is carried out and followed by the second hilling two weeks after the first one.

<u>Pests and diseases</u>

Two to four weeks after planting, pesticides are regularly applied once a week. Pesticides are applied twice a week or even more depending on the severity of pest/disease infestation when the plants reach the age of 30-70 days. Contact and systemic insecticides (such as Curacron, Marshal, Spontan, Decis, Padan, Kalikron, Arrivo, and Pounce) and fungicides (such as Redomil, Trineb, Preficur, Daconil, Vandozeb, Dithane, Curci, and Polyram) are applied alternately to avoid pest resistance.

<u>Inspection for viruses</u>

Potato virus inspection is carried out by using visual method, plant indicators, and Elisa test.

<u>Harvesting and storage</u>

Haulm cutting is implemented 7-10 days before harvest. The haulm cutting is aimed: (i) to strengthen the skin of harvested tubers, (ii) to obtain the right tuber size (LL, M or S), (iii) to prevent disease dissemination from haulm to tubers, and (iv) to guarantee easier harvest. Tubers are harvested manually, cleaned from soil, put in plastic boxes and stored for a week. After one week of storage, harvested tubers are sorted and graded. Grading is mainly based on tuber weight and classified into six classes. These classes are LL = > 120 g, L2 = 90-120 g, L1 = 60-90 g, M = 30-60 g, S = 10-30 g, and SS = < 10 g. Before the seeds are further stored, they are washed with clean water, dried, and treated with Mipcin 50 WP.

(3) Production of G2 and G3 Seed Tubers

Field requirements

Minimum requirements that should be satisfied in selecting location and field for producing G2 and G3 potato seeds are:

- The elevation should not be less than 1,400 m above sea level. The elevation is closely related to the temperature and relative humidity. The temperature will affect the growth and tuberization of potato, disease incidence and optimum performance of virus symptoms;
- At least 10 m isolated from potato or other Solanaceae plants;
- At least 1.5 year, the field is not used for cultivating Solanaceae crops;
- Free from soil borne diseases (nematode, bacteria);
- Close to water source; and,
- Should pass the field inspection of the Agency for Seed Control and Certification (BPSB).

The field must have a good rotation system for cutting off the life cycle of important pests and diseases. Time interval from potato to potato is 1.5 year. Rotation method practiced by BBI and BBU Pangalengan is to grow one crop of corn, shallots, and cabbage following a potato seed crop, and then to leave the field in fallow for two months before planting the next potato seed crop.

Potato — corn/shallot/cabbage — clean (2 months) — Potato

± 1.5 year

Tillage and planting

After two months of fallow, the soil is hoed 30 cm deep. The plant spacing depends on the tuber size; i.e. LL = 70 x 35 cm (1 tuber/hole); L1 and L2 = 70 x 30 cm (1 tuber/hole); M = 70 x 20 cm (1 tuber/hole); S = 70 x 20 cm (3 tubers/hole), and SS = 70 x 20 cm (4 tubers/hole). The seeds are planted approximately 15 cm deep in wet season and 20 cm deep in dry season. The length of rows depends on the type of sprayer used to control pest and disease. The length of rows is 6.0 m when using power sprayer, and 3.0 m when using knapsack sprayer. The amount of manure and fertilizer used will depend on planting season. The recommended amount for dry season crop is: 20 - 30 ton/ha of cow manure, 80 - 100 kg/ha of N, 80 kg/ha of P2O5, 100 - 120 kg/ha of K2O and 40 kg/ha of MgO. Meanwhile, the recommended amount for the rainy season is: 20 - 30 ton/ha of cow manure, 100 kg/ha of N, 100 kg/ha of P2O5, 150 kg/ha of K2O and 40 kg/ha of MgO. For rainy season, the source of N is ZA, while in dry season N will come from both Urea and ZA. Nematicide applied at the same time with fertilizer is Furadan 3 G (78 - 103 kg/ha) or Rhocarp 10 G (36 -6 2 kg/ha).

Weeding, hilling and roguing
Weeding is carried out manually by hand. Hilling is conducted two times (30 days and 40 days after planting). The height reached from each hilling is 10 cm, thus after second hilling the height of seedbed is approximately 20 cm. Roguing is usually carried out twice a week or more.

Pests and diseases
The use of insecticides and fungicides is mainly aimed as preventing measure rather than controlling measure of pests and diseases. Some suggestions that are followed for using pesticides wisely are: (1) to use pesticides alternately based on group/class, active ingredient and mode of action; and (2) to clearly understand the five principles of correctness (5 C), i.e. correct pesticide, correct dose, correct time, correct method and correct target.

Field inspection by BPSB
The Agency for Seed Control and Certification (BPSB) performs three field inspections. Those inspections are: (a) preliminary field inspection; (b) first plants inspection (30 - 40 days after planting); and (c) second plants inspection (40 - 50 days after planting).

Harvesting, grading and storage
Seed tubers are harvested when approximately 80-90% of the tubers reach the correct seed size, usually at 70-75 days after planting. Seed size percentage is estimated from plant samples. When the percentage of seed tubers has not reached 80-90%, the harvest is postponed for 7-10 days. Haulm cutting is conducted at 70–85 days after planting and 7-10 days before harvest. Harvesting, grading and storing methods are similar to those applied when producing G1 seed tubers.

Inspection and certification
The second seed tubers selection is carried out at 10-12 weeks after storage, especially to control seed-borne nematode. Healthy seed tubers are collected and put in a box based on their grades. One box contains 20 kg of seed tubers. The number of tuber in each box is recorded. BPSB personnel conducts the tuber inspection. After passing the inspection, the seed tubers are packed in netted nylon bags (each bag contains 20 kg seed tubers). The label is then sewn to the netted nylon bags in the presence of BPSB personnel.

(4) Production of G4 Extension Seed

In producing G4 potato seeds, the inspection and labeling methods are exactly the same to those applied in producing G3 potato seeds. The altitude should not be less than 1,200 m above sea level. Recommended amount of manure and fertilizers is 20-30 ton/ha of goat/chicken/cow manure, 120-150 kg/ha of N, 200-250 kg/ha of P2O5, 120-150 kg/ha of K2O

Potato seed certification service

Potatoes are prone to many diseases, and certification schemes are in place to ensure a minimal level of disease carry-over. Monitoring of seed crops is a necessity because of the risk of a diseased plant transferring the same problem to tubers. These tubers are then replanted, both magnifying the problem and assisting disease spread, leading to eventual unsustainable yield loss. The purpose of all certified seed schemes is to minimize disease incidence and provide the best quality seed, at an affordable price. Seed certification usually starts in the field with crops being inspected at least twice during the growing season to monitor cultural management and disease presence. During these inspections, visual determination of diseases and other undesirable factors that may influence the quality of the harvested seed takes place. Such factors include blackleg, *Rhizoctonia*, wilt, as well as varietal mixes. Erratic crop emergence and poor weed control may also result in crop rejection. “Certified” means that a particular seed line has passed all the requirements of inspection. Certified does not mean that there is not any disease present, only that the seed has met the criteria as set down in the certified seed potato guidelines.

In Indonesia, the Agency for Seed Control and Certification is not only responsible for issuing certificates for high quality potato seeds after field and laboratory inspections, but also determining and evaluating potato variety. Some aspects covered during inspections are the source of seeds, potato cultivars, field conditions, as well as pests and diseases status both in the field and storage. The inspections start from BBI (G2) to BBU (G3) and seed grower (G4). The procedure of seed control and certification is as follows:

1. Acceptance of application form
2. Preliminary inspection before planting;
3. First field inspection (30-40 days after planting);
4. Second field inspection (40-50 days after planting);
5. Tuber inspection (after harvesting and storing);
6. Issuance of certificates and labels.

The color of label indicates the quality of potato seed, i.e. white for G2 (Foundation Seed /FS), purple for G3 (Stock Seed/SS) and blue for G4 (Extension Seed/ES). In the instruction manual issued by the Directorate General for Food Crops and Horticulture, there is no standard for pre-basic seed (micro cuttings), super seed (G0), and super elite seed (G1). Available standards for both field and tuber inspections are given in Table's A1 and A2, respectively.

Table A1. Field Inspection Standards

Factors	Foundation Seed (G2)	Stock Seed (G3)	Extension Seed (G4)
Isolation (min)	10 m	10 m	10 m
Virus diseases (max)	0.1 %	0.5 %	2.0 %
Bacterial wilt (max)	0.5 %	1.0 %	1.0 %
Late blight and other diseases (heavy) (max)	10.0 %	10.0%	10.0 %
Mixed with other varieties (max)	0.0 %	0.1 %	0.5 %
Field management *			

* The field inspection will be stopped when the existence of volunteer potato plants, weeds, and aphids as virus vectors seems to be uncontrollable.

Table A2. Tuber Inspection Standards

Factors	Foundation Seed (G2)	Stock Seed (G3)	Extension Seed (G4)
Brown rot and soft rot (max)	0.3 %	0.5 %	0.5 %
Common scab, black scurf, powdery scab, late blight (high infestation) (max)	3.0 %	5.0 %	5.0 %
Dry rot (max)	1.0 %	3.0 %	3.0 %
Damage by potato tuber mush (max)	3.0 %	5.0 %	5.0 %
Root knot nematodes (max)	3.0 %	5.0 %	5.0 %
Varietal mixture (max)	0.0 %	0.1 %	0.5 %
Mechanical damage, insect damage and damage by small animals	3.0 %	5.0 %	5.0 %