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Farm demand for quality potato seed in Indonesia

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Abstract

Seed is the one of the most costly components of potato production in developing countries. Since potato is a vegetatively reproduced crop, diseases such as viruses build up and yield declines as tubers are saved from one harvest for use as seed the next season. Replacing farm-saved seed with clean seed is one means to increase yield, but information asymmetry between buyers and sellers on seed quality may restrict market supply of this input. In this article we develop a model of the seed market in which clean seed is treated as a capital good providing benefits over several seasons. To determine farm demand for clean seed, we conducted a survey of 182 potato farmers in the major potato growing areas of Indonesia to elicit their perceptions of seed quality from different sources, and derive farmers' "willingness-to-pay" for quality potato seed. Results indicate that the effects of information asymmetry on seed supply may be partially offset by the "reputation" of specialized seed producers. Nevertheless, marginal returns to disease-free seed appear to significantly exceed marginal costs, indicating that improving supply of quality seed will contribute strongly to productivity growth in potato. We discuss several policy options to encourage supply and utilization of quality potato seed.

JEL classification: Q11, Q12, Q18

Keywords: Asymmetric information; Informal seed system; Market failure; Seed certification; seed policy; Tissue culture

1. Introduction

One of the major constraints facing crop production in developing countries is a lack of low-cost, quality seed. This is especially true for vegetatively reproduced crops such as potato (*Solanum tuberosum*), because diseases tend to accumulate in vegetative material over time causing yield to decline. Farmers therefore need to periodically replenish their seed stocks from an outside source thought to be "clean." But since visual inspection is insufficient to reveal seed quality in potato (Struik and Wiersema, 1999), market supply of quality seed is constrained by information asymmetry between the buyer and seller. In tropical environments, market failure is compounded by technical difficulties in producing quality seed due to high disease pressure. For these reasons potato seed supply has been the target of many public-sector initiatives to improve potato productivity in developing countries.

Various approaches have been tried or suggested to improve supply of quality potato seed in developing countries. Some countries have relied 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 the exporter. Other countries have sought to replicate certified seed systems of industrialized countries to supply quality potato seed, often with foreign technical and financial support. Many of these projects, unfortunately, have not had a good track record of sustainability after the project support ended (Crissman, 1990). Furthermore, the certification standards used by formal seed systems in industrialized countries for temperate regions may not be appropriate for developing countries in tropical environments (Tripp, 1997). Others argue that considerable success can be achieved by introducing stepwise 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.[1]

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[1] Technical advances have made it possible to produce market-grade potatoes directly from the tiny botanic seeds found in the tomato-like fruits of the potato plant, know as true potato seed, or TPS (Simmonds, 1997). However, on-farm evaluations in the 1990s showed that TPS is not economically viable in most developing countries where it has been tested, including Indonesia (Chilver et al., 1999). Therefore, TPS is not examined as a seed strategy in this article.

Indonesia presents a good laboratory for assessing alternative approaches to improving the supply of quality potato seed. Over the past several years there have been several efforts underway in Indonesia to supply higher quality potato seed and to lower its cost to farmers. Though not a traditional staple food in Southeast Asia, potatoes are becoming an important agricultural commodity in the region (Fuglie et al., 2003). In Indonesia, annual potato production grew from around 120,000 tons in 1970 to nearly 1 million tons by 2000, a rate of growth unequaled in any other country of the world over this period (FAO, 2003). To supply the growing demand for potatoes in Indonesia, both the private and public sectors have been involved in improving the availability and quality of potato seed. Indonesia regularly imports a modest amount of certified potato seed from countries in temperate zones. In addition, Indonesia recently established its own formal seed production and certification system. Local private seed companies are another source of clean seed: in the 1990s, a number of companies began producing disease-free potato seed in Indonesia using micropropagation (tissue culture) methods. Finally, farmers themselves have developed an "informal" seed system to manage and renovate their potato seed stocks.

In the next section we present a model of the market for seed, in which clean seed is treated like a capital good—it provides superior services over farmers' traditional sources of seed for several seasons until its quality deteriorates due to diseases and other factors. While the model is constructed with vegetatively reproduced crops in mind, the issue of seed quality degeneration also applies to other crops. For example, in South Asia, wheat seed is periodically replaced both as a means of assuring seed quality, varietal purity, and for avoiding breakdown of resistance to rust disease (Heisey and Brennan, 1991). Farmers in eastern Africa often save the progeny of hybrid maize for seed to reduce seed costs despite sharply reduced yield in subsequent generations (Small and Jayne, 2003). We then apply our model to examine farm demand for quality potato seed in Indonesia. We conducted a national survey of potato growers to elicit information on farmer seed practices and perceptions of seed quality from different sources. From these data we examine farmers' seed management strategies and derive a theoretical "willingness-to-pay" for quality seed. The final section contains conclusions and implications.

2. Methodology

Previous models of farmers' demand for replacement seed can be found in Heisey and Brennan (1991) and Crissman and Hibon (1996). Our conceptual model differs from these models by endogenizing the price of seed as a function of quality. Further, we introduce information asymmetry on seed quality between buyers and sellers. We assume that farmers have access to a source of "disease-free" seed but cannot distinguish quality differences among subsequent generations of this seed unless they multiply it themselves. We begin with a description of the farmer's optimization problem in which producers take prices as given and seed is treated as a capital good that depreciates over time. Then we aggregate to the level of the market to derive equilibrium prices for seed of different known qualities.

In our model, we assume that seed saved from previous generations of the farmer's crop gradually loses quality through the build up of diseases and other factors. Yield from a farmer's saved seed declines over seasons and eventually stabilizes at a low level, say y^f. Disease-free 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 it too eventually degenerates until yield again stabilizes at the same yield as farmers' original seed.[2] A farmer chooses between buying disease-free, or "quality" seed, versus using farm seed in order to maximize the present value of net returns, or profits.

Gross benefits to a 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

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

where e is the exponential function, r is the (monthly) discount rate, and P_t is the market price of potato at 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).[3] The difference in crop yield between certified seed and farm seed ($y_t^c - y^f$) is highest in the first season of use ($t = 1$) but falls in subsequent generations.

Now, consider the change in costs associated with using quality seed. These include the (presumably higher) price paid for the quality seed times any change in seeding rate and changes in the use of other inputs. The present value of the change in costs is given by

$$\text{Seed Costs} = \left(W^c q_0^c - W^f q^f\right) + \sum_{t=1}^{T} e^{-r\lambda(t)} \left[W^f\left(q_t^c - q^f\right) + \sum_{i=1}^{N} W_i\left(x_{ti}^c - x_i^f\right)\right], \tag{2}$$

[2] Experimental evidence has shown that virus infection (the main cause of yield degeneration in vegetatively reproduced crops) tends to increase over generations of seed use in a sigmoid fashion so that yield loss will at first accelerate and then stabilize at some low level once there is 100% infection in the planting material (Struik and Wiersema, 1999).

[3] $\lambda(t)$ 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.

where W^c is the market price of quality seed and W^f is the price or opportunity cost of farmer's seed. The seeding rate for improved seed is q_t^c, and for farm seed it is q^f. A farmer may also change the use of other inputs (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.

We introduce information asymmetry in seed quality by assuming that once quality seed has been used, in subsequent generations its market value is the same as farmer's own seed, even if it still continues to out-yield farm-grown seed. While a farmer may know that the 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 above the price of regular farm seed.

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 Eq. (1) gives a result greater than Eq. (2). To simplify the model, we assume that the market price of potatoes remains constant over time[4] 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. The profitability π of improved seed is then

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

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

For a population of farmers each growing potatoes on a small parcel or parcels of land, the performance of quality seed might not vary much across their plots. However, the benefits of quality seed may vary significantly among 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. Some farmers may not find the improved seed to be profitable, 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 quality 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 greatest, and second farm to adopt is the one where the yield advantage is next greatest, and so on. Then, at the margin, the yield difference between quality seed and farm seed falls as more farmers adopt it. Let ΔY_t^c be the aggregate increase in yield achieved by all farmers who adopt quality seed, and let $\Delta Y_t^c\,(Q^c)$ be the aggregate "yield improvement function" from farmer adoption, where $Q^c = \sum q^c$ is the total amount of improved seed purchased by farmers.[5] The positive but declining yield improvement as more farmers adopt implies that $\Delta Y_t^{c\prime}(Q^c) \geq 0$ and $\Delta Y_t^{c\prime\prime}(Q^c) < 0$ (i.e., the yield improvement earned by adopting farmers is positive but the marginal level of improvement falls as more farmers adopt it).

With these notations and assumptions, we can now derive the aggregate farm demand for improved seed. Rewriting Eq. (3) for the aggregate net return from seed to all farmers who adopt it

$$\Pi(Q^c) = \sum_{t=1}^{T} e^{-r\lambda(t)} P\,\Delta Y_t^c(Q^c) - Q^c(W^c - W^f). \tag{4}$$

For farmers who adopt quality seed, the first-order necessary condition for profit maximization is

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

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

It is convenient to normalize prices on the market price P for consumption grade potatoes (referred to below as "table" potatoes) by letting $\hat{W}^c = W^c/P$ and $\hat{W}^f = W^f/P$. Solving Eq. (5) for $\hat{W}^c$ gives the inverse farm demand function of improved seed, i.e., the market price of improved seed as a function of quantity demanded:

$$\hat{W}^c(Q^c) = \hat{W}^f + \sum_{t=1}^{T} e^{-r\lambda(t)} \Delta Y_t^{c\prime}(Q^c). \tag{6}$$

Equation (6) has a simple interpretation. The unit value of quality 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 quality seed. The "marginal increase in yield" is the yield increase obtained from the last farmer to adopt quality 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 near the margin) would just barely break even from adoption. Furthermore, under our assumption of declining marginal benefits from adoption (i.e., $\Delta Y_t^{c\prime\prime}(Q^c) < 0$), farm demand for seed falls as the price of quality seed rises. Finally, note that the

[4] Actually, it is the expected future price of potatoes that enters the calculation of (expected) net profits. We assume that a farmer bases this expectation on his or her past 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 the price of table potatoes, the effects of price variation can be taken into account by "normalizing" seed prices on the price of table potatoes, which we do later in the model.

[5] We use small letters (q, x, y, π) to represent input levels, yield, and profit by individual farmers, and capital letters (Q, X, Y, Π) to present aggregate input, yield, and profit by all farmers who adopt improved seed.

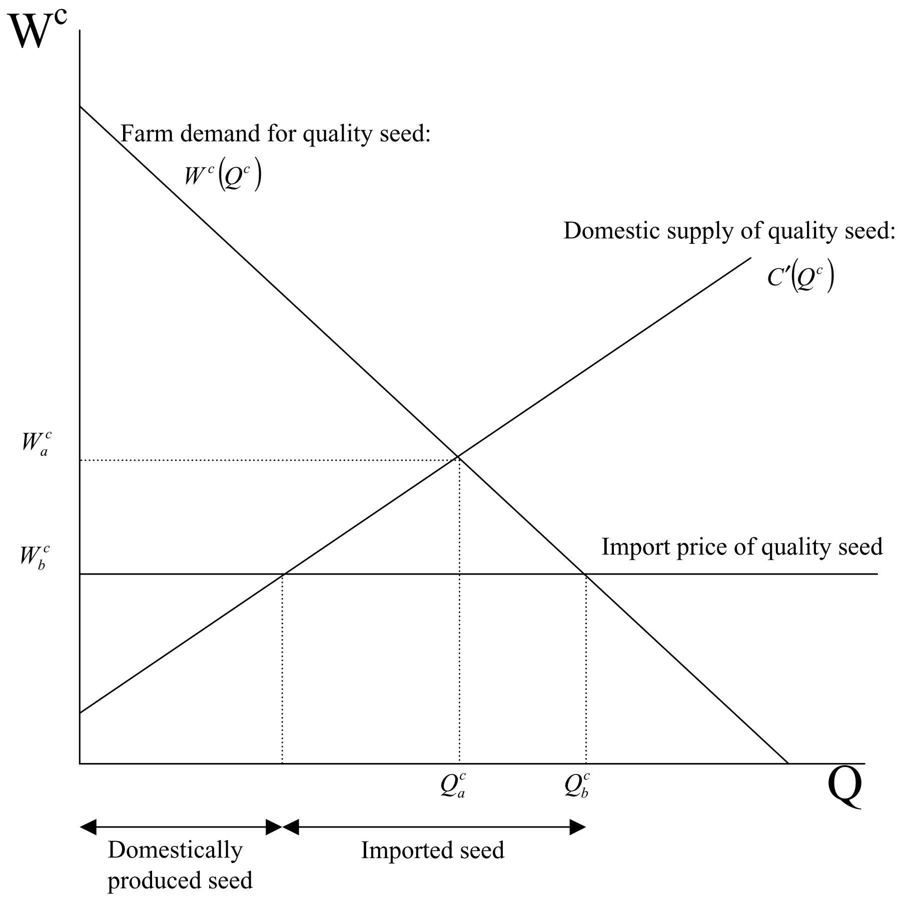

Fig. 1. Model of the market for quality potato seed.

amount of quality seed that passes through market channels 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 quality 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. We can further use the model to determine the optimal number of seasons a farmer should keep seed before renovating his seed stock. This can be done by comparing, in season 2 and subsequent seasons, the present value of net benefits from continuing to use the progeny of improved seed or replacing it with newly purchased quality seed each season. The optimal number of seasons to keep seed will be influenced by the price of quality seed and the discount rate.

To complete the model of the seed market, we need to specify the supply function for quality seed. If imports of certified seed are allowed[6] and the importing country is a relatively small importer, then the import price specifies a perfectly elasticity source of supply of improved seed. Domestic producers of quality seed face a cost function given by $C(Q_D^c)$ where $C'(Q_D^c) > 0$. The marginal cost of producing quality 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.

We can now solve the equilibrium market price for improved seed. If imports are not allowed, then all improved seed must be provided by domestic seed producers. In Fig. 1, the equilibrium price and quantity supplied of quality seed in the absence of imports is given by the intersection of the farm-derived demand for seed ($W^c(Q^c)$) given in Eq. (6) and the supply (marginal cost) function of domestic seed producers ($C'(Q_D^c)$). This results in a supply of Q_a^c of improved seed sold at price W_a^c. If imports are allowed, then according to the market structure in Fig. 1 the resulting supply of improved seed will be Q_b^c selling at price W_b^c. Part of the supply of quality seed is provided by the most efficient domestic seed producers, and part through 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 was above W_a^c, all of the quality seed would be supplied by domestic producers even in the absence of trade restrictions.

The model provides a framework for examining the economic performance of alternative sources of potato seed supply. By

[6] Some countries severely restrict the importation of potato tubers on phytosanitary grounds while other countries allow importation so long as disease-free certification is provided by a recognized regulatory body in the country of origin.

comparing the yield performance and production management of different sources of seed over generations, we can draw conclusions regarding the value of the corresponding types of seed to farmers. To test the model, we interviewed a random sample of 182 farmers from the five most important potato production areas in Indonesia. Interviews were carried out between October 2001 and May 2002 and covered 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. Village leaders then provided a list of potato farmers in the selected villages, and from this list 10 farmers were randomly chosen and interviewed. Thus, about 40 farmers were interviewed in each of the following provinces: 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 18 farmers) were selected for the survey. Together, the five provinces where we conducted our survey account for about 95% of Indonesia's total potato production.

3. Results

The results of our farm survey show that small-scale farms dominate highland potato and vegetable production in Indonesia. The average cropland owned by a farm in our survey was 1.16 ha (Table 1). Many farmers also rented cropland, so that average area operated was 1.60 ha. State-owned forest and estate land were major sources of rented cropland for highland vegetable farmers. Even though these production areas are almost exclusively rainfed, most farmers harvested two or three crops a year from at least part of their land. Average cropping intensity (area harvested divided by cropland operated) varied from 1.25 in North Sumatra to over 2.0 in Central Java and West Sumatra. Potato was the most important crop in the highland vegetable system, with an average of 0.96 ha of potatoes planted per farm per year (Table 1).

By far the most important potato variety grown in Indonesia at the time of our survey was Granola (Table 2). Granola was 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 was grown on 91% of the potato area of our sample of farmers in 2000–2001. However, 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. About 6% of potato area was sown to processing varieties (Table 2). Processing potatoes were especially prevalent in West Java, where they were sold to processing factories in nearby Jakarta. The rest of the potato area was planted to an assortment of other varieties, including a popular farmer selection in East Java known as Ritex.

Table 3 describes the sources of potato seed sown in the 2000–2001 crop year by our sample of farmers. Nationally, 81% of growers used seed selected from their previous potato crop, while 43% purchased at least some seed from the market (some farmers used seed from more than one source). Farmers had their own naming system to identify the source and "age" of seed purchased in the market. Imported seed was known as "F1" by farmers, and its subsequent multiplications in the field were called F2, F3, etc. Of the farmers purchasing seed in

Table 1
Potato farming in Indonesia

	West Java	Central Java	East Java	North Sumatra	West Sumatra	Indonesia*
Annual potato harvested area in province (1999–2001 average ha)	25,548	10,591	7,330	14,530	3,899	68,819
Number of farmers interviewed	42	42	40	40	18	182
Average farm size (ha owned)†	1.51 [2.12]† (2.16)	1.10 (1.10)	1.11 (0.95)	0.90 (0.76)	1.17 (0.97)	1.16 [1.30]† (1.30)
Average farm land operated (ha)†	2.22 [5.19]† (2.27)	1.53 (1.53)	1.46 (1.03)	1.19 (0.78)	1.63 (1.44)	1.60 [2.29]† (1.49)
Average cropping intensity (ha harvested/ha operated)‡	1.61 (1.38)	2.12 (0.83)	1.06 (0.82)	1.25 (0.94)	2.23 (0.97)	Na.
Average potato area harvested per farm (ha/year)	1.34 (0.74)	1.87 (0.43)	0.46 (0.29)	0.46 (0.33)	0.47 (0.30)	0.96 (0.51)

Standard deviations in parentheses, Na. = not available.

Source: Area planted to potato is from Badan Pusat Statistik. Other data are from the authors' survey.

*The national average reported here is a weighted average of the five provinces (weighted by potato area in the province). These five provinces account for about 95% of Indonesia's potato production.

†In West Java, there was one very large farm in the survey (27 hectares owned and 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 square brackets.

‡Includes area planted to annuals and perennials.

Table 2
Potato varieties grown by farmers in Indonesia in 2002

	West Java	Central Java	East Java	North Sumatra	West Sumatra	Indonesia*
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

Granola is almost entirely sold in the fresh market and is by far the dominant variety grown in Indonesia. It is not suited for processing, however, because of its high sugar and low dry matter content. Varieties used for processing (which can also be sold in the fresh market) include Atlantic, Columbus, Heart, and Panda. Other varieties consist mainly of Ritex, a farmer-selected variety popular in East Java.
Source: Authors' survey.
*The national average reported here is a weighted average of the five provinces (weighted by potato area in the province). These five provinces account for about 95% of Indonesia's potato production.

2000–2001, about 21% bought imported seed. Another source of seed was minitubers developed through micropropagation (tissue culture) by private companies in Indonesia. These companies produced small pea-sized minitubers from tissue culture plantlets (called "G0") and multiplied it once further to get egg-sized minitubers ("G1"). Both G0 and G1 were grown in net houses to prevent virus infection from aphids. Subsequent multiplications of the minitubers in the field produced normal-sized tubers and were referred to by farmers as G2, G3, etc. About 14% of farmers who purchased seed bought G0 or G1 from private companies. But most purchased seed was obtained from other farmers or seed traders: two-thirds of the farmers who bought seed in 2000–2001 obtained in through the informal seed system. In total, about three-fourths of the annual seed need of the farmers in our sample were from self-supply, and one-fourth was purchased from the market.

Table 3
Source of potato seed used for the 2000–2001 cropping season (% of farmers)

Sources of potato seed*	West Java	Central Java	East Java	North Sumatra	West Sumatra	Indonesia†
Imported seed (F1)	14.6	7.1	2.5	0.0	16.7	8.6
Seed from private companies using tissue culture (G0 or G1)	9.8	0.0	7.5	0.0	11.1	5.6
Seed from other farmers or traders	19.5	38.1	27.5	32.5	55.6	29.0
Seed self-supply	85.4	85.7	75.0	75.0	66.7	80.6

Source: Authors' survey.
*According to the farmer's nomenclature, F1 is imported seed that was certified to meet the seed standards of the exporting country, and G0 and G1 are seed produced locally using micropropagation methods (tissue culture) in net houses to protect the potato plants from aphids and other insects that may transmit viruses.
†The national average reported here is a weighted average of the five provinces (weighted by potato area in the province). These five provinces account for about 95% of Indonesia's potato production.

Farmers generally considered imported seed (F1) and seed produced in net houses from micropropagation (G0 and G1) to be disease free even though it was not certified as such by the local seed certification authority. Farmers recognized that imported seed met certification standards of the exporting country, and they could identify G0 and G1 by the small size of these tubers and by procuring the seed directly from a company's production site. While farmers generally recognized that seed quality would progressively decline through subsequent field multiplication, they could not verify the age of field-multiplied seed unless they had produced it in their own fields. Nevertheless, many farmers in our survey indicated some knowledge of the age of seed purchased from other farmers, especially if this seed came from a known, "reputable" source.

Many farmers indicated that they based their decisions about seed renewal on the reported age of seed when purchased. Table 4 shows the frequency of seed renewal for farmers in our survey. We have separated out the responses from farmers in West Java from other provinces because this is a major area of seed multiplication in Indonesia for the informal seed system. Some producers in this province specialize as seed producers and supply other farmers in Java and elsewhere with field-multiplied seed (Adiyoga et al., 1999). All of the farmers in our survey from West Java thought they knew the age of seed when purchased, even seed purchased from other farmers through the informal system. Farmers in West Java generally renewed their seed every four seasons, more frequently than farmers in other provinces. In other provinces, only 73% of the farmers had an idea of the age of seed when purchased. Among these farmers, those who purchased "younger" seed indicated they planned to self-supply their seed longer than farmers who purchased "older" seed. Farmers buying imported or micropropagated seed renewed their seed stocks every six seasons, on average, while farmers buying seed that had already been field multiplied one to three times (F2 to F4 or G2 to G4) renewed seed stocks after an average of 4.7 seasons. Farmers purchasing seed older than F4 or G4 renewed their seed stocks after an average of 2.6 seasons (Table 4). However, farmers' perceptions on the age of seed purchased through the informal system should be considered as only approximations, as they had no independent means of verifying the age of seed procured through the informal seed system.

Farmers reported a wide variation in prices paid for purchased potato seed depending on the source (Table 5). Prices for imported seed (F1) ranged from Rp. 13,300/kg in West Java to Rp. 15,100/kg in West Sumatra, or six to eight times the market price of table potatoes. Micropropagated seed from local private companies (G0 and G1) costs about Rp. 10,000/kg, or about five times the price for table potatoes. Micropropagated seed was mainly available to potato growers in West Java where private

Table 4
Frequency of seed renewal as a function of the "age" of seed at purchase

Location		"Age" of seed at purchase*			
		F1, G0, or G1	F2–F4 or G2–G4	Older generations	Unknown
West Java (n = 40 respondents)	% of farmers purchasing this seed age for their seed renewal	22.5	77.5	0	0
	Mean number of seasons before renewal	4.00 (0.50)	3.74 (0.17)	–	–
	t-test of difference between means	0.49			
Other provinces (n = 132 respondents)	% of farmers purchasing this seed age for their seed renewal	22.6	44.7	8.1	26.6
	Mean number of seasons before renewal	6.11 (0.37)	4.67 (0.31)	2.55 (0.65)	4.21 (0.60)
	t-test of difference between means	2.94**	3.10**		

Source: Authors' survey.

*Farmers generally considered F1, G0 and G1 to be "clean" seed that had not been exposed to diseases. Subsequent multiplications (F2, F3, etc., and G2, G3, etc.) are done in farmers' fields where they are exposed to viruses and other degenerative factors. The older the seed, the more degenerative diseases are likely to have built up in the tubers, causing yield to fall.

** $P < 0.01$.

companies maintained most of their net houses used for seed production. The average price of seed supplied by other farmers or traded through the informal system was Rp. 3,600/kg, although the variation in price paid for farmer-traded seed was relatively high. The price differences charged for farmer-traded seed may reflect perceived differences in its quality. A common rule of thumb used by seed sellers and traders was to price seed sold through the informal seed system at 1.5 times the current market price for table potatoes, although some seed sellers charged as much as Rp 7,400/kg, or 3.7 times the price of table potatoes.

The fact that at least some farmers were willing to pay substantially different prices for seed reflected their perception of differences in quality. In our survey, farmers were asked to estimate the expected yield from potato seed purchased from different sources over four generations of use, for each variety and seed source. They were usually able to provide reasonable estimates of the expected rate of yield degeneration over successive seasons, provided they had experience using seed from that source. But since not all farmers had experience using seed from all listed sources in the survey, response rates to this question varied depending on the variety and the source of seed. For the variety Granola, 158 out of a total of 182 farmers in the survey provided estimates of the expected yield of seed bought from other farmers or traders, 139 reported the expected yield of imported seed, 21 estimated the yield of micropropagated seed bought from private companies, and 10 gave estimates for the yield of seed that had been certified by the new government

Table 5
Average potato prices in 2000–2001, by source of seed

Source of seed	West Java	Central Java	East Java	North Sumatra	West Sumatra	Indonesia*
	(Rp/kg)					
Imported potato seed (F1)	13,278	14,583	14,000		15,125	13,833
	(1,236)	(1,572)	(†)		(2,750)	(1,244)
Potato seed supplied by private companies using tissue culture (G0 or G1)	10,167					10,167
	(1,756)					(1,756)
Potato seed supplied by other farmers and seed traders	4,056	3,329	3,362	3,058	4,045	3,614
	(2,270)	(1,285)	(1,172)	(1,176)	(1,313)	(1,795)
Table potato price at harvest	1,700	2,196	2,213	1,531	2,307	1,945
	(690)	(905)	(573)	(652)	(1,236)	(834)
	(normalized price—seed potato price/table potato price)					
Imported potato seed	7.81	6.64	6.33		6.56	7.11
Potato seed supplied by private companies using tissue culture	5.98					5.23
Potato seed supplied by other farmers and seed traders	2.39	1.52	1.52	2.00	1.75	1.86
Table potato price at harvest	1.00	1.00	1.00	1.00	1.00	1.00

Standard deviation in parentheses.

Source: Authors' survey.

*The national average reported here is a weighted average of the five provinces (weighted by potato area in the province). These five provinces account for about 95% of Indonesia's potato production.

†Only one observation was available on the price of imported potato seed in East Java, so no standard deviation is given.

Table 6
Expected yield and yield degeneration of potato seed from different sources (Variety = Granola)

Seed source	Number of farmers responding	Expected yield from seed by generation* Mean values (t/ha)			
		1st	2nd	3rd	4th
Publicly certified seed	10	23.6 (3.06)	22.9 (2.50)	22.1 (2.71)	17.8 (2.80)
Imported seed	139	20.0 (0.66)	21.3 (0.68)	19.7 (0.65)	15.9 (0.84)
Seed supplied by private companies using tissue culture	21	19.0 (1.32)	18.3 (1.64)	17.6 (1.64)	13.0 (1.69)
Seed sold by other farmers and seed traders	158	17.5 (0.57)	16.2 (0.55)	14.5 (0.56)	12.1 (0.61)

Standard errors of means are in parentheses.
Source: Authors' survey.
*Underlined yields are statistically lower ($P < 0.10$) than 1st generation yield according to a t-test of differences in means.

potato seed certification system (Table 6). Estimates for private-sector micropropagated seed and publicly certified seed were only provided by some farmers in West Java, as these sources were not widely available in other provinces. Furthermore, estimates of the rate of yield degeneration for varieties other than Granola were spotty, so the rest of the analysis reported below is limited to this variety.

The average farmer response on yield over time from seed from different sources is shown in Table 6. Farmers expected that potato seed from all sources would degenerate over time and give lower yields when saved for planting in subsequent seasons. Moreover, the rate of yield decline was expected to accelerate in generationally older seed. One exception is that the yield of imported seed was expected to increase slightly between the first and second generation 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 season was also expected to decline. These trends generally conform to our *a priori* expectations based on discussions with potato specialists and with results of experimental evidence (Struik and Wiersema, 1999; Khurana and Singh, 1988; Jandan et al., 1980).

Based on the model of farm demand for quality seed presented in the previous section, a theoretical "willingness-to-pay" for quality potato seed in Indonesia was estimated. The results are shown in Table 7. The "willingness-to-pay" for seed is defined as the maximum amount a farmer could afford to pay and still gain economically from purchasing the seed. It is based on the average rate of yield degeneration reported in the survey and reported in Table 6. Table 7 also shows the average price paid for seed, which our model predicts should be roughly equivalent to the marginal willingness-to-pay for the seed in market equilibrium. At nominal discount rates of 2%/month and 3%/month,[7] the willingness-to-pay for farmer-traded seed is within the range of actual prices reported for this seed source (Rp. 3,500 to 4,000/kg). In other words, the value of farmer-traded seed appears to be close to the cost of this seed as described by the model of the seed market. For private-sector micropropagated seed, the willingness-to-pay exceeds the market price at a low discount range (2–3%/month) but it approaches the market price at a high discount rate (4–5%/month). For imported seed and publicly certified seed, the estimated willingness-to-pay is significantly above the market price even at a high rate of discount. For these sources of seed, it appears that benefits exceed the additional costs of this seed.

Below we offer some possible explanations for why the reported marginal benefits of quality seed appear to exceed its

Table 7
Market prices and estimated average "willingness-to-pay" for potato seed from different sources

Seed source	Approximate market price (Rp/kg)*	"Willingness-to-pay" for seed (Rp/kg) Nominal monthly discount rate (%)			
		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†	2,700				

The "willingness-to-pay" for potato seed is a theoretical concept and is not based on an expressed opinion of farmers. Rather, it is the seed price at which the present value of added benefits from using this seed source would just equal the added seed cost. It is derived from the farmer estimates of yield gains reported in Table 6.
Source: Authors' survey.
*Approximate market prices taken from survey results in Table 5. The price of publicly certified seed is set by the public seed system at 4.5 times the current farm price of table potatoes according to government policy.
†The opportunity cost of own saved seed is determined by adding the cost of seed storage to the harvest price such that saved seed is "ready to plant" Storage costs include interest, value of losses, labor, and materials for four months of seed storage. The harvest price of table potatoes assumed to be 2,000 Rp/kg.

[7] The nominal interest rate is the real discount rate plus the rate of price inflation. Among farmers in our survey, 45% reported obtaining credit for agricultural purposes in 2000–2001 and paying an average of 2.14% per month on loans averaging six months in duration. About 10% of the farmers obtaining credit reported paying interest of more than 5% per month. It is likely that farmers who did not use credit would have had to pay similar or higher rates of interest for agricultural credit.

marginal cost. It is possible that the results could be due to measurement error: the sample size is not very large (182 farmers out of about 60,000 potato growers in Indonesia), and their estimates of yield as a function of seed age should be viewed as only approximations. However, yield differences of 30–50% between disease-free seed and farmer-saved seed are consistent with results from experimental evidence from other countries. Another explanation, which we think is of particular importance, is that the informal seed system may be partially overcoming market failure due to asymmetric information on seed quality through the "reputation" of the seller. Reputation in the informal seed system may have provided farmers with an intermediate seed option between local seed of unknown quality and expensive of more assured quality. However, establishing and maintaining reputation in the informal seed system likely involves relatively high transactions costs that create an entry barrier for new potential seed suppliers. Therefore it may not be a very efficient means at overcoming information asymmetry about seed quality. A third possible explanation for the differences between willingness-to-pay and the market price for quality seed in Indonesia is that the estimates of willingness-to-pay are average, not marginal, benefits, at least for the group of adopters of this type of seed. Thus, the last farmer to adopt quality seed may not realize the same benefit suggested by the average value. Nevertheless, the model appears to do a reasonable job at predicting the value of farmer-traded seed, the most important source of seed renewal in our farm sample.

A final explanation for the discrepancy between the value and cost of seed is that the seed market may not be in equilibrium. In fact, there is indirect evidence of significant undersupply of quality seed in Indonesia. For publicly certified seed, the market price is actually not determined by market forces but rather it is subsidized by the seed authority. Conversations with farmers during our survey indicated that the supply of publicly certified was significantly below farm demand: Many farmers expressed a wish to buy this seed but could not find it available on the market. For imported seed, nontariff barriers and seed regulations may restrict timely availability of seed. In 2002, for example, seed imports were temporarily banned after a new potato disease (the potato cyst nematode *Globodera rostochiensis*) was detected in Indonesia. Furthermore, Indonesian seed law—although not strictly enforced—requires varieties to be officially registered by the Indonesian Seed Board before they may be legally marketed in the country. These legal and regulatory uncertainties add to the cost of seed imports and may discourage its supply. All of these factors may serve to limit the supply of quality potato seed in Indonesia.

4. Conclusions and implications

Improving the supply and lowering the cost of disease-free potato seed is a significant challenge in potato production. Asymmetric information on seed quality between buyers and sellers constrains the market supply of improved seed. In developed countries, formal seed certification systems provide assurances to buyers on seed quality, but such systems are often lacking in developing countries. Most farmers rely on the informal system to obtain their seed. In this system, they save a portion of their harvest as seed and periodically renovate their seed stocks by purchasing seed from other farmers or traders when their own seed has degenerated due to the build-up of diseases and other factors.

Our study of the market for potato seed in Indonesia revealed that producers are well aware of the value of quality seed in potato production. Farmers generally recognized that disease-free seed would significantly out-yield farm seed and seed traded through the informal seed system, and that these yield gains would persist for several generations of use. The principal constraint to the wider use of quality seed was its high cost: disease-free seed (either imported or produced locally through micropropagation methods) costs three to four times as much as seed purchased through the informal system. Furthermore, if a farmer faces a high discount rate, the net benefit of quality seed is reduced since the value of future improvements in crop yield is more heavily discounted. Even at current seed prices and relatively high discount rates, however, it appears that many farmers could benefit from increased use of quality seed, whether supplied through imports or locally produced.

Policymakers wishing to improve technology and inputs for potato production face trade-offs between alternative seed strategies. A relative liberal policy toward seed imports would provide farmers with a more reliable source of high-quality, although expensive, seed. Policies to promote competition among importers, such as relaxing quarantine and variety registration regulations, may help increase the supply and reduce the cost of imported seed. However, the drawbacks of increased reliance on seed imports include a greater likelihood of inadvertent introduction of exotic seed-borne pests or diseases, and possible restriction of varietal choice to foreign-bred varieties (although this drawback could be overcome by contracting seed growers in exporting countries to produce seed of local varieties).

A second policy option is to promote local public and/or private production of quality seed, for example through establishment of formal seed certification systems and use of micropropagation (tissue culture) methods. The recent experience of Indonesia suggests, however, that this option has not yet proven to be financially or technically sustainable. Disease-free seed produced by the private sector appeared to be initially successful but later proved to be financially unsustainable (Fuglie et al., 2005). The public-sector seed certification system that has been developed in West Java has produced a limited supply of disease-free seed but this seed has been heavily subsidized (Fuglie et al., 2005). Without subsidies, it will be difficult for these systems to compete with imported seed. Restricting imports of seed would help local seed producers 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 strengthen the informal seed system itself, through technical training to farmers and seed growers and by the adoption of relaxed certification standards. Currently, the informal system appears to partially offset the effects of asymmetric information between seed buyers and sellers through the "reputation" of the seller. However, such a system is likely to involve high transactions costs and serves as an entry barrier for new seed suppliers. Since degenerative seed-borne factors tend to accumulate over time, an independent means of verifying the age of locally multiplied seed, even though it may not meet the criterion of "disease free," may serve to increase the supply of seed of intermediate cost and quality. At the farmer level, most farmers do not currently distinguish between their seed crop and table potato crop, simply keeping the smaller-sized tubers from the harvest as seed and selling the larger tubers to the market. Instead, farmers could be trained in seed plot techniques, thereby enhancing the quality of their saved seed and reducing the rate of seed degeneration. But the potential gains from these approaches need to be further validated for the case of Indonesia.

Policies to support the potato seed system cannot 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 from abroad. New varieties that have resistance to degenerative seed-borne diseases such as viruses are likely to be popular with farmers because farmer-saved seed of these varieties can be used for a longer period (Walker, 1994). Technologies that intensify crop production, such as 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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