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ABSTRACT

Potato is a crop of growing importance in Indonesia. Small potato farmers are currently dependent on costly European potato seed. Seed quality and availability are widely perceived as the major constraints for improving yields. Since 1988 farmers have experimented with botanical or True Potato Seed (TPS) as an alternative to imported seed. Earlier studies suggested that the future was bright for TPS in Indonesia. This research, based on a longer period of monitoring and data collection, indicates that the cost savings from TPS do not compensate for higher initial yields and lower rates of yield decline of the European variety in farmers' fields in West Java. The economic viability of a TPS-based seed system hinges on competitive TPS yields in the first generation in which they are grown from botanical seed. Improved TPS progenies are needed to achieve and maintain high yields in Indonesian conditions which place a premium on earliness and late blight resistance.

BACKGROUND

Potato is a crop of growing importance in Indonesia's horticultural sector; planted area has expanded from 26,000 ha in 1981 to around 40,000 ha in 1989; average yields have also risen from around 7 t/ha in 1981 to approximately 13 t/ha in 1989 (DJPTP, 1991). Growing demand for potato exports to Singapore and Malaysia, an expanding tourist and processing industry in Indonesia, and growing domestic consumption which increased by 90 percent to 3.13 kg/capita between 1981 and 1984 (CBS, 1984) emphasizes this importance.

Potato has traditionally been an upland rainfed (> 900m) crop with both major cropping seasons during the wet season from October to May (Figures 1 and 2). If soil moisture can be maintained, potato is occasionally grown during the dry season when disease pressure is reduced, minimum temperatures are lower and ware prices are higher (Figure 3).

Potato farmers are currently dependent on imports to renew their seed stocks. Around 80 percent of the current potato area is planted to cv. Granola (Potts et al., 1992) which is imported from Europe and purchased by farmers at around $1,500 per ton, usually late in the year ready for planting during the second wet growing season (February to May). Other varieties from Europe are also imported at similar prices. Seed availability is dependent on the European growing season and is affected by uncontrollable external events; for instance, no seed shipment was received in 1991 because of the Gulf War. The high price of seed means that ware production is not usually viable until further seed multiplication is carried out. Ware producers usually purchase third or fourth generation seed which is often infected with bacterial, fungal, and viral diseases.

Thus seed quality and availability are widely perceived as the major constraints to improving potato yields. As a result, considerable research efforts have been made to alleviate this constraint, including the utilization of True Potato Seed (TPS).

TRUE POTATO SEED (TPS)

TPS is the sexual seed found in potato berries. TPS has been used as an alternative to tuber seed in parts of China and has received attention from researchers in industralized countries. Over the past 15 years, the International Potato Center (CIP) has invested considerable resources in developing TPS into a viable alternative seed technology to vegetative reproduction (seed tuber)

to overcome the major problems of potato seed quality and availability in developing country agriculture.

TPS is a radical and clearly identifiable new technology which was developed for cash-constrained small potato farmers. A rich experience of on-farm testing and experimentation with TPS is accumulating in several countries including Egypt, India, Nicaragua, and Indonesia. Because of the importance of degeneration rates in conditioning profitability and varietal choice, information from several years is needed for a reliable comparative evaluation of the economics of TPS. This research, based on a longer period of monitoring the comparative performance of TPS in farmers' fields, updates earlier reports which concluded that TPS was promising.

INITIAL INDICATIONS OF TPS VIABILITY

On-station research began in 1983 to identify appropriate TPS progenies and cultural practices (Asandhi & Satjadipura, 1985; Satjadipura & Sutapradja, 1985). On-farm research based on farmer-led experimentation began in 1988 and led to the rapid establishment of TPS use amongst farmers in Cibodas, West Java (Potts et al., 1992; Gunadi et al., 1992). In the first season, farmers grew TPS in beds to produce seedling tubers for planting in future seasons. Subsequently, all farmers chose to sow and then transplant TPS seedlings to the field, consistent with traditional vegetable seedling practices (Potts et al., 1992). Some of the resulting seedling tubers were further multiplied in subsequent seasons.

During the on-farm research activities in Cibodas in 1988, cost of production, and yield data were collected from four cooperating farmers. These data were combined with estimates of TPS prices and returns in a partial budget approach to determine the viability of TPS. Farmers achieved yields from TPS crops that were 80 percent of those estimated for imported Granola seed tubers (described by farmers as Granola G1), whilst reducing costs by around $1,750 per ha, equivalent to a reduction of production costs of around 55 percent. These results indicated an increase in net income from TPS compared with Granola G1 of $1,010 per hectare, largely because of reduced seed costs and to a leser degree because of reduced fungicide costs (Gunadi et al., 1992).

A similar study was subsequently conducted in Cibodas in 1990. Twenty farmers planting TPS and another 20 farmers planting degenerated Granola were surveyed (Rusdia, Unpublished). The results supported the earlier findings, indicating 10 percent lower production costs per hectare and 20 percent lower production costs per kilogram with TPS than with degenerated cv. Granola; in contrast to the earlier findings, TPS yields were 15 percent higher than Granola. This resulted in an increase in net income of approximately $5,000 per ha (Ibid, p.48).

Both studies implied a bright future for TPS in Indonesia, particularly as the data were collected from farmers. Several issues however suggest that these results should now be interpreted with caution as they may be time and situation specific.

METHODOLOGICAL ISSUES ARISING FROM PREVIOUS STUDIES

In the 1988 study, sample sizes were necessarily small. In the absence of imported seed, certain assumptions also had to be made regarding the yield performance of the tuber seed, a critical variable in determining relative crop profitability. At the time of this study,

"The TPS transplanted crop required approximately nine days less in the field than crops derived from tubers." (Gunadi et al., 1992:36-7).

However, more recent comments from the same farmers indicate that TPS material actually requires more time in the field than tuber seed (Chilver & Ameriana, forthcoming). Sinung-Basuki (Unpublished) also noted farmers used minimum inputs with TPS whilst it was still a new technology, allocating poorer quality land to TPS than their traditional seed crops and investing minimal effort in crop management to reduce the cost of the undesirable outcome of total crop failure. Both of these latter factors have implications for land utilization costs and other input costs which were not accounted for in the partial analysis.

In the 1988 study, the basis for comparison was imported Granola seed, therefore assuming that this was farmers' usual seed and their benchmark for comparison. In fact, these farmers rarely purchase imported seed, preferring cheaper degenerated material. In addition, the seed that the farmers did use in the study was given to them by the researchers as a form of repayment for the intensive cooperation given, which may have influenced the way they treated this Granola crop.

The intensive interactions among farmers and researchers may also have biased the results of the 1988 study and made them less representative for other farmers using TPS. Although good relationships between farmers and researchers might have encouraged the reporting of honest results, the intensity of technical advice received during these interactions would be expected to ensure a higher level of technical efficiency amongst these farmers than amongst those without the intensive and beneficial contact with researchers (e.g. TPS yields averaged 22 t/ha during the 1988 study, but around 8 t/ha in the current survey).

There were indications from the data collected in the 1990 survey that one-off or infrequent interviews with farmers were likely to mask variations among farmers in potato production practices. Rusdia (Unpublished:42) reports a coefficient of variation in TPS total input costs of only 2.5 percent across a sample of 20 farmers; the same figure from the current survey of 23 farmers in one season was 44 percent. Similarly, recent casual remarks made by farmers

indicated that they agreed on answers amongst themselves when they knew such a survey was to be made, and reported data that they felt was expected of them.

Neither of the two studies compared the performance of seedling tubers against the benchmark, Granola. To date, few farmers have sold the seedling tubers derived from their TPS crop (ie. G1 seedling tubers) as seed; similar to Granola, their preference is to multiply the seedling tubers over successive seasons to enable ware sales to be made. It is now becoming clear that farmers' evaluation of new seed material is long term, and certainly exceeds one growing season before a final adoption decision is made. Caution should therefore be exercised over the interpretation of results from one growing season. Such behavior exemplifies the point made by Antle & Crissman (1990:535) that technology efficiency evaluations are best made some time after initial introduction when the level of experimentation is likely to be reduced.

DATA COLLECTION

Informal observations indicated that potato production practices varied between farmers (eg. differences in seed quality and chemical input levels). To ensure these variations were accurately recorded, a multiple-visit survey design was selected where each farmer was visited at least once a week during the growing season, preferably in the field to prompt recollection of activities undertaken.

Data were collected on all potato crop activities in order to construct full crop budgets. Farmers were only given TPS and information regarding the production of potato from TPS using a bed system and transplants. For comparison, farmers used their own tuber seed, regardless of whether this was Granola G1 or G7. Farmer-produced seedling tubers were included in the comparisons. The survey was conducted over several seasons to monitor seasonal variations, seed degeneration, and also to monitor new farmers as they gained experience with TPS.

The original intention was to include farmers from Cibodas who had been included in the 1988 and 1990 studies. However, these farmers were unwilling to partake in the research unless given Granola tuber seed. Degenerated but supposedly healthy seed from a seed trial was reluctantly given, but this turned out to be less healthy than earlier thought. These factors combined to make data collection difficult amongst Cibodas farmers, who in any case were 'survey-weary', leading to suspicions that inputs and yields were under-reported. As a result, the data from Cibodas farmers will be presented separately because of reservations about their quality.

Meetings were held with farmers in four villages in the Lembang area in West Java during August 1991, prior to the main growing season. No farmers, other than those in Cibodas, had grown TPS before; some had grown seedling tubers in the past and wanted to grow TPS for themselves. Unfortunately, only two farmers had seedling tubers at that time to include in the evaluation. Around 125 farmers requested and received seedlots of between 2,000 - 10,000 seeds of various progenies. Each recipient's potato production plan for the imminent planting season was elicited; an agreement was made with each farmer intending to plant tuber seed, as well as TPS, permitting researchers to make visits twice a week to collect cost and return information regarding their potato crops.

It was originally intended that farmers should plant their TPS seeds with Granola in the same field to control for variations in environmental conditions. Few farmers did this, but when they did, ascertaining variations in management practices between the crops became difficult. For example, if both crops were sprayed with pesticide together, the farmer estimated that pesticide use and spraying time was split evenly between the crops according to relative crop area; however, observation of crop spraying revealed that the denser foliage of TPS crops often meant more pesticide and time necessary for TPS crops than for Granola.

During periods when farmers stored ware or seed potato prior to sale or replanting, less frequent visits were made to assess storage losses and sales made. Information regarding the farmers' social and economic status was also collected at a later date.

In view of the relatively small number of farmers who actually planted tuber seed and TPS in the same season, no sample selection criteria were applied (Table 1).

Two research assistants were employed full-time to collect data. Informal methods were used combining house and field visits to verify the information given by the farmer. All the data were subsequently categorized by crop and activity and stored in a database.

Over 50 percent of the farmers who had requested seed decided not to sow it in the coming season. A further five percent experienced very poor seed germination at sowing and did not wish to try again. In the first season, data were collected from around 40 farmers. This number was subsequently expanded to 65 over the following months into the second wet growing season (February to May), as other farmers saw the transplanted crops established in the field and requested TPS. All TPS crops were transplanted.

Table 1. Number of crops monitored by planting material and season.

		SEASON (Last planting date)				
Crop	Generation	WET-1 15-Dec-91	WET-2 30-Apr-92	DRY-1 15-Aug-92	WET-3 15-Dec-92	Total
TPS	0	21	44	5	2	72
Stuber[a]	1	0	0	20	7	27
Stuber	2	0	1	0	0	1
Stuber	3	0	4	1	0	5
Stuber	4	2	3	0	0	5
Stuber	5	0	0	1	1	2
Granola	1	1	7	0	0	8
Granola	2	2	1	2	2	7
Granola	3	4	3	4	0	11
Granola	4	18	4	5	2	29
Granola	5	2	4	3	1	10
Granola	6	1	3	1	0	5
Granola	7+	1	2	3	0	6
Total		52	76	45	15	188

[a] Seedling tuber.
Source: Multiple Visit Survey.

By the 1992 dry season (June-September), 24 farmers had first generation seedling tubers which they replanted. All seedling tuber crops were derived from transplanted crops. Few farmers planted TPS in this dry season. In order to gain an appreciation of the performance of successive seedling tuber generations, 18 farmers from Pangalengan district, where other TPS research hao been conducted, were included in the study.

PROFILE OF FARMER CHARACTERISTICS

Information on the relative socioeconomic status of farmers in the main survey was elicited (Table 2). It was universally agreed by farmers that wealth was reflected primarily by land ownership. In addition, assets such as animals, vehicles and homes were also counted and valued to provide a further indication of financial resources, particularly if a farmer owned no land. The correlation between asset value and land area owned was 0.7.

Farmers' level of education and role within the village community were also elicited. Previous experience of TPS or seedling tubers was determined by the number of times they had planted these crops themselves.

In view of the fact that the average landholding by farmers in this area is below 0.3 ha, the relative wealth of the potato farmers who experimented with TPS is apparent from Table 2.

Table 2. Summary of farmer characteristics.

Characteristic	Mean	Maximum	Minimum
Land Ownership (Ha)	1.6	8.0	0
Assets (M. Rp)[a]	6.4	50.5	1
TPS experience	0.5	5.0	0
Seedling Tuber experience	0.9	5.0	0

[a] ($1 = Rp. 2070)
Source: Multiple Visit Survey.

ASSUMPTIONS

Farmers used a wide variety of manures, fertilizers and chemicals. Farmgate prices incurred by the farmer were used for purchased inputs. It was assumed that the price paid reflected the quality and active ingredients of manure, fertilizer or chemicals, ie. transport-cost variations between sites did not appear to significantly influence prices. In the rare cases in which potato was intercropped with tomato or beans, the costs of any joint inputs were split based on the relative planted area.

Seed and ware prices were collected from farmers and local markets throughout the survey period. For farmers using their own degenerated seed, seed values were imputed based on the seed generation and current market prices. The occasional sales of seedling tubers that were made indicated that prices of seedling tubers were similar to prices for Granola tuber seed that had been multiplied one generation more. Seed values for seedling tubers were therefore determined using the following formula:

$$PR\ (Stuber{:}Gx) = PR\ (Granola{:}Gx+1)$$

where: PR = seed value
x = seed generation

The TPS used was imported at various prices and repackaged in vacuum sealed aluminium foil before being distributed free to farmers. A packet of 2,000 seeds was estimated to be worth approximately Rp. 2,000 or about US$1.00.

Where seed or ware sales were made, prices received were used to estimate returns. Potatoes consumed by the farmer, were usually partially damaged, of low quality, and therefore unmarketable. These potatoes were valued at 0.75 of the minimum ware price at harvest time. Potato stored as seed was valued at its market price when replanted, less storage losses and storage costs. Storage costs were assumed to be the same per storage period across all crops, but storage losses varied between crops (Table 11).

All tuber seed crops except one were cv. Granola; eight TPS progenies were grown as transplant crops and six progenies were planted as seedling tubers. For the purpose of comparisons between progenies, all progenies derived from the CIP-India breeding program were grouped together (HPS I/67, II/13, II/67, 7/13, 7/67) and compared against the two other popular progenies, Atzimba x DTO-28 and Atlantic x LT-7.

Family labor, a major input, was valued at the prevailing local market rate. Wage rates for women were approximately 70 percent of those for men, but rates varied between villages only a few kilometres apart. Where contract labor was paid on a piece-rate basis, total hours worked was imputed from market rates for men and women.

Most land planted to potato was owned by the farmer. To determine land values, a brief survey of the rental market was made. Three classes of land were broadly identified by farmers based on their proximity to a motorable road. Land opportunity costs were determined by the average rents in each class.

Farmers' access to credit is normally through traders, but other sources exist such as loans through cooperatives and from friends. Interest rates were assumed to equate to four percent per month.

CROP INPUTS

Seed

Seed rates were similar for Granola and seedling tuber crops at around 1.4 to 1.5 t/ha., but because of the high price of imported seed, seed alone accounted for 57 percent of Granola G1 variable costs. This decreased to between 40 and 26 percent with successive generations of Granola.

Producing TPS transplants ready for field planting (to a stage equivalent to a sprouted seed tuber) usually involved transplanting the seedlings from a seedbed to banana-leaf pots after two weeks, and managing these until they were sturdy enough for field planting.

These costs accounted for 15 percent of TPS variable costs on average, but varied among progenies.

Transplant establishment costs per transplant and per planted hectare were highest for the HPS progenies, in spite of these progenies having the lowest average transplant density (Table 3). HPS progenies exhibited the lowest initial seed viability; however, surviving seedlings were transplanted to the field after about five weeks, the same length of time as with other progenies. The higher transplant production costs with HPS progenies arose largely through extra labor costs during seedling management. Farmers probably managed these seedlings more intensively than they did other progenies, despite low and late initial emergence, because HPS became known as the best yielding progeny.

Table 3. Transplant production costs by progeny.

	HPS	Atz x DTO28	Atl x LT-7
% seeds surviving to pots	52	57	75
Costs per 1,000 transplants (Rp):			
TPS	2,500	2,500	1,700
Labor	6,800	4,100	4,900
Fertilizer	2,000	2,600	1,700
Fungicide	500	500	200
Other	100	100	200
Total	11,900	9,800	8,800
Transplants per ha.	43,712	52,241	43,545
Transplant costs per ha.(Rp)	520,173	511,962	383,196
Number of observations	32	19	17

Source: Multiple Visit Survey.

Fertilizer

The physical units of organic manure applied varied between 15 t/ha and 60 t/ha for chicken and cow manure respectively. The value of organic and inorganic fertilizers accounted for between 20 and 30 percent of variable costs, and remained fairly constant across various seed generations of Granola. TPS and G1 seedling tuber crops received fertilizer doses worth 20 percent more

than G1 Granola crops, but subsequent seedling tuber crops received fertilizer applications worth about 70 percent of those applied to Granola crops. This difference concurs with farmers' stated intentions to reduce the excessive and extended growth of seedling tuber haulms and stolons to enable earlier harvesting.

Pesticide

Chemical fungicides and insecticides accounted for 20 to 25 percent of variable costs; contact sprays were normally used and applied with hand or machine sprayers. Applications and their associated costs were expected to increase with the length of time a crop was in the field and with the incidence of pests and diseases, but to decrease with germplasm exhibiting some resistance to pests and diseases, particularly Phytopthera infestans (Late Blight). Late Blight is widespread, and therefore fungicide costs were expected to be greater during wet seasons when pressure is highest as contact fungicides require frequent re-application. Fungicides accounted for the greatest proportion of pesticide costs for all crops both in the wet (81%) and dry seasons (70%).

Pesticide costs for Granola crops in the dry season were 22 percent lower than in the wet season, despite the longer dry season growing period, due to less frequent sprays and less concentrated applications of fungicide (Table 4). Only Atzimba x DTO28 seedling tuber crops exhibited a similar pattern to Granola with lower overall pesticide costs in the dry season than in the wet, despite an average growing period of 10 more days. Contrary to expectations, Atlantic x LT7 and HPS progenies actually incurred higher chemical costs and more frequent sprays in the dry season, but sample sizes were small.

TPS crops exhibited lower labor, machine and fungicide costs in the dry season than the wet because of reduced late blight pressure which was further compounded by a shorter dry season growing period. The pattern of shorter dry season growing periods (unlike Granola) is likely because of the greater tolerance to late blight exhibited by the Atzimba x DTO28 and HPS progenies which discourages early harvest in the wet season, and greater susceptibility to drought stress which encourages early harvest in the dry season.

Comparisons between seed germplasm during the wet season revealed that Granola incurred the highest overall pesticide cost, closely followed by Atlantic x LT-7 seedling tubers, which had the highest fungicide costs (Table 4). This difference reinforces the farmers' observations that Atlantic x LT-7 was even more susceptible to Late Blight than Granola.

Table 4. Pesticide applications and costs ('000 Rp/ha.)

	WET SEASON						
	Cv.	Seedling tubers			TPS		
	Granola	HPS	ATZ	ATL	HPS	ATZ	ATL
Number of fields sampled	42	4	9	2	17	16	16
Kg/ha/season	66	50	65	77	81	80	50
Sprays/season	8.4	6.6	9.0	8.0	8.6	9.3	11.6
Growing season (days)	84	103	85	87	107	103	95
Costs per growing season per ha.:							
Fungicide	733	466	652	924	655	736	458
Other chemicals	248	43	279	135	124	108	198
Labor for application	215	142	139	162	144	170	261
Machinery	53	8	52	14	13	10	56
Total	**1,249**	**659**	**1,122**	**1,235**	**936**	**1,024**	**973**

	DRY SEASON					
	Cv.	Seedling tubers			TPS	
	Granola	HPS	ATZ	ATL	HPS	ATZ
Number of fields sampled	18	13	7	1	2	2
Kg/ha/season	55	53	61	120	56	24
Sprays/season	6.9	7.5	9.3	12.0	10.0	6.5
Growing season (days)	91	102	95	98	97	85
Costs per growing season per ha.:						
Fungicide	690	487	537	1,024	512	209
Other chemicals	157	169	252	500	270	119
Labor for application	106	122	152	82	138	135
Machinery	17	22	52	65	8	48
Total	**970**	**800**	**993**	**1,671**	**928**	**511**

Source: Multiple Visit Survey.

Farmers consistently observed that Atzimba x DTO28 and the HPS progenies were more resistant to Late Blight than their benchmark Granola and therefore required fungicide applications approximately half as frequently as Granola; however, due to the longer overall growing period and dense foliage of TPS and seedling tuber progenies, and the necessity to begin spraying transplants long before seed tubers have emerged, the net pesticide cost savings were reduced to 22 percent in the wet season and 26 percent in the dry season for TPS, and 19 percent in the wet season and 7 percent in the dry season for seedling tubers.

Labor

Most field activities involved a coordinated effort between both male and female labor, with women generally doing the physically lighter work. Gender-specific activities included crop spraying (male) and transplanting TPS seedlings to pots prior to field transplanting (female).

Field labor costs accounted for between 20 and 25 percent of variable costs for seedling tuber and Granola crops and around 30 percent of TPS crops. In absolute terms, however, average labor costs per hectare were similar across all crops during the wet seasons and TPS costs were higher than both tuber crops during the dry season (Table 5). The extra care and irrigation required when planting TPS seedlings meant that land preparation, fertilization and planting costs accounted for around 50 percent of TPS field labor costs. Average labor costs for seedling tuber and Granola crops were higher during the wet season than the dry, due partly to extra hilling-up, spraying and land preparation costs.

Table 5. Field labor inputs (monetary value) by crop.

Crop	Season	Labor costs[a] (rp/ha)	% of variable costs
Granola	WET	1,112,776	22
STuber	WET	948,138	22
TPS	WET	1,064,483	31
Granola	DRY	892,061	20
STuber	DRY	854,062	18
TPS	DRY	1,121,397	33

[a] Excludes transplant establishment labor with TPS and sparying.
Source: Multiple Visit Survey.

Land

Land costs ranged from Rp. 1,500/ha/day to Rp. 2,100/ha/day. These accounted for an insignificant proportion (2-4%) of overall costs although they ranged between Rp. 220,000/ha/season for the late maturing TPS progenies planted on prime land to Rp. 100,000/ha/season for Granola planted on the cheapest land.

Interest

The opportunity costs of investing in potato production were a significant proportion of total costs; these increased with production costs and the crop growing period. The high investment required for Granola G1 crops meant interest costs of Rp. 905,000 or 10 percent of total production costs. Interest costs for other tuber derived crops ranged between Rp. 400,000 and Rp. 600,000, accounting for around 10 percent of total costs for Granola and 12 percent of total costs for seedling tubers due to the generally longer seedling tuber growing period. Interest accounted for around 12 percent of TPS costs, and was slightly higher for the longer duration HPS and Atzimba x DTO-28 progenies than the Atlantic x LT-7 progeny.

YIELDS

Seasonal Factors

Both Granola and seedling tuber crops were left in the field for longer and gave higher average yields in the dry season than during the wet season; Granola marginally outyielded seedling tubers during both wet and dry seasons, despite the fact that on average the Granola seed consisted of more degenerated material (Table 6). TPS (transplants) yielded significantly less than tuber derived crops in both seasons, with the exception of HPS progenies in the wet season (Table 8), but TPS was rarely grown in the dry season due to its greater susceptibility to drought stress. These data contrast sharply with previous studies noting farmers' average wet season TPS yields of 22 t/ha and 15 t/ha (Gunadi et al., 1992; Rusdia, 1990 respectively).

Table 6. Average growing period and yields by season.

	Granola		Seedling Tuber		TPS	
	Days	Yield t/ha(SE)	Days	Yield t/ha(SE)	Days	Yield t/ha(SE)
Wet Seasons	84	13.1(1.1)	92	12.7(0.8)	103	7.8(0.8)
Dry Season	91	15.0(2.0)	99	14.9(1.8)	94	6.5(1.5)

Source: Multiple Visit Survey.

Yie'J variability was greatest amongst harvested TPS crops, even excluding the 14 percent of farmers who sowed TPS but failed to harvest a crop. However, it is interesting to note the generally higher yield variability of Granola compared to seedling tubers which held true across

generations (Table 7). This may imply that the heterogeneity of seedling tuber progenies confers greater yield stability across environments and seasons than the homogeneous cultivar Granola.

Table 7. Yield variability across seed generations.

Generation	Yield coefficient of variation (%)	
	Granola	Seedling Tubers
1	53	50
2	43	--
3	49	22
4	52	23
5+	55	42

Source: Multiple Visit Survey.

Inter Progeny Variation

There were noticeable differences between the yields of transplanted crops of different progenies. HPS progenies consistently and significantly outyielded Atzimba x DTO-28 and Atlantic x LT-7 as a transplanted crop and a seedling tuber crop, even when the difference in seed generations was taken into account (Table 8). The relative susceptibility of Atlantic x LT-7 to Late Blight was a significant factor in determining its low yields as a transplanted crop.

Table 8. Yield (kg/ha) variations between progeny.

Progeny	Crop	Season	Average Generation	Average Yield (SE)
HPS	TPS	Wet	0	12.1 (1.7)
Atz x DTO28	TPS	Wet	0	7.2 (1.3)
Atl x LT-7	TPS	Wet	0	4.0 (0.7)
HPS	TPS	Dry	0	7.2 (1.8)
Atz x DTO28	TPS	Dry	0	5.5 (2.7)
HPS	S.tuber	Wet	1.0	15.1 (1.0)
Atz x DTO28	S.tuber	Wet	3.4	11.2 (0.9)
Atl xLT-7	S.tuber	Wet	1.0	13.5 (0.8)
HPS	S.tuber	Dry	1.0	15.2 (2.1)
Atz x DTO28	S.tuber	Dry	1.9	11.7 (2.8)
Atz x DTO28	S.tuber	Dry	1.0	9.3 (2.3)

Source: Multiple Visit Survey.

Large tubers (Class A - over 40 grams) received 20 - 80 percent higher ware prices than medium (Class B) or small (Class C) tubers or chats (Class D) depending on the time of year. There were only minor differences in the proportion of large, medium and small tubers between Atzimba x DTO-28 and HPS progenies as transplants and seedling tubers (Table 9). The older Atzimba x DTO-28 seedling tuber material on average yielded a higher proportion of large tubers than Granola crops. The few Atlantic x LT-7 transplant and seedling tuber crops harvested had far fewer large tubers than either Granola or other TPS progenies, but they were planted at a higher density.

Table 9. Variations in yield size grades.

Progeny	Crop	Plant Density[a]	Average Proportion by Grade AB	C	D
HPS	TPS	41,750	58.3	38.4	3.3
Atz x DTO28	TPS	40,370	57.8	34.6	7.7
Atl x LT-7	TPS	42,470	17.6	65.1	17.2
HPS	ST	1,371	58.8	32.7	8.5
Atz x DTO28	ST	1,323	67.9	27.8	4.3
Atl x LT-7	ST	1,704	32.2	57.9	9.9
Granola	CV	1,467	63.2	33.4	3.4

[a] Plant density = transplants/ha or kg/ha.
Source: Multiple Visit Survey.

Seed Degeneration

Inter alia, yields of successive potato seed generations are expected to decline as seed is multiplied and tuber-borne diseases build up (Harris, 1978). Rates of yield degeneration are critical to farmers seed replacement needs, and to the viability of Indonesia's traditional seed system. A comparison was therefore made of the yield degeneration rates for Granola and for seedling tubers (Table 10).

In view of the limited data available on seedling tuber crops of generations older than one, only wet season data were used. Seedling tuber progenies were grouped as one, and the yield data were grouped into first, second and third, and greater than four generations. This concurs with the traditional system whereby first generation crops are usually harvested early to minimise soil pathogen infestation as the harvest is primarily destined for use as seed. Yields are therefore

not usually maximised. Second and third generation crops are often destined for use as seed as well as ware, while the bulk of fourth generation (and higher) crops supplies the ware market.

Table 10. Average wet season yields (t/ha) for tuber-derived crops.

Generation	Average yield (S.E.)	
	Granola	Seedling Tubers
1	14.86 (2.8)	14.66 (0.8)
2/3	13.88 (1.9)	12.44 (1.2)
4+	12.00 (1.4)	9.69 (1.0)

Source: Multiple Visit Survey.

Equations 1 and 2 below derived from farmers' tuber-derived crop yields in the wet season, indicate a lower yield potential and more rapid rate of yield degeneration with seedling tuber crops than Granola. However, the statistical validity of the equations is weak, and the only seedling tuber material available that was older than G1 was from the progeny Atzimba x DTO-28.

1. *Granola:* $Y = 16.4 - 0.93G \quad R^2 = 0.06$
   $(6.9) \quad (0.57)$

2. *STubers:* $Y = 15.8 - 1.28G \quad R^2 = 0.30$
   $(2.7) \quad (0.50)$

where Y is estimated yield (t/ha)

G is seed generation; standard errors are in parentheses.

Storage Losses

Potato seed was normally stored in baskets in a room of the home which admitted some diffused light. The seed was often dusted with insecticide when placed in store and checked once a month to sort and discard any rotting seed. The proportion of total harvest that was reported as rotten varied significantly between TPS, seedling tuber, and Granola harvests as shown below.

Table 11. Harvest losses in store.

Crop	Progeny	Rotted Harvest (%)
TPS	All	16
Seedling Tuber	All	6
Granola		2
TPS	Atzimba x DTO-28	25
TPS	HPS	17
TPS	Atlantic x LT-7	11
Seedling Tuber	Atzimba x DTO-28	6
Seedling Tuber	HPS	3
Seedling Tuber	Atlantic x LT-7	16

Source: Multiple Visit Survey.

Within the TPS and seedling tuber harvests, Atzimba x DTO-28 appeared to incur the highest losses due to seed rotting (Table 11). It was notable also that no rotting seed was reported with dry season Granola crops although 32 percent of dry season seedling tuber crops experienced up to 20% post harvest losses through rotting. There was no evidence of a relationship between fertilizer dosages and rotting seed. It was expected that as seed degenerated a higher incidence of rotting would be found; however, there did not appear to be a strong relationship between the generation of Granola crops or the few degenerated seedling tuber crops and rotting seed. In the case of seedling tubers this may be due to farmers' seed selection resulting in an increasingly resistant crop over successive generations. It is also perhaps an indication of the importance of field conditions in determining the incidence of rotting tubers. There did appear to be a greater chance of rotting seed the earlier a crop was harvested as illustrated in Table 12 and Figure 4.

Table 12. Growing period and rotting harvest.

	Average days to harvest (n)		
% Rotting Seed	TPS	Seedling Tuber	Granola
0	102 (30)	95 (26)	88 (46)
1-10	104 (7)	100 (4)	83 (10)
11-20	103 (13)	98 (8)	74 (3)
21-40	101 (14)	93 (1)	--
41-60	99 (6)	98 (1)	74 (1)
60+	93 (2)	--	--

Source: Multiple Visit Survey.

PRODUCTION EFFICIENCY AND ECONOMIC VIABILITY

Total production costs per hectare for a Granola G1 crop (Rp. 8.9m) were almost double that of successive generations of Granola crops (Rp. 5.1m) and G1 seedling tuber crops (Rp. 5.2m) largely due to differences in seed values (Rp. 3300/kg for Granola G1, Rp. 1102/kg for Granola G2-3 and Rp. 1191/kg for G1 seedling tubers). In subsequent generations, overall production costs for seedling tuber crops were similar to those of the equivalent Granola crop (Rp. 3.5 - 5.0m). TPS crops incurred the lowest total production costs (Rp. 3.7 - 4.1m) at around 80 percent of G1 seedling tuber crops. Of these, Atlantic x LT-7 had the lowest costs due to slightly lower seed (transplant), chemical and land costs than the other progenies.

However, TPS crops were among the least efficient because of their low yields, on average, producing the second most expensive potatoes per kg behind the Granola G1 crop. There were marked differences between progenies though, notably the outstanding production efficiency shown by HPS progenies is attributed to their high yields (Table 13). TPS crops were consistently more efficient during the wet season than the dry. Conversely, tuber-derived crops consistently exhibited greater production efficiency in the dry season; in general, degenerated Granola seed and first generation seedling tubers planted in the dry season produced potato at lowest cost. During the wet season, the more degenerated tuber-derived crops performed less efficiently than earlier generations (Table 13). As with TPS crops, HPS seedling tubers outperformed other progenies.

Table 13. Ranking of crops by production cost per kg (Rp/kg).

Wet Season				Dry Season			
Variety/progeny	**Crop**	**Gen[a]**	**cost/kg**	**Variety/progeny**	**Crop**	**Gen[a]**	**Cost/kg**
Granola	Cv.	1	601	All	TPS	0	585
All	TPS	0	501	All	ST	1	369
Granola	Cv.	5.1	413	Granola	Cv.	5.2	333
Granola	Cv.	2.6	366	Granola	Cv.	2.7	295
All	ST	1	353				
Atlantic x LT-7	TPS	0	928	Atzimba x DTO28	TPS	0	704
Atzimba x DTO28	TPS	0	555	HPS	TPS	0	524
HPS	TPS	0	338				
Atlantic x LT-7	ST	1	438	Atzimba x DTO28	ST	1	621
Atzimba x DTO28	ST	4.3	432	HPS	ST	1	335
Atzimba x DTO28	ST	2.8	387				
HPS	ST	1	323				

[a] Average generation of planting material.
Source: Multiple Visit Survey.

The economic profitability of the potato crops was determined by the total production costs incurred, the yield produced, and the price received for (or imputed value of) the yield. The relative explanatory power of the equations below indicate the importance of yield, and to a lesser extent price, relative to production costs in determining the difference between total crop revenue and total crop costs. It is also interesting to note the positive coefficient in equation 5 implying that increased profitability is associated with increased production costs.

$$3.\ P = -3{,}529{,}470 + \underset{(45.1)}{478.8Y} \qquad n = 143 \quad R^2 = 0.44$$

$$4.\ P = -3{,}705{,}857 + \underset{(1{,}328)}{10{,}594PR} \qquad n = 143 \quad R^2 = 0.31$$

$$5.\ P = -119{,}262 + \underset{(0.26)}{0.52C} \qquad n = 143 \quad R^2 = 0.03$$

$$6.\ P = 7{,}017{,}287 + 584.4Y + 11{,}534PR - 0.94C \quad n = 143 \quad R^2 = 0.83$$

where P is total revenue less total costs (Rp/ha)
PR is price received or value of yield (Rp/kg)
Y is yield (kg/ha)
C is total costs (Rp/ha)

The proportion of yield which can be sold or re-used as seed, which is valued at between two to four times that sold as ware or eaten (Figure 5), is critical to crop viability. This is dependent on the farmers perception of the crop's potential yield in the following season, which in turn is a function of the yield from the current season and the degree of losses incurred during storage. Thus the high value of harvests from Granola G1 reflects the high proportion of harvest sold or re-used as seed (Table 14). Similarly, the higher average prices for TPS crops than seedling tuber crops reflects a greater proportion available as seed, despite higher storage losses from TPS crop harvests. Average prices received decline with successive tuber generations as a greater proportion is sold as ware.

Prices received for Atzimba x DTO-28 transplant harvests were significantly below those for HPS transplanted crops in both seasons. The particularly low price received during the dry season was because one of the two farmers sold all his harvest very cheaply on the ware market as he did not wish to continue multiplying this progeny of seedling tubers. An important reason for this is the higher post harvest losses incurred with Atzimba x DTO-28 than with HPS or

Atlantic x LT-7 (Table 11 above); a contributory factor evidenced through informal comments from farmers is that they were inclined to keep and replant G1 HPS seedling tubers (on average, 44 percent of HPS transplant harvest was replanted compared with 32 percent of Atzimba x DTO-28) even if the transplant harvest was poor, on the basis of high yields from seedling tuber crops achieved by neighbouring farmers. These high expectations of HPS progenies may also have influenced the care invested in seed storage, although the quality of data required to support this hypothesis are not available.

Interprogeny patterns amongst seedling tuber crops were not as clear cut as with transplanted crops, but HPS progenies consistently recieved high average prices.

Table 14. Ranking of crops by harvest value per kg (Rp/kg).

Wet Season				Dry Season			
Variety/progeny	**Crop**	**Gen[a]**	**Val/kg**	**Variety/progeny**	**Crop**	**Gen[a]**	**Val/kg**
Granola	Cv.	1	939	All	TPS	0	623
All	TPS	0	715	All	ST	1	522
All	ST	1	564	Granola	Cv.	2.7	470
Granola	Cv.	2.6	503	Granola	Cv.	5.2	399
Granola	Cv.	5.1	346				
HPS	TPS	0	833	HPS	TPS	0	808
Atlantic x LT-7	TPS	0	692	Atzimba x DTO-28	TPS	0	265
Atzimba x DTO28	TPS	0	619				
Atlantic x LT-7	ST	1	627	Atzimba x DTO28	ST	1	563
HPS	ST	1	542	HPS	ST	1	545
Atzimba x DTO28	ST	2.8	453				
Atzimba x DTO28	ST	4.3	424				

[a] Average generation of planting materials.
Source: Multiple Visit Survey.

In terms of overall net crop profit, irrespective of the size of initial investment, Granola G1 and G2-3 crops yielded the highest profits in wet and dry seasons respectively, reflecting high average yields and prices received, despite having the highest production costs (Table 15). First generation seedling tubers also returned high profits; profitability declined with seed generation for all tuber-derived crops. TPS profits were much higher both in absolute terms and relative to other crops during the wet season.

However, the overall crop performances mask considerable variation amongst progenies where HPS consistently and significantly outperformed Atzimba x DTO-28 and Atlantic x LT-7.

Wet season HPS transplanted crops gave higher profits than Granola G1 even, reflecting high average yields (12.1 t/ha) compared to the other progenies (7.2 t/ha, 4.0 t/ha respectively), a high value of the harvested crop which was mostly kept as seed, and low production costs. Similarly, HPS G1 seedling tubers gave higher profits than all other progenies and outperformed Granola G2-3. Atzimba x DTO-28 and Atlantic x LT-7 seedling tubers only outperformed the loss making degenerated Granola seed in the wet season when several of the Granola crops were completely lost due to floods and Late Blight.

Table 15. Returns (MRp/ha) by crop and season.

		WET SEASON		
Variety/progeny	Crop	Gen[a]	Returns	n
Granola	Cv.	1	5.0	8
ALL	STuber	1	3.1	7
Granola	Cv.	2.6	1.9	12
ALL	TPS	0	1.7	54
Granola	Cv.	5.1	-0.8	22
HPS	TPS	0	6.0	16
Atzimba x DTO-28	TPS	0	0.5	16
Atlantic x LT-7	TPS	0	-0.9	16
HPS	STuber	1	3.3	5
Atlantic x LT-7	STuber	1	2.5	2
Atzimba x DTO-28	STuber	2.8	0.8	5
Atzimba x DTO-28	STuber	4.3	-0.1	4
		DRY SEASON		
Variety/progeny	Crop	Gen[a]	Returns	n
Granola	Cv.	2.7	3.2	6
ALL	STuber	1	2.5	20
Granola	Cv.	5.2	0.9	12
ALL	TPS	0	0.2	5
HPS	STuber	1	3.2	13
Atzimba x DTO-28	STuber	1	-0.5	5
HPS	TPS	0	2.0	3
Atzimba x DTO-28	TPS	0	-2.4	2

[a] Average generation of planting materials.
Source: Multiple Visit Survey.

From the above, there is little optimism that the Atzimba x DTO-28 or Atlantic x LT-7 progenies can consistently outperform Granola crops unless TPS yields can be improved and TPS harvest losses reduced. Sufficient evidence exists to suggest that HPS progenies could offer a competitive alternative to the existing seed tuber system in upland rainfed farming systems, with transplanted crops offering higher returns to farmers than Granola crops under most circumstances; the performance of HPS G1 seedling tubers also indicates potential.

Unfortunately, data regarding the performance of subsequent HPS seedling tuber generations are not yet available. If yields remain high then there are good reasons to promote HPS; however, if subsequent yield deterioration is rapid, then the high values attributed to HPS seedling harvests could no longer be assumed and the viability of this progeny would also become questionable.

DISCUSSION

It is interesting to note that despite the fact that production costs of a transplanted crop are reduced compared to tuber seed crops, the viability of a TPS based seed system is critically dependent on seedling tuber **yields** rather than **reduced costs** (as seedling tuber crop production costs are not significantly reduced when compared to Granola crops). This is because seedling tuber yields and the degeneration rate of their yields determines seedling tuber values and therefore returns. The continued collection of cost and return data of subsequent seedling tuber generations is therefore critical, particularly in view of the informal comments from farmers implying rapid seedling tuber yield degeneration, and the initial indications from the data available in equation 2.

For Atzimba x DTO-28 G1 seedling tubers to attain competitiveness with Granola G2-3 in a dry season, it is estimated that average yields in excess of 17 t/ha are necessary. Based on the assumption that production costs remain similar across successive generations and average harvest values decline by around 8 percent, HPS G2 seedling tubers require average yields around 14 and 17 t/ha in wet and dry seasons respectively to remain a competitive alternative to Granola G2/3.

The viability of HPS relative to other progenies hinges on its consistent yield performance which is further enhanced by its superior resistance to Late Blight over Granola. However, the lateness of this progeny appears to be an important drawback for farmers in an intensive vegetable cropping system. Crop lateness means a greater likelihood of attack by nematodes and soil-borne diseases; it implies increased credit and land costs, and interferes with delicately balanced seasons and crop rotations.

In summary, it can be concluded that the concept of TPS technology has been readily and widely (see Chilver & Suherman, forthcoming) accepted as technically viable, and the apparently greater yield stability across environments compared to Granola indicates potential that could be further developed. However, in order to attain widespread and sustained adoption it seems likely

that improved progenies will need to be developed which achieve and maintain high yields across generations under Indonesian conditions.

Further research could usefully focus on the storage losses associated with TPS and seedling tuber crops and the means to reduce these. Possible avenues include selecting earlier progenies to reduce the length of time a TPS derived crop is subjected to disease attack; also, reducing the current two seedling transplantations, by encouraging a bed system with no transplanting, or sowing directly into pots to eliminate one transplanting, could reduce the potential for physical seedling damage which facilitates disease infection.

Greater attention to seed quality with HPS progenies would ensure the genetic potential of these progenies is maximized and transplant establishment costs are minimized, although the ultimate impact on economic viability from seed quality alone would appear to be minimal.

The lower yields realized in the current survey than those achieved previously where researchers cooperated closely with farmers indicate possible technical deficiencies in farmers' practices; it also points to the need for careful consideration of the conditions under which on-farm research results were obtained, in terms of the methods used and relationships between farmer and researcher, before broader conclusions are drawn and recommendations made.

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FIGURE 1. AVERAGE MONTHLY RAINFALL

Margahayu-Lembang

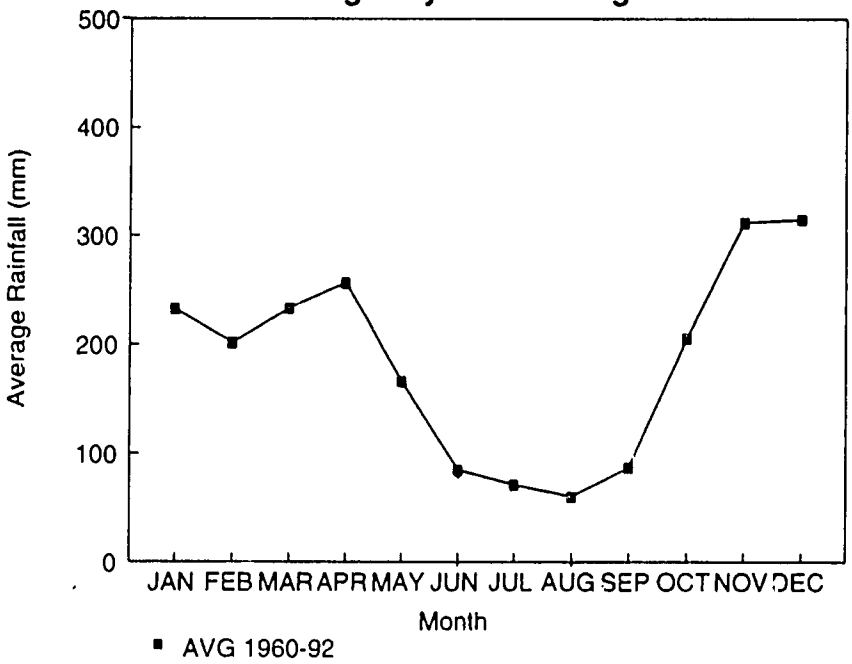


FIGURE 2. AVERAGE MONTHLY TEMPERATURE

Margahayu-Lembang

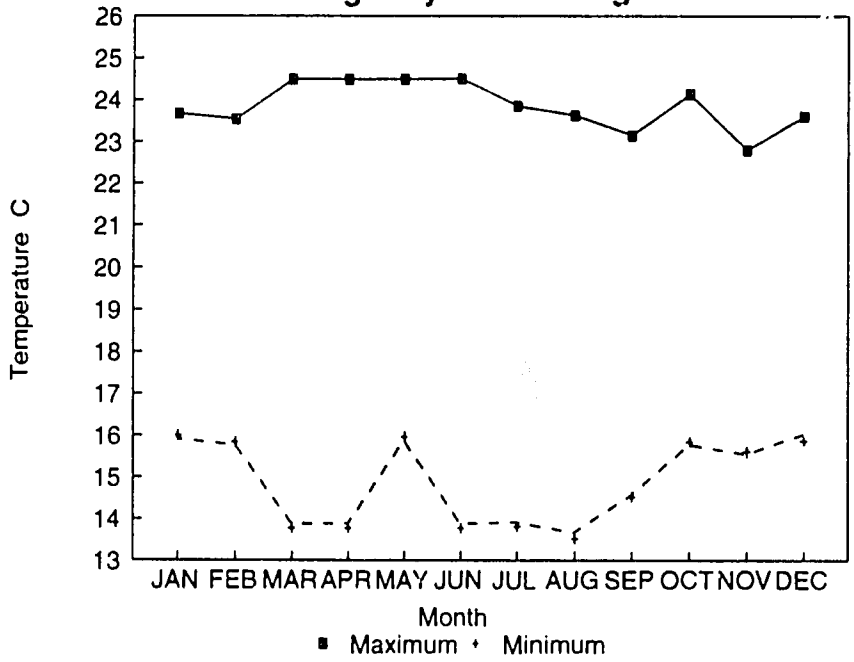


FIGURE 3. AVERAGE MONTHLY WARE PRICES
Lembang 1991-92

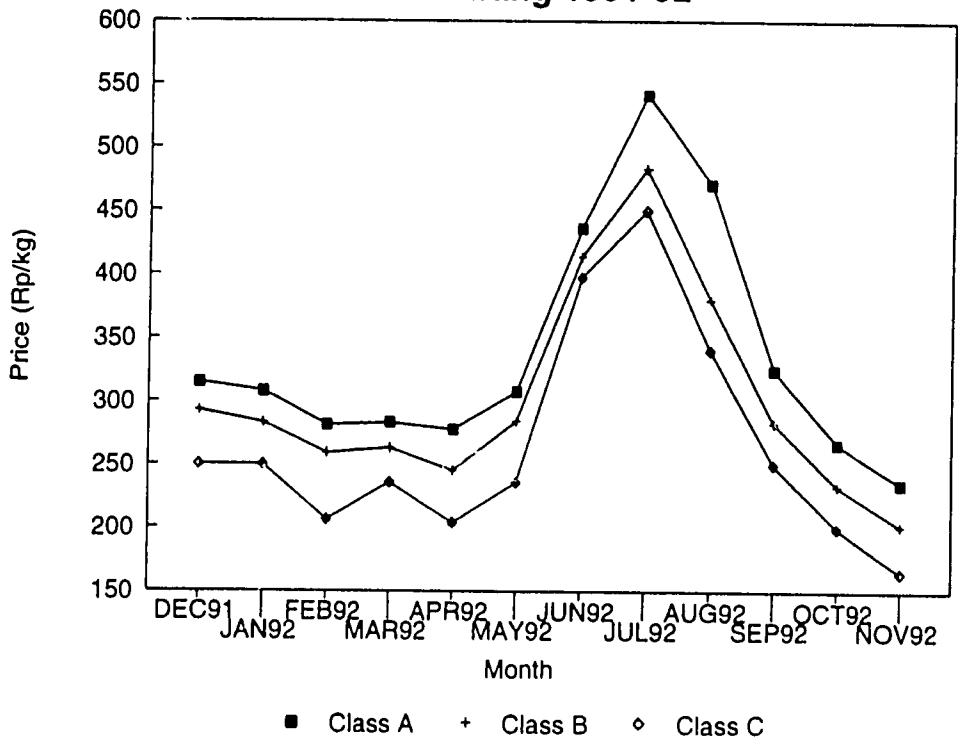


FIGURE 4. TUBERS ROTTING IN STORE
Incidence of rotting and growing period

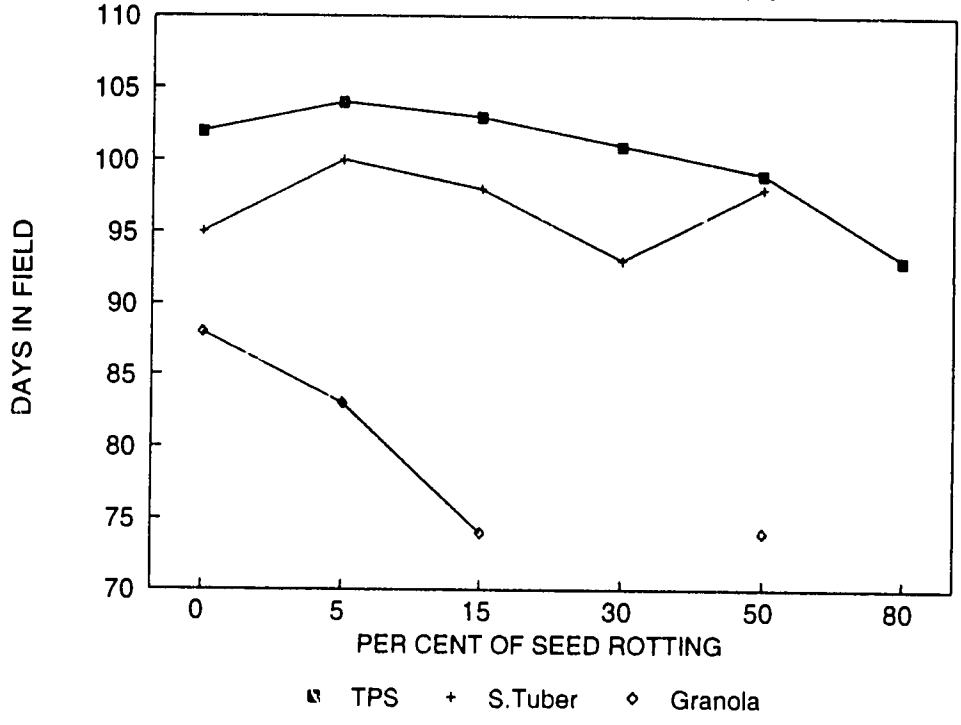
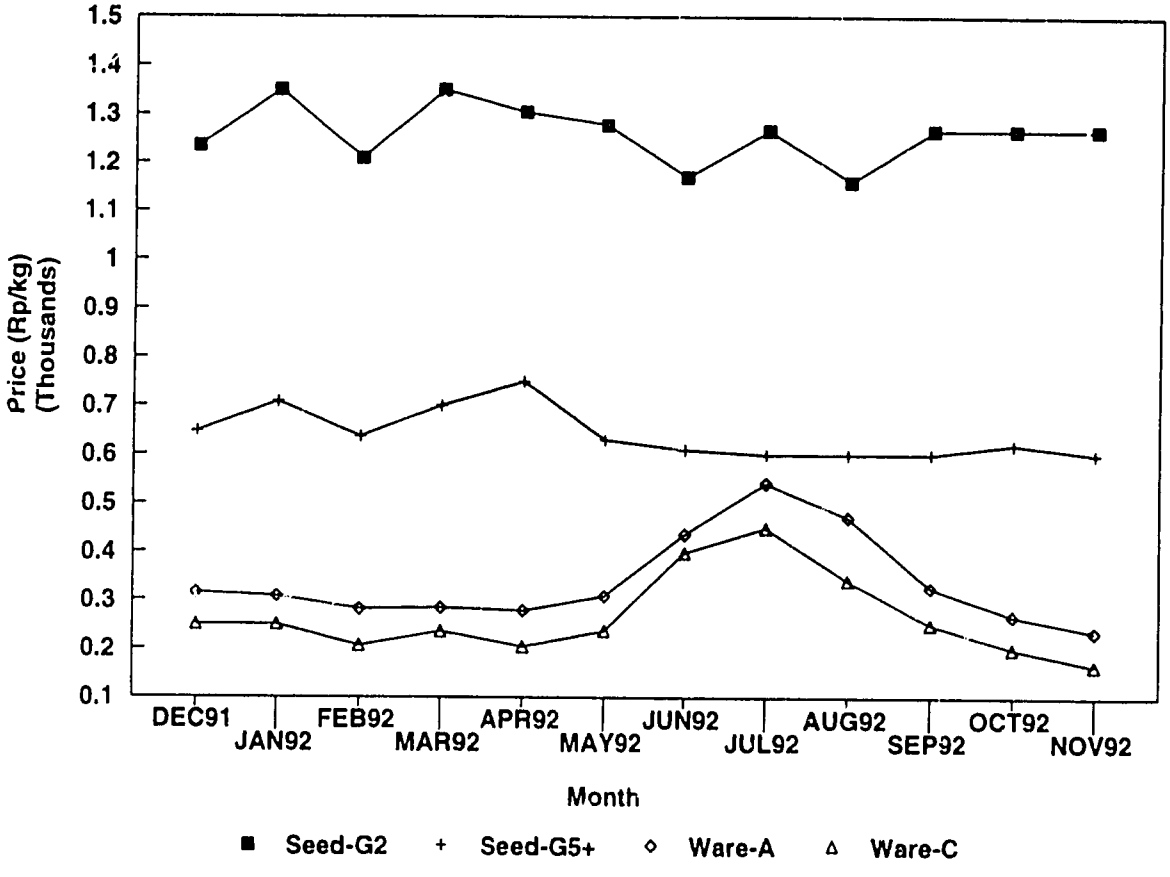


FIGURE 5. AVERAGE SEED & WARE PRICES

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