Vol. 16(7), pp. 992-1006, July, 2020
DOI: 10.5897/AJAR2019.14433
Article Number: 223ACE764213
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

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African Journal of Agricultural Research

Full Length Research Paper

Relative costs and benefits of implementing desiccant bead drying/hermetic storage and alternative drying and storage technologies for vegetable seeds in Kenya and Tanzania

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Received 2 September, 2019; Accepted 8 May, 2020

This paper assesses the relative costs and benefits of desiccant beads drying/hermetic storage and alternative drying and storage technologies. The study was conducted in Kenya and Tanzania in areas producing and trading vegetable seeds using a sample size of 280 respondents. The study revealed that costs of desiccant bead drying/hermetic storage are relatively higher for smaller quantities of seeds compared to alternative technologies. No storage losses are incurred with hermetic storage but high losses occur for ordinary storage. Using a combination of desiccant bead drying and hermetic storage is relatively more economical compared to using desiccant drying alone. There are economies of scale in the use of desiccant bead drying/hermetic storage compared to alternative technologies. Quantities of seeds that generate equal net benefits for both desiccant bead/hermetic storage and sun drying/ordinary storage range from 120 to 900 kg for African night shade and Amaranthus, and 300 to 1500 kg for beans. Efficiency in production and marketing is likely to encourage the use of desiccant bead drying/hermetic storage, which would be beneficial to farmers. Taking 15 kg of African night shade seeds and 18 kg of Amaranthus seeds, price premiums that would be necessary for farmers to receive for there to be an economic incentive for them to use the beads are approximately 35% for Amaranthus and 20% for the African night shade. Given efficiency of desiccant bead drying/hermetic storage it is likely to offer more benefits to farmers and traders compared to sun drying and other storage technologies.

Key words: Drying, storage, desiccant beads, moisture content, costs and benefits.

INTRODUCTION

High-yielding, high-quality seeds are a key technology input for the growth of the horticulture sector. Good quality seed alone can contribute 20-30% yield increase in vegetables (SSG, 2019; Poonia, 2013). However, a critical limitation to seed quality in warm and humid tropical regions is the inability to dry seeds to safe storage moisture content (MC). In general, seed longevity is reduced by half for every 1% increase in seed MC (percent of fresh weight) or 5°C increase in temperature, as inferred by Harrington's rule.

The combination of high MC and high temperature is particularly deadly for seeds (Ndung'u and Kimiti, 2017;

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Thomsen, 2000; Ellis and Roberts, 1981), so optimal storage recommendations include both low MC and low temperature. However, seed drying and cold storage facilities are generally unavailable or unreliable in many developing countries, particularly at the farm level. Seeds are much more resistant to high storage temperatures when their MC is low. Thus, drying to low MC and storage in hermetic containers to prevent rehydration from ambient air is the most realistic strategy for effective storage of seeds in warm tropical climates (Bradford et al., 2017; Ellis, 1988). A major impediment to this strategy is the difficulty of drying seeds to low MC under conditions of high ambient relative humidity (RH).

Desiccant ceramic beads can absorb water and reduce the RH to very low values in closed spaces, drying seeds to the optimum MC. After drying the seeds can be stored in hermetic containers/bags. Hermetic storage bags are made of woven polypropylene tapes of virgin resin. Drying products to levels low enough to reduce or prevent insect activity (~35% ERH) and maintaining dryness using hermetic packaging is a complementary strategy for controlling storage insects when adequate drying is possible (Kunusoth et al., 2012). Hermetic bags prevent insect damage by suffocating the insects and also by inhibiting penetration (Murdock et al., 2003). In this regard, hermetic bags would be good given that storage insects account for up to 40% of the total physical and nutritional loss of grain and dry food products in the developing world (Kumar and Kalita, 2017; Chomchalow, 2003; FAO, 1994). A key question is whether the technology would be economically beneficial for users. This paper assesses the relative costs and benefits of different seed drying and storage methods including the desiccant beads/hermetic bags, to determine under what circumstances the beads might be cost effective. The paper addresses three objectives, which are to: estimate the costs and returns using the current drying and storage methods; compare costs and returns of different drying and storage methods with the use of the desiccant bead technology; and identify possible scenarios under which the returns for using the beads could be enhanced. A specific question in this context is, “what price premium would be necessary for farmers to receive in order for there to be an economic incentive for them to use the beads?” Use of the beads becomes more economical with larger volumes of seeds, so a related question is “at what scale of seed production does use of the beads become economically attractive?”

MATERIALS AND METHODS

The study was conducted in Kenya and Tanzania in areas where farmers were involved in vegetable seed production using different approaches and there was seed trade. The seed production systems farmers used were contract, informal and quality declared seed. Vegetables used in the study included African night shade, amaranthus, beans, shelled groundnuts, onions, tomatoes and kale.

Two regions, Arusha and Dodoma, were covered in Tanzania. Respondents in the Arusha Region provided data for the contract and informal seed systems. Dodoma Region in Tanzania is where vegetable seed producers operate under the Quality Declared Seed (QDS) production system. In the case of Kenya data were collected from Bungoma for the contract seed growers, while Busia, Kinale and Yala areas provided data for informal seed growers. The seed producers were selected from each of the study areas using systematic sampling from lists of producers provided by the seed companies for the contract system, and from lists provided by local agricultural extension officers for the informal and QDS systems.

Data were also collected from seed traders including seed collectors, traders in the local market, wholesalers and agro-vets. Vegetable seed traders also provided data on costs and benefits as well as the activities involving drying, storage, distribution and marketing of the vegetable seeds in their respective areas of operation. Vegetable seed traders were randomly selected in local markets in each of the study areas. The distribution of the respondents from each of the data source categories is indicated in Table 1. A total of 280 respondents were selected for the study. Data were collected using structured questionnaires administered through face-to-face interviews. Data were collected for a range of different vegetables on the methods and costs for different drying and storage practices. Information was also collected on the selling prices for the seeds of the different vegetables with or without storage. As seed may deteriorate in storage for a range of reasons, estimates were also made of the amount of seed lost during storage by farmers before sale, which is effectively an additional cost of storage. Similar estimates were made from interviews with seed traders. In each case the volumes of seed involved were also recorded. As well as costs associated with drying and storage, an overall estimate was made of other production costs. This allows an estimate of actual returns to be made, as well as an estimate of the costs of drying and storage relative to other costs. To compare the use of desiccant beads with other drying and storage methods, a simple model specified below was used:

Returns = Selling price × Weight of seeds – Costs (production, drying, storage)

The parameters used in the computation of costs for comparison are included in Table 2. In the case of the seed traders the costs involved included the purchase price from the seed producers and the logistics costs consisting of the transportation costs and cess in the market places as well as labour costs. To make the comparison, the model was evaluated for the different vegetables using either the current or new drying and storage methods, and the difference in net returns calculated.

A sensitivity analysis was conducted for specific parameters in the above model. To examine the price premium that would be required, the selling price of the seeds varied while holding the other parameters constant. To establish the economies of scale, the model was evaluated for a range of values for the weight of seed, again while holding other values constant for the particular vegetable and production system. In each case, the benefit of using the desiccant bead technology is expressed as a per kg difference in returns when the beads are used and not used.

RESULTS AND DISCUSSION

Costs and income from the current drying and storage methods

Production costs for the different vegetable seeds

The types of production costs considered were seed,

Table 1. Distribution of respondents involved in the study.

Region	Informal seed producers	Contract seed producers	QDS seed producers	Traders
Bungoma		15	0	35
Busia	20	0	0	40
Kinale	10	0	0	10
Yala	15	0	0	25
Arusha	14	35	0	21
Dodoma	0	0	20	20

Table 2. Description of the parameters used in the model.

Parameter	Description
Production costs	A fixed cost per kg. The average production costs for different crops under the different production systems were determined and used in the model.
Drying costs: Current method	A fixed cost per kg. The actual values for drying by different methods under the different production systems were determined and are presented. For the model an average for each crop and production system combination is used.
Drying costs: Desiccant beads	Cost per kg, calculated from the existing model (see section 3.2.1). Inputs for this model are: (i) Species of crop (ii) Starting moisture content of the wet seeds (iii) Target moisture content of the dry seeds (iv) Weight of seeds to be dried (v) Cost of the equipment (drying beads) Values for starting and target moisture content were estimated by key informants, and are used as fixed values in the model.
Storage costs: Current method	A fixed cost per kg. The actual values for different storage methods under the different production systems were determined, but for the model an average for each crop and production system combination is used. Storage cost is assumed to be independent of storage duration.
Storage costs: Desiccant beads	Cost per kg, calculated with the drying costs as above.
Storage losses	Percentage loss. The actual values were obtained from the survey, assumed to be for a 3 month period. Percent loss using the new method is zero. The percentage loss thus reduces the amount of seed available for sale.
Selling price	Price per kg. Prices for the seeds were determined during the survey, for immediate sale following drying, and after storage for 3 months, when prices are generally higher.
Weight of seed	Because the cost per kg using the desiccant beads reduces with increasing weight dried/stored, actual weights of seed have to be used. The survey established the amounts of seed that farmers were drying and storing for the different crops and under the different systems, so for the basic comparison we use standard weights for the different crops.

fertilizer, pesticide and labour cost. Total production costs per kg of vegetable were relatively different for the vegetable seeds under different production systems (Table 3). The costs were similar for Kenya and Tanzania, which means that similar storage and drying methods could be used for the two countries. In fact,

Table 3. Production costs for the vegetable seeds (US$/kg).

Seed production system	Type of vegetable	Production cost (Kenya)	Production cost (Tanzania)
Contract (formal)	African night shade	1.80	1.78
	Amaranthus	0.68	0.71
	Beans	0.99	1.10
Informal	African night shade	1.22	1.22
	Amaranthus	3.27	3.26
	Beans	0.63	0.59
	Groundnuts	0.93	0.96
	Kale	1.74	1.72
Quality Declared Seed (QDS)	African night shade	QDS Not used in Kenya	1.56
	Amaranthus	QDS Not used in Kenya	0.89
	Beans	QDS Not used in Kenya	0.63
	Groundnuts	QDS Not used in Kenya	0.94

Table 4. Seed growers' average sun drying costs per kg.

Seed drying system	Vegetable	Kenya (US$/kg)	Tanzania (US$/Kg)
Contract seed system	African night shade	0.08	0.50
	Amaranthus	0.02	0.04
	Beans	0.03	0.01
Informal seed system	African night shade	0.59	0.56
	Amaranthus	0.77	0.38
	Beans	0.32	0.19
	Groundnuts	0.70	0.44
	Kale	0.43	0.16
Quality Declared Seed (QDS) System	African night shade	QDS Not used in Kenya	0.53
	Amaranthus	QDS Not used in Kenya	0.30
	Beans	QDS Not used in Kenya	0.10
	Groundnuts	QDS Not used in Kenya	0.39

some of the seed companies in Tanzania such as Simlaw seeds originally operated in Kenya and still have branches in Kenya.

Drying costs for the vegetable seeds

In all the project areas in both Kenya and Tanzania, the method that farmers and traders used for drying vegetable seeds was sun drying. Under the sun drying method the growers harvest the seeds and after harvesting the seeds are placed at the front of the houses on canvas, bags, mats, sacks or polythene papers on the ground or in a few instances on raised tables. The preferred method was drying on polythene paper. There was more diversity in the seed drying materials used in Kenya compared to Tanzania. No standard methods were used for checking moisture except visual inspection. The cost of drying was an aggregation of the cost of the various materials used for drying. The drying costs per kg for the different crops under the different production systems were variable but on average the costs were higher under the informal system (Table 4). The informal seed growers incurred more costs possibly due to the limited technical know-how. The technical skills required for the actual drying of the seeds are also relatively low among the informal seed growers. The quality declared seed producers have relatively more skills compared to the informal seed growers possibly because of the training that they receive from the Tanzania Official Seed

Table 5. Average storage costs incurred by the seed growers for 3 months.

Seed production system	Vegetable	Kenya (US$/kg)	Tanzania (US$/kg)
Informal	African night shade	0.46	0.23
	Amaranthus	0.05	0.13
	Beans	0.09	0.08
	Groundnuts	0.23	0.16
	Kale	0.03	0.02
Quality Declared Seed (QDS)	African night shade	QDS Not used in Kenya	0.26
	Amaranthus	QDS Not used in Kenya	0.06
	Beans	QDS Not used in Kenya	0.07
	Groundnuts	QDS Not used in Kenya	0.12

Table 6. Storage losses (%).

Production system	African night shade	Amaranthus	Beans	Groundnuts	Kale
Informal	22.0	25.0	14.0	10.2	16.0
QDS	8.5	10.5	10.0	7.50	

Certification Institute (TOSCI). The contract seed growers spend relatively less on drying compared to all the other categories of seed producers, possibly because they have adequate technical know-how relating to the proper physiological age of harvesting, the harvesting approaches and the techniques for drying the seeds. The findings suggest the need for capacity building for the informal seed growers with respect to post-harvest handling especially drying of seeds.

Storage costs for the vegetable seeds

After drying seeds were packed in different containers for storage. The packing materials included sisal sacks/bags, polythene bags/plastic containers, bottles and khaki papers. The seeds in any of the packing formats were then placed in the house or in some store pending sale and/ or use as appropriate. The main packing facilities were sisal sacks/bags. No special efforts were undertaken to ensure that the moisture content was maintained at the desired levels. The costs associated with each of the storage methods vary depending on the vegetable crop involved and the system of production (Table 5). Contract seed growers reported no storage costs because the seeds were collected by the seed companies immediately after drying. The computation of the storage costs involved adding together the costs incurred in purchasing equipment/materials and the labour costs incurred during storage of the seeds. The total costs were then divided by the quantity of seeds dried to arrive at the storage cost per kg of the seed stored by the different seed growers.

Some storage losses were incurred and an assessment was conducted for the key crops under the different seed production systems (Table 6). The storage losses were higher in the informal seed system compared to the quality declared seed system. This may be because the seed growers under QDS receive training on production and post-harvest handling practices. As such they are able to undertake storage in a more efficient manner that lowers the losses. This is also an indication that there is need to reduce storage losses given the corresponding monetary losses to the producers.

Selling prices for the vegetable seeds

The prices paid per kg for the different vegetables seeds after drying and storage were variable indicating the values the seed users attach to the different vegetable seeds (Table 7). The prices paid depended on whether the seeds were sold immediately after drying or after storage for some time. There were very few instances where seeds were stored for 6 months or longer. As a consequence, the analysis in subsequent sections is based on storage for 3 months. Prices after storage were relatively higher because selling was undertaken during times when seed supply was relatively lower compared to demand. Some losses were incurred during storage and hence prices after 3 months relate to the marketable seed that was left after storage losses. This suggests that better storage methods that reduce storage losses are likely to benefit the producers more. As a consequence, investment in better storage methods is warranted. No prices were reported for storage by the contract growers

Table 7. Seed sale price (US$/kg) by the seed growers after drying and storage.

Seed production system	Vegetable	Kenya (US$/kg)		Tanzania (US$/kg)	
		Immediate sale	Sale after 3 months	Immediate sale	Sale after 3 months
Contract (formal)	African night shade	5.81	No storage	3.75	No storage
	Amaranthus	2.33	No storage	3.13	No storage
	Beans	1.05	No storage	1.00	No storage
Informal	African night shade	7.19	11.05	6.25	7.19
	Amaranthus	6.98	11.63	2.50	3.75
	Beans	1.16	2.56	1.00	1.38
	Groundnuts	1.98	2.91	1.56	2.03
	Kale	2.91	3.49	1.25	1.31
Quality Declared Seed (QDS)	African night shade			6.09	6.88
	Amaranthus	No QDS	No QDS	2.63	3.38
	Beans	No QDS	No QDS	1.15	1.40
	Groundnuts	No QDS	No QDS	1.60	2.25

Table 8. Drying, storage and transaction costs of the traders.

Vegetable	Buying price from suppliers (US$/kg)	logistics costs (US$/ kg)	Drying costs (US$/kg)	Storage costs (US$/kg)	Selling price to the final users [no storage] (US$/kg)	Selling price to users after 3 months (US$/kg)
African night shade	7.19	0.06	0.22	0.07	11.05	16.40
Amaranthus	4.03	0.02	0.35	0.05	7.91	8.25
Beans	1.16	0.11	0.10	0.08	2.56	3.00
Groundnuts	1.98	0.12	0.13	0.03	2.91	6.24
Kale	2.91	0.07	0.18	0.19	3.49	7.79

because they sold seeds to the seed companies immediately after drying. QDS system is found in Tanzania alone and not Kenya.

Trader costs and selling prices

The drying costs incurred by the seed traders were not related to the time that harvesting was done but instead on the extent to which the seed had been dried by the seed growers or the seed collectors that eventually sold to the seed traders. There would be no need for the seed traders to dry the seeds in instances where the seeds had been dried to the correct moisture content by the seed growers and the seed collectors in the various places. However, all the seed traders that provided information stated that they dried the seeds before selling.

In both Kenya and Tanzania, the seed traders used the same methods and equipment for drying and storage of the seeds as the seed growers in the two countries. The costs and selling prices are shown in Table 8. Some losses were incurred during storage. The losses were attributed to pests and spillage during the transfers. For the key traded crops, the losses incurred were 10.2, 8.0 and 5.0% for beans, African night shade and amaranthus respectively. For the traders involved in sales and purchases of groundnuts and kale the losses reported were 6.4 and 10.5% respectively. It emerged that the prices paid by the buyers were relatively high in case seeds had been stored for some time. This is because it is possible to sell at relatively high prices after storage. Traders who do have storage facilities are able to set market prices and take advantage of higher prices when incoming supplies dwindle (RSA, 2015). The value of any surplus crop tends to rise during the off-season period, provided that it is in a marketable condition. Therefore, the principal aim of any storage system must be to maintain the crop in prime condition for as long as possible. This is in line with the understanding that correct design of storage after proper drying is a key to business success (Cromarty et al., 1982; Jones et al.,

Table 9. Moisture content and seed oil for the different vegetable seeds.

Name of vegetable		Starting MC	Desired MC	Seed Oil
Common name	**Botanical names**			
African night shade	*Solanum vilosum*	24.0	9.0	*27.2
Amaranthus	*Amaranthus tricolor*	29.0	9.0	6.0
Beans	*Phaseolus vulgaris*	45.5	12	21.0
Groundnuts	*Arachis hypogaea*	17.0	8.0	47.3
Kale	*Brassica oleracea var. acephala*	56.0	10.0	25.9

* The value used is for *Solanum nigram.*

2014). Seed traders are therefore likely to benefit more given good storage facilities.

Comparison of the current methods with the use of desiccant beads

Costs of using the desiccant beads

The materials needed for using zeolite desiccant beads to dry seeds are the beads themselves, baking oven, deep baking pan and sturdy gloves, funnel, plastic baskets, moisture-proof metal or plastic containers, temperature/humidity metre and small packets of silica gel (optional).

To determine the costs of using the desiccant beads for drying and the hermetic containers for storage it was necessary to specify values for the initial moisture content (MC) of the seed and the final/desired MC for storage. For long-term storage, seeds should be in equilibrium with 20-30% RH. Once dry the seeds should be stored in a room under prevailing environmental conditions in a moisture proof container. The initial and target moisture content used for the different species is given in Table 9. The target or desired moisture content is what is recommended for good storage of the seeds as per the standards of the seed companies. The initial/starting moisture content for the different seeds was obtained from consultations with experts in the seed industry and particularly those dealing with seeds at the farm level. The desired/safe moisture content for seed storage was obtained from Simlaw Seed Company. The costs of the desiccant beads were generated using the bead economic calculator from Rhino Research using the values reported above. The computation used US$ 22 as the price per kg of beads and assumed 7 days between batches which is the most acceptable duration by over 75% of the seed growers and traders. The temperature used was 25°C, which is the average from the areas based on information from the Meteorological Department. The period of storage is taken as 90 days.

Using the economic bead calculator and the necessary conditions documented in Table 9, which are consistent with Ahuja et al. (1987), CEAPRED (2010) and Ellis (1988), the costs of drying and storage for 3 months using the desiccant beads were calculated and documented in Table 10. The costs are computed on a per kg basis and compared to the costs of sun drying and ordinary storage. The costs of drying and storage decrease as the quantity of seeds involved increases (Figure 1) in the case of using the beads. For sun drying and ordinary storage the costs are assumed to remain constant per kg of seeds dried. The results suggest that it would necessary to increase productivity to ensure efficient use of desiccant beads and hermetic bags.

Returns using the current methods and beads

In the computation of returns standard values are used, which are the average quantities of the seeds that the seed growers reported in the survey. Average prices and production costs were also used in the computation to generate the returns (Table 11). In the case of traders, logistics costs and the buying price from the seed suppliers were used. The costs are computed on a per kg basis and the corresponding net income is obtained as the difference between price per kg and the costs per kg. The same table also provides comparable net income using the sun drying method.

A comparison of the usage of beads for drying and hermetic containers for storage with sun drying and ordinary storage showed that at the current small scale seed production beads drying is less lucrative (Table 12). However, the gains are much higher compared to using the beads for drying only. The volume of seeds from sun drying and ordinary storage is reduced by the storage losses (Table 6) while no storage loss is assumed when beads/hermetic containers are used. This assumption is based on a previous study which established that when compared with ordinary bags, the losses when hermetic bags are used are less than two percent (Murdock and Baoua, 2014).

Net income is obtained as the difference between the price per kg and the cost of drying per kg or the price per kg and the drying and storage cost per kg. Tables 11 and 12 indicate that the current individual production is insufficient to support the use of beads. The use of beads

Table 10. Comparison of the costs of drying and storage using the beads and hermetic containers with sun drying and ordinary storage.

Name of vegetable	Costs of bead drying (USD/kg)	Costs of sun drying (USD/kg)	Costs of Bead drying and hermetic storage (USD/kg)	Costs of sun drying and ordinary storage (USD/kg)
Informal seed system				
African night shade (15 kg)	3.92	0.59	4.51	1.05
Amaranthus (18 kg)	4.00	0.77	4.24	0.82
Beans (246 kg)	0.38	0.32	0.78	0.41
Groundnuts (10 kg)	5.44	0.70	6.32	0.93
Kale (40 kg)	2.57	0.43	3.01	0.46
Contract seed system				
African night shade (33 kg)	2.18	0.08	No storage	No storage
Amaranthus (450 kg)	0.21	0.02	No storage	No storage
Beans (488 kg)	0.19	0.03	No storage	No storage
QDS system				
African night shade (40 kg)	1.80	0.53	2.35	0.79
Amaranthus (50 kg)	1.88	0.30	2.32	0.36
Beans (70 kg)	1.34	0.10	1.97	0.17
Groundnuts (20 kg)	2.72	0.39	3.16	0.51
Traders				
African night shade (50 kg)	1.35	0.22	1.79	0.29
Amaranthus (100 kg)	0.94	0.35	1.58	0.40
Beans (940 kg)	0.10	0.10	0.86	0.18
Groundnuts (475kg)	0.15	0.13	0.94	0.16
Kale (100 kg)	1.16	0.18	1.58	0.37

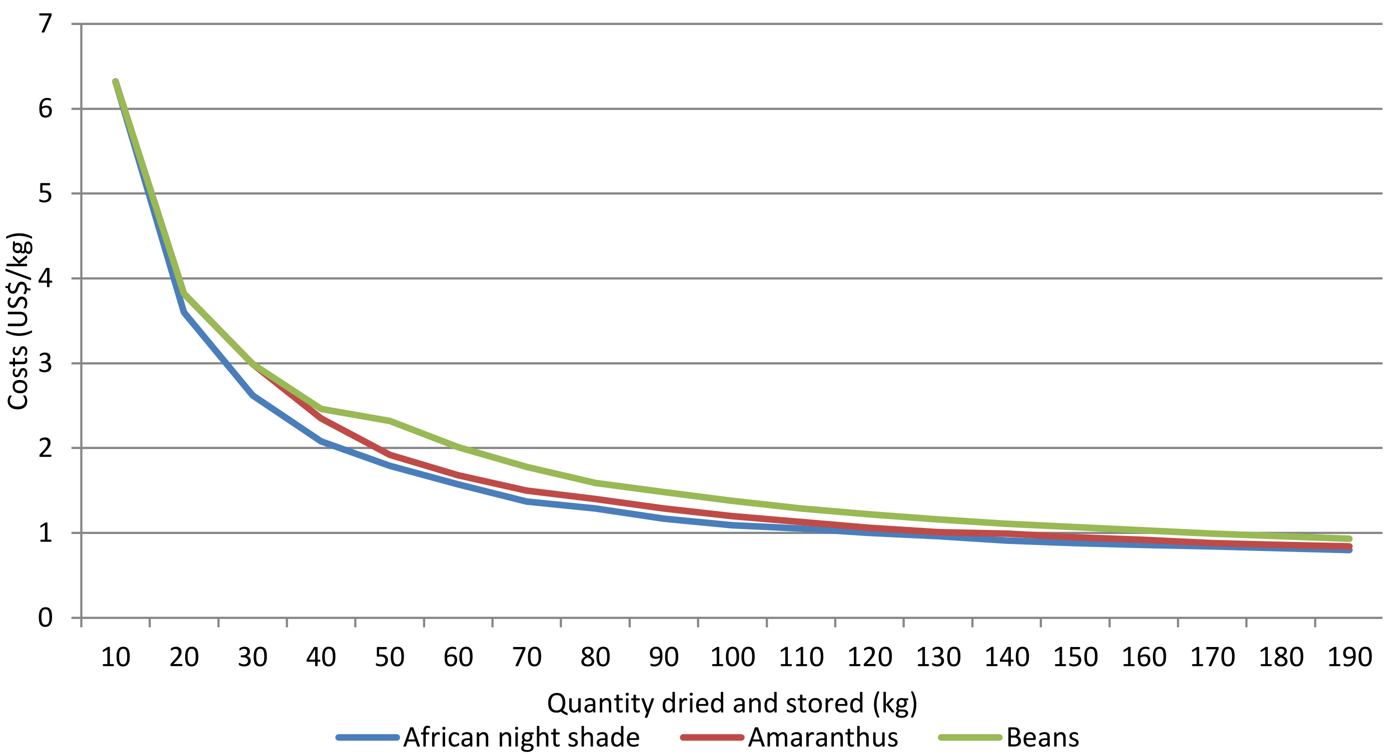

Figure 1. Costs of drying and storage of selected vegetable seeds using beads.

Table 11. Comparison of income from the different drying methods and beads for immediate sale.

Name of vegetable	Net income from sun drying (USD/kg)	Net income from desiccant beads drying (USD/kg)
Informal seed system		
African night shade (15 kg)	5.38	2.05
Amaranthus (18 kg)	2.94	-0.29
Beans (246 kg)	0.21	0.15
Groundnuts (10 kg)	0.35	-4.39
Kale (40 kg)	0.74	-1.40
Contract seed system		
African night shade (33 kg)	3.93	1.83
Amaranthus (450 kg)	1.63	1.44
Beans (488 kg)	0.03	-0.13
QDS system		
African night shade (40 kg)	4.00	2.73
Amaranthus (50 kg)	1.44	-0.14
Beans (70 kg)	0.42	-0.82
Groundnuts (20 kg)	0.27	-2.06
Traders		
African night shade (50 kg)	3.58	2.45
Amaranthus (100 kg)	3.51	2.92
Beans (940 kg)	1.19	1.19
Groundnuts (475 kg)	0.68	0.66
Kale (100 kg)	0.33	-0.65

Table 12. Comparison of income from sun drying and ordinary storage with bead drying and hermetic storage for 3 months.

Name of vegetable	Net income from sun drying and ordinary storage (USD/kg)	Net income from desiccant beads/hermetic storage (USD/kg)
Informal seed system		
African night shade (15 kg)	6.65	4.46
Amaranthus (18 kg)	5.42	2.65
Beans (246 kg)	1.31	1.10
Groundnuts (10 kg)	0.94	-4.34
Kale (40 kg)	1.08	-1.26
QDS system		
African night shade (40 kg)	3.82	2.49
Amaranthus (50 kg)	2.45	0.93
Beans (70 kg)	0.54	-1.2
Groundnuts (20 kg)	0.72	-1.85
Traders		
African night shade (50 kg)	8.15	7.36
Amaranthus (100 kg)	3.35	2.62
Beans (940 kg)	1.39	0.87
Groundnuts (475 kg)	3.73	3.20
Kale (100 kg)	3.97	3.23

Table 13. Quantities (kg) at which drying with beads gives equal returns to sun drying.

Vegetable	Contract seed system	Quality declared seed system	Informal seed system	Traders
African night shade	850	325	120	200
Amaranthus	900	600	120	380
Beans	1500	1000	300	900

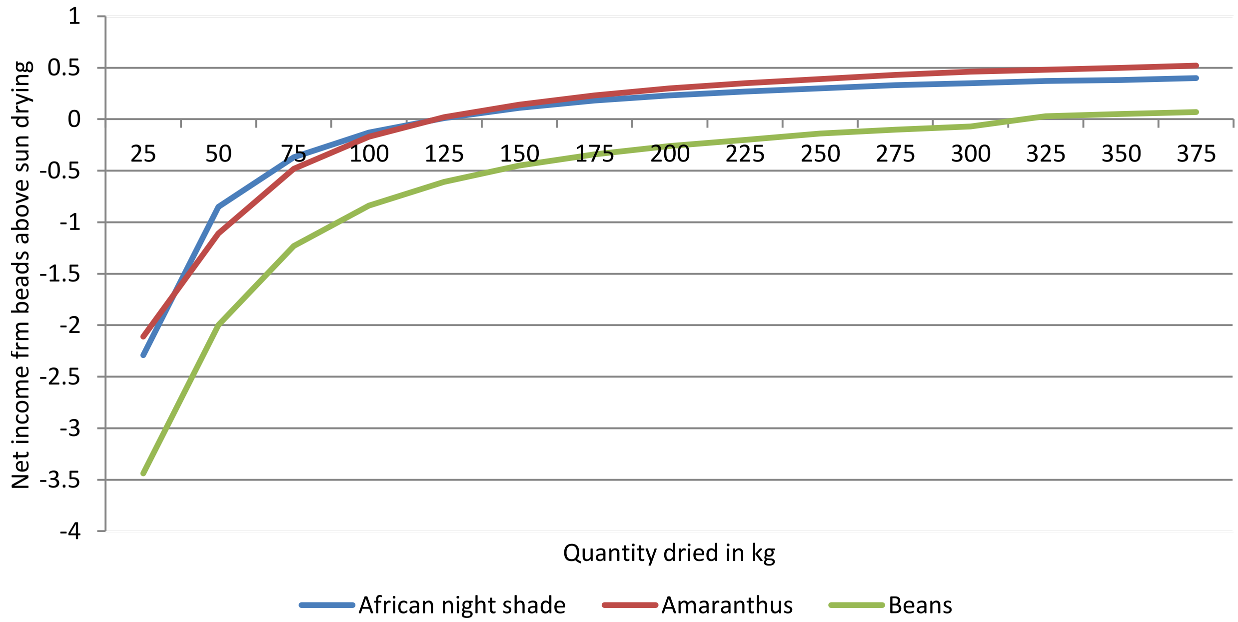

Figure 2. Net income from beads drying minus income from sun drying (US$/kg) for immediate sale in the informal seed system.

will require more production or pooled production from groups of farmers or large scale production of seeds. Given the potential of small scale production there is opportunity for using beads as efficiency in production of seeds increases. In addition, large scale seed production is likely to benefit more from use of the beads for drying and hermetic storage.

Situations under which using the beads is beneficial

A key driving factor in the use of any technology is the financial returns although there are also other benefits and costs that are more difficult to quantify. All the producers that provided information use sun drying as the method of choice. As a consequence, analysis is based on comparison of sun drying and ordinary storage with desiccant bead drying and hermetic storage. In the above comparisons with the 'standard' values, use of the beads/hermetic storage was not economically beneficial. However, under different circumstances this would change, so we investigated whether the returns become positive with greater volumes stored, or if there was a price premium for seeds stored properly.

Economies of scale

The use of beads at the current seed production level by the small scale seed growers was less profitable. However, as the per kg cost of using the beads decreases with increasing volume of seeds (Figure 1), the question then is at what quantity of seeds does use of beads become attractive? We assume that use of the beads would be economically attractive once the returns are greater than with traditional methods. Table 13 shows the seed volumes at which the returns in the two systems are equal.

Figure 2 shows how returns increase with increasing quantities of seed, for the informal seed growers. Although at different points use of the beads does become economically beneficial, the curves level off at a low level of return. Storage using hermetic containers also becomes more attractive when larger quantities are involved. The corresponding incomes increase and are relatively higher than using the beads for drying only. As

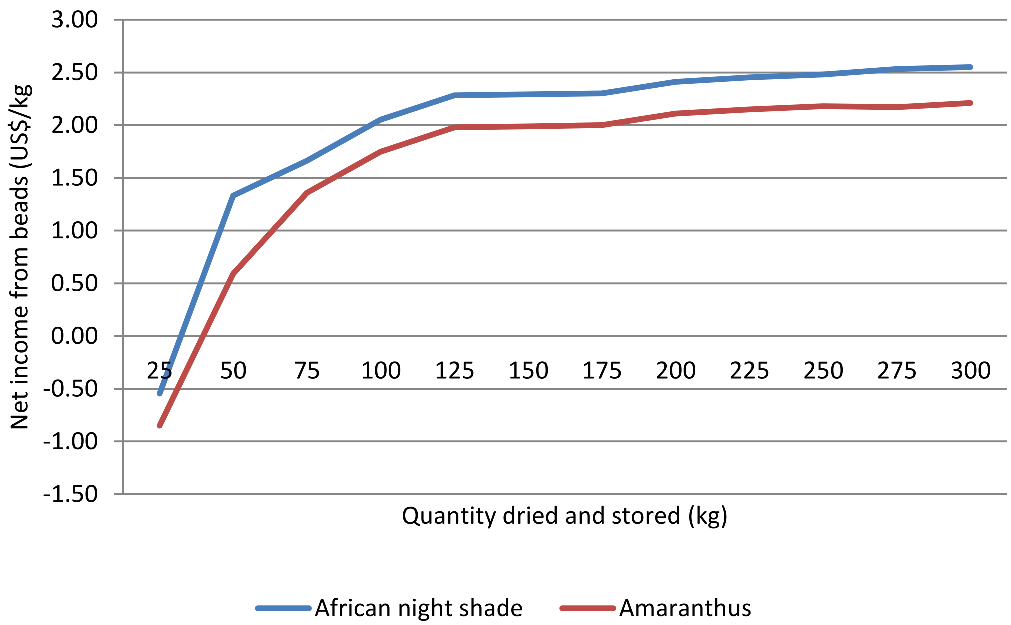

Figure 3. Net income from beads drying and storage minus income from sun drying in the informal seed system.

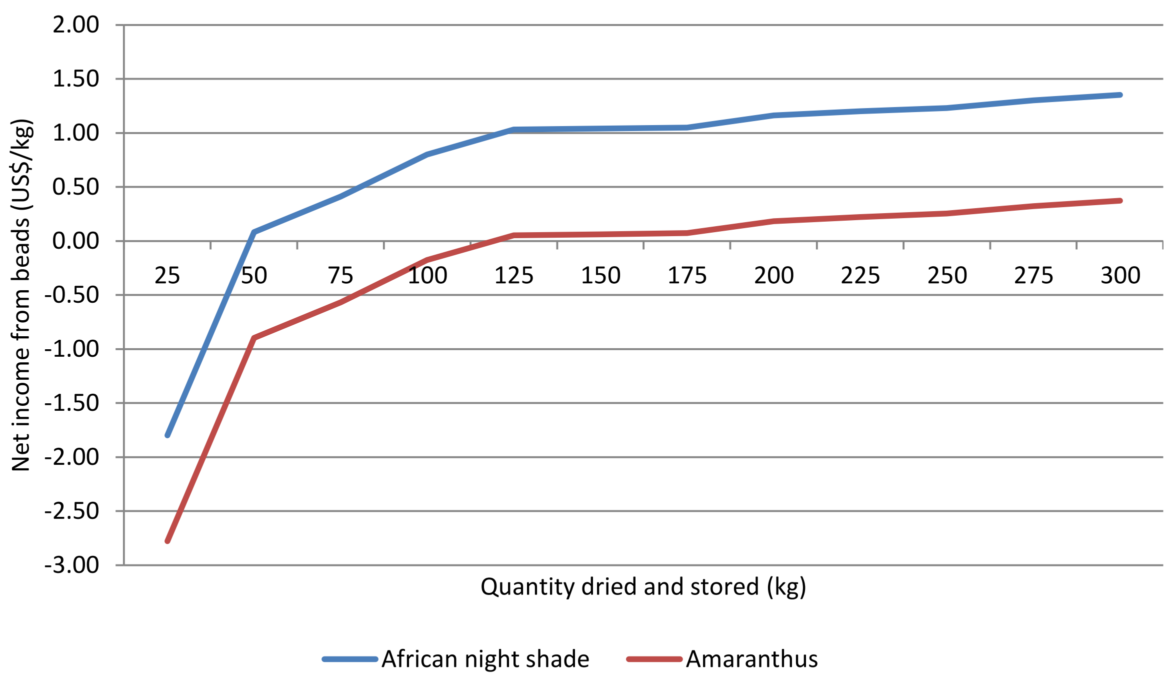

Figure 4. Net income from beads drying and storage minus income from sun drying in the quality declared seed system.

before, losses are assumed to be non-existent in the case of drying with beads and hermetic storage but sun drying and ordinary storage incur losses. Figures 3 and 4 show the difference in returns between the traditional and new methods for drying and storage as volumes increase for African night shade and Amaranthus, in the informal seed production system and the quality declared seed system respectively. The economies of scale apply to the traders as well. As the quantity of seeds dried and stored by the traders increases the net income associated with the use of desiccant beads/hermetic containers for drying starts increasing (Figure 5).

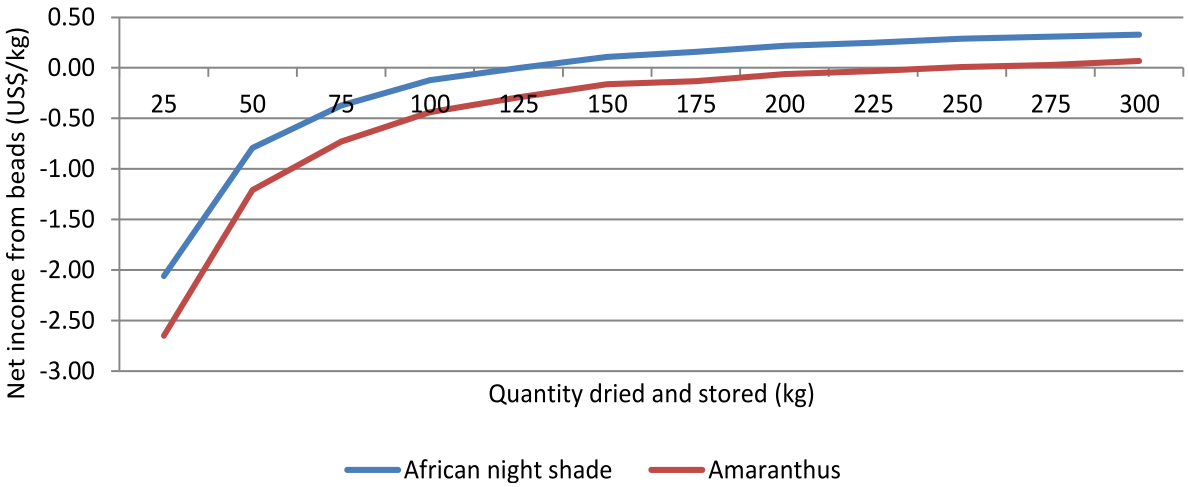

Figure 5. Net income from beads drying and storage minus income from sun drying for the traders.

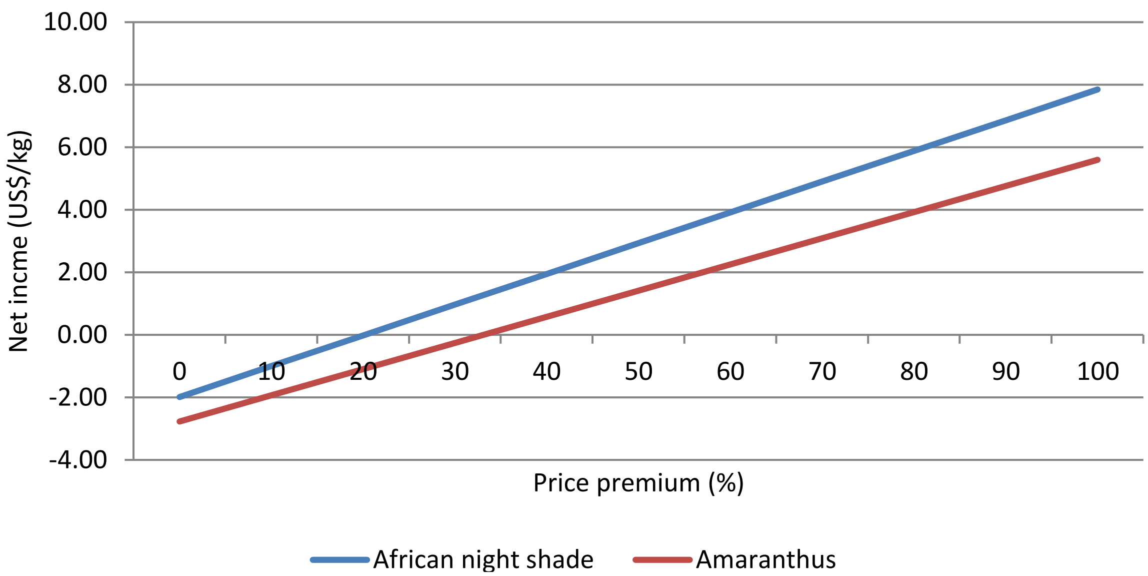

Figure 6. Effect of price premiums on net income from bead drying and storage in the informal seed system.

Price premiums

Price premiums for well dried and stored seeds would encourage efforts towards quality improvements as well as diversification of the drying and storage processes particularly given that efficient processes like bead drying appear expensive for smaller quantities. Starting with a zero premium which is the current price and adjusting the premium to 100% it was possible to establish the price premium at which the returns for the two methods were equal. Using the two preferred vegetables and the quantities of seeds currently produced in the informal seed system the premium is calculated. Taking 15 kg of African night shade seeds and 18 kg of amaranthus seeds, and the corresponding selling prices from Table 7, the net returns are as shown in Figure 6. The price premiums that would be necessary for the farmers to receive in order for there to be an economic incentive for them to use the beads are approximately 35% for Amaranthus and 20% for the African night shade.

For the quality declared seed system the quantity produced and used as base were 40 kg for African night shade and 50 kg for amaranthus. The baseline (0% premium) seed selling prices are again as in Table 7. Figure 7 provides the incomes adjusted by the price premiums for the two crops. The price premiums required are about 25% for African night shade and 60% for Amaranthus.

In the case of traders, the quantity produced and used as base were 50 kg for African night shade and 100 kg

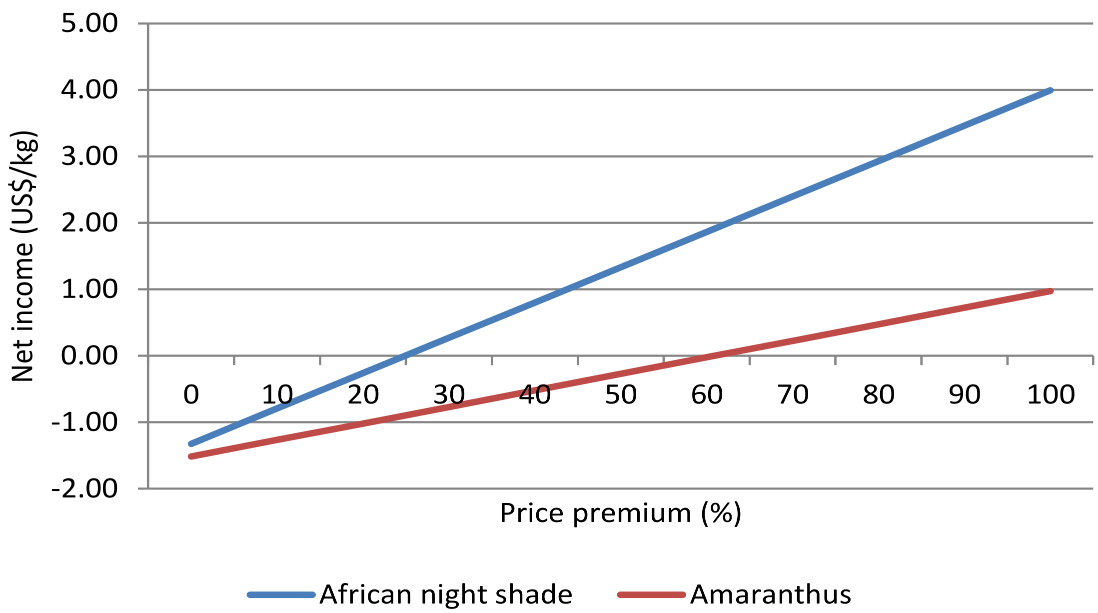

Figure 7. Effect of price premiums on net income from bead drying and storage in the QDS seed system.

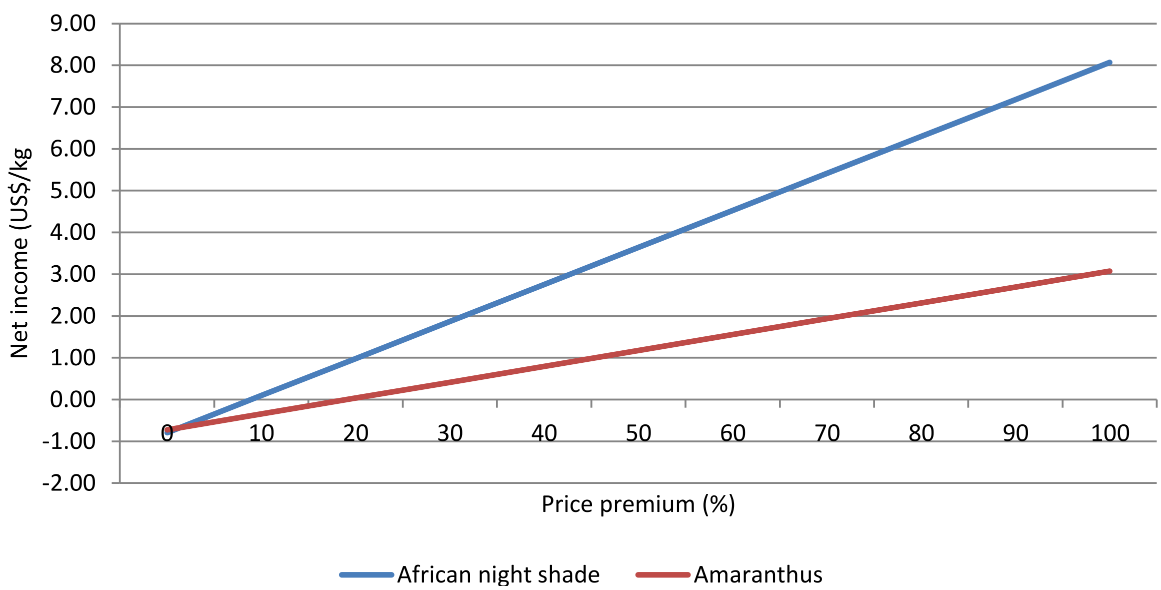

Figure 8. Effect of price premiums on net income from bead drying and storage by the traders.

for amaranthus. The seed selling prices were US$ 16.40/kg and US$ 8.25/kg for the African night shade and amaranthus respectively. Figure 8 provides the incomes adjusted by the price premiums for the two crops. The breakeven price premiums required are 7% for African night shade and 20% for Amaranthus.

Conclusions

Many different approaches to drying and storage are used, with widely varying estimates of costs. This suggests there may be at least some scope for improving the implementation of the traditional methods. The wide variability also suggests that in many cases farmers do not have a very good idea of their actual costs. The costs of desiccant drying/hermetic storage were relatively high compared to traditional methods under current production levels. The losses incurred in the traditional methods and improved production efficiency can offset the costs thereby justifying the use of desiccant bead drying/hermetic storage.

Using the values obtained from the field for current drying practices, use of the beads was less profitable. Extrapolation to relatively large quantities including production potential revealed that desiccant bead drying/hermetic storage can be profitable. Comparing the different seed systems is difficult, because the “standard” weight of seeds used in the model varied according to what was recorded in the field. However as larger amounts of seed are usually produced and sold by farmers under the contract system, the new technology is feasible.

When comparing the returns from drying and storage using the current methods with those from use of the beads and hermetic containers, the new methods were only profitable in case of larger quantities. The benefits would increase when a combination of bead drying and hermetic storage is used. This is because the storage costs using hermetic containers would be more than offset by the reduction in loss during storage.

Using larger volumes of seed is more cost effective because the cost per kg of using the beads and hermetic containers falls quite sharply as volume increases. Of interest here is the seed volume at which the traditional and new methods give equal returns, effectively the breakeven point on investing in the new technology. But the rate at which returns increase with higher volumes above the break-even point is also of interest, as technology users would want to see better than break even. When looking at drying alone, although break-even points (for the informal seed system) were at around 120 kg for Amaranthus and African night shade, above that point the graphs were flat, with returns from larger volumes only increasing slightly. Thus, for drying only, such as farmers in the contract system would use, the drying beads do not appear to offer economic benefits. When drying and storing using the new methods, there do appear to be economies of scale that could make the use of the technology attractive.

Given that individual farmers are usually drying and storing small volumes, this supports the suggestion that use of the beads is more likely to be appropriate in organisations such as farmer groups or cooperatives, as well as seed traders and companies. Gene banks are another organisation where larger volumes of seed might be stored, but this is only a very small potential market. The new methods would be more appropriate for seed species for which larger volumes are produced and traded. More widely grown species (such as beans) might therefore be a more successful entry point.

A price premium of around 20-30% would be needed to offset the higher costs of using the new methods and a higher premium would be needed to make the investment positively attractive. Price premiums are more likely to be sustainable in a more regulated and controlled market, where buyers can be confident that the higher price paid will actually ensure higher quality. This is likely to be effective under the QDS and contract seed systems. Sustainability of a price premium would also require farmers to be more aware of the value of buying good seed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

This study is part of the project entitled, “Seed Systems: Improving Seed Quality for Smallholders” led by the University of California, Davis, and implemented by CABI in Kenya and Tanzania. The authors appreciate the core financial support from their member countries (and lead agencies) including the United Kingdom (Department for International Development), China (Chinese Ministry of Agriculture), Australia (Australian Centre for International Agricultural Research), Canada (Agriculture and Agri-Food Canada), Netherlands (Directorate-General for International Cooperation), United States Agency for International Development (USAID) and Switzerland (Swiss Agency for Development and Cooperation).

REFERENCES

Ahuja KL, Singh H, Raheja RK, Labana KH (1987). The oil content and fatty acid composition of various genotypes of cauliflower, turnip and radish. Plant Foods for Human Nutrition 37:33-40.

Bradford KT, Dahala P, Asbrouck JV, Kunusothc K, Belloa P, Thompson J, Wue F (2017). The dry chain: Reducing postharvest losses and improving food safety in humid climates. Trends in Food Science and Technology 71:84-93.

CEAPRED (2010). Center for Environmental and Agricultural Policy Research, Extension and Development Annual Report (July 2009-July 2010). Available at: www.ceapred.org.np

Chomchalow N (2003). Protection of stored products with special reference to Thailand. Assumption University Journal of Technology 7(1):31-47.

Cromarty AS, Ellis RH, Roberts EH (1982). The design of seed storage facilities for genetic conservation. Rome: IBPGR.

Ellis RH (1988). The viability equation, seed viability nomographs, and practical advice on seed storage. Seed Science and Technology 16:29-50.

Ellis RH, Roberts EH (1981). The quantification of aging and survival in orthodox seeds. Seed Science and Technology 9:373-409.

FAO (1994). Grain storage techniques - Evolution and trends in developing countries. FAO Agricultural Services Bulletin (No. 109). Rome, Italy: Food and Agriculture Organization

Jones M, Corinne A, James LD (2014). A simple methodology for measuring profitability of on-farm storage pest management in developing countries. Journal of Stored Products Research (2014). Available at: https://dx.doi.org/10.1016/j.jspr.2013.12.006

Kumar D, Kalita P (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. Foods 6(1):8-30.

Kunusoth K, Dahal P, Van Asbrouck JV, Bradford KJ (2012). New technology for postharvest drying and storage of seeds. Seed Times (New Delhi) 5:33-38.

Murdock LL, Baoua IB (2014). On Purdue Improved Cowpea Storage (PICS) technology: Background, mode of action, future prospects. Journal of Stored Products Research 58:3-11.

Murdock LL, Seck D, Ntoukam G, Kitch L, Shade RE (2003). Preservation of cowpea grain in sub- Saharan Africa—Bean/Cowpea CRSP contributions. Field Crops Research 82(2):169-178.

Ndung'u S, Kimiti J (2017). Effect of moisture content and temperature on viability and longevity of Cordia Sinensis Lam. Seeds. Journal of Resources Development and Management 28:14-19.

Poonia TC (2013). History of Seed Production and its Key Issues. International Journal of Food, Agriculture and Veterinary Sciences 3(1):148-154.

Thomsen K (2000). Handling of desiccation and temperature sensitive tree seeds. Technical Note No. 56. Danida Forest Seed Centre. Humlebaek, Denmark 30 pp.

RSA (Research Solutions Africa) (2015). Report of a study on fresh vegetables market in Kenya: Desk review. Ministry of Economic Affairs, Agriculture and Innovation.

SSG (Seed Systems Group) (2019). Improved seeds improve lives: Extending the benefits of better crop varieties to all of Africa. Available at: http://seedsystemsgroup.org/wp-content/uploads/2019/08/SSG-Launch-Report-web.pdf