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THE ECONOMIC BENEFITS OF SMALL-HOLDER USE OF HERMETIC STORAGE FOR WHEAT IN AFGHANISTAN

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Abstract

Farmers in Afghanistan are able to produce quality grain, however, are unable to store the grain to maintain quality and seed viability. This greatly contributes to high rates of poverty and food insecurity. The Purdue Improved Crop Storage (PICS) bags are a means of low-cost hermetic storage that provides efficient, airtight grain storage for small size farmers that can reduce the loss of crops during storage and provide more food to people. The expected profitability of PICS bags compared to current storage used by farmers was determined before a specific distribution strategy for PICS bags in Afghanistan is implemented. Wheat samples from Balkh, Herat, and Nangarhar provinces were stored in either PICS bags or local woven polypropylene (PP) bags and sampled following 3 and 6 months of storage. The samples were examined for insect damage and percent germination following storage to determine the economic return from each type of storage system. The value of reduced storage loss with use of the PICS bags is greater than the cost of the bag, therefore, the economic return on PICS bags is higher than that of PP bags. This indicates the use of PICS bags is better than current storage practices. The PICS bag storage technology appears to be a viable option for grain storage in Afghanistan to prevent grain damage and to maintain seed quality and viability for wheat.
Keywords: *Wheat, Hermetic Storage, Economic Assessment, Technology, Afghanistan*
Jel Codes: *Q12, O13*

1. Introduction

Agriculture has been an important part of human society with wheat crops being among the first staples that people cultivated (Zohary, 1999). With the fast-growing rate of the world population, shortages of food and poverty are threatening low-income countries, such as Afghanistan. The shortage of food results from low productivity, climate change, financial constraint, and postharvest losses (World Bank, 2011). In the last three decades, 95% of research has been directed toward increasing productivity and only 5% on reducing postharvest losses (Costa, 2014).

Afghanistan faces several problems due to conflict, poor governance, drought, and an isolated geography that has resulted in low agriculture productivity, unemployment, and poverty throughout the country (Levin, 2009; Islamic Republic of Afghanistan Central Statistics Organization, 2018). Approximately three million people live in poverty and face severe food shortages (Oxfam, 2015) with 78.2% of urban households falling below the poverty line (Hall, 2014). An estimated 7.6 million Afghans (30% of the Afghan population) are very severely to moderately food insecure. Approximately 34% of the urban population is food insecure compared to 29% of the rural population (Central Statistics Organization, 2018). Storage loss, such as with wheat, is one factor contributing to the shortage of food and low incomes (Ahmadzai, 2011). FAO estimates the loss at 15% of the total production (Food and Agriculture Organization of the United Nations, 2013).

Half of the wheat (*Triticum aestivum*) production in Afghanistan is produced in the northern plains. The northern part of the country used for crop production has both rainfed and irrigated land. Wheat is the most consumed staple in Afghanistan and accounts for 70% of Afghanistan's total daily diet intake (FEWS NET, 2010), however, wheat production has experienced a 2% annual decline between 1978 and 2001 (World Bank, 2005). Wheat crops account for 80% of the total cereal production, followed by maize and rice, respectively (Jilani, Pearce, & Bailo, 2013). Wheat production is subdivided into rainfed and irrigated land with approximately 45% of the total acres planted being in irrigated land that accounts for 70% of the total production. Yields on the remaining 55% of wheat farms depend on timely rainfall, generally accounting for 30% of the domestic production. Wheat production yields vary across the country, and especially in Northern Afghanistan, due to the high percentage of farms that rely on rainfed agriculture (USDA, 2014).

The major losses of grain during storage are caused by insects, molds, birds and rats. The most common insect species that impact wheat quality during storage are the khapra beetle (*Trogoderma granarium*), lesser grain borer (*Rhizopertha dominica*), rice weevil (*Stitophilus Oryzae*) and the red flour beetle (*Tribolium castaneum*). Other insect species that infest wheat in storage include the angoumois grain moth (*Sitotroga cerealella*), rice moth (*Corcyra cephalonica*), saw toothed grain beetle (*Oryzaephilus surinamensis*), long headed flour beetle (*Latheticus oryzae*), and the flat grain beetle (*Cryptolestes pusillus*; Baloch, 1999). It has been estimated that every insect present in 100 seeds reduces the price of the grain by 2.3% (Jones, Alexander & Lowenberg-Deboer, 2014) following storage.

Farmers often use chemical sprays to prevent grain damage by insects, however, the effectiveness of insecticides is limited and the long term effects do not greatly reduce grain loss (Njoroge et al., 2014). Common insecticides used for grain pests in developing countries are Actellic® Super (1.6 % pirimiphos-methyl + 0.3% permethrin) and Sofagrain® (1.5% pirimiphos-methyl + 0.5% deltamethrin; Njoroge et al., 2014). Njoroge et al. (2014) determined that 7% of weight loss depreciates the market value of grain by 27% when Sofagrain® insecticide is used for preventing pests. In addition, identical results have been reported for Actellic® Super (Najoroge et al., 2014). Grain loss during storage still persists although insecticides are routinely being used.

Farmers in Afghanistan utilize very basic storage methods, with most farmers storing their grain on the farm in metal drums, bags and/or on the floor in their homes (Ahmadzai, 2011). Most farmers save their yield for household consumption, seed for the next growing season, and then sell their surplus right after harvest. The sale of surplus grain occurs when all farmers are selling their surplus so the market is saturated and the farmers receive low payments for their wheat. Afghan farmers could greatly benefit by having a safe, inexpensive storage technology, such as the Purdue Improved Crop Storage (PICS) bags, which would reduce the loss of crops during storage and provide more food to people. In addition, this would allow the grain to be sold at a later date and give the farmer a premium price for their wheat.

Extension and educational programs that are designed to teach farmers storage technologies would reduce storage loss and hence increase farm income to reduce the prevalence of food insecurity and poverty in Afghanistan.

Although various storage technologies are available, adoption of the technology, even after successful implementation by the farmers, does not guarantee sustainability unless it produces more profit than the older technology currently being used. Potential demand for a technology requires a careful analysis of the local market to determine if the technology is profitable for small size farmers. Comprehensive economic analysis needs to be performed to determine losses and whether farmers are better off using the new technology compared to the method of storage they are currently using. If the new storage method does not generate interest among farmers, then the producers of the technology would lose their initial investments in the production of the technology. Jones et al. (2014) argues that profitable storage technology relies on commodity price, price seasonality, and storage costs. Storage losses are measured based on how the grain will be utilized. Growers who produce grain for household consumption are primarily concerned with dry weight losses. Growers who produce grain to store for next season seed are primarily concerned with seed viability and germination rates. Market producers are concerned with the discounted price of the grain after the damage caused by pests. Total revenue is affected by both dry weight losses and price discounts (total value loss) so both are equally important to focus on to reduce during storage.

1.1 Seed Quality and Germination

Healthy seeds that are free of pests, disease, and damage are likely to result in plants that will produce a high yield at harvest. Retaining quality seeds for future use will require pre-storage treatment before seeds are stored. Not all grain loses quality at the same rate as some grains are more vulnerable and deteriorate more quickly than others. Good quality seeds can be maintained for 9-12 months if proper management techniques are practiced. Most Afghan farmers are not knowledgeable regarding the proper time to store seeds. Seeds that are to be stored need to be dry, and the moisture content should be reduced to minimum levels in order to avoid seed spoilage during storage (Sukprakarm, Juntakool & Huang, 2005). If the moisture content is too high, the seeds will become moldy as sealed storage does not allow moisture to evaporate (Golob, 2009). In addition, high temperatures deteriorate grain viability and accelerate seed respiration. Storing seeds at a low temperature and humidity will prevent deterioration and pest attack (Sukprakarm, Juntakool & Huang, 2005). It is common that stored grains will lose quality due to seed respiration, but those losses can be reduced when seeds are stored hermetically (Hodges & Stathers, 2012).

Several studies have demonstrated PICS bags retain grain quality and seed viability. A comparison of seed germination tests was conducted to determine the difference between the viability of seeds stored in PICS bags compared to those stored in woven bags (Baributsa et al. 2014). The result from this trial demonstrated that storing seeds in a woven bag drastically decreased seed viability, while seed stored in PICS bags maintained seed germination. The germination rate of seeds stored in woven bags decreased by 26%, while germination rates decreased by 3% for seeds that were stored in PICS bags. Similar results were found when mung beans were stored for 6 months in woven polypropylene (PP) bags. The germination rate of these seeds decreased to 41.9%, while mung bean seeds stored under similar conditions and time in PICS bags retained germination rates above 70% (Mutungi et al., 2014). Most farmers in developing countries rely on their own seed to plant for the next growing season. Maintaining good quality seeds with high germination rates is vital for a good harvest.

1.2 Hermetic Storage Using PICS Bags

The main storage techniques used in Afghanistan are identical to other developing countries. Grain is typically stored in the field, in open storage, in jute sacks, polyethylene or polypropylene bags, on raised platforms, in clay structures, or in giant woven baskets. These are considered traditional methods, while semi-traditional methods include storage in improved covered structures and/or cribs. Formal or semi-modern storage includes silos and warehouses. Bag or sack storage is common for grains and pulses and the bag is often made of jute or woven polypropylene, hemp, sisal or polythene (Jones, Alexander, & Lowenberg-DeBoer, 2011). Farmers typically also use old fertilizer bags for grain storage (Golob, 2009). The durability of these bags depends on the quality of the material that is used to produce the bags. Due to lack of data, it is difficult to predict the annual cereal loss in Afghanistan, but rough estimates are between 10-30% (Reynolds, Safi, & Bunnel, 2014). Therefore, there is a need for improved methods of grain storage in Afghanistan.

Grain damage does not occur only after harvest. Many factors such as poor cultivation practices, pest infestation, type of seed cultivated, time of harvest, climatic conditions, and handling during storage are the main factors that have to be examined to reduce grain loss at the farm (Golob, 2009). The United States Department of Agriculture (USDA) launched the PICS technology in Afghanistan, which has been widely adopted in African countries, to tackle postharvest losses. These bags have a triple layer design that prohibits the movement of oxygen into the PICS bag. The lack of oxygen reduces insect respiration that ultimately prevents insect growth and regeneration. It was determined that the volume of oxygen in the bag decreases from 21% (v/v) to 2-3% (v/v) within two days of storage (Baoua, Margam, Amadou, & Murdock, 2012). Insects that are inside the PICS bags use oxygen for respiration and produce carbon dioxide (Baoua et al., 2012). Insect feeding activity ceases when oxygen levels reach 5% and carbon dioxide levels increase to 15-20% in the bag so damage done to the grain significantly decreases at these environmental conditions (Murdock et al., 2012). Oxygen reduction in the PICS bags eventually causes the insects to die or become inactive (Murdock, Margam, Baoua, Balfe, & Shade, 2012).

The damage from the insects to the grain that is present causes dramatic weight loss of the seeds. Grains stored in woven bags lost considerable weight, 21.5%, during 6.5 months of storage. However, grains stored in PICS bags had no weight loss and no damage to the grain over the same storage period (Baributsa et al. 2014). PICS bags have been used and tested in many countries and have been found to have a higher comparative advantage over local woven bags (Mejia, 2008).

There are many factors that need to be considered before PICS bags are recommended for grower use. Studies have shown that storing low value crops, such as corn, in PICS bags is not profitable if the seasonal price increase is not greater than 50%. However, high value crops require less than 50% price increase (Jones, Alexander, & Lowenberg-DeBoer, 2014). Before a specific distribution strategy for PICS bags in Afghanistan is recommended, the expected profitability of PICS bags with current storage used by farmers needs to be assessed. To determine if storing wheat using PICS bags can improve seed quality and viability, storage tests were performed that compared local woven bags to identical trials using PICS bags for three and six months of storage in Balkh, Herat and Nangarhar provinces in Afghanistan. In addition, the economic return of using the two types of storage systems in each province could be determined to provide insight into the profitability of using PICS bags for storage compared to currently used woven bags.

2. Methodology

2.1 Experimental Overview

On-farm storage trials were conducted in three different provinces of Afghanistan in 2011and 2012 using wheat grain. Newly harvested local wheat varieties that were not treated with insecticides were chosen from voluntary farmers from nine villages in the Nangarhar province. Similarly, nine villages from both Balkh and Herat were selected to participate in an on-farm trial comparing both PP and PICS bags. From each village, a total of five farmers were randomly selected to participate in the on-farm storage trials. The wheat was sampled at the beginning of the trial (0 months of storage) and following three and six months of storage.

2.2 Bagging, Storage, and Sampling

PICS bags were manufactured by the Shandand Company in Herat, Afghanistan. The PICS bags are comprised of two 80 µm thick inner high-density polyethylene bags that are covered by a woven polypropylene bag. The seals of the PICS bags were tested to ensure the bags were properly sealed during manufacturing so a hermetic storage environment could be attained following the final sealing of the bag. The PICS bags were supplied to the farmers and both PICS bags and PP bags were filled with 24 kg of wheat from the farm harvest and the bags sealed using plastic rope. The bags were opened, 100 seeds removed from the sample, and then resealed following sampling.

2.3 Determination of Germination Rates

Following sampling, the seeds were moistened with tap water for 30 minutes and two pieces of filter paper were used to cover 100 seeds. The seeds were then placed in Ziploc® (S.C. Johnson Company, WI, USA) bags and stored for three days at 25°C. Seeds that were positive for germination had the emergence of the plumule and radical after three days of incubation. The germination rate was measured on a scale from 0-100.

2.4 Statistical Analysis

Grain damage and germination rate data from the on-farm wheat storage trials in Balkh, Herat and Nangarhar provinces were analyzed using a two-sample t-test with unequal variance (Stata SE version 13, StataCorp LP, Texas, USA) to determine if there were significant ($p < 0.05$) differences between PP and PICS bags.

3. Results and Discussion

3.1 Nangarhar Province

There were significant differences between the two types of storage systems in Nangarhar province (Table 1). Germination rates of grain stored in PP bags decreased significantly from 94% to 69% in six months of storage, while germination rates in PICS bags only decreased from 94% to 92% during the same storage time. There were also significant differences in the germination rates for grains stored for three months in PICS bags compared to conventional PP bags (Table 1).

Table 1. Average Grain Damage and Germination Rates (100 Seeds) of Wheat Stored In PP Bags and PICS Bags in Nangarhar Province for Six Months of Storage.

Nangarhar	0 months		3 months		6 months	
Damage	Mean	SD	Mean	SD	Mean	SD
PP bag	0.22%	0.59	8.95%	7.49	17.75%	9.72
PICS bag	0.22%	0.59	0.44%	0.91	0.31%	0.73
Germination						
PP bag	94.22%	2.96	85.28%	7.68	69.08%	11.16
PICS bag	94.22%	2.96	93.31%	2.95	92.15%	2.86

Grain damage from insects increased for the wheat stored in PP bags, while no damage was found from the wheat stored in PICS bag over the six months of storage (Table 1). The number of seeds damaged (defined by the presence of an insect hole in the seed) in 100 seeds was significantly higher at three and six months of storage in PP bags compared to PICS bags. Wheat stored in PP bags had nine damaged seeds in 100 seeds during three months of storage, however, increased to 18 seeds following six months of storage. Seed had an average of 0.22% damage in 100 seeds at the start of the trial for 45 farmers in nine villages, but after three and six months of storage in PP bags the grain damage was 9% and 18%, respectively (Table 1). Wheat stored in PICS bags had significantly lower damage compared to storage in PP bags with an average of 0.44% and 0.31% damaged at three and six months, respectively (Table 1). Nangarhar province typically has a higher level of grain damage due to favorable weather conditions (higher humidity and temperature) for seed decay and insect attack. PP bags allowed insect populations to increase in the bag and cause damage to the wheat seeds. However, PICS bags inhibited insect growth and reduced grain damage.

Table 2. Comparison of Economic Loss from Germination Losses Using PICS Bags Compared to Using Traditional PP Bags in Nangarhar Province.

PICS Bags		PP Bags		Differences (PP-PICS)
Seeds per hectare	3,700,000	Seeds per hectare	3,700,000	0
Adjusted for health seed	4,015,193	Adjusted for health seed	5,356,109	1,340,916
Gram seed per Ha	180,687	Gram seed per Ha	241,024	60,341
Kg seed per Ha	180	Kg seed per Ha	241	60.34
Value of seed per Ha (AFN)	3,613	Value of seed per Ha (AFN)	4,820	1,207
USD per Ha	$70.85	USD per Ha	$94.51	$23.66
Area planted in Nangarhar	68,400	Area planted in Nangarhar	68,400	0
Total USD used for seeds in Nangarhar	$4,846,574	Total USD used for seeds in Nangarhar	$6,465,138	$1,618,565
Kg of total in Nangarhar	12,358,763	Kg of total in Nangarhar	16,504,920	4,146,157
Ton of seed used in Nangarhar	12,358	Ton of seed used in Nan	16,505	4147
# PICS required	247,175	# PP required	330,098	82923
PICS cost USD	$271,408	PP cost USD	226,538	-44870
Return if PICS is used for entire province	PICS bag return (Net market value – PICS cost) = $1,618,565-$44,870=$1,573,695			

A comparative analysis of seed viability and grain damage on the two types of storage was calculated to determine how much grain is needed for the next growing season when germination rates declined in PP and PICS bags (Table 2). To calculate the comparative advantage of PICS bags over conventional bags, it was determined that an average of 3.7 million seeds are required per hectare (1.5 million per acre) for wheat crop seeding (NEBRASKA–LINCOLN, 2014). The number of seeds was then adjusted to 3.7 million seeds based on the germination rates for six months of storage for PICS bags and conventional PP bags. It was determined that PICS bags retain a 92% germination rate over six months of storage and the adjusted seed rates are roughly 4 million seeds based on the 92% germination rate. The number of seeds was then converted into grams, kilograms, and tons. According to the literature 1,000 seeds are equal to 45 g (Protic et al., 2007), therefore, the seed rate of 4 million seeds was multiplied by 45 and then divided by 1,000 to determine the seeds (in grams) needed for one hectare. It was determined that 180 kg of seeds were required for one hectare of land to propagate. To determine the market value for one hectare in Afghanistan currency (Afghani), the number of seeds required (180 kg) was multiplied by 20. Based on a 2013 report (MAIL 2013), 68,400 hectares of land were cultivated in 2013, therefore, this value was multiplied by the market price to measure the market value for seeds for the entire Nangarhar province.

Based on these calculations, 12,358 tons of grain is required for Nangarhar when stored in 247,175 PICS bags. The PICS bags used could store up to 50 kg of grain. The total cost for the PICS bags for one year was determined to be $271,408. It was assumed that the PICS bags would be usable for 2 years, thus PICS bags would cost $1.02 USD and $0.68 USD for the local PP bag per year. Market value for grain and PICS bags were calculated based on 2013 exchange rates with similar calculations done for conventional PP bags. The total value of seeds stored in PICS bags in Nangarhar would be $4.8 million USD and $6.45 million USD for conventional bags indicating the value difference between PICS bags and conventional bags is $1.61 million USD. This indicates that if grain is stored in PICS bags it would save $1.61 million dollars. The storage cost for PICS bags would be $271,408 and $226,538 for conventional PP bags. If the difference between storage costs ($44,870) is subtracted from the total saving of using PICS bags for storage (1.61 million – 44,870 = $1,573,695) then the overall saving of using PICS bags would be $1.57 million USD if the seeds are stored for the next growing season (Table 2). PICS bags would save farmers roughly $24 USD per hectare or 60 kg of seeds by reducing seed planting requirements. The estimated impact of using PICS bags for a farmer with one hectare of land is $22.17. Seeding rates per hectare would be 180 kg with grain stored in PICS bags versus 241 kg for grain stored in local bags.

3.2 Balkh Province

The amount of damage to the wheat was measured at time zero for both PP and PICS bags. A total of 3.44% of the wheat seeds sampled had the presence of damage at the beginning of the trial for both PP and PICS bags (Table 3). However, further damage was not observed in the PICS bags stored samples after three and six months of storage. Damage to the seeds increased to 5.53% in the PP bag stored samples after six months of storage (Table 3). The presence of damage decreases the quality of the grain and the ability for the seed to germinate. The amount of damage observed from the wheat stored in PICS bags and PP bags after three and six months of storage was significant.

Differences were observed between the wheat germination rates over a period of six months of storage in PICS bags and PP bags. The germination rate decreased from 94.33±2.84% to 93.82±2.77% following three months of storage in the PICS bags and to 93.15±2.73% within six months of storage. However, seeds stored in PP bags decreased to 84.35±5.16% from 94.33±2.84% within six months due to extensive insect damage. These differences between germination rates following three and six months of storage in PICS bags and local PP bags were statistically significant (Table 3).

Table 3. Average Grain Damage and Germination Rates (100 Seeds) of Wheat Stored in PP Bags and PICS Bags in Balkh Province

Balkh	0 month		3 months		6 months	
Damage	Mean	SD	Mean	SD	Mean	SD
PP bag	3.44%	2.80	3.15%	2.35	5.53%	2.80
PICS bag	3.44%	2.80	0%	0	0%	0
Germination						
PP bag	94.33%	2.84	90.13%	3.42	84.35%	5.16
PICS bag	94.33%	2.84	93.82%	2.77	93.15%	2.73

The economic comparison of the two types of storage technology based on germination loss in Balkh province was determined (Table 4). The PICS bags would generate a $532,253 margin compared to local PP bags for the entire Balkh province. The PICS bags reduce seeding rates from 197 kg to 178 kg per hectare indicating there is roughly a $7 USD margin between PICS bags and local bags per hectare. A comparative analysis of seed viability and grain damage on the two types of storage was done to determine the amount of grain needed when germination rates decline in local PP and PICS bags in the Balkh province. The comparative advantage of PICS bags over local PP bags was then calculated as described above for Nangarhar province. A total of 178.74 kg of seed are required when PICS storage is used for one hectare of land to propagate and this was then multiplied by 20 Afghani, the cost of one kg in local currency. Based on available data (MAIL, 2013), 87,300 hectares of land were cultivated in 2013 so this value was multiplied by market price to measure the market value for seeds for the entire Balkh province.

A total of 15,604 tons of grain were required for seed stored in PICS bags and 17,232 tons in of seed if they were stored in local PP bags in Balkh province. Therefore, a total of 312,087 PICS bags would be required for 15,604 tons of grain. The total cost of the PICS bags for one year was determine to be $342,683. Assuming the PICS bags would be usable for two years, it would cost $2.04 USD per PICS bag. The market value for grain and PICS bags were calculated based on 2013 exchange rates. Similar calculation was done for conventional PP bags (Table 4).

The total value of seeds if stored in PICS bags in Balkh would be $6.1 million USD, and it would be $6.7 million USD for conventional bags indicating the difference between PICS bags and conventional bags is $638,000 USD. In other words, the provincial government administration would need to spend roughly $6.7 million USD to store seed in PP bags for the next growing season while PICS bags would cost $6.1 million USD. This means that if grain stored in PICS bags would save $638,000 USD and this estimate is not including storage cost. If storage costs are considered, PICS bags would have a storage cost of $342,683 and for conventional bags it would be $236,522. The difference of cost between PICS bags and PP bags is $106,161, and if this is subtracted from the storage saving ($638,414– $106,161 (extra cost of PICS)), then it would be $532,253. In summary, PICS bags would save approximately $500,000 USD if the seeds are used for next growing season. Overall, the PICS bags would save farmers roughly $7.4 USD per hectare or 19 kg of seeds by reducing seed planting requirements. Seeding rates per hectare would be 178 kg for grain stored in PICS bags versus 197 kg for grain stored in local PP bags (Table 4).

Table 4. Economic Comparison of Using PICS Bags and Local PP Bags Based on the Germination Loss for Wheat during Storage in Balkh Province

PICS Bags		PP Bags		Differences (PP-PICS)
Seeds per hectare for Irrigated wheat	3,700,000	Seeds per hectare	3,700,000	0
Adjusted for health seed	3,972,088	Adjusted for health seed	4,386,484	414,396
Gram seed per Ha	178,743	Gram seed per Ha	197,392	18,649
Kg seed per Ha	178	Kg seed per Ha	197	19
Value of seed per Ha (AFN)	3,575	Value of seed per Ha (AFN)	3,948	373
USD per Ha	$70	USD per Ha	$77.40	$7.4
Area planted in Balkh	87,300 Ha	Area planted in Balkh	87,300 Ha	0
Total USD used for seeds in Balkh	$6,119,352	Total USD used for seeds in Balkh	$6,757,767	$638,415
Kg of total in Balkh	15,604,347	Kg of total in Balkh	17,232,305	1,627,958
Ton of seed used in Bal	15,604	Ton of seed used in Bal	17,232	1,628
# PICS required	312,087	# PP required	344,464	32,377
PICS cost USD	342,683	PP cost USD	236,522	-106,161
Return if PICS is used for entire province	PICS bag return (Net market value – PICS cost) = $638,415-$106,161=$532,253 USD			

4.3 Herat Province

Herat province had a similar amount of grain damage as Balkh province over the three and six months of storage. There was an average of 0.02% seed damage at the start of the trial from 45 farmers in nine villages for both PP and PICS bags. After three months, the grain damage increased to 4% from 0.02% in the local PP bags. In comparison, the PICS bags had no additional damage in the samples following three and six months of storage (Table 5). These differences between the PICS bags and the local PP bags were found to be statistically significant following three and six months of storage.

Table 5. Average Grain Damage and Germination Rates (100 Seeds) of Wheat Stored in PP and PICS Bags in Herat Province

Herat	0 month		3 months		6 months	
Damage	Mean	SD	Mean	SD	Mean	SD
PP	0.022	0.14	3.97	6.57	3.24	1.44
PICS	0.022	0.14	0	0	0	0
Germination						
PP	99.53	1.02	93.6	2.46	90.44	4.41
PICS	99.53	1.02	98.66	1.24	97.93	1.19

The seed viability following three and six months of storage in local PP and PICS bags in Herat province was higher compared to Nangarhar province. Seed germination decreased to 93.6% from 99.53% in PP bags, while grain germination decreased to 98.66% within three months of storage in PICS bags. Germination rates and grain damage following three and six months of storage in PICS bags and local PP bags were significantly different. These results suggest that the use of PICS bags for storage of grains greatly improves the seed viability and quality.

The economic return using the two different types of storage technologies was determined (Table 6). PICS bags in Herat province would generate around $350,000 USD for all grain that would be used for the following growing season. Similar calculations were performed as done for the Nangarhar and Balkh provinces (Table 6). The seeding rates for PICS bags would be 170 kg per hectare, while the local PP bags would require 184 kg. This means that there is a $5.5 USD margin between PICS bags and local PP bags.

Table 6. Comparison of the Economic Loss Due to Germination Loss Following Storage in PICS Bags and Local PP Bags in Herat Province

PICS Bags		PP Bags		Differences (PP-PICS)
Seeds per hectare irrigated wheat	3,700,000	Seeds per hectare	3,700,000	0
Adjusted for health seed	3,778,209	Adjusted for health seed	4,091,110	312,901
Gram seed per Ha	170,019	Gram seed per Ha	184,099	14,080
Kg seed per Ha	170	Kg seed per Ha	184	14
Value of seed per Ha (AFN)	3,400	Value of seed per Ha (AFN)	3,682	282
USD per Ha	$66.67	USD per Ha	$72.19	$5.52
Area planted in Herat	82,400 Ha	Area planted in Herat	82,400 Ha	0
Total USD used for seeds in Herat	$5,493,960	Total USD used for seeds in Herat	$5,948,955	$454,995
Kg of total in Herat	14,009,598	Kg of total in Herat	15,169,836	1,160,238
Ton of seed used in Herat	14,009	Ton of seed used in Herat	15,170	1,161
# PICS required	280,192	# PP required	303,397	23,205
PICS cost USD	307,662	PP cost USD	208,213	-99,449
Return if PICS is used for entire province	PICS bags return (Net market value – PICS cost) = $4549,95 - $99,449 = $355,546			

4.4 Cross Provinces Comparison

Cross province results of germination rates between Nangarhar and Balkh province are different when grain is stored in local PP bags for three and six months of storage. There is an increase in germination loss and grain damage in the Nangarhar province, but grain stored in the PICS bags in all three provinces maintained similar grain quality and viability. PICS bags for storage had similar results in every province as little grain damage was observed and the quality of the grain was retained.

Table 7. Summary of the Economic Loss Between Using PIC Bags and Local PP Bags for Storage to Reduce the Germination Loss for Winter Wheat in Three Provinces (Balkh, Herat, Nangarhar) in Afghanistan.

Provinces	Balkh		Herat		Nangarhar	
Storage types	PICS	LOCAL PP	PICS	LOCAL PP	PICS	LOCAL PP
Seeds per hectare for irrigated wheat	3,700,000	3,700,000	3,700,000	3,700,000	3,700,000	3,700,000
Adjusted for grain quality	3,972,088	4,386,484	3,778,209	4,091,110	4,015,193	5,356,109
Gram seed per Ha	178,743	197,392	170,019	184,099	180,687	241,024
Kg grain per Ha	178	197	170	184	180	241
Value of grain per Ha (AFN)	3,575	3,948	3400	3682	3613.67	4820
USD per Ha	$70	$77.40	$66.6	$72.19	$70.85	$94.51
Area planted	87,300 Ha	87,300 Ha	824,00 Ha	82,400 Ha	68,400 Ha	68,400 Ha
Total USD used for grain	$6,119,352	$6,757,767	$5,493,960	$6,465,138	$4,846,574	$6,464,138
Kg of total	15,604,347	17,232,305	14,009,598	15,169,836	12,358,763	16,504,920
Ton of grain used	15,604	17,232	14,009	15,17	12,385	16,505
# PICS required	312,087	344,464	280,192	303,397	247,175	330,098
PICS cost USD	$342,683	$236,522	$307,662	$208,213	$271,408	$226,538
Return if PICS is used for entire province	$638,415		$454,995		$1,618,565	
Storage cost difference of PICS and local	$106,161		$99,448		$44,870	
Net return	$532,253		$355,546		$1,573,695	

The net return from PICS bags in the three provinces is summarized in Table 7. Nangarhar province generated the highest margin in terms of value for one hectare compared to Balkh and Herat province using PICS bags. Nangarhar province had a four times higher return compared to other provinces indicating it would be the most profitable to use the PICS bags in this province. There is approximately $24 USD difference between PICS bags storage and local PP bags for one hectare in Nangarhar province, while for Balkh and Heart province it is between $6 and $7 USD.

5. Conclusions

The PICS bag storage technology appears to be a viable option for grain storage in Afghanistan to prevent grain damage and to maintain seed quality and viability for wheat. These studies suggest that current practices result in low quality grain due to poor storage and pest infestation. PICS bags can reduce storage loss compared to PP bag storage systems in

Afghanistan. The value of reduced storage loss with the use of PICS bags is greater than the cost of the bags. The World Bank works on a Strategic Grain Reserve Project for Afghanistan that is designed to establish a wheat strategic reserve to meet emergency needs and improve the efficiency of the grain storage management (World Bank, 2017). The use of PICS bags as an element of national storage to meet household needs should be considered.

The economic return on PICS bags appears to be higher than that of PP bags indicating the use of PICS bags are better than current practices. Future work to improve the knowledge and adoption of PICS bags in Afghanistan include 1) conducting research using the PICS bags for storage in other geographical regions in Afghanistan, 2) introduce the PICS bag storage system to more farmers throughout Afghanistan, and 3) conduct future studies that examine local production and vulnerability of the crops to pests and poor storage practices.

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