Session 8

Postharvest Pest Management and Extension in Developing Countries

Postharvest knowledge, perceptions and practices of African small-scale maize and sorghum farmers

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Abstract

Due to a single annual food production season in southern Africa, small-scale maize and sorghum farmers store grain until the next harvest. The farmers' postharvest knowledge, perceptions and practices (KPP) is important in reducing postharvest losses (PHLs); a key component of household food and nutritional security. Using random sampling, 310 farmers from two districts of Zimbabwe with contrasting agroecologies and agricultural systems (maize and sorghum) were interviewed to assess their KPP on post-production aspects. Maize and sorghum grain were stored in new and recycled polypropylene bags (93.5% and 42.6%) placed in ordinary rooms (44.5% and 27.1%), brick store houses (28.4% and 54.2%) and traditional huts (23.2% and 16.1), respectively. Farmers recognised field infestation as important source of insect infestation in sorghum (60%) but not in maize (21.3%). Synthetic commercial grain protectants were used more on maize (90.2%) than on sorghum grain (63.2%). Majority of farmers (> 75%) perceived these insecticides as both effective and safe to use. Farmers' household reserved grain ran out before the next harvest and was supplemented through buying grain or mealie-meal with cash, or exchanging grain with labour or livestock. Postharvest information and training were scarce in both systems. The study provides important information to extensionists, policy makers, development agents and researchers for reviewing and benchmarking extension services and farmer training requirements to effectively accelerate progress towards PHL reduction and contribute to household and national food and nutritional security.

Keywords: stored maize and sorghum grain; post-production practices, knowledge and perceptions; small-scale farmers; household survey.

Introduction

Maize is the staple crop in Southern Africa with dietary, economic, social and political importance (Mvumi et al., 1995; Tefera, 2012). Similarly, sorghum is one of second most important cereal staples in semi-arid areas of the region (Taylor, 2003). Stored product protection of these staple cereals is a key component of food and nutritional security largely missing in Africa (World Bank, 2011; Tefera, 2012). This is especially critical to more than 70% of southern African population that depend on unimodal rainy season for rain-fed crop production (Abbass et al., 2014). This means that the major cereal staple grain is harvested only once per year and farmers have to rely on their storage techniques and knowledge to preserve reserves during the long off-season lean-supply-high-demand period before the next harvest. Small-scale farmers are custodians of their household food harvesting, processing, storage and budgeting throughout this non-productive season.

Research has shown that grain is most vulnerable to rodent, moulding and insect pest attack during the storage period. In Southern Africa alone, independent reports from APHLIS and Worldbank show postharvest losses between 10 – 20% (World Bank, 2011; APHLIS, 2014) which is worth about

US$4 billion dollars (World Bank, 2011). After maturity, maize or sorghum grain undergoes various processing steps along the harvesting and postharvest chain of activities. Therefore, farmers' knowledge, perceptions and practices along this post-production chain are strong determinants of the level of losses incurred on-farm (Abbass et al., 2014). Since losses occur at various stages of the post-production chain (Tefera, 2012; APHLIS, 2014), it is imperative to study farmers' practices throughout the various post-production stages to identify major loss points that need redressing.

It has been more than two decades since the last published study that focussed on small-scale farmers' postharvest practices in Zimbabwe which revealed a lot of knowledge gaps (Mvumi et al., 1995). The objective of the current study was not only to compare and contrast the postharvest knowledge, perceptions and practices of maize and sorghum-based farming systems, but also to establish knowledge gaps considering the advances made in developing postharvest technologies in the last two decades. This is important to establish whether the status quo research and extension systems are effective in disseminating postharvest information for future curriculum and policy adjustments.

Materials and Methods

Study sites

The study was conducted in two districts in the semi-arid Insiza District (S20º.54'14.00"; E29º. 27'89.00") Matebeleland South province and the semi-humid Murehwa district (S17°. 64'99.97"; E31°.78'33.30") in Zimbabwe from March to June 2013. Insiza district is a sorghum-producing area, which typically receives an average rainfall of 450-650 mm annual rainfall while Murehwa district is a maize-producing area with a comparably higher average annual rainfall of 650-1,000 mm. Murehwa and Insiza districts lie in Zimbabwe agro-ecological zones II and V, described as intensive and extensive farming regions respectively due to huge differences in rainfall patterns and aridity (Mugandani et al., 2012; Muhoyi et al., 2014). This separates them into maize and sorghum farming areas respectively.

The study approach and data collection

A standard structured coded questionnaire was used for data collection using face to face interviews during the harvesting season (April-May 2014). In each district, four wards (Wards 1, 2, 17 & 19 for Insiza district and 8, 13, 16 and 28 for Murehwa district) were selected using a purposive sampling technique in consultation with agricultural extension staff. Prior to this study (2012 and 2013 storage seasons), under the same grant (UZ-RUFORUM postharvest project grant) farmers from wards 17 & 19 (Insiza District) and 13 & 28 (Murehwa District) were trained on good postharvest practices including pesticide use practices, proper mixing of grain and grain protectants, proper grain storage and insect pest identification and basic ecology. One hundred and fifty-five households were interviewed across all four wards (75 from trained wards and 75 from untrained wards and 3 reserve households for discard questionnaires) in each district, giving a total of 310 respondent households for the study. For the trained wards, households were purposely sampled following the list of participants (attendance lists), while a random sampling (every 5th household) was used for the untrained wards. Both researchers and trained extension staff conducted the interviews in local languages; Shona and Ndebele for Murehwa and Insiza districts respectively. In addition, field observations were used to collect anecdotal evidence where possible; farmers were asked to show researchers grain protectant containers, traditional harvesting equipment and/or techniques. Data were entered in CSPro 6.1 software for Windows 7 and IBM SPSS Statistics 23 was used for statistical analysis. Cross tabulation was used to determine associations between categorical factors and variables of interest through Wald's χ^2 tests at 95% Confidence Interval (CI).

Results

Demographics

More females (62.6%) were observed participating in maize grain postharvest than males (37.4%) whereas more males (68.4%) participated in sorghum postharvest activities (Tab. 1).

Tab. 1. Socio-economic characteristics of farmers from Murehwa and Insiza districts

Characteristic	**District**	
	Murehwa (maize)	*Insiza (sorghum)*
Sex (%)		
Male	37.4	68.4
Female	62.6	31.6
Age (years)		
≤ 40	13.2	10.0
40 – 60	48.7	55.5
> 60	38.2	35.5
Education (%)		
No school	3.3	8.4
Primary	62.5	55.5
***ZJC**	7.2	6.5
Ordinary level	27.0	4.5
Tertiary	0	3.9
Land sizes (acres)		
≤ 2	7.7	34.8
2.1 – 5	72.3	25.8
> 5	38.2	39.3
Farming experience (years)		
≤ 10	18.7	7.8
10 - 15	19.4	58.7
> 15	60.0	35.5
Cannot remember	1.9	-

*Zimbabwe Junior Certificate of Education (equivalent to Form 2 or two years of secondary education).

There were more middle aged farmers in Insiza compared to Murehwa. Trends in education were generally similar except that more farmers attained the generally recognised Ordinary level in Murehwa than in Insiza district. Land sizes are much bigger in Insiza (Tab. 1), but Murehwa (60.0%) farmers have more years (> 15 year) of farming experience compared to the Insiza farmers (35.5%).

Knowledge

In both districts, postharvest information was scarce and for the remote sorghum district, the government extension services were the major source of information (94.4%) compared to maize (68.7%) which supplemented by NGO trainings (22.7%) as well as private companies and research institutions (5.3%). Nevertheless, postharvest information was generally not recognised and not perceived as important by farmers from both systems. All farmers knew about grain varietal susceptibility to insect pest attack (85.5%) and (60.0%) for maize and sorghum respectively. However, farmers reported continuously using the more susceptible varieties for reasons of high yields and seed availability. More maize farmers (50.3%) knew about the newly arrived pest, the larger grain borer *Prostephanus truncatus* (Horn) compared to sorghum farmers (29.7%). However, the awareness was spatial depending on the wards that were trained ($\chi^2_{(8.1)} = 42.12$, $p < 0.001$) (maize) and ($\chi^2_{(8.1)} = 97.89$, $p < 0.001$) (sorghum) and gender in maize ($\chi^2_{(2.1)} = 13.69$, $p = 0.001$) but not sorghum) ($\chi^2_{(2.1)} = 1.73$, $p = 0.422$). This awareness was however, independent ($P > 0.001$) of education level, age and time of farming experience in both systems. Most farmers just knew the name ‘LGB’ but could not physically identify the pest. Almost all maize farmers believed that LGB was absent from their stores (78.1%) compared to about half (51.6%) in sorghum (the rest did not answer the question or were not sure) although anecdotal evidence showed that some of the maize farmers had the LGB in their stored grain but unaware of it.

We assessed if farmers in trained wards had changed some of their traditional 'methods' as a result of the training. Tab. 2 shows the farmers' responses from both maize and sorghum

Tab. 2. Postharvest aspects changed by farmers after in the UZ-RUFORUM trained wards compared to farmers from non-trained wards

Did you improve the following aspects after training?	Maize			Sorghum		
	**Yes*	*No*	*ǂNo response*	**Yes*	*No*	*ǂNo response*
Cutting time	59.3	3.5	37.2	67.7	0.6	31.6
Drying method	58.4	1.8	39.8	60.0	0	40.0
Drying time	72.6	2.7	24.8	59.4	0	40.6
Dehusking time	56.6	2.7	40.7	N/A	N/A	N/A
Threshing/Shelling method	54.0	6.2	39.8	52.9	0	47.1
Threshing/Shelling time	54.9	3.5	41.6	67.7	0	21.8
Types of pesticides	61.9	2.7	35.9	74.2	0	25.8
Moisture testing	60.2	2.7	37.2	63.2	0.6	36.1
Grain treatment time	67.3	2.7	30.1	67.7	0	32.3
Grain treatment method	60.2	2.7	37.2	78.1	0	21.8

*Trained wards, 13 & 28 (maize); 17 & 19 (sorghum)
ǂNon-trained wards, 8 & 16 (maize); 1 & 2 (sorghum)

In both systems, most farmers reported having changed their timing and methods of some postharvest practices (see Tab. 2). Most of these farmers were from the wards previously trained in on good postharvest practices as confirmed by the positive significant association between the trained wards and changing a postharvest practice both in maize ($\chi^2_{(8.1)} = 47.89$, $p < 0.001$) and in sorghum ($\chi^2_{(8.1)} = 44.12$, $p < 0.001$) farming systems. Considerable proportion of 'no responses' to this question came from the –non-trained wards, since they mostly were not aware of any training.

Practices

Farmers harvested both maize (97.1% and sorghum (94.2%) between March and May every year. Due to relatively high rainfall, 83.6% of maize farmers harvested ≥ 0.5 tonnes, compared to 62.5% of farmers harvesting the same quantity of sorghum. From the field, maize was mainly transported using scotch carts (40.6%), wheelbarrows (31.3%), head-carrying (9.4%) or hired trucks (7.8%) and transport was reported as one of the major challenges. However, most sorghum farmers (78.7%) did not respond to how they carried their produce. Corresponding to their yields, more maize farmers (38.4%) retained more grain (300 – 1000kg) after harvest compared to sorghum respondents (29.7%) who retained the same amount of grain (Fig. 1). However, more sorghum farmers preferred to store more than a tonne of grain (Fig. 1) compared to maize farmers.

Although farmers in both districts did not generally sell their retained grain, the family reserved grain ran out more for sorghum (56.8%) than maize (37.4%) although sorghum farmers stored more. Reserved maize grain started running out starting in November (19.4%), peaking up in December (32.3%) and subsiding gradually in March, whereas for sorghum, grain started running out in March (19.7%) and peaking up in April (27.4%) and subsiding in May (9.4%) every season. Almost equal proportion of farmers supplemented their grain mainly by buying grain with cash from other farmers (35.5% and 37.1%) or buying mealie-meal (27.4% and 31.9% sorghum) for maize and sorghum respectively (Fig. 2). In the maize based system, exchanging grain with labour was more prominent (21.0%) whereas Non-Governmental Organisation (NGO) rations were perculiar in sorghum (6.0%) systems. Exchanging grain or mealie-meal for livestock was less common in both districts (see Fig. 2).

Before threshing and storage, sorghum farmers tested grain for storable moisture content mainly through biting (56.8%), crushing between fingers (29.0%) and by easiness of threshing (8.4%).

Although maize farmers also largely depended on biting (41.3%), a significant proportion also used experienced eyes (24.5%), the kernel sound method (14.8%), crushing (9.7%) and the salt method (6.5%). Maize grain was mostly stored in polypropylene bags (94.8%) which were new (23.2%), recycled (16.1%) or a mixture of both (54.2%). Most of these bags (78.7%) were placed on stones/bricks/timber dunnage in ordinary rooms (44.5%), brick and motor store houses (28.5%) or in traditional huts (23.0%) also used as cooking houses or 'kitchens'. However, only 45.8% of sorghum grain was stored in polypropylene bags in ordinary rooms, most of the farmers (54.2%) stored bulky grain in brick and motor storehouses (54.2%). Therefore, most farmers still largely stored their maize grain in in polypropylene bags (94.8%) in in ordinary rooms as previously reported by Nyagwaya et al. (2010). Unlike in maize, most sorghum farmers (54.2%) preferred storing their grain in bulk inside raised brick and motor storehouse compartments (54.2%) referred to as 'granaries'. Fewer farmers (45.8%) used polypropylene bags for grain storage.

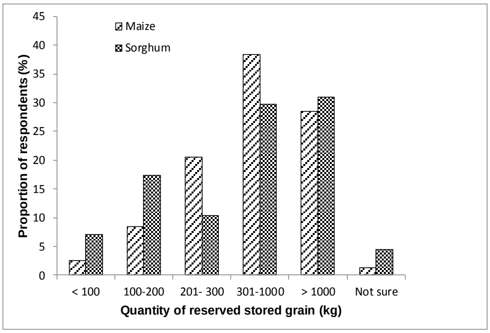

Fig. 1. The quantities of household consumption grain reserves stored by farmers in Murehwa (maize) and Insiza (sorghum) districts after a normal harvesting season.

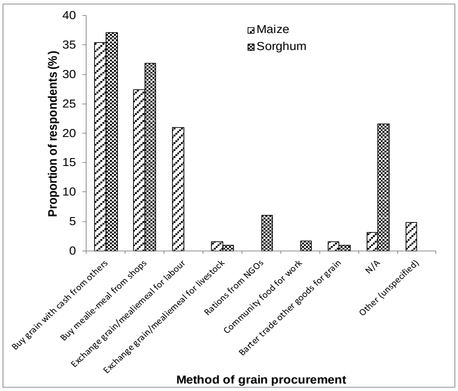

Fig. 2. Farmers methods of household grain procurement in Murehwa (maize) and Insiza (sorghum) districts.

The storage facility was significantly influenced by location (wards) ($\chi^2_{(12, 1)} = 65.146$, $p < 0.001$) and sex ($\chi^2_{(4, 1)} = 23.103$, $p < 0.001$). Commercial chemical grain protectants were mostly used (90.2%) to protect maize than sorghum (63.2%) grain (Fig. 3).

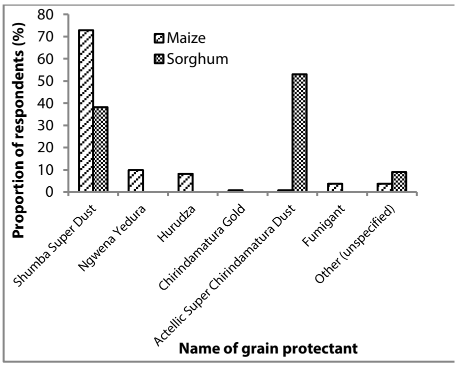

Fig. 3. Types of insecticides used by farmers within the previous five years in Murehwa (maize) and Insiza (sorghum) districts.

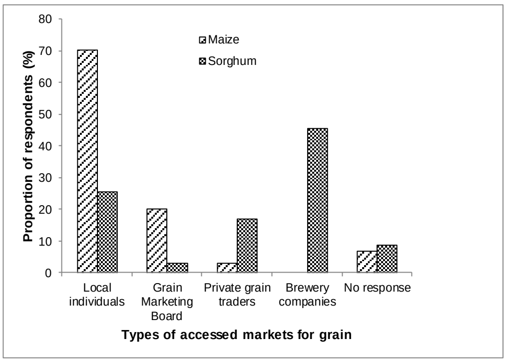

Fig. 4. The types of markets that farmers accessed by the farmers for selling their sorghum and maize grain in Insiza and Murehwa districts respectively

Farmers purchased commercial grain protectants from the local agro-dealer shops (78.0% and 67.9%) respectively for the maize and the sorghum farming systems. Only two insecticides were dominant in the sorghum area; Shumba Super Dust® (fenitrothion 1% + deltamethrin 0.13%) and

Actellic Super Chirindamatura Dust® (pirimiphos-methyl 1.6% w/w + permetrin 0.3% w/w. On the contrary, six registered grain protectants were recorded in the maize farming district, including Hurudza Grain Dust® (fenitrothion 1.7% w/w + deltamethrin 0.05% w/w) and Ngwena Yedura® (pirimiphos-methyl 2.5% w/w + deltamethrin 0.2% w/w) including the two already recorded for sorghum (Fig. 3). More maize farmers knew and had access to more pesticides than sorghum farmers because of their proximity to major cities. Farmers from both farming systems perceived chemicals as safe (94.7% and 76.9%) and effective (77.2% and 75.4%) for maize and sorghum respectively. In the contrary, a significant number of maize farmers (40.6%) reported that insect pests remained a problem post-chemical grain treatment compared to sorghum (23.9%), citing chemical ineffectiveness (15.5%) and improper insecticide use, which was more pronounced in maize (53.4%) than in sorghum (11.6%). Traditional grain protection methods were very minimal, 3.8% and 4.5% in both maize and sorghum respectively. The major postharvest pests for sorghum were quelea birds, *Quelea quelea* L. (81.9%), *Sitophilus species* (90.7%) and rodents (3.2%); while in maize, the major insect pests were *Sitophilus species* (91.0%). The larger grain borer was mentioned as a major pest by only 1.5% farmers in maize while *Tribolium casteneum* (1.3%) was mentioned by few farmers in sorghum.

Perceptions

Farmers perceived insect infestation as originating from the field (81.3%) from March and April when maize is between the hard dough stage and physiological maturity (63.2%). On the contrary, although sorghum farmers equally acknowledged field infestation initiating from the field (95.3%), they believed that infestation started much earlier (milky dough stage) (79.4%) from February to March than observed in maize. Correspondingly in storage, insect pests were first seen earlier (August) (8.4%) on sorghum grain and later (September) (10.3%) on maize. Likewise, peak insect pest populations were reported to occur earlier (September – December) (73.9%) for sorghum and slightly later (October- December) (63.3%) for maize. Farmers recognised and perceived pre-harvest field infestation as an important source of insect inoculum in stored sorghum (60%) but not in maize (21.3%). Apart from insect pests (91.0% and 67.1% for maize and sorghum; respectively), farmers from sorghum farming systems perceived labour shortage during harvesting time (56.8%), domestic and wild animals (11.0%) and poor prices (7.7%) as major postharvest challenges. In maize, most farmers perceived labour shortages at shelling (23.9%) and transport challenges from the field (12.9%) as major challenges while the bulk of farmers (45.8%) perceived having no notable challenges during the harvesting process. Types of markets accessed by the farmers differed with the type of grain that they produced (Fig. 4).

Most maize sold their maize grain to local individuals (70.3%) within their communities compared to sorghum (25.7%), whereas most sorghum was sold to the brewery companies (45.7%). Few farmers, 20.3 (maize) and 2.9 (sorghum) sold their grain to the government parastatal Grain Marketing Board (GMB) (see Fig. 4).

4. Discussion

More females participated in maize grain postharvest than males whereas more males participated in sorghum postharvest activities than females. This is attributed to ethnical differences in gender roles between the two tribes where grain processing is more of a female role (Mvumi et al., 1995; Manda and Mvumi, 2010) in some areas (tribes) than others in Zimbabwe. In addition, the maize district, Murehwa, is nearer to urban areas (Harare and Marondera) where males migrate to seek formal employment in the cities, leaving females in charge of farming activities whilst Insiza district is far from such urban areas. On the other hand, there were more middle aged farmers in Insiza compared to Murehwa, this may be explained by more early adolescent cross border migration to South Africa in Insiza district which borders Southern part of Zimbabwe with South Africa. Trends in education were generally similar except that more farmers attained the generally recognised Ordinary level in Murehwa than in Insiza district; again this is attributable to early adulthood migration to South Africa before completing school dominant in Insiza District. Land sizes were much bigger in Insiza (Tab. 1) because farmers were resettled in this area by the Government of Zimbabwe whereas Murehwa was a traditional tribal trust land (generational landholdings) where land has been inherited from forefathers and partitioned continuously to current generations over the years, thus gradually dwindling in percapita landholdings as populations increased. This also explains why farmers have more years of farming experience in Murehwa than in Insiza, because they have traditionally been on the same land.

Although almost equal number of farmers from both maize and sorghum systems preferred to store 300-1000kg of grain as reserves for family consumption, more sorghum farmers preferred to store more than a tonne of grain compared to maize farmers. This is because the sorghum producing area is generally arid with low and unpredictable rainfall patterns and farmers store more grain to cushion against frequent droughts, whereas, in Murehwa district, farmers are cautious not to store more than a tonne to avoid storage losses due to insect pests, rodents and thieves. This compels farmers to sell part of their grain early, mainly to local individuals in exchange for cash, livestock or labour. The parastatal responsible for buying the grain, normally offers too low prices to attract both maize and sorghum farmers. Most sorghum farmers rely on the brewery companies (especially Ingwebu Breweries®) for market, which in some cases provides them with inputs under contract farming. Although most farmers from both farming systems stored considerable amount of grain, most farmers ran out of grain before the next harvest without extra income sources for cash requirements to buy grain. New postharvest technologies that could increase the stored grain per household have been introduced in some parts of Zimbabwe (Chigoverah and Mvumi, 2016; Mlambo et al, 2017), most farmers have limited access to this information including new storage technologies and the high cost associated with new technologies (Mvumi, 1997; Nukenine, 2010).

The significant positive correlation between trained wards and changes in postharvest practices and knowledge about the P. truncates suggests that our farmer trainings in the previous 2 seasons were to a larger extent, effective. Majority of farmers from untrained wards in both districts were not aware of any postharvest training. This showed that there is need for huge investment in farmer training to cover as many farmers in as many areas as possible since farmers do not seem to freely share postharvest information even when trained (Mvumi, 1997). The scarcity of postharvest information also shows that dynamics and modern changes in postharvest activities, grain protectants, innovations, stored product insect ecology and research have not been closely followed up by the relevant postharvest technical back-stopping support to improve and update farmers and extension staff knowledge and skills on stored product pest control (Larsen and LilleØr, 2014, Chigoverah and Mvumi, 2016). In addition, postproduction activities have comparably received little institutional and extension efforts (Mvumi, 1997; Abass et al., 2014), limited research investment and limited publication of research results, especially in Southern Africa (Mvumi, 1997; Larsen and LilleØr, 2014; Mvumi and Stathers, 2015; Affognon et al., 2015).

In the maize-based farming system, we recommend the introduction of chemical-free hermetic storage systems such as hermetic bags, cocoons and metal silos to address storage pests and pesticide mis/overuse challenges. Hand-operated shellers and cheap produce transporting systems are also necessary to reduce labour bottlenecks during shelling and transportation for both systems. In the sorghum farming system, we recommend early harvesting to avoid extensive bird damage (Mutisya et al., 2016). There is also need to explore the possible use of new bird-scaring techniques such as the Unmanned Aerial Vehicles (UAV) popularly known as 'drones' to reduce losses by quelea birds. However, benefit-cost analysis will be essential to determine viability of such investments and the potential for wide-spread use of the technology under small scale conditions.

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Evaluation of five storage technologies to preserve quality composition of maize in Nigerian markets

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Abstract

Maize needs to be stored using good and safe postharvest management measures that will maintain the quality as at harvest. Insects and moisture must be controlled in storage to ensure quality and methods to achieve this, such as the use of reduced-risk measures were evaluated in this study, conducted February–December 2016. The efficacy of Bularafa diatomaceous earth (DE), *Piper guineense* (Botanical), PICS bags, ZeroFly® bags and permethrin (Rambo™) in preserving maize quality in Nigerian markets was assessed. A sixth treatment comprised maize in untreated polypropylene bags. Study locations were in four markets in Ibadan, Ilorin and Oyo towns. Each market had a storehouse, which contained experimental 100-kg bags. In each storehouse, each technology