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INTRODUCING IMPROVED CULTIVARS: UNDERSTANDING FARMERS' SEED DRYING AND STORAGE PRACTICES IN CENTRAL GHANA

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SUMMARY

Improved upland rice cultivars introduced in Volta Region, Ghana, have been perceived to store poorly compared to farmers' traditional cultivars. A survey was conducted in 2003 in the Hohoe district of this region, where a Participatory Varietal Selection programme had started in 1997, to gain insight into farmers' seed production and storage practices that are likely to affect seed quality in storage. Farmers rated keeping quality ($p < 0.001$), tolerance to storage pests ($p < 0.001$), seed quality ($p < 0.001$) and establishment of their local cultivars Kawomo, Viono and Wuwulili as much better than the improved cultivar IDSA 85. Initial seed moisture content ranged from 12.8 to 18 % and germination from 0 to 82 %. There was a significant relationship between seed moisture content and duration of drying prior to storage ($p < 0.001$) and storage method ($p = 0.015$). Germination loss in storage was rapid at high moisture content and slow at low moisture content. Between 60 and 80 % of seeds germinated after six months storage at 12.8 % moisture content. The viability equation predicted accurately germination of farmer-saved seed stored under ambient temperature in Ghana. Except for the *japonica* rice cultivar WAB 126-18-HB, the traditional cultivars Kawomo, Viono and Wuwulili survived better in storage than improved cultivars. There is a need to improve seed quality of improved cultivars if farmers are to benefit from their higher yields and grain quality and to improve storage practices.

INTRODUCTION

Rice is a key staple in Ghana and ranks next to maize in importance (Bam *et al.*, 1998). However, over US$100 million is spent annually on rice imports to meet demand for its consumption (MOFA, 2003). Increasing domestic rice production is therefore a priority in Ghana. About half the area under rice production in Ghana is an upland/hydromorphic ecosystem and only a few improved cultivars of rice adapted to the upland ecology have been released, and that was over 20 years ago (DfID, 2000). The choice and supply of seeds of improved upland rice cultivars to farmers is limited and therefore the main source of seed is farmers' saved seed from previous harvests (Marfo *et al.*, 2000). Most upland rice farmers therefore continue to grow low-yielding, traditional *Oryza glaberrima* cultivars.

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Seed quality is of great agronomic and economic concern, and its importance in crop production cannot be over-emphasized. Seeds undergo deterioration during storage with the rate dependent on storage temperature, moisture and storage period (Ellis and Roberts, 1980). Seed companies maintain quality using seed quality tests to monitor seed from harvest to purchase (McDonald, 1998). In Ghana, however, in common with most developing countries, rice and other cereal seed production is in the hands of many small-scale producers (Lyon and Afikorah-Danquah, 1998) who cannot afford the cost of cold storage, even where available. This means that seed producers and individual farmers have to store their own seed and maintain its viability and vigour in storage until the next cropping season. Such seeds are often stored in inappropriate storage materials under ambient and fluctuating temperature and relative humidity conditions. Poorly stored seed will therefore result in poor seed quality leading to poor stand establishment, low seedling vigour and low grain yield (McDonald, 1998).

Improved upland rice cultivars have been tested with farmers in a Participatory Varietal Selection (PVS) programme in the Hohoe district of the Volta Region, Ghana (DfID, 2000, 2004; Dogbe *et al.*, 2002; Marfo *et al.*, 2004), with the objective of offering farmers the opportunity to identify and select acceptable new rice cultivars to replace obsolete cultivars. A survey conducted in 2003 to determine the uptake and spread of PVS cultivars showed that IDSA 85 was the most preferred and widely cultivated PVS cultivar (DfID, 2004). However, farmers have reported poor storability and poor seedling establishment of IDSA 85 and some of the new cultivars they selected. The perception was that the storage characteristics of the new cultivars were inherently poorer than the traditional *O. glaberrima* and *O. sativa* cultivars currently grown (DfID, 2004).

The aim of this study was: (i) to determine if IDSA 85 and other improved cultivars did indeed have poorer seed quality (germination) in storage; and (ii) to investigate relations between seed quality and farmers' seed production, post-harvest and storage practices. Approximately 120 upland rice farmers in Hohoe, Volta Region, Ghana were interviewed and seed samples collected shortly after harvest. These samples were then stored for six months, and relations between seed germination and initial seed moisture content in local and improved cultivars determined. Relations between production, post-harvest and storage practices, and seed moisture content at harvest, were then examined to see which factors affect seed viability in storage.

MATERIALS AND METHODS

A survey was conducted in 2003 in the Hohoe district of the Volta Region of Ghana, where a PVS programme had started in 1997, to gain insight into farmers' seed production and storage practices that are likely to affect seed quality (germination and vigour) in storage. A structured questionnaire was designed, pre-tested and administered to upland rice farmers in 12 communities in the district between January 29 and February 1 2003. The questions asked covered farmers' seed production practices (sowing date, ability to recognise off-types, plant characteristics used by

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farmers to distinguish off-types, how off-types were treated, harvesting date); post-harvest and storage practices (number of days panicles were left in the field before threshing, method of threshing, duration of drying before storage, storage method, storage material); perceptions on storage behaviour of the different rice cultivars; and assessment of the previous year's level of stand establishment of the different cultivars.

In the administration of the questionnaire, a two-stage sampling methodology was followed. A list of all the communities who participated in farmer testing of PVS cultivars between 1999 and 2002 was compiled out of which 12 were selected for the survey. Communities were selected on the basis that local farmers had grown PVS cultivars for at least two years. Hence, all the communities which grew PVS cultivars between 1999 and 2001 were surveyed. In each of these communities, a list of rice growers was compiled and 10 farmers from each community were randomly selected for interview. In sampling farmers, the modified quota sampling approach was used. This was to ensure that there were sufficient cases of farmers (50 %) growing PVS cultivars in 2002 in the survey. Thus if the normal random sampling did not have at least five farmers growing a PVS cultivar, then PVS farmers were selected intentionally. The data generated from the questionnaires were coded and analysed using Statistical Package for the Social Scientist (SPSS) version 11.5.

Seed samples (100–200 g) of both local and improved cultivars, as appropriate, were collected from farmers' stored seed stocks for moisture determination at the time of administering the questionnaire in January 2003. A total of 165 seed lots covering 16 cultivars were sampled. Seed samples were sealed in high-density polyethylene bags and transported to the Seed Science Laboratory at the Crops Research Institute, Ghana for seed quality analysis. For each seed sample the name of the cultivar, the farmer from whom seed was collected, community and the date of storage was recorded. The weather conditions (rainfall and relative humidity) from seeding until sampling are presented in Figure 1. Mean minimum and maximum temperatures during the period between seeding and sampling were 23.2 ± 0.90°C and 32.7 ± 2.21°C respectively.

All the seed samples collected were cleaned and transferred into airtight plastic containers. Moisture content of duplicate 2 g sub-samples from each sample were determined at 105 °C for 24 h. Seed samples were stored in the Seed Science Laboratory under ambient conditions from February to July 2003. Temperature and relative humidity during storage were logged at hourly intervals throughout the storage period using Tiny tag data loggers (Gemini Data Loggers, UK) placed on shelves on which the sealed plastic containers were located. Mean daily minimum and maximum temperatures and relative humidity were recorded for each location for the six-month period. Maximum and minimum temperatures for each day were averaged to provide an average maximum and minimum for each month. Average monthly maximum and minimum temperatures were then used to estimate effective temperature for each month. Effective storage temperature was estimated using equations developed by Hung *et al.* (2001) (Figure 2). Relative humidity during storage ranged from 29 to 95 % between February and July.

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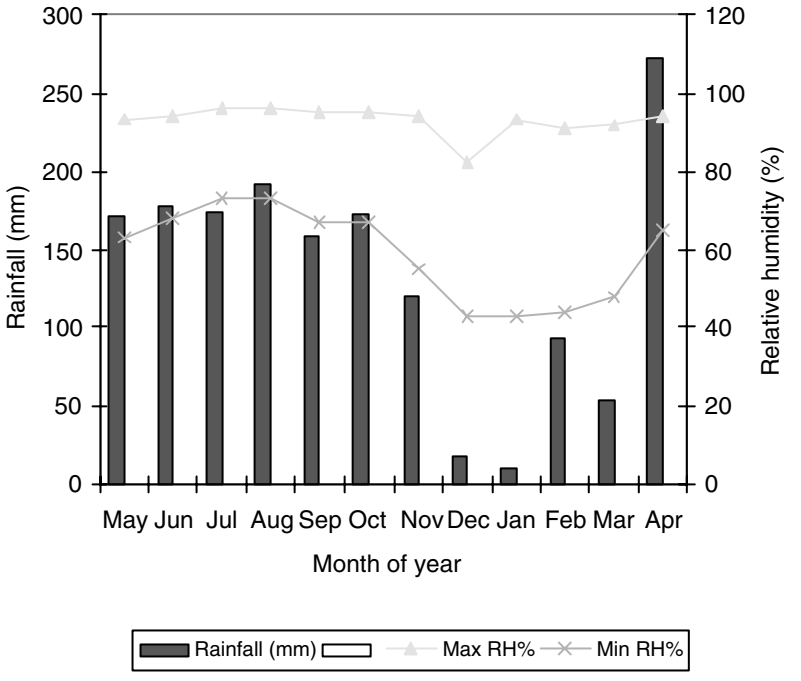


Figure 1. Total monthly rainfall and mean maximum (at 0600 hours) and mean daily minimum relative humidities (%) (at 1500 hours) between May 2002 and April 2003 at Hohoe, Ghana.

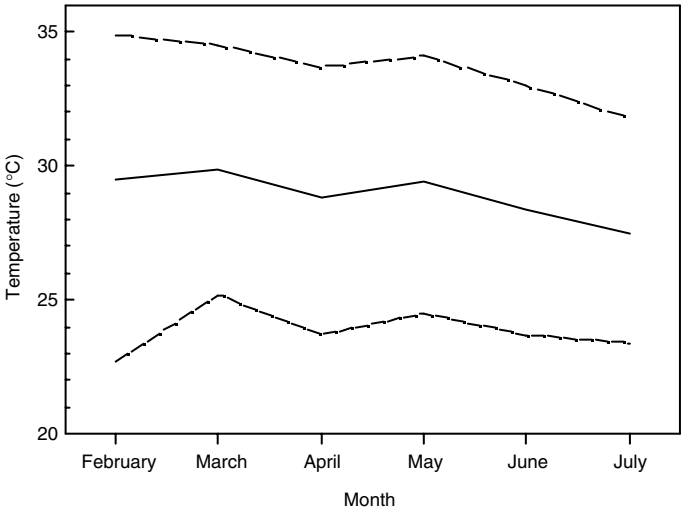


Figure 2. Minimum and maximum ambient temperatures (lower and upper broken lines) recorded at the Crops Research Institute, Kumasi, Ghana. The effective temperature (solid line) was estimated from minimum and maximum monthly temperatures using equations provided by Hung *et al.* (2001).

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In July, six months after collection, a one-time sample was drawn to determine the germination of the seed samples. Samples were taken in July because it is the peak sowing period in the district. The cultivars collected have distinct grain characteristics, which made distinction between the seed lots easy. Samples taken for the germination assay were therefore critically examined to ensure that no admixtures were included. Four replicates of 50 seeds of each sample were tested for germination between moist rolled paper towels at room temperature (mean temperature = 28 °C). The criterion for normal germination was normal seedling development (ISTA, 1993). Data obtained were subjected to regression analyses using GLIM (Genstat, 1997). Adayisi which appeared to be mixed with other cultivars in almost all the samples collected and other cultivars with a sample size $n < 7$ were excluded from the analysis. The analysis of the survey data was therefore based on seven cultivars.

The seed viability equation (Ellis and Roberts, 1980) was used to predict germination during storage, where:

$$v = K_i - p/10^{(K_E - C_W \log_{10} m - C_H t - C_Q t2)} \quad (1)$$

In this equation, v is the probit percentage viability after p storage days; K_i is an estimate of initial seed quality in probits and was assumed to be 1.645 (i.e. initial germination of 95 %) for all the sampled seed lots; m is percentage seed moisture content (fresh weight basis); and t is effective storage temperature (°C). The constants K_E, C_W, C_H and C_Q describe the relationship between seed moisture, temperature and seed deterioration during storage and are species constants. The values of the constants K_E (8.9518 and 8.7088 for Kawomo and IDSA 85 respectively) and C_W (5.51 for both Kawomo and IDSA 85) were obtained from viability constants reported by Bam *et al.* (in press). While C_H and C_Q are species constants with values 0.0329 and 0.000478 respectively (Dickie *et al.,* 1990).

RESULTS

Farmers' perceptions of seed quality

Sixteen cultivars were being grown by farmers, of which Kawomo and Viono (both traditional cultivars of *O. glaberrima*), and IDSA85 (improved *O. sativa japonica* introduced through PVS) were grown most frequently (Table 1). Other cultivars grown commonly included WAB 209-5-HB, WAB 126-18-HB and WAB 224-18-HB (all japonicas introduced through PVS) and Wuwulili, an *O. glaberrima* cultivar.

Farmers were asked to rate (as good, fair or bad) storage behaviour in terms of keeping quality and tolerance to insect pests. Farmers rated keeping quality and tolerance to pests as 'good' in their traditional *O. glaberrima* cultivars Kawomo, Viono and Wuwulili (Table 2). In contrast, storage behaviour of the improved *O. sativa japonica* IDSA 85 was rated as 'bad' by many farmers. Similarly, within the improved cultivars, IDSA 85 was rated as 'bad' by many farmers in keeping quality ($\chi^2_{(1\ d.f.)} = 10.59$; $p < 0.001$) and tolerance to pests ($\chi^2_{(1\ d.f.)} = 11.21$; $p < 0.001$). The improved japonica,

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Table 1. Seed lots of different cultivars of rice (*Oryza* spp.) sampled from farmers' seed stores and the range of seed moisture content (%, fwb) at sampling.

Cultivar	Species†	No. of samples	Moisture content (%, fwb)			
			Minimum	Maximum	Mean	*s.d.*
		Cultivars used for further analysis				
Kawomo	Og	31	13.1	15.9	14.3	0.65
Viono	Og	31	13.3	15.9	14.5	0.69
Wuwulili	Og	11	13.7	15.2	14.3	0.49
IDSA 85	Os	26	12.9	18.0	14.5	1.04
WAB 209-5-HB	Os	11	13.5	15.9	14.6	0.75
WAB126-18-HB	Os	7	12.8	15.0	14.1	0.73
WAB 224-18-HB	Os	8	13.8	15.3	14.7	0.53
		Cultivars discarded				
Damansa	Os	5	14.5	15.5	15.0	0.44
Adayisi	Os	6	13.5	15.9	14.5	0.79
Beauty	Os	2	14.0	14.4	14.2	0.28
Kawawa	Og	4	13.2	14.3	14.0	0.51
Mighty	Os	3	15.0	15.5	15.3	0.25
WAB340	Os	1	14.6	14.6	14.6	–
WAB 450	Os	3	14.4	15.0	14.8	0.32
Iguape cateto	Os	4	13.7	14.7	14.3	0.43
OS6	Os	2	14.4	15.4	14.9	0.71

†Og: *Oryza glaberrima*; Os: *O. sativa*. fwb: fresh weight basis.

Table 2. Farmers' perception on storage behaviour and vulnerability to pests of traditional and improved (PVS) cultivars.

Cultivar	No. of farmers reporting keeping quality as			No. of farmers reporting vulnerability to pests as		
	Good	Fair	Bad	Good	Fair	Bad
			Traditional			
Kawomo	53	1	0	46	4	2
Viono	59	1	2	50	9	2
Wuwulili	15	1	2	11	4	3
Mean	42.3	1.0	1.3	35.7	5.7	2.3
			Improved			
IDSA 85	8	10	15	7	5	20
WAB 209-5-HB	8	4	2	5	1	7
WAB126-18-HB	8	2	1	7	2	2
WAB224-18-HB	5	1	2	3	3	2
Mean	7.2	4.2	5.0	5.5	2.2	7.7
χ^2 (2 *d.f.*, traditional vs improved)		20.34 $p < 0.001$			16.94 $p < 0.001$	

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Table 3. Farmers' assessment of stand establishment (%) of the different cultivars of rice grown in 2002 by the farmers.

Cultivar	No. of farmers	Stand establishment (%)		
		75–100	50–75	Less than 50
		Traditional		
Kawomo	56	93	7	0
Viono	36	89	11	0
Wuwulili	20	95	5	0
		Improved		
IDSA 85	33	24	12	64
WAB 209-5-HB	15	73	13	14
WAB 126-18-HB	11	100	0	0
WAB 224-18-HB	8	75	25	0

WAB 126-18-HB, WAB 224-18-HB and WAB 209-5-HB were therefore generally good compared to IDSA 85.

Farmers were also asked to assess the level of stand establishment of the different cultivars of rice they had grown the previous year. Assessment of the level of field establishment of the cultivars was in agreement with farmers' perceptions of storage behaviour. Kawomo, Viono, Wuwulili and WAB126-18-HB were assessed as having the highest level of stand establishment. In contrast, IDSA 85 was rated by 64 % of the respondents as having less than 50 % stand establishment (Table 3). Thus farmers clearly perceived germination and stand establishment as a problem in the improved cultivar, IDSA 85.

Seed moisture content and germination

Seed moisture content shortly after harvest in January in individual samples ranged from 12.8 % in WAB 126-18-HB to 18.0 % in IDSA 85. Average moisture content ranged between 14.0 % in Kawawa and 15.3 % in Mighty (Table 1). The *s.d.* for IDSA85 (1.04) was higher than for other cultivars with similar sample sizes (0.65 to 0.80).

Across cultivars, germination after storage ranged from 0 to 82 %. Samples with zero germination values were not included in the analysis. As expected, there was a strong relation between germination and initial moisture content (Figure 3). Seeds lost viability rapidly or slowly depending on their moisture contents. The seed viability equation of Ellis and Roberts (1980) accurately predicted germination of cultivars collected from farmers' stores and stored hermetically at ambient fluctuating temperatures. The farmers cultivars Kawomo, Viono and Wuwulili survived better in storage and therefore had greater germination at equivalent moisture contents than the improved cultivars IDSA 85, WAB 209-5-HB, and WAB 224-18-HB (Table 4). The only improved cultivar with good germination after storage was WAB 126-18-HB.

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Table 4. Estimates of intercepts of regression lines of seven rice cultivars sampled from farmers stores and stored at ambient temperature. Based on the intercepts of the regression lines, cultivars were categorized into three groups.

Group	Intercept ± *s.e.*	Slope ± *s.e.*	R^2 Overall model
1. Kawomo, Viono, Wuwulili, WAB126-18-HB ($n = 80$)	382.3 ± 9.96		
2. IDSA 85, WAB 224-18-HB ($n = 32$)	374.1 ± 1.04	24.3 ± 0.69	91.7 ($p < 0.001$)
3. WAB209-5-HB ($n = 10$)	370.0 ± 1.66		

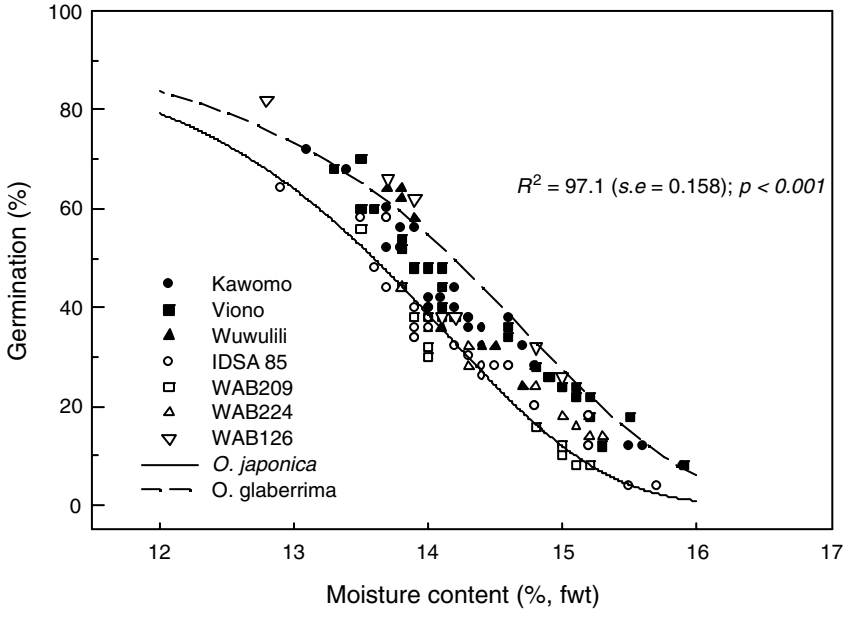


Figure 3. Relationship between seed storage moisture content and germination after six months of hermetic storage. Seeds of 122 lots of seven contrasting cultivars including four *japonica* (open symbols) and three *O. glaberrima* (solid symbols) cultivars collected from farmers' seed stores were stored in sealed bottles at ambient temperature at the Crops Research Institute, Kumasi, Ghana. The broken and solid lines provide predicted germination after six months' storage at the moisture contents shown for *O. glaberrima* and *japonica* cultivars, respectively. Loss in germination was calculated at monthly intervals from effective temperature (Figure 2), with $K_i = 1.645$ (i.e. initial germination of 95 %) and the viability constants reported in Bam *et al.* (in press) for *O. glaberrima* and *O. sativa japonica*, respectively.

Pre-harvest practices

Generally, all agronomic practices for traditional and PVS cultivars were similar, except for sowing date, which was later ($\chi^2_{(2\ d.f.)} = 27.76$; $p < 0.001$) for improved cultivars (Figure 4). Farmers' traditional cultivars were sown from May with the peak in July. Sowing of improved cultivars started from June but also peaked in July. Hence, July appears to be the peak sowing period in the area. Farmers know from previous experience that improved cultivars are generally of shorter duration, and these are planted later to ensure all crops mature at about the same time. This practice reduces the period over which bird scaring has to be done (DfID, 2004).

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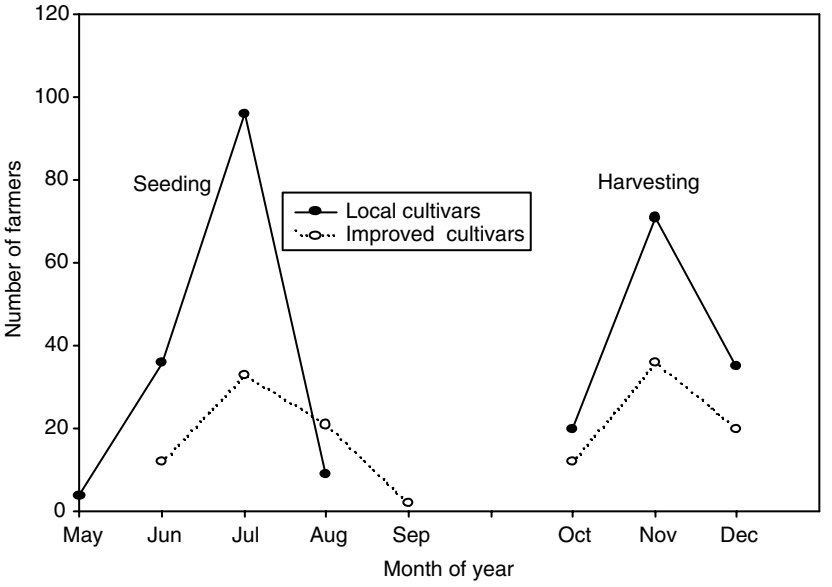


Figure 4. Month in which farmers planted and harvested their traditional and improved rice (PVS) cultivars. Source: 2003 Survey.

Harvesting of all cultivars was done between October and December ($\chi^2_{(2\ d.f.)} = 0.22$; $p < 0.896$) with November as the peak harvesting period (Figure 4). Harvesting was done almost exclusively by cutting panicles with straw (99 %) and only 1 % of the farmers harvested panicles separately from straw. A few (4 %) of the farmers also selected panicles for seed at harvest, while 26 and 22 % carried out some seed selection before storage and at planting respectively.

The majority (60 %) of farmers recognised off-types in their fields using different plant characteristics. Culm colour (28 % of farmers), grain type (18 %) and leaves (9 %) were the main plant characteristics farmers used to distinguish off-types (Table 5). However, of those who recognised off-types, 60 % harvested off-types together with their cultivars, 33 % carried out roguing and 7 % harvested them separately from their cultivars. Harvesting off-types together with farmer's cultivars has serious consequences on genetic purity and grain quality.

Post-harvest and storage practices

Eighty-eight percent of farmers did not thresh their panicles immediately after harvest. Reasons given for delayed threshing were: (1) to allow adequate time between harvesting and threshing for drying (76 %); (2) unavailability of labour (20 %); and (3) to make threshing easier (5 %). Only 12 % of farmers threshed panicles immediately after harvest, and the reasons for doing so were given as ease of threshing (64 %) for cultivars that were perceived to be difficult to thresh, and to prevent grains from becoming mouldy (29 %).

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Table 5. Plant characteristics used by farmers in identifying off-types.

Plant characteristic	Frequency	%
Leaves	11	9.2
Culm colour	33	27.5
Days to flowering	4	3.3
Grain type	22	18.3
Maturity period	2	1.7
Not applicable	48	40.0
Total	120	100.0

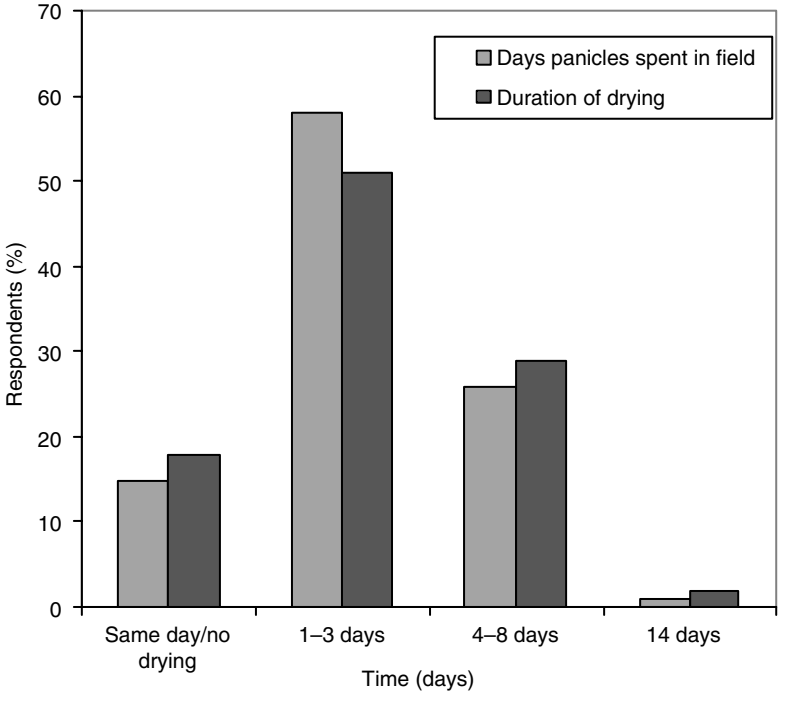


Figure 5. Number of days harvested panicles were left in the field before threshing and duration of drying seeds before storage. (Source: 2003 Survey).

Farmers were also asked the length of time they kept panicles in the field before threshing and how they were kept. Panicles were kept between one and 14 days in the field before threshing (Figure 5). Fifty-eight percent of the 120 farmers interviewed said panicles harvested together with straw were heaped at a common threshing point. Thirty percent left the tied bundles of panicles and straw spread on the field and only gathered the panicles together when they were ready for threshing.

The majority of farmers threshed harvested panicles by beating them against objects such as boards (91 %). A few farmers (5 %) used a threshing box called 'bambam' – a wooden box designed for threshing and collection of grains. Drying of seed may not

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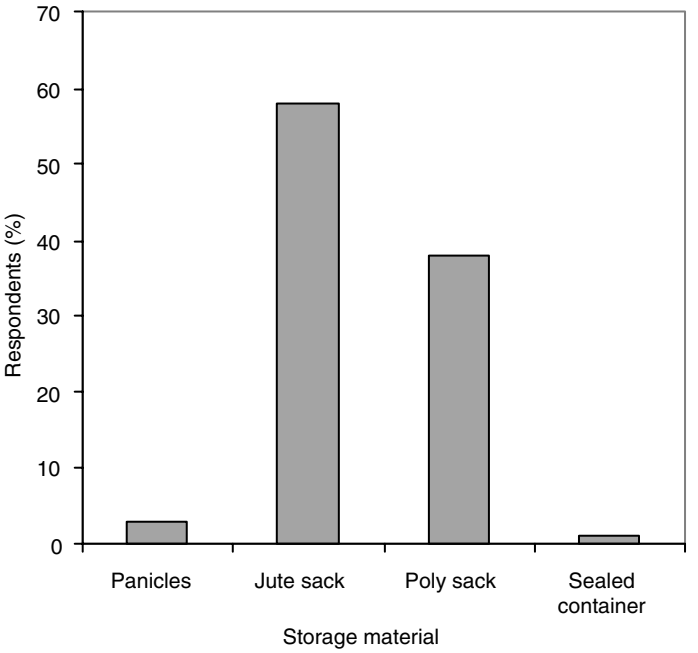


Figure 6. Proportion of farmers storing seed on the panicle, in jute or polythene sacks, and in sealed containers. Source: 2003 Survey.

be carried out again after threshing if the farmer perceived that seed was adequately dried after it had been left in the field before threshing. The duration of drying after threshing ranged between one and 14 days (Figure 5), but the majority of the farmers (98 %) dried seed for a period between one and eight days.

Seed was usually stored in jute sacks or unlined polythene sacks (Figure 6). Seed was stored in homes, almost exclusively in rooms on platforms (98 %) out of reach of rodents. Fifty-eight percent of the respondents said they practised bulk storage while the other 42 % stored seed for sowing next season separately from grain stored for consumption.

Relations between production and storage practices, and seed moisture content

Seed moisture content at harvest has a significant effect on subsequent germination (Figure 3). Therefore cross-tabulations were performed across all cultivars, and within cultivar groups (traditional vs IDSA 85), to determine if variation in seed moisture content was related to differences in production and storage practices among farmers. Chi-square analysis of the relationship between moisture content and the type of storage (panicles, jute sack, polythene sack and sealed container) showed no significant (Pearson $\chi^2_{(2\ d.f.)} = 6.55$; $p = 0.088$) relationship. These data were therefore combined and the relationship reanalysed. No significant associations between moisture content and the date of harvest and the number of days panicles were left in the field before threshing (Figure 5) were observed. Significant associations were, however, observed

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Table 6. Number of samples of Kawomo and IDSA 85 with seed moisture contents < or ≥ 14 % in relations to (a) month of harvest, (b) number of days panicles were left in the field before threshing, (c) duration of drying before storage and (d) type of storage/storage material.

	Moisture content (%)	
	<14.0	≥14.0
(a) month of harvest		
October	0	4
November	8	15
December	15	14
Pearson $\chi^2_{(2\ d.f.)} = 4.52$ *n.s.*†		
(b) number of days panicles were left in the field before threshing		
0–3 days	18	6
4–14 days	18	15
Pearson $\chi^2_{(1\ d.f.)} = 2.50$; $p = 0.114$ *n.s.* †		
(c) duration of drying before storage		
0 to 3 days	9	30
4 to 10 days	15	3
Pearson $\chi^2_{(1\ d.f.)} = 18.34$; $p < 0.001$		
(d) type of storage/storage material		
On panicle + sealed container	4	0
Jute sack + polythene sack	20	33
Pearson $\chi^2_{(1\ d.f.)} = 5.91$; $p = 0.015$		

†*n.s.*: not significant at $p > 0.05$.

between moisture content and duration of drying prior to storage and the storage method (Table 6c, d). In general the frequency of higher moisture contents was greater in crops harvested in October and November (Table 6a). Likewise, higher moisture contents were associated with a shorter drying period (<3 d) and those dried for >3 d all had moisture contents <14 % (Table 6b). The two farmers who stored seed in sealed containers had the lowest seed moisture contents of 12.8 and 12.9 %.

DISCUSSION

Loss of seed viability prior to sowing is a major problem in tropical and subtropical regions (Ellis, 1988). Maintenance of seed viability in storage from the time of production until the seed is planted is therefore very important in assuring planting value. However, seeds stored in uncontrolled tropical environments undergo seed deterioration at a faster rate than seed stored in dry, cool environments (Delouche, 2005).

Seed deterioration depends on understanding the quantitative relationships between seed longevity, initial seed quality, seed moisture content and storage temperature. The seed viability equation of Ellis and Roberts (1980) accurately predicted the germination of the seed lots collected from farmers and stored

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hermetically at ambient fluctuating temperatures. The results of the study confirmed that seeds of farmers' cultivars were superior to the PVS cultivars in storage as claimed by farmers, except for cultivar, WAB 126. This finding is consistent with the findings of Bam *et al*. (in press) who reported that IDSA 85 (*O. sativa japonica*) is intrinsically somewhat poorer than Kawomo (*O. glaberrima*). Ellis *et al.* (1992, 1993) also reported that *japonica* rice cultivars possess poorer longevity characteristics than *indica* or *javanica* cultivars. These findings suggest the existence of varietal differences in rice seed longevity in warmer seed production environments. The Ellis-Roberts deterioration model is based on the assumption that all seed lots within a species deteriorate at the same rate under identical storage conditions. In contrast, several hybrids of corn with variation in initial seed quality did not deteriorate at the same rate in the same storage environment (Tang *et al.*, 1999). Hay *et al.* (1997) also reported variable rates for foxglove (*Digitalis purpurea*) as did Naylor (2003) for Italian ryegrass (*Lolium multiflorum*). In this study, each seed sample was stored at a different moisture content and therefore they may have deteriorated at different rates. Therefore, varietal differences observed at the end of storage may not necessarily reflect differences at sampling and hence the order of performance of the cultivars in storage may have changed.

Germination was almost completely lost irrespective of the cultivar at 16 % moisture content, and was highest at lower moisture contents. Hence, 60–80 % of viable seeds germinated after six months of storage at 12.8 % moisture content. The generally low germination among seed lots from farmers was therefore to be expected based on the high initial moisture contents at which farmers stored their seed. Factors such as pre-harvest seed production environment, post-harvest practices and genotype have been reported to affect the longevity of seeds in storage (Ellis and Roberts, 1981; Ellis *et al.*, 1992; Kameswara Rao and Jackson, 1996). These factors can influence longevity of seed lots within a species and between cultivars. Our findings suggest that seed moisture content at storage was influenced by duration of drying before storage and type of storage or storage material used for storage.

The drying rate for seed lots under the same drying environment depends on the initial seed moisture content (Hong *et al.*, 1997). Higher seed moisture content was associated with shorter duration of drying and suggests insufficient drying by farmers. How does a farmer determine the moisture content at which seed can be safely stored? This is one of the biggest challenges facing farmers who produce not only their own seed but also produce seed for sale. The moisture content at which seeds were dried to before storage could not be captured in the study as the samples were drawn from storage. While insufficient drying results in a reduction in longevity, over-drying may also reduce vigour and may have adverse effect on ageing rates (Walters *et al.*, 1998).

Seed moisture content fluctuates with changes in relative humidity. The magnitude of these fluctuations can vary with the type of storage and type of storage material used. The relationship between seed moisture content and storage material suggests the importance of storage material in the maintenance of seed viability. Bam *et al.* (in press) reported similar isotherms for both IDSA 85 and Kawomo. Their findings suggested that both Kawomo (*O. glaberrima)* and IDSA 85 (*O. sativa japonica*) have similar seed composition and therefore do not differ in the relationship between equilibrium

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moisture content and relative humidity. The practice of storing seed in jute sacks or unlined polythene sacks in rooms is a general practice across the country and in some parts of the country paddy is heaped in rooms on mats (Langyintuo and Oldham, 1997) or spread on floors in rooms (Opoku-Apau and Otoo, 1997). These practices have serious consequences for seed moisture content and hence viability. Seed stored in poor storage materials will absorb moisture from the storage environment and will reach equilibrium with the ambient environment. Viability of paddy dried for two weeks before storage in ordinary gunny bags was reported to fall to 30 % over nine months (Anon, 2005) due to moisture absorption from the storage environment. Seeds stored in humid and warm environments tend to absorb moisture from their surroundings leading to increases in seed moisture content until equilibrium is established (Roberts, 1972) and therefore form the basis for tests for accelerated ageing (Delouche and Baskin, 1973) and controlled deterioration (Matthews, 1980). Paddy stored at 32 °C and 85–91 % relative humidity was reported to have a corresponding equilibrium moisture content of between 15.5 and 17.3 % (Anon, 2005). As seed moisture content increases, the rate of deterioration also increases. Even where seed moisture content at the time of storage was low, seed moisture will increase during storage due to the increasing ambient relative humidity. Seed moisture content at the time of sampling was already high for most of the samples and this was likely to increase further with increasing ambient relative humidity. Consequently, accelerated physiological ageing of seed would occur and this would result in reduced seed viability or complete loss of viability at time of seeding leading to poor seedling establishment.

Although the number of days panicles were left in the field before threshing did not influence seed moisture content, such a practice may influence initial seed quality before storage and also reduce seed longevity in storage. This practice is common not only among upland rice farmers in the Hohoe district but is general in the country among rice farmers in the other rice-growing ecologies. It is even more serious in the inland valley rice systems where the crop is harvested under waterlogged conditions and yet harvested panicles are left in the field for days or weeks before threshing (Day *et al.*, 1997). Panicles left in the field for longer periods before threshing could result in field weathering and physical damage at threshing due to diurnal changes in temperature and relative humidity. Cycles of alternate drying and moistening of paddy in the field may cause crack formation, which may reduce viability and vigour of seeds (Shephard *et al.*, 1995). These practices will also create favourable conditions for seed microflora activity especially fungi. The activities of such organisms can lead to seed deterioration. Also, heaping panicles at a common threshing point for days before threshing may result in the shedding and loss of grains. Heaping panicles for days before threshing has been reported to result in seed deterioration due to fermentation in the rice straw (Matsuzaki, 1999).

The results of this study have shown that the moisture content of farmers' seed lots was associated with duration of drying before storage and the type of storage material used. Higher seed moisture content was associated with a shorter drying period and storage in jute and unlined polythene sacks. The results of the study also confirmed farmers' perception that their own cultivars were superior in storage to the introduced

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cultivars, except for WAB 126. The rate of germination loss was dependent on the moisture content at which seed was stored. The Ellis-Roberts seed deterioration model accurately predicted germination loss of farmer-saved seed stored under ambient conditions. Farmers can therefore improve the storability of their cultivars by drying seeds to a safe moisture content, about 12–13 %, and storing them in sealed containers or moisture proof bags. Extensive education and training of farmer groups and seed producers on seed production, post harvest and storage practices is urgently needed to improve the management of seed viability and vigour in storage, and also increase seedling establishment and grain yield of the new cultivars. Seed storage behaviour was cultivar dependent and highlights the importance of breeding and selecting cultivars for improved seed storability in tropical countries. However, pre- and post-harvest environmental effects on seed longevity are substantial and make the identification of genetic effects difficult (Lyall *et al.*, 2003). Biochemical markers such as soluble sugar metabolism (e.g. seed oligosaccharides) have been suggested as analytical markers for determining seed quality during storage and therefore can be useful in varietal selection. However, genetic analysis of seed oligosaccharide composition and seed storability has been difficult due to the quantitative nature of these traits (Bentsink *et al.*, 2000). Recently, development of molecular marker technologies has made the analysis of quantitative traits possible. Farmers, especially those in tropical regions such as Ghana will benefit greatly if breeders are able to incorporate successfully enhanced seed longevity into genotypes which have good agronomic characteristics and high yield potential.

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