

Seed Management and Quality of Farmer Saved Seeds of Bambara groundnut from North Western, Northern and Eastern Uganda

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ABSTRACT

Bambara groundnut (BG) is a protein and energy-rich legume crop of African origin with the potential to contribute to food and nutrition security. There is limited information on seed management and quality of farmer saved seed of BG in Uganda. This study was conducted to investigate seed management practices and evaluate the quality of farmer saved seed from Uganda. Four hundred BG farmers were chosen using purposive sampling and information gathered on their seed management. A semi-structured questionnaire was used to interview the farmers. Seed colour and size determination, standard germination and electrical conductivity tests were done on seed samples collected from farmers. Results from survey revealed that farmers recycled seeds for more than 4 years (39.2%) and maintained mostly single landraces (52.5%). Seed was sun-dried on the ground (81%), stored in gunny bags (93.5%), and threshed mostly by hand (52.0%). Collected landraces had varied seed coat colours and significantly differed at $p = 0.05$ in their seed sizes, final germination percentage (FGP), electrical conductivity (EC), germination velocity index and seedling vigour index II (SVI-II). Local Bam landrace recorded highest SVI-II (485.3) and EC (0.52MSg^{-1}) while TVSU 688 landrace recorded the highest FGP (96.0%) and lowest EC (0.06MSg^{-1}).

Keywords: Bambara groundnut; Farmer saved seeds; Farmers' seed management; Germination capacity; Seed vigour

Original scientific paper. Received 29 Jul 2020; revised 25 Apr 2021

Introduction

Bambara groundnut (*Vigna subterranea* L. Verdc) is an annual legume belonging to the family Fabaceae (APG IV, 2016). It is considered a food security crop because of its drought tolerance and ability to perform better than other crops in poor soils (Effa & Uko,

2017; Tsoata *et al.*, 2016; Anchirinah *et al.*, 2001), yet it is one of the underutilized African legumes (Harouna *et al.*, 2018). Bambara groundnut is a good nitrogen fixer thus complementary in cereal intercrops (Halimi *et al.*, 2019; Sprent *et al.*, 2010), and is also a good source of nutrients as the seeds contain

63% carbohydrate, 18% proteins and 6.5% fats (Bamishaiye *et al.*, 2011). It can be consumed as fresh boiled or dried seeds ground into flour, spiced and made into paste or cakes (Jonah *et al.*, 2010; Adebowale & Lawal, 2002). Burkina Faso, Niger and Cameroon are the world's leading producers with annual production of about 42,514t, 21,416t and 20,705t respectively (FAO, 2019). Being a neglected crop, there are no commercial varieties available for cultivation (Mayes *et al.*, 2008) and farmers use landraces whose seeds are exchanged and recycled for generations (Ibrahim *et al.*, 2018). The quality of such recycled seeds is either low, variable or/ and unknown. Good quality seed is desirable in farming as it ensures uniform field stand, establishment and maturity, and has better response to added inputs. Good quality seed is that seed with all physical, physiological, pathological and genetic characteristics that contribute to yield (Basra, 1995). These quality characteristics are influenced by several factors including postharvest handling practices (Patel *et al.*, 2018). Some studies have evaluated the physiological seed quality of Bambara groundnut landraces differing in seed coat colour (Mandizvo & Odindo, 2019; Chibarabada *et al.*, 2014), and its physical seed dormancy behaviour (Miya & Modi, 2017), but there is still very limited information on the quality of farmers' saved seeds. In Uganda, there is very scarce information on farmers' seed handling practices and the quality of farmers' saved seeds of Bambara groundnut. This study was therefore undertaken to investigate seed management practices and evaluate the quality of farmers' saved seeds of Bambara groundnut from the predominant production areas of North Western, Northern and Eastern Uganda.

Materials and Method

Survey

A survey was conducted between June and July, 2019. Purposive sampling technique targeting Bambara groundnut farmers was used to select 400 respondents from North Western, Northern and Eastern Uganda. A total of 13 districts and 26 sub-counties were sampled in the predominant Bambara groundnut production areas of the country. One district (Nebbi) from North Western region, eight (Gulu, Omoro, Agago, Pader, Kole, Oyam, Otuke and Lira) from Northern region and four (Tororo, Kumi, Amuria and Kapelebyong) from Eastern region were chosen for the study. The selection of the number of districts per region was based on the information obtained from a reconnaissance study which revealed that Bambara groundnut production was more in Northern region, followed by Eastern and very limited production in North Western. A semi-structured questionnaire was administered to the respondents to collect information on seed source, seed composition, period of seed recycling, time of seed selection, seed drying method, seed storage and seed processing prior to planting. Seed samples were also collected from farmers in each district during the survey and kept separately in paper bags. Data were analyzed using IBM® SPSS® Statistics Version 20 statistical software (IBM Corporation, Armonk, New York, USA, 2011).

Quality of farmers' saved seeds

Collected seed samples were threshed carefully and gently with a stone, sorted according to the respective landraces and grouped by regions. From the samples, landraces AbiBam 001 and Local Bam (from Nebbi), AbiBam 003 (from Amuria), TVSU 688 (from Kapelebyong) and

TVSU 759 (from Lira) were used for seed quality analysis. These landraces were selected for regional representation and availability of their seeds for laboratory analysis. Seed colour description was done using Royal Horticultural Society colour chart and seed size (length and width) was measured using a Vernier calliper. Electrical conductivity (EC) test was performed on three replicates of 10 seeds each. Seeds were separately weighed and soaked in deionized water for 24 hours and the conductivity of the leachate (MSg^{-1}) was measured with an EC meter. A standard germination test was performed with 25 seeds in three replications. Seeds were sterilized with 1% sodium hypochlorite solution for two minutes and rinsed with distilled water. The sterilized seeds were then placed in germination trays in sterilized sand moistened with distilled water. Seeds were incubated in growth chamber (BJPX-B40011, Biobase Biodustry (Shandong) Co. Ltd) at alternating temperature of 20°C/30°C in 16 hours darkness and eight hours light for 14 days (Mandizvo & Odindo 2019; Chibarabada *et al.*, 2014), and germination count recorded daily. Final germination percentage (FGP) was determined on the 14th day using the formula according to Nichols and Heydecker (1968) as

$$FGP = \frac{S}{T} \times 100;$$

Where; S is the number of germinated seeds and T is the total number of seeds sown. Germination velocity index (GVI) was calculated according to Maguire (1962) as

$$GVI = G_1/N_1 + G_2/N_2 + \dots + G_n/N_n$$

Where G_1, G_2, \dots, G_n are number of seeds germinated on 1st, 2nd and last count. N_1, N_2, \dots, N_n are number of days at 1st, 2nd and last count from

the sowing day. 10 normal seedlings (normal seedlings had well-developed root and shoot systems) were oven-dried at 65°C for 48 hours and seedling dry weight (SDW) measured using a digital balance (TP-B2000). Seedling Vigour Index II (SVI-II) was computed by multiplying the final germination percentage with seedling dry weight (Abdul-Baki & Anderson, 1973). Germination data were arcsine transformed and analysis of variance performed in GenStat® 14th Edition (VSN International Ltd, Hemel Hempstead, UK, 2011). Least significant difference (LSD) was used to separate means at 5% significance level. A correlation of seed size and physiological seed quality parameters was done using Microsoft Excel 2016.

Results

Seed sources

The major seed sources were the local market (35.2%) and farmers' own saved seeds (30.8%) for most farmers. A higher percentage of farmers in North Western (55.2%) and Northern (30.9%) regions used their own saved seeds while 44.0% of those in the Eastern region sourced their seeds from local markets (Figure 1).

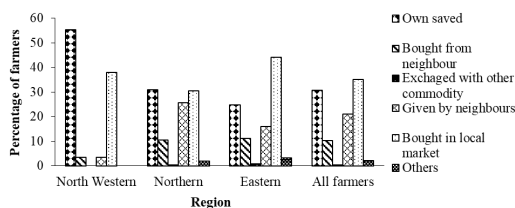


Fig. 1: Farmers' seed sources of Bambara groundnut

Seed composition

Farmers used seed coat colours to differentiate landraces. A larger proportion of farmers had single (52.5%) and mixed (33.5%) landraces as opposed to “more than one not-mixed” landraces. More than half (65.5%) of farmers in North Western region had mixed landraces while 60.2% and 44.0% of those in Northern and Eastern regions respectively had single landraces (Figure 2).

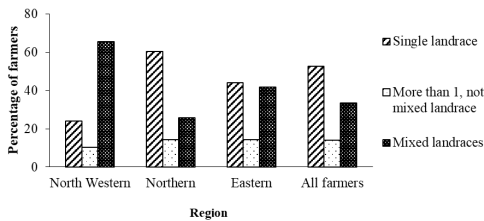


Fig. 2: Seed sample composition of Bambara groundnut

Period of seed recycling

Generally, farmers recycled the same seed for more than four years (39.2%), two years (22.8%) and three years (21.0%). This was similar across all the three regions, with seed recycling for more than four years and two years dominating except for North Western region where seed recycling for three years was higher than that of two years (Table 1).

TABLE 1
Period of seed recycling among Bambara groundnut farmers

Percentage of farmers				
Period (years)	North Western	Northern	Eastern	All farmers
1	6.9	9.3	7.2	8.5
2	20.7	22.4	24.0	22.8
3	24.1	19.5	23.2	21.0
4	3.4	7.3	12.0	8.5
>4	44.8	41.5	33.6	39.2

Seed selection

Seed selection was common during drying (47.8%) and at planting (36.0%). Very few farmers selected seeds before the whole crop was harvested (1.8%). Nonetheless, 20.7% of farmers in North Western region selected seeds during crop harvest (Figure 3). A larger percentage (84.3%) of farmers did not use any seed selection criterion. However, a few farmers used big-sized pods, high-yielding plants and healthy-looking plants and pods as seed selection criteria (Figure 4).

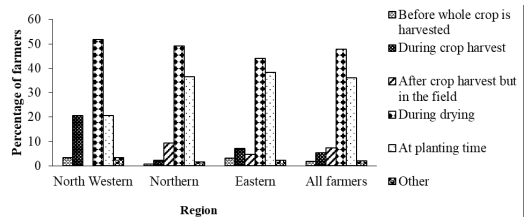


Fig. 3: Time of Bambara groundnut seed selection

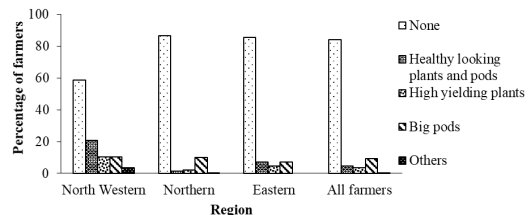


Fig. 4: Seed selection criteria among Bambara groundnut farmers

Seed drying methods

Generally, farmers dried Bambara groundnut directly on the ground (81%) or on tarpaulin (21.3%), a practice similar in all three regions (Figure 5). Farmers in Eastern region mostly used the sound of pods (pods are shaken during drying) (80%) and hardness of seeds (70.4%) to ascertain that Bambara groundnut was dry

enough for storage. This was also similar to their counterparts in Northern region (Table 2).

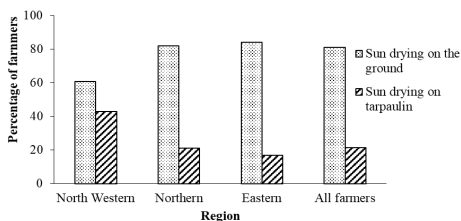


Fig. 5: Bambara groundnut seed drying methods

TABLE 2
Indicators of Bambara groundnut seed drying and suitability for storage
Percentage of farmers

Indicator of seed drying	Northern	Eastern
Sound of pods	81.1	80.0
Hardness of seeds	57.0	70.4
Duration of drying	2.0	0.0
Others	4.9	1.6

**This data was not captured for North Western region*

Seed storage methods

Farmers in all the three regions stored Bambara groundnut in pods (in shells). The most preferred seed storage method was gunny bags on a raised platform (on stone, top of other produce or timber) (93.5%) and this was common for all three regions. Only a few farmers stored Bambara groundnut in pots and open containers (Figure 6).

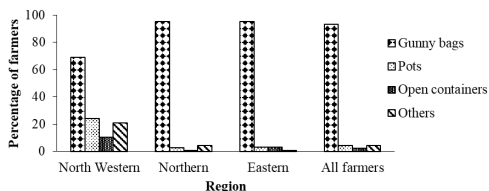


Fig. 6: Bambara groundnut seed Storage methods

Seed processing prior to planting

Farmers used several methods to process seeds before planting, but shelling by hand (52.0%) was the dominant method followed by shelling with mortar (31.2%). Whereas farmers in Northern (37.3%) and Eastern (26.4%) regions used shelling with mortar, none of their counterparts in North Western region used this method (Figure 7). Farmers also sorted seeds after shelling to remove all undesirable ones.

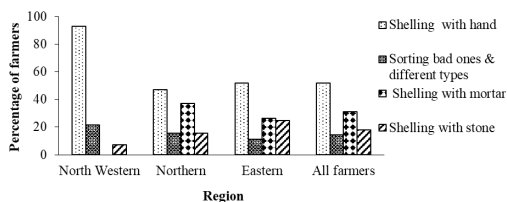


Fig. 7: Bambara groundnut seed processing methods

Seed morphology of collected Bambara groundnut landraces

There was a significant difference among landraces with respect to seed length and width ($p < .001$). The largest seeds were those of Local Bam (1.37 cm and 1.01 cm, length and width respectively) while AbiBam 001 had the smallest seeds (0.89 cm and 0.74 cm) (Table 3). Landraces also had varied seed coat colours. Local Bam was brown spotted, TVSU 688 was plain cream, AbiBam 003 was black, AbiBam 001 was cream with black stripes, and TVSU 759 had plain cream, black and brown seeds (Table 4).

TABLE 3






Comparison of collected Bambara groundnut landraces on the basis of seed size (length and width)

Landrace	Seed length (cm)	Seed width (cm)
AbiBam 001	0.89a	0.74a
AbiBam 003	1.00bc	0.84b
Local Bam	1.37d	1.01c
TVSU 688	1.07c	0.83b
TVSU 759	0.94ab	0.81ab
CV (%)	7.1	6.0
LSD	0.113	0.076
F pr.	<.001	<.001

Means with same letters do not differ significantly ($p = 0.05$)

TABLE 4

Seed colour description of collected Bambara groundnut landraces

Landrace	Colour description	Illustration
Local Bam	Brown spotted	
TVSU 688	Plain cream	
AbiBam 003	Black	
AbiBam 001	Cream with black stripes	
TVSU 759	Plain cream, black & brown	

Physiological seed quality of collected Bambara groundnut landraces

Landraces showed a significant difference in relation to EC ($p = 0.008$). Local Bam recorded the highest EC (0.52 MSg^{-1}), while TVSU 688 recorded the lowest EC (0.06 MSg^{-1}) (Table 5). Landraces also significantly differed in their germination capacity ($p = 0.007$) with TVSU 688 showing the highest germination (96.0%) and AbiBam 001 (66.67%) having the lowest final germination percentage respectively (Table 5). Similarly, significant differences were observed among landraces with respect to Germination Velocity Index ($p = 0.040$), being highest in AbiBam 003 (2.91) and lowest in AbiBam 001 (2.03) (Table 5). There was also a significant difference among landraces with respect to Seedling Vigour Index II ($p = 0.003$), with local Bam (485.3) and AbiBam 001 (213.3) having the highest and lowest Seedling Vigour Index II respectively (Table 5).

TABLE 5

Final germination percentage (FGP), Germination Velocity Index (GVI), Electrical conductivity (EC) and Seedling Vigour Index II (SVI-II) of collected Bambara groundnut landraces

Landrace	FGP	GVI	EC	SVI-II
AbiBam 001	66.67a	2.03a	0.24ab	213.3a
AbiBam 003	93.33b	2.91b	0.15ab	477.3b
Local Bam	68.00a	2.05a	0.52c	485.3b
TVSU 688	96.00b	2.70ab	0.06a	448.5b
TVSU 759	84.00ab	2.76b	0.33bc	283.6a
LSD	19.44	0.677	0.221	134.1
F pr.	0.007	0.040	0.008	0.003

Means with same letters do not differ significantly ($p = 0.05$)

Relationship between seed size and physiological seed quality

Seed size was negatively correlated with FGP ($r = -0.24$ and -0.19 , seed length and width respectively) and GVI ($r = -0.36$ and -0.23 , seed length and width respectively) but was positively correlated with SVI-II ($r = 0.71$ and 0.74 , seed length and width respectively) (Table 6).

TABLE 6
Correlation coefficients of seed size (seed length and width) and physiological seed quality parameters of collected Bambara groundnut landraces

	<i>Seed length</i>	<i>Seed width</i>	<i>FGP</i>	<i>SVI-II</i>	<i>GVI</i>
Seed length	-				
Seed width	0.97	-			
FGP	-0.24	-0.19	-		
SVI-II	0.71	0.74	0.43	-	
GVI	-0.36	-0.23	0.93	0.29	-

Discussion

Seed sources

The major seed sources were farmer's own saved seeds and the local market. This is in agreement with Ibrahim *et al.* (2018) who reported the use of farmer's recycled seed and purchase from local markets as major seed sources for Bambara groundnut in Dosso region of Western Niger. Nevertheless, this study indicated that seed was exchanged among farmers, highlighting a typical characteristic of an informal seed system particularly of a neglected crop like Bambara groundnut. Seed exchange among farmers is attributed to uncertainty about seed savings (Louwaars, 2007). However, seeds obtained from an informal system may have lower quality compared to those from the formal system, possibly due to the quality control in the formal system (Biemond, 2013).

Seed composition

Farmers' seed composition was mostly single and mixed landraces although some reported having "more than one but not mixed" landraces. A similar seed composition among Bambara groundnut farmers in North Eastern Nigeria was reported by Aviara *et al.* (2013). Furthermore, heterogenous mixtures of Bambara groundnut seed has been shown to be common among farmers in Sub-Saharan Africa

(Mohammed *et al.*, 2016). Non-improved crops such as Bambara groundnut tend to be mixed yet farmers are not very keen to sort them according to different categories. This implies that even the category "more than one but not mixed" landraces can be a mixed type upon threshing and observing the seeds. A mixed landrace may not entirely entail poor seed quality but performance-wise, different landraces in the mixture may have different maturity periods, yields and responses to environmental factors. A case in point is Bambara groundnut landraces varied reaction to Fusarium wilt infection (Wakhungu, 2016) and water stress (Chibarabada, 2014). Such diversity could have implication on subsequent yield and seed quality. In addition, sowing of mixed seeds of a crop species results in non-uniform field stand establishment, causing heterogeneity in the vigour of plants (Mishra *et al.*, 2010).

Period of seed recycling

Farmers frequently recycled seed for more than four years (four times). This corroborates with Aviara *et al.* (2013) who reported that local communities in North Eastern Nigeria selected and maintained Bambara groundnut landraces for long periods. Increased periods of seed recycling leads to poor seed quality and low yields particularly in hybrids, with minimal effects on open-pollinated varieties (Amaza *et al.*, 2010; Warburton *et al.*, 2010; Clayton *et al.*, 2009). However, seed recycling is likely to have a minimal effect on the seed quality of Bambara groundnut which is autogamous (Gonné *et al.*, 2013). It is therefore likely that farmers' seed handling practices during recycling periods are a major determinant of seed quality (Gebeyehu *et al.*, 2019).

Seed selection

Seed was largely selected at drying and planting. Farmers who select seeds at planting run the risk of losing seed as it may be sold or consumed in the household, but they ensure that they plant good quality seeds. On the other hand, seed selection at drying ensures that seeds are stored separately and, in most cases, handled differently from the grains, for example, re-drying to prevent mould growth. Interestingly, however, most of the farmers did not use any criterion to select seeds, although big-sized pods, high-yielding plants and healthy-looking plants and pods were used by a few farmers. Supply of seeds for crops such as Bambara groundnut are entirely informal, hence seed selection is done either from farmer's production or other sources (Louwaars, 2007).

Seed drying

Bambara groundnut seeds were typically sun-dried on the ground. This was the common practice probably because it is a cheap and convenient method. Farmers normally harvest Bambara groundnut when the pods are already detached from the plant, hence alternative drying methods such as hanging or bunching as with groundnuts are not possible. In addition, access to tarpaulins or construction of a raised drying platform is usually a challenge for most farmers. Sun-drying of Bambara groundnut is commonly done by farmers in Dosso region of Western Niger (Ibrahim *et al.*, 2018). Sun-drying of seeds directly on the ground for both grain legumes and cereals is practiced by most farmers in Eastern Kenya (Njoroge *et al.*, 2019). This practice is likely to cause infestation by aflatoxin causing fungi *Aspergillus flavus* which would have a negative health impact if seeds are consumed as food (Adithya *et al.*, 2016). However, farmers in our study reported

drying Bambara groundnut seeds when in pods, thus it would also be necessary to establish the level of fungal infestation on both the seeds and pods under different drying methods.

Seed storage

Seed was mostly stored in gunny bags and placed on raised platforms (on stone, top of other produce or timber). The non-hermetic bags are the most common storage materials used by farmers because they are readily available, affordable and adequately aerated, providing short to medium term storage (Sultana *et al.*, 2016; Jebuni, 2014). Placing the bags on raised platforms keeps seeds free from dampness that could cause mould growth and seed deterioration. Storage of Bambara groundnut in pots and local granaries made of grass materials by farmers in North Eastern Nigeria has been reported (Aviara *et al.*, 2013). However, the use of such structures resulted in high insect pest infestation for seeds in shelled conditions (Aviara *et al.*, 2013). Farmers in our study reported storage of Bambara groundnut in pods (unshelled condition). Bambara groundnut pods are very hard when dry and insect infestation and damage on seeds stored in pods is likely to be minimal.

Seed processing prior to planting

Threshing of pods to obtain seeds prior to planting was mostly done using the hands, pounded in a mortar with a pestle, or cracked with a stone. Information on seed processing indicates that seed shelling by mortar and pestle, stones and treading with feet is commonly practiced among Bambara groundnut farmers in Dosso region of Western Niger and North Eastern Nigeria (Ibrahim *et al.*, 2018; Aviara *et al.*, 2013). Other methods include pouring pods into jute or hessian bags and beating with sticks on flat surfaces, and beating jute or hessian

bag containing the pods against the wall of a building (Aviara *et al.*, 2013). However, these methods involve the application of force to the seeds, which is likely to cause more mechanical damage to the seeds as compared to shelling with hand, although some care is taken when exercising these methods. Mechanical damage on the seed tissues has implication on seed quality. Comparison of manual and mechanical threshing of maize at 12% moisture content revealed that mechanical damage on the seeds was higher for mechanical threshing, resulting in lower germination capacity and seed vigour as compared with manual threshing (Riliang *et al.*, 2019). Determining the extent of mechanical damage of different seed threshing methods on the seeds and correlating with physiological seed quality would help in advising Bambara groundnut farmers on appropriate seed threshing methods.

Seed morphology

Landraces showed variability not only in their seed coat colours but also in their sizes, with Local Bam and AbiBam 001 having the largest and smallest seeds respectively. This variability could be explained by the production of heterogenous seeds by plants for their survival (Imbert, 2002). Heterogeneity in seeds usually happens due to physiological, environmental and genetic factors (Bhatt *et al.*, 2016) and is exhibited by features such as colour, size and shape (Matilla *et al.*, 2005). Seed heterogeneity is also known to affect seed germination (Smith *et al.*, 2004; Bhatt *et al.*, 2016). Bambara groundnut landraces differing in their seed coat colours have been reported to have varying seed coat thickness, water imbibition and germination capacity (Mandizvo & Odindo, 2019; Chibarabada *et al.*, 2014). Seed colour also affects the light and temperature requirement of seeds during germination (Bhatt *et al.*, 2016). On the other

hand, seed size is an important indicator of physiological seed quality as it affects seed germination and seedling growth particularly under stress conditions (Steiner *et al.*, 2019). Seed size is also known to affect field emergence, plant growth and performance in the field (Adebisi *et al.*, 2013). Generally, large seeds have higher vigour than small seeds due to more accumulated reserves (Ambika *et al.*, 2014). The first germination count test of small peanut seeds was higher than that of large seeds of the same crop in both non-stressful and water-stressful conditions, indicating a delay in the germination process of large seeds (Steiner *et al.*, 2019). Similarly, the germination speed index of large-sized wheat seeds was reportedly lower than that of medium and small-sized seeds (Shahi *et al.*, 2015). The high germination rate in small-sized seeds is attributed to their less need for water absorption hence imbibing water faster than large-sized seeds (Steiner *et al.*, 2019; Sadeghi *et al.*, 2011). However, the effect of seed size on seed germination and crop establishment varies between crop species and growth environments (Shahi *et al.*, 2015; Rastegar & Kandi, 2011; Gholami *et al.*, 2009).

Physiological seed quality

Germination capacity

Germination capacity varied among landraces with the highest percentage in TVSU 688 (96.0%) and the lowest in AbiBam 001 (66.67%). Seed harvesting stage is known to affect the germination capacity of seeds as the stage at which the crops are harvested directly relates to the physiological state (development and maturation) of seeds. Evaluation of three soybean varieties revealed that germination capacity of 85.25%, 77.25% and 67.33% in Nangbaar, 85.25%, 68.0% and 60.92% in Anidaso, 66.75%, 64.67% and 58.83% in Jeguma varieties were attained when seeds were harvested at physiological maturity, one

week after physiological maturity and two weeks after physiological maturity respectively (Isaac *et al.*, 2016). It is therefore likely that seeds harvested at different times will have different germination capacities, as exhibited in this study. However, it was not possible to pinpoint the exact maturity stages of seeds used in this study since the seed samples were collected from different farmers. Seed handling practices such as drying (how long and to what moisture content) and storage (storage materials, duration and storage conditions) could also account for such differences observed in FGP of landraces. The germination pattern observed in this study could also be explained by the seed coat colours of landraces. This study revealed that the light coloured (plain cream) landrace (TVSU 688) had the highest germination percentage, which is in agreement with Mandizvo and Odindo (2019) who reported higher germination percentages in light coloured Bambara groundnut landraces at the University of KwaZulu-Natal, South Africa.

Seed vigour

Local Bam recorded the highest EC (0.52 MSg⁻¹) while TVSU 688 recorded the lowest (0.06 MS g⁻¹) among the landraces. Electrical conductivity test measures the concentration of leachates discharged into the solution, which is linked to the integrity of seed coat membrane (Binotti *et al.*, 2008). Differences in EC observed in landraces could be due to differences in their seed coat structure particularly number and size of pores which are likely to influence electrolyte leakage from imbibed seeds. In addition, seed handling practices such as storage (storage period and conditions which influence seed ageing) and seed threshing methods (which may cause mechanical damage in seed coat) influence electrolyte leakage from the seeds (Vishwanath *et al.*, 2019). Mechanical

damage on the seed tissues has been reported to be positively correlated with EC of seeds (Ri-liang *et al.*, 2019). Electrical conductivity of a seed lot has been further demonstrated to be influenced by seed age and initial seed moisture content (Ferreira *et al.*, 2017; Vieira, 1994). Still another study suggested that seed coat thickness determines leakages of electrolytes from the seed (Sinefu, 2011), though this was disputed by Chibarabada *et al.* (2014) who found no relationship between electrical conductivity and seed coat thickness. The same study by Chibarabada *et al.* (2014) reported that Bambara groundnut landrace with highest calcium content had lowest electrical conductivity and they attributed it to greater cell wall integrity due to high calcium content. However, the underlying seed coat structure (seed coat thickness, number and size of pores on the seed coat), seed mineralogy and the extent of mechanical damage on the seeds were not determined for the landraces in our study. Besides, it was not possible to trace a specific landrace and pinpoint its exact seed age (duration of storage) and storage conditions (relative humidity and temperature) by the time of this analysis. Therefore, a more detailed study on seed coat structure, seed mineralogy and age of these landraces would give more light on the electrical conductivity exhibited.

AbiBam 003 a dark-coloured (plain black) landrace had the highest germination velocity index among the landraces. This corroborates with Chibarabada *et al.* (2014) who reported the highest germination velocity index in black speckled Bambara groundnut seeds. This is related to the rapid water imbibition in dark coloured seeds which is likely to cause faster initiation of the germination process (Mandizvo & Odindo, 2019). From EC, GVI and FGP, Local Bam had less vigour and low germination capacity. Interestingly, however, the same landrace

had the highest seedling vigour index II. This suggests that Local Bam seed lot could be less vigorous but the individual seeds that germinated had high vigour, which was demonstrated by seedling growth. Local Bam had the largest seeds, which is an indication of large food reserves that cause rapid seedling growth upon hydrolysis and translocation to the growing regions. This study also revealed that seed size was positively correlated with seedling vigour index II, indicating a higher vigour for those seedlings arising from large seeds. Seeds of different sizes have different levels of food reserves hence determining the initial growth of seedlings (Shahi *et al.*, 2015). Large seeds of peanut produce seedlings with higher dry weight and seedling weight vigour (seedling vigour index II) than small seeds in both stress and non-stressed conditions (Steiner *et al.*, 2019). Similarly, large-sized seeds of soybean were reported to produce plants with the highest shoot dry matter (Limede *et al.*, 2018).

Conclusion and Recommendations

Bambara groundnut landraces obtained from farmers were evaluated to establish their seed quality in relation to farmers' practices. The landraces TVSU 688, TVSU 759 and AbiBam 003 showed relatively good seed quality in terms of germination capacity and electrical conductivity except, TVSU 759 whose EC did not seem to correspond to the good germination. Despite Local Bam having a relatively low germination capacity and high electrical conductivity that would suggest low quality, it recorded the highest seedling vigour index apparently because of its relatively large seed size. The relatively good seed quality exhibited suggests that seed management practices commonly adhered to by farmers such as proper drying and unshelled storage in gunny bags placed on raised platforms that

minimizes seed deterioration from dampening and pest infestation are important in seed quality maintenance in farmer saved seeds. Farmers should therefore be trained on good seed handling techniques so as to improve on the quality of their farm saved seeds.

A similar study targeting Bambara groundnut farmers from other parts of Uganda should also be done to find out their practices, landrace types and the seed quality of those landraces they are growing. Determining the level of mechanical damage imposed on the seed by different seed threshing methods and correlating with physiological seed quality would help in advising farmers on appropriate seed threshing methods. Studies on seed coat structure and mineralogy of landraces used in this study would also help in explaining the observed seed quality.

Acknowledgement

This study was funded by the Intra-Africa Academic Mobility Scheme of the European Union through SCIFSA project.

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