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Assessment of Seed Quality of Selected African Leafy Vegetables Produced in Western Kenya using Informal and Semi-formal Seed Systems

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ABSTRACT

Seed quality is an important determinant in field performance and marketable yields of crop production. Low quality and small quantities of available seeds are major constraints in African leafy vegetable (ALV) production and limit the ability to provide farmers more options for growing health food. Capacity building was done through the Horticultural Innovation Lab, programme to assist farmer groups to produce quality ALV seed using the semi-informal seed system (SSS) for the dissemination of five newly released, high yielding improved ALV varieties. The ALVs seed plots were monitored by programme implementers during seed production. Thereafter, to determine the quality of ALVs seed produced through the SSS, seed samples of African nightshade (*Solanum scabrum*), spider plant (*Cleome gynandra*) and amaranth (*Amaranth cruentus*) were collected from farmer group members in Nandi South and Busia Counties. Another set of seed samples of the same species of vegetables produced through the Informal seed system (ISS), were sourced from the local market in Kakamega for quality comparison with seeds from the SSS. Seed quality parameters tested were physical purity, pure live seeds (PLS) and germination percentage at the Kenya Agricultural Research and Livestock Organization (KALRO) laboratory in Kakamega. The seed quality results are reported here and show that there is little difference in quality between semi-formal and informal seed systems, but in both cases, each of these systems produce seed quality below national seed standards (physical purity is 98%, PLS and Germination is 75 % for amaranth and 50% for other ALV seeds). There was no difference in the seed quality from the ISS and SSS. Mean scores for physical purity were ISS (91%), SSS (90%); PLS were ISS (29%) and SSS (31%) and Germination percent were ISS (33%) and SSS (35%). Seed quality between the vegetable species also showed no significant differences. The results reflect the limitations of farmers producing seed through the semi-formal to manage their seed plots during crop growth, harvesting and processing, and storage of seeds. **Given that the majority of ALV growers access their seed through these seed systems, greater attention is needed to strengthen both the ISS and SSS systems.**

INTRODUCTION

Appreciation for African leafy vegetables (ALVs) in Kenya is in part due to their medicinal values and high nutritive contents (Abukutsa-Onyango, 2010; Ayua and Omware, 2013). Other advantages are food security and adaptability to marginal agricultural production areas and their ability to provide dietary diversity in poor rural communities (Weller et al., 2015; Maseko et al., 2017; Hoffman et al., 2018).

The special attributes of ALVs have encouraged research that has mainly been directed towards identification, characterization of traditional landraces and development of agronomic packages and evaluation of nutrient contents. (Afari-Sefa et al., 2011). Breeding of ALVs in Africa has a short and limited history as reviewed by Mnzava et al. (1999). Nevertheless, the national agricultural research institutions NARS, universities in the continent and the World Vegetable Centre have made strides and evaluated, tested and developed many new improved ALV varieties. Most of the new varieties are open pollinated

Increase in demand for ALVs has led to increased demand for seed that has made seed become a crucial input and constraint in expanding commercialization efforts and in ensuring access to high quality seeds by farmers and even family gardeners (Kanslime et al., 2018; Weller et al., 2015). Women mainly conduct seed production under the informal seed system, with over 90 percent of ALVs growers saving their own seed (Croft et al., 2017). The quality of ALVs seed purchased in local markets cannot be guaranteed and yet seed quality is such a critical determinant of vegetable and seed yields (Louwars and De Boef, 2012).

The meaning of the term 'seed quality' as used here is the overall value of seed depending on the requirements and intended purpose of the user that can include seed mass, storability, vigour, and reliable emergence for farmers; longevity and maintenance of genetic integrity for gene-banks (Li et al., 2017) and absence of disease that would be carried onto the next generation. Attributes of seed quality include genetic purity, physical purity, germination capacity and vigour, moisture content and seed health (George, 1987). A quality seed is a seed that possesses high genetic purity, high physical purity, good germination rate, and is free from diseases and pests, and has proper moisture content.

A seed system refers to the different ways by which farmers access seed, including the different actors in the seed chain from breeding to marketing (Muthoni and Nyamongo, 2008). In Kenya, seed systems have been broadly divided into two groups: formal and informal systems. The informal seed system is the main source of seed of the traditional crops in Kenya (Munyi and De Jonge, 2015). About 80% of smallholder farmers depend on the informal system for their seed (Biemond, 2013). The quality of seed from the formal system is guided and regulated by the government regulatory bodies but supplies only 3-30% of seeds of a limited number of crops and improved varieties (Hirpa et al., 2010). Given ALVs are considered minor or underecognized crops relative to all agronomic and commercial seed crops, the relative percentage of Kenyans accessing ALVs seeds using the informal system is likely far higher than the 80%.

An alternative approach that can improve seed quality and support the informal system is the semi-formal or integrated seed system where the strengths of formal and informal system are combined (Almekinders, 2000, Francis and Waithaka, 2014). This can include the introduction of improved varieties and strict standards for seed production that ensure high seed quality within the informal seed system (or seed chain). The semi-formal seed system is regarded as an improved alternative seed supply system that can provide opportunities for establishing linkages with formal institutions to produce good quality seed and meet farmers' different seed requirements (Rajendrana et al., 2016).

The Horticulture Innovation Lab project on African Indigenous Vegetables focused on African leafy greens or ALVs, with support by USAID, brought together KALRO, AMPATH, Rutgers University, Purdue University and the World Vegetable Center to conduct activities with the objective to enhance the production of ALVs in western Kenya between 2015 and 2019. During the implementation period, five new improved varieties of ALVs sourced from World Vegetable Center (WorldVeg) were field tested and released by the Kenya government for commercial production starting in 2018. To make seeds of these newly released improved varieties more rapidly available, accessible and affordable, farmer groups were trained in quality seed production of African nightshade (*Solanum scabrum*), spider plant (*Cleome gynandra*) and Amaranth (*Amaranth cruentus*). This project aimed to increase farmers' access to the six new improved varieties, to ensure the grower groups could produce sufficient quality seed of ALVs, thereby increasing ALV production using the semi-formal seed system (SSS).

Farmer groups were provided with breeder seed of the six released ALV varieties to speed up production of seeds and quickly make them available to their communities. Following the path or process used by the formal system would have required far longer before adequate seed would be supplied to majority of the farmers, and at a higher price point. Visits were made by project implementers, and farmers were provided with trainings as to how best to produce and save seed. Generally, it was left to the community seed growers to champion this effort following trainings and to use the knowledge gained during their trainings to ensure that the seed produced would be of good quality. In 2020, a study was conducted with the objectives of evaluating the quality of seed produced by the project farmers using the semi-formal system and to compare with the quality of seed from the Informal seed system (ISS).

MATERIALS AND METHODS

Study area. The study was conducted in 2020 in the counties of Busia, Kakamega and Nandi South found in western Kenya. Seed samples were collected from farmers and seed sellers in the counties. The study areas receive rainfall in two seasons – from late March to June, and July to November. More rainfall was received in the first season, March to June. Evaluation of the farmers' seed quality was conducted at Kenyan Agriculture and Livestock Research Organization (KALRO) laboratory in Kakamega.

Seed sampling. Samples of seed (30 g to 50 g) were collected from seed lots produced by 27 farmers (12 men and 15 women) in 2019. The amount of seed saved by these farmers was not more than 3kg per species per farmer. The number of seed samples collected from farmers practicing (SSS) were six for African nightshade, seven for spider plant and 16 for amaranth. Seed samples collected from farmers (the semi-formal seed producers) were of the new improved varieties of ALVs, two African nightshade varieties, one spider plant and two amaranth varieties. A second set of seeds was obtained from seed vendors from the local Kakamega county market. The varieties of seed bought from vendors could not be determined at the point of sale. Seed samples collected were five each for African nightshade, spider plant and amaranth. The number of seed samples collected depended on what was available with the recruited farmers at the time of collection.

Purity analysis. Seed testing was done for physical purity (pure seed and pure life seed) and germination percentage based on the ISTA (1999) rules. A working sample of 20g seed was drawn from each collected sample to determine the degree of the seed purity. The working sample was sorted by hand and divided into three components, pure seed, seeds of other species and inert matter. The components were weighed and recorded in grams to three decimal places. The physical pure seed percentage was calculated as: Pure seed (%) = weight of pure seed divided by working sample seed weight multiplied by 100. Pure live seed is the percentage of viable seed in a given seed sample. The purpose of calculating the PLS is to gauge the percentage of seed that will germinate and grow into healthy plants from a seed lot. Pure live seed (germination capacity) was calculated by multiplying the physical purity percentage by the total germination percentage of a seed sample (% Purity * % Germination Rate / 100 = % PLS) as described in International Seed Testing Association rules (ISTA, 1999).

Germination testing. The objective of the germination test was to determine the maximum germination capacity of the seed sampled. A completely randomized design was used for germination tests. Each working sample included 400 seeds that were divided into four replicates of 100 seeds each. The blotting paper was used as the substrate and the top paper (TP) placement method was applied for all the seeds. The planted seed samples were kept at room temperatures of 22-24^0 C for 16 days. Germination test data were collected in five categories. Percentage of germinated normal seedling, abnormal seedling, and un-germinated seeds. Seeds that germinated normally were counted first and removed. Those seeds that germinated into abnormal seedlings or did not germinated were counted at the end and classified as abnormal or un-germinating seeds.

Data analysis. Data obtained from purity and germination tests were subjected to analysis of variance (ANOVA) using SAS software to determine significant differences. The mean comparison was done using the least significant difference (LSD) test at 5% level. Descriptive analysis was conducted to show trends in purity and germination using the Microsoft Excel program.

RESULTS

Analyses were conducted for a total of 49 samples. The results showed that the physical purity, the PLS and germination percentage from both the ISS and SSS were below the required national requirement of 98% for physical purity and 78% for amaranth, 50% for PLS and germination in African nightshade and spider plant vegetables. There were no significant differences (NSD) between the ISS and SSS in seed purity (P>0.6), PLS (P>0.5) and germination percent (P>0.6). The mean scores for physical purity were ISS (91%) and SSS (90%), for PLS were ISS (29%) and SSS (31%), and for germination percent were ISS (33%) and SSS (36%) (Table 1). Seed quality between the vegetable species also showed no significant differences. The mean scores for physical purity were 91%, 91% and 87% for amaranth African nightshade and spider plant respectively; those for PLS were amaranth (35%), African nightshade (28%) and spider plant (27%). Germination percentages were, 37%, 31% and 31% for amaranth, African nightshade and spider plant respectively (Table 1).

Physical purity. Regarding seed physical purity, only three out of 17 of samples from the ISS and 9 out of 32 samples from the SSS had purity values of 98% and above. These are the samples that met the minimum national standard for purity of basic or commercial seed in Kenya. (Fig.1). In the vegetables species, amaranth had 10 out of 23 and the African nightshade two out of 14 seed samples with purity percentage of 98 and above. All the spider plant seed samples registered seed purity values less than 98%. The highest purity percentage recorded in spiderplant was 97%, a sample sourced from Mwombe, but samples with the lowest purity percentages were from amaranth samples at 51 % and 53 %, sourced from Olayo and Nagambo (Fig. 2).

Pure live seed. Seed samples from the ISS and SSS had very low pure live seed levels. Only two out of 17 seed samples from the ISS and three out of 32 seed samples from the SSS had PLS of above 50% (Fig. 3). The seed samples showed varied PLS results in both the ISS (0% to 57 %) and SSS (0% to 95%). The lowest PLS values in the vegetable species of 0% were recorded from amaranth and African nightshade seed samples (Fig. 4). The samples with 0% germination were sourced Masia Luma, Omurai, Nangabo and Mkt10. Samples from Masia and Luma were African nightshade seeds, but samples from Mkt10, Omurai and Nangabo were amaranth seeds (Fig 4).

Germination. Only two seed samples from ISS with a germination percentage of 55 and 59 met the national requirement of 50% and above. In the SSS only 3 out 32 seed samples would qualify as quality seed. (Fig. 5). Among the vegetable species only two seed samples of amaranth sourced from Taboo and Laval germinated as required at 89% and 96 % respectively. Spider plant had one sample with a very good germination percentage of 79. It was sourced from Almasi. Three samples of African nightshade had good germination at 55%, 59% and 68%. These were sourced from Mkt11 and Mkt 5 and Almasi respectively. The lowest germination percentages in amaranth, African nightshade and spider plant were 0%, 1% and 13%, respectively, while the highest germination percentages in that order were 96%, 68% and 79% (Fig. 6).

DISCUSSION

Seed purity. From the purity results of the study, farmers appreciate clean seed even in the informal seed system. The average seed physical purity of 91% (Table 1) in the ISS was expected to have lower purity levels than the results showed because ALVs have very small seeds and are difficult to clean. Furthermore, traditionally, soil, ash and cow dung are commonly added to the ALVs seeds as seed dresser to control pests

(Ndinya, 2003). Soil is also added to seed during planting to avoid exceeding the seed rate per area. The addition of soil and ash contributed to the lower purity levels of seed samples analysed, although the practice is important to farmers for seed protection. According to Kenyan national standards, the recommended seed purity level is 98% (KEPHIS, 2020), but only 20% of the current samples met this requirement. Lowering the physical purity requirement of 98% cannot be recommended especially where seeds are being sold to the general public, as seed production of ALVs need to be aligned to national and international standards. Seed quality is considered superior when the percentage purity is above 98% (Odongo et al., 2015).

The (PLS) as a means of expressing seed quality, is helpful in calculating the required seed rate that ensures the recommended stand count of a crop is obtained during production. The low PLS mean values of 29-35% (Table 1) in the seed samples tested in this study, suggest that farmers using these seeds would have to use seed rates three times the recommended amounts to achieve the same correct plant populations in their farms. The observed high seed rate used by women ALV farmers could be a way to overcome the low PLS problem and obtain the desired plant populations in their vegetable gardens.

Germination. Germination percentages of seed samples from the ISS and SSS were very low for the minimum national requirement of 70% for ALVs (KEPHIS, 2020). Farmers would want to ensure that they plant seeds that have a high germination percentage and produce good seedlings. However, both the ISS and SSS did not meet the ALV farmers' needs of high seed germination. Unlike in other crops, seed production of African nightshade, spider plant and vegetable amaranth is solely for seed as an input and cannot be converted to grain. So whenever seed germination is low, all the seed still has to be planted or discarded. Quality of seed determines the success of crops in terms of yield and product quality and when farmers plant low-quality seed they risk poor field establishment and low plant vigour (Matthews et al., 2012). The necessity of high quality seed for the growth and development of the ALVs sector cannot be underestimated (Francis and Waithaka, 2014).

The variation of germination and viability of seeds from year to year and from one production site to another has been attributed to differences in environmental factors in space and time, including temperature and soil moisture (Li et al., 2017). Seeds sourced from the market showed great variation in germination. The extremely low quality of ALVs seed may not just be as a result of poor management by farmers.

Germination capacity in Amaranth was found to be a response to temperatures. Ye and We (2017) compared the effects of high temperature and water stress on seed germination in two varieties each of spiny amaranth and edible amaranth. As was expected the invasive spiny amaranth seeds exhibited higher tolerance to both continuous and daily periodic high-temperature treatment at 45°C compared to edible amaranth seeds. Unexpectedly, edible amaranth seeds exhibited higher germination at extreme temperatures (10°C, 15°C, and 40°C)' Modi (2007) found that seed germination capacity significantly decreased (($P < 0.01$) for all amaranth species when seed production took place under cool and hot temperatures, but germination improved in response to after-ripening. In another study of grain amaranth (*A. cruentus* and *A. hypochondriucus*). Loonat et al., (2003) found that only A. hypochondriacus could germinate (70%) well at temperatures as low as 12°C. *A. cruentus* had a poor germination of less than 1% at the same temperature, but generally the overall germination was improved by increasing the temperature.

Factors that affect seed quality. The extremely low quality of ALV seed may not just be as a result of poor management by farmers. Factors that affect seed quality are the biological characteristics of a species (Nanduri et al., 2017) and production practices namely, agronomy and post-harvest practices notably seed storage conditions. Seed deterioration that leads to loss of vigour can occur quickly or slowly depending on the biochemical changes in cell membrane integrity, enzyme activity and protein synthesis, that are determined by genetic constitution, environment at seed development stage (Shaban, 2013) and physical damage during harvesting and processing and storage conditions (Castillo, 1992).

Genetic factors, the inherent capacity of seed to resist environmental and mechanical effects on seed quality affect negatively certain types of crops like spider plant that are naturally short lived.

Spider plant is characterized by low germination especially when planted immediately after harvest (Muasya et al., 2009). However, different levels of dormancy also occur in the African nightshade and amaranth as well. Sohindji (2020) suggested that to break dormancy store seed for a period of 6 months to one year, alternating in the dark temperatures between 20-30^{0} C, scarifying seeds by puncturing at the radicle end, soaking seeds for 12 hours and gene identification and breeding. Seed germination and seed dormancy processes are still seemingly unclear for many ALVs, thereby limiting farmers' production due to loss of seed viability and resulting in poor and delayed.

Environmental stresses such as nutrient deficiency, water shortage and grading that come about due to poor crop management, can lead to low seed quality (FAO, 2018). Njonjo et al. (2019) attributed the poor physical quality of ISS to failure to rogue out off-types during seed crop production, inappropriate harvesting and shelling practices and poor processing, and storage conditions. The extraction of African nightshade seeds from berries is a challenge to many farmers. Improper seed extraction leads to poor seed quality. During storage, if seeds are kept at high moisture content, temperature and relative humidity, deterioration will be rapid due to mould growth. Storing seeds in the tropics is a challenge because of the high temperatures and relative humidity (Croft et al., 2013). Temperature alternation was found to increase germination in species of amaranth (Steckel et al., 2004). Seed quality can be affected at any stage of crop production, whether vegetative, reproductive or post-harvest (drying, processing and storage), and therefore, sound management should always be practiced.

The common perception is that seeds from the ISS are the most inferior compared to the other systems but some studies indicated the contrary and that the issue of seed quality is of equal important across the seed system (Gebeyu et al., 2019). Results of the current study agree with a survey from in western Kenya, in which only 12% of 70 trained contact farmers provided with initial seed produced quality seed for their use (Abukutsa-Onyango, 2010). In contrast, other studies indicated good germination and seed quality that resulted from farmers' produced seed. Odongo et al. (2015) reported that all spider plant accessions collected from farmers in western Kenya in 2014 had at least 80% germination value.

CONCLUSIONS

Results for seed from both the ISS and SSS showed physical purity and germination percentages that were below the national requirement. The physical and physiological qualities of seed from the SSS were not superior to those from the ISS contrary to common perception. Considering the increasing demand of ALVs, and the quality level reflected from this study, the ALVs seed sector development is crucial in meeting the consumer's needs.

Strengthening both the informal and semi-formal seed systems in ALVs is an urgent priority so that the poor seed quality of ALVs is successfully addressed and growers can access highest quality seeds in the easiest and most rapid way possible. Seed policies in Kenya as in other countries are naturally focused on the formal seed system. Yet policies should also be developed for the SSS and ISS, considering that they are the main source of seed and thus food for farmers in Kenya. These policies should be more supportive rather than regulatory. More technical support should be provided to ISS and SSS in ALVs by training farmers. Post- harvest operations and seed processing of AVLs among small-scale farmers are usually manual and labour intensive. Development of small equipment for harvesting, cleaning and sorting would assist in improving seed purity. Western Kenya climate is humid, often with high rainfall and the changing weather attributed to climate change only makes the seed chain more vulnerable. This poses challenges in the drying and storage of seed. Innovation in solar or wood-fuelled drying equipment could help improve the drying and consequently the germination of AIV seeds. Multiplication rates of most ALV seeds are high and a few plants are able to produce much seed. Therefore, increasing the seed quantities should not be a challenge so long as pest and diseases that may affect seed production are managed. Future investigations should be done to determine other biotic and abiotic factors that contribute to low quality of ALV seeds.

Table 1: Mean scores for physical purity (%), Pure live seed percentage and germination percentage in Western Kenya

	Seed system			Vegetable species			
Seed quality parameter	ISS	SSS	LSD (0.05)	Amaranth	African nightshade	Spider plant	LSD (0.05)
Physical purity (%)	91	90	7.23	91	91	87	8.81
PLS (%)	29	31	14.10	35	28	27	17.19
Germination (%)	33	36	14.98	37	31	31	18.25

LSD indicates least significant difference between the means at the required level of probability (P≤0.05)

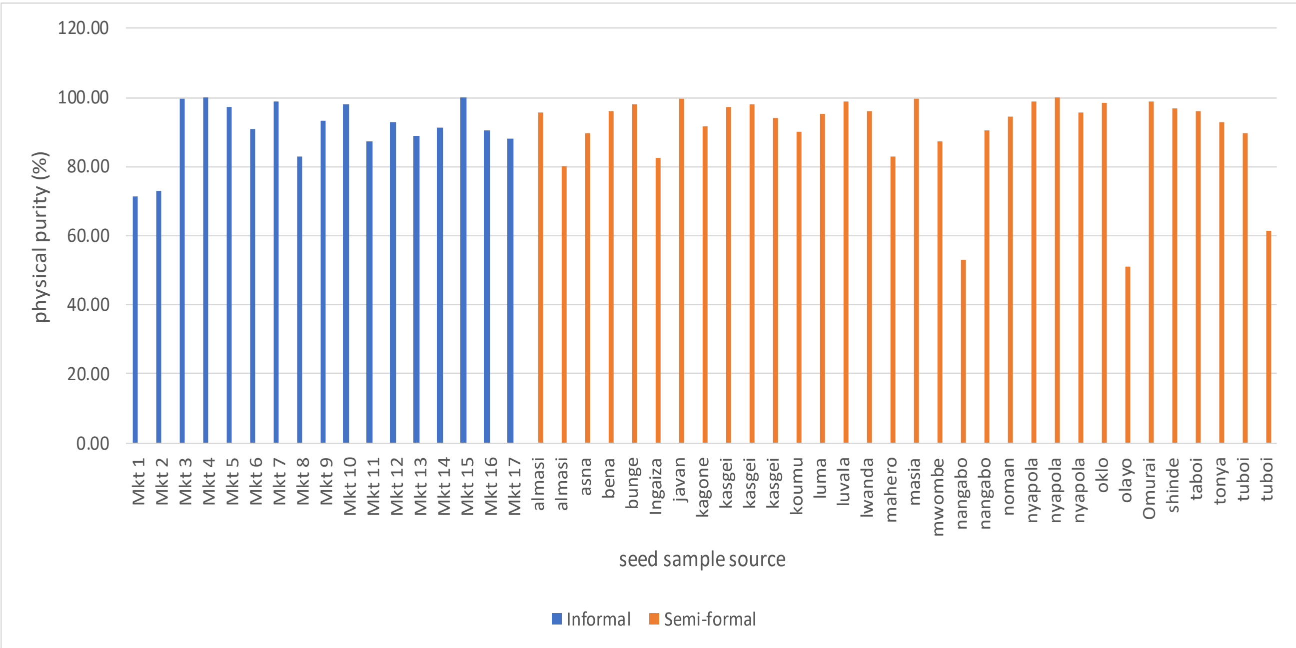

Figure 1. Seed purity (%) of 49 seed samples collected from informal and semi-formal seed systems in western Kenya.

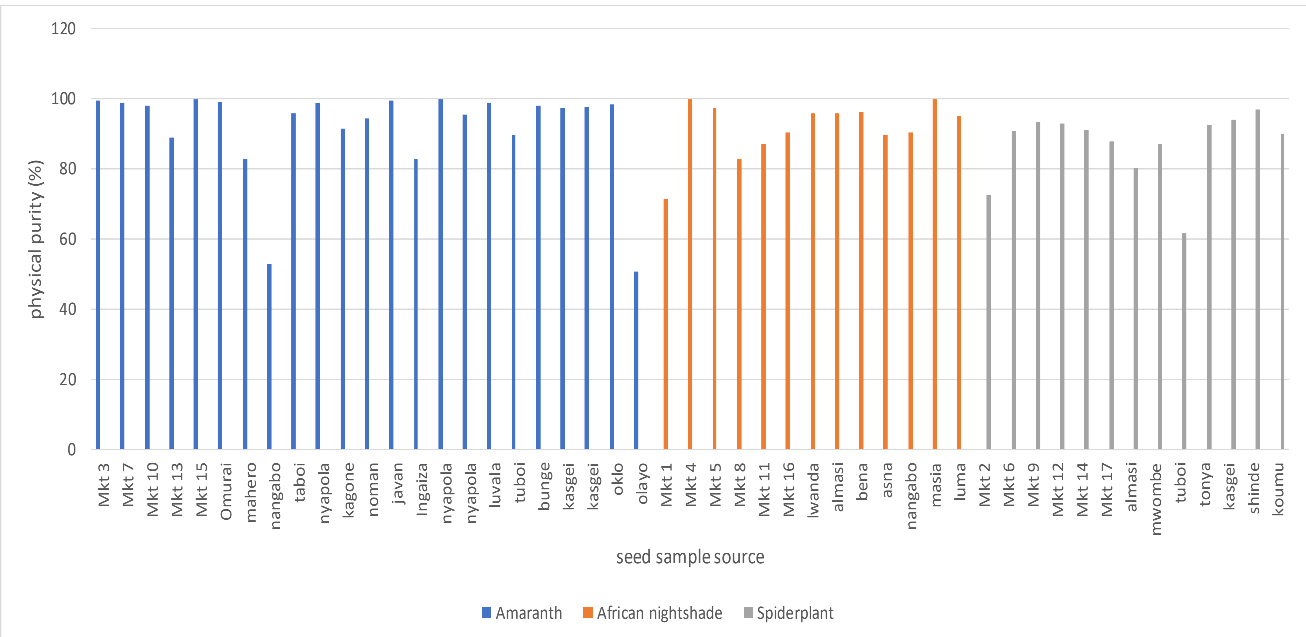

Figure 2. Seed purity (%) of 49 seed samples of three African leafy vegetable species in western Kenya.

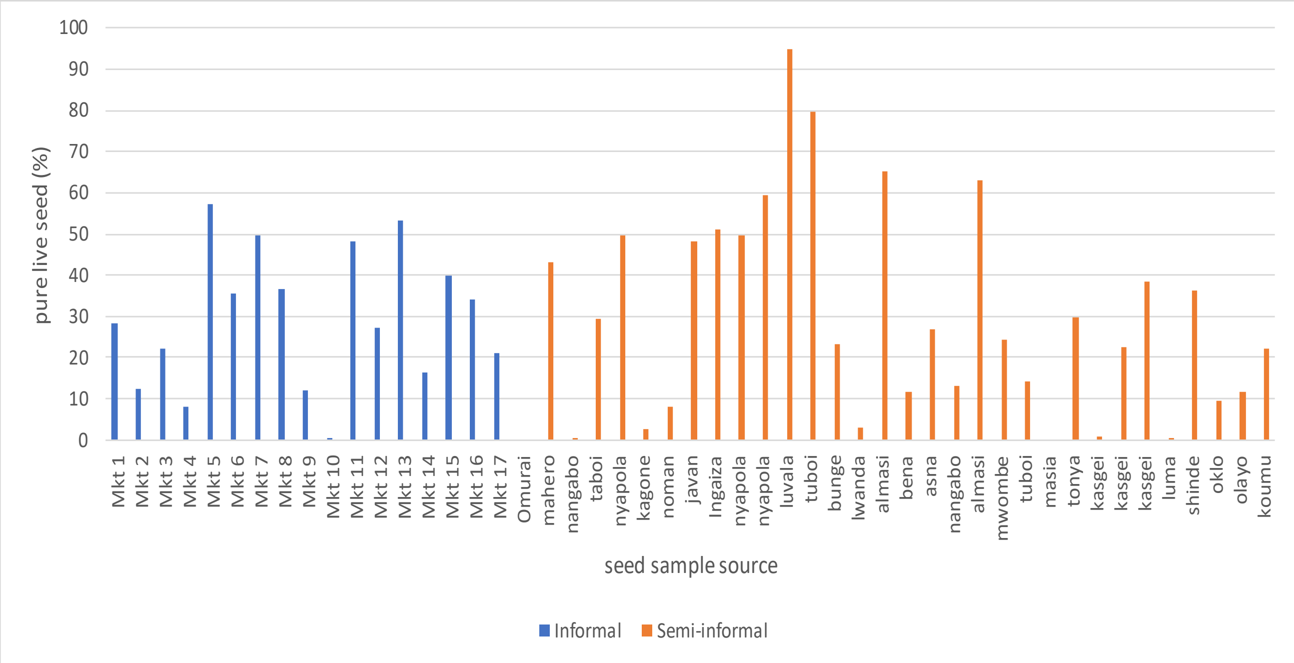

Figure 3: Pure live seed (%) of seed samples from informal and semi-formal seed systems in western Kenya

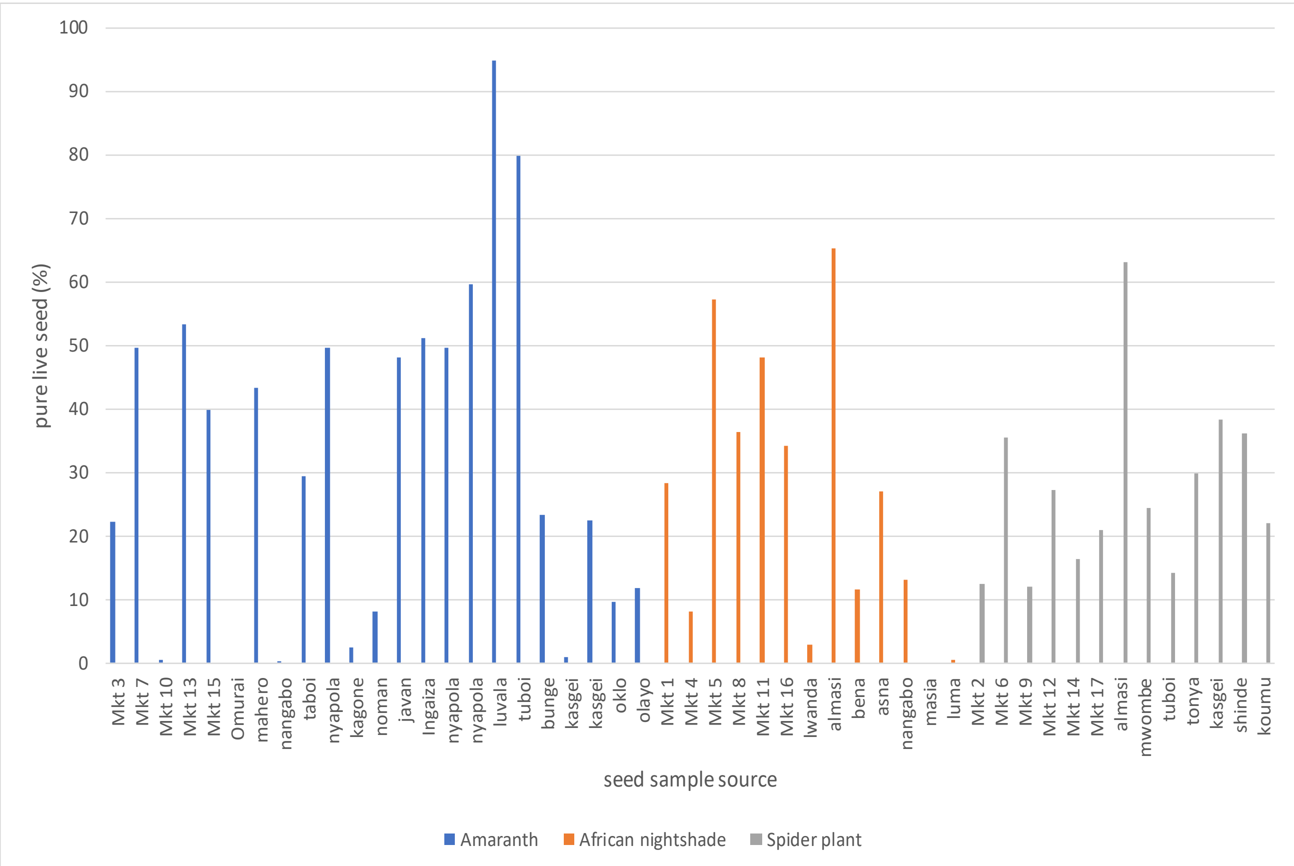

Figure 4. Pure live seed (%) of seed samples from three African leafy vegetable species in western Kenya.

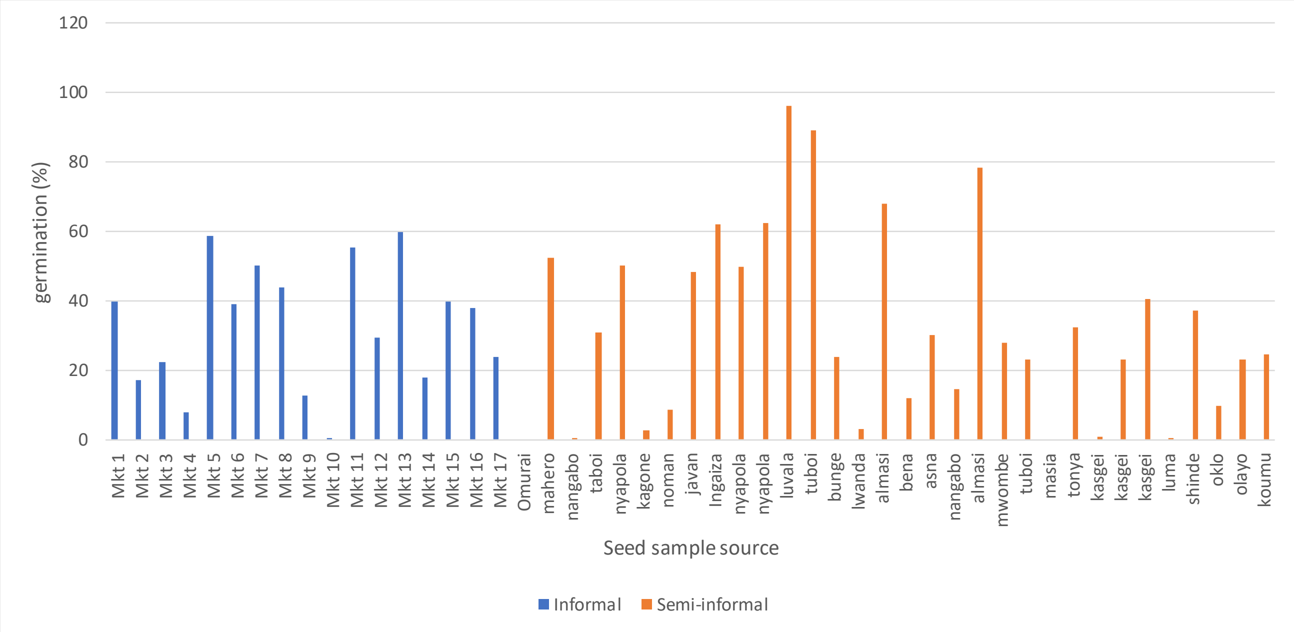

Figure 5. Germination % of seed samples from informal and semi-formal seed system in three locations in western Kenya.

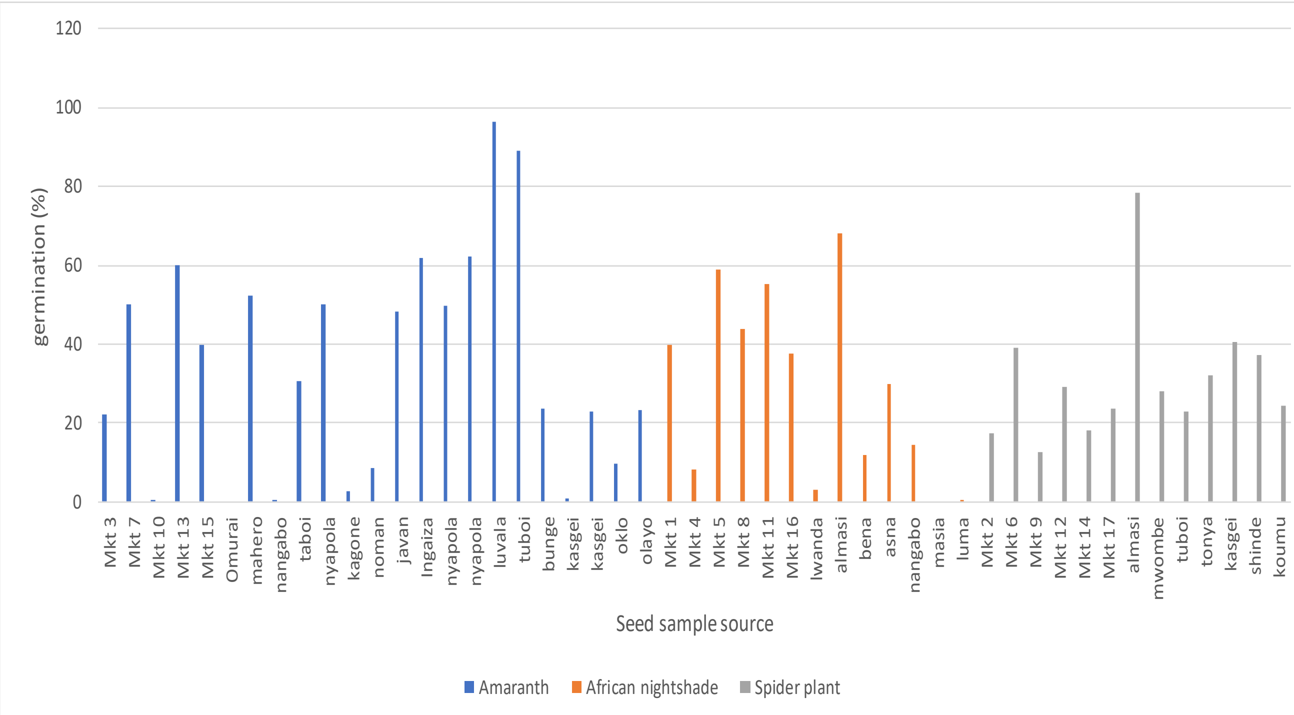

Figure 6. Germination (%) of seed samples from three African leafy vegetable species in western Kenya.

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