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Physiology of Legume Grain in Informal Markets Used As Seed: Implications for Food and Nutrition Security

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Abstract Grain legumes are a key source of nitrogen-rich edible seeds, providing a wide variety of high-protein products that constitute the major source of protein in the diets of the poor within the smallholder farming sector in Zimbabwe. However, low yields are realised in these legumes due to a variety of reasons that include poor quality planting material, biotic and abiotic factors. Understanding of physiology of legume grain in local markets will bring to light the planting worth of grain from these self pollinated crops and help to strengthen approaches to improve legume yield culminating in food and nutrition security for smallholder farmers particularly in drought prone Matabeleland region of Zimbabwe. The objectives of this study were to evaluate grain of selected legumes from local markets for physiological attributes critical for crop establishment and to assess the emergence of legume grain from local markets under field conditions. The experimental design adopted was a two-factorial in a Randomised Complete Block Design. Treatments in the experiment comprised of four legume species, *Arachis hypogea, Vigna unguiculata, Vigna subterrenea, Phaseolus vulgaris* and four markets around the city of Bulawayo which is the key market in Matabeleland region. The results indicated poor vigour, low germination percentage, low viability and marked incidences of seed borne diseases in all the samples assessed. In addition, there was no significant difference ($p>0.05$) between grain sourced from the local market and seed sourced from the commercial market. Poor quality legume planting material available predisposes smallholder farmers to low yields and food insecurity. Accordingly there is need to foster investment in research, development and introduction of quality legume seed that guarantees increased plant performance.

Keywords: *crop establishment, informal markets, seed systems, seed vigour*

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1. Introduction

Important legumes in Zimbabwe include Bambara nut (*Vigna subterranean),* Beans (*Phaseolus vulgaris),* Cowpeas *(Vigna unguiculata)* and Groundnut (*Arachis hypogea).* These grain legumes are a key source of nitrogen-rich edible seeds, providing a wide variety of high-protein products that constitute the major source of protein in the diets of the poor in most parts of Sub Saharan Africa. Cereals are low in the amino acid lysine and tryptophan but adequate in the amino acid methionine. Thus, the amino acid profile of cereals and legumes complement each other so that the combination provides high quality protein. Many cultures rely on a cereal-legume combination to provide a major portion of their energy, for example, maize and beans, millet and groundnut [1]. Largely grown as subsistence food crops, grain legumes are predominantly crops grown by women and used within the family. In addition, legume grain often has a steady market demand and when farmers are linked to output markets, legumes can fulfil roles as important cash crops. Many types of legumes also provide an excellent source of feed to livestock, especially during the dry season when animal feeds are in short supply [2].

Seed is the primary agricultural input which is used for regeneration purposes and is vital for crop production. Crop establishment and status largely depends on the seed material used for sowing, as well as, response of other inputs in crop production. Enhanced yields and crop diversity in turn contribute to enhanced food security and improved nutritional value [3]. Evidence shows that smallholder farmers source the majority of their seed from the informal system; they grow, exchange and sell a wide range of varieties that fall outside the production and distribution functions of the formal sector. In Africa informal seed systems provide approximately 80% of the seed that smallholder farmers plant [4].Similarly in Zimbabwe, the informal seed sector dominated the seed supply sources during the agricultural season 2015/16 [5]. Yields levels of legume grain within the rainfed smallholder system are low in Zimbabwe, being less than 0.8 tonnes per hectare [6].

In comparison, the pulse yield in Canada improved from 1.1 t/ha in 1961 to 1.8 t/ha in 2012. Other countries such as Brazil, China and Myanmar showed similar trends through the same period [7].

Table 1. Yield levels (kg/ha) of selected legumes across the provinces in Zimbabwe for 2011/2012 season

Crop	Manicaland	Mash. Central	Mash. East	Mash. West	Mat. North	Mat. South	Midlands	Masvingo	Average
Vigna subterranean	226	799	489	517	196	27	535	297	326
Arachis hypogea	252	403	433	398	125	39	378	221	307
Phaseolus vulgaris	263	436	445	489	193	34	557	131	347
Vigna unguiculata	-	-	-	-	-	-	-	-	-

Source: ZIMSTAT (2012) –data not available.

In Zimbabwe, seed certification is mandatory for eight crops that are of commercial importance, namely maize, soya-bean, tobacco, cotton, wheat, barley, oats and potatoes [8]. Lack of quality control in the informal seed sector predisposes farmers to poor crop establishment. Moreover, most extension initiatives focus on crop husbandry practices with limited attention given to seed quality. No studies have been conducted to assess the physiological attributes of seed available on the local markets in Matabeleland from the major markets of Bulawayo. Accordingly, this study sought to evaluate the physiological properties of legumes to understand the nature of material found in the informal seed system.

2. Materials and Methods

2.1. Study Area

The study was conducted in the local markets of Bulawayo City, the second largest city in Zimbabwe where samples were collected from. The germination experiment was conducted at the Lupane State University laboratory and the field emergence experiment performed in a farmer's field 7 kilometres from Bulawayo City Centre. The selection of the sample collection area was based on availability of sample and level of activity of farmers in the market place. Four sites were selected from Renkini, Entumbane, Bulawayo city centre (Town) and commercial certified seed purchased from a registered dealer as a control.

2.2. Sample Collection

Samples of four different kinds of legumes *Vigna subterranean, Arachis hypogea, Vigna unguiculata, and Phaseolus vulgaris;* were collected from four major local markets within Bulawayo City. Sampling was done at random from different vendors within these market areas. All the 60 samples 500 grams in weight were collected and stored in air tight plastic bags according to their type. Four sample bags of commercial seed of the four selected legumes were also purchased from a formal market in Bulawayo (Table 2). All the samples were taken to Lupane State University laboratory for preparation and treatment.

Table 2. Commercial seed performance standards according to the package label

Legume	Variety	Purity	Germination Percentage
Bambara nut	Jugo	100%	98
Sugar bean	Sugar Bonus	100%	98
Cowpea	IT18	100%	92
Groundnut	Natal Common	99%	92

2.3. Seed Physiology Tests

2.3.1. Standard Germination Test

The experiment room and apparatus were disinfected with ethanol 70% to create a sterile environment for proper experimentation. The sampled grain for experimentation was also soaked in ethanol 70% for two minutes in order to properly assess internal seed borne infection. Germination tests were done where 100 legume grains are randomly selected from a sample and placed in a container [9]. Moistened paper towel was placed on the germination tray and seed evenly placed on top. Ungerminated seeds and germinated seedlings were separated and counted after the stipulated period for each legume species.

2.3.2. Tetrazolium Topographic Test

To determine seed viability a 2,3,5 triphenyl tetrazolium chloride 1% solution was used to soak collected grain for 48 hours in order to seed to imbibe the solution. After 48 hours the legume grain cotyledons were split to assess the colour change and pattern. The living tissue in the seed (the germ or embryo) turns red. Based upon the colour and location of dead or injured tissue, a potential germination percentage can be determined as well as seed viability.

2.3.3. Field Emergence Test

Field emergence evaluation for seed vigour studies using the same seed lots for groundnut, cowpea, Bambara nut and sugar bean in laboratory experiment were conducted in a farmer's plot. The plot soil type was loam, on a relatively flat landscape. No fertiliser was applied to the seed bed to simulate rural farmer environment. Sowing rows were spaced 30 cm apart and seed sown 5cm apart within the rows at a depth of 2 – 5 cm. Emergence was recorded in recording sheet at 24± 1 hour intervals and continued until day 14.

2.3.4. Seed Health Test

Seed health was assessed from a sample of 100 seeds for each legume replicated three times. Seed were soaked in 70% ethanol for surface sterilization, prior to placing in a petri dish between paper and incubation at 27±2°C temperature and 90±2% relative humidity. The paper napkins were kept constantly moist by distilled water. Fungal contamination was assessed after 5 days for all the legumes.

2.4. Experimental Design and Data Collection

A two factorial randomised complete block design was followed with 2 blocks and 3 replicates in the laboratory experiment. Blocking was done according to proximity to light, with block one being closer to the light source than block two. A two factorial randomised complete block design with 2 blocks and 2 replications guided the field experiment lay out. Blocking was conducted to cater for variation in moisture regime. The factors were market and legume crops at four levels.

2.5. Data Collection

Germination percentage was measured over a one week period beginning from day seven up to day 14 in the laboratory experiment. Qualitative measurements were used to observe the disease incidences in all the samples at the end of the laboratory experiment. Germination rate in the field experiment was also observed over a one week period commencing from day seven up to day 14. The observations were made after every ±24 hours interval.

2.6. Data Analyses

Data on proportion of germinated seeds in standard germination test and field emergence across all legumes were subjected to ANOVA using GENSTAT 13th Edition [10]. Significant means were separated using Fisher's least significant differences (LSD) at 5% probability to rank the quality of seedlots. Correlation coefficients were also be calculated between the laboratory test and field emergence across the seed lots.

3. Results

3.1. Evaluation of Standard Germination Test

Commercial seed did not exhibit the best performance as would have been expected, signified by superior informal market sugar bean germination percentage (Figure 1). Bambara nut had the worst performance recorded with less than 20% germination across the four markets. Cowpea commercial seed germinated better than seed grain sourced from the City Centre, Entumbane and Renkini informal markets.

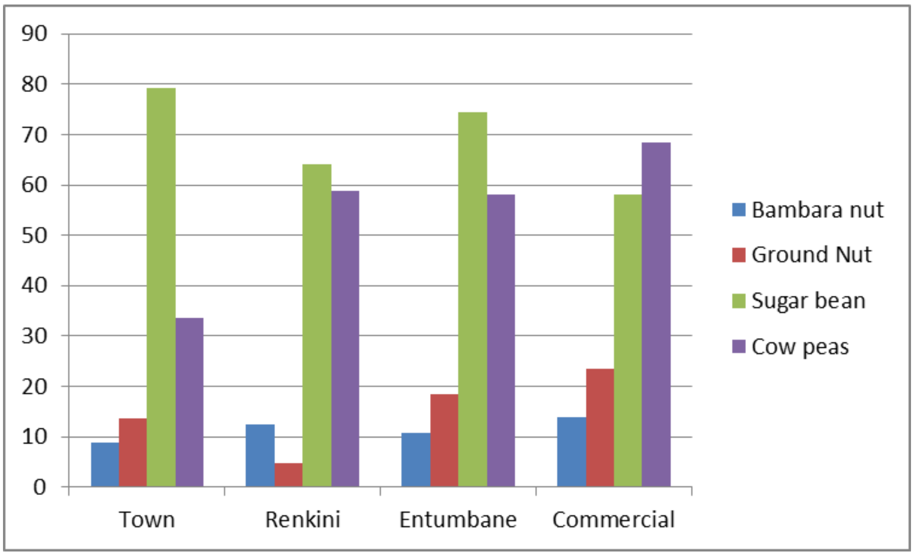

Figure 1. Mean germination percentage on day 10 of four legume grain sourced from markets in Bulawayo

3.2. Evaluation of 2,3,5 Triphenyl Tetrazolium Test (TZ)

Commercial seed had a superior percentage of viable seed compared to grain from informal market with a difference between 7% to 22%. Grain sourced from Entumbane exhibited the highest non-viability of 51% compared to all other sources.

3.3. Evaluation of Field Emergence Test

Sugar bean had the worst field emergence less than 20% not what would have been expected considering its highest performance in the standard germination test (Figure 2). Bambara nut and groundnut also performed relatively well for the different sources.

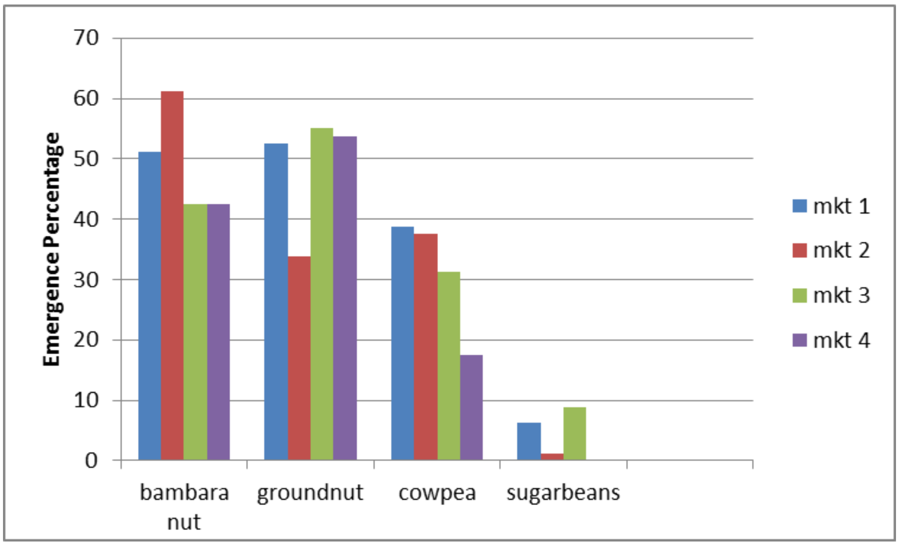

Figure 2. Field emergence percentage on day 14 of four legumes from four markets in Bulawayo

3.4. Evaluation of Seed Health

Ground and Bambara were the most infested crops exhibited the highest frequence of fungal infestation. Commercial seed had minimal disease infestation levels, with grain sourced from the City Centre and Renkini exhibiting more severe cases of infestation (Table 3).

Table 3. Mean contamination levels of four legume grain sourced from four local markets in Bulawayo

Market	Crop	Contamination level (%)			
		Nil	Slight	Moderate	Severe
City Centre	Bambara nut	0	50	50	0
Renkini	Bambara nut	0	33	67	0
Entumbane	Bambara nut	0	0	100	0
Commercial	Bambara nut	0	100	0	0
City Centre	Groundnut	0	50	50	0
Renkini	Groundnut	0	17	33	50
Entumbane	Groundnut	0	50	50	0
Commercial	Groundnut	0	100	0	0
City Centre	Sugar bean	0	100	0	0
Renkini	Sugar bean	0	83	17	0
Entumbane	Sugar bean	0	100	0	0
Commercial	Sugar bean	0	33	67	0
City Centre	Cowpea	0	0	17	83
Renkini	Cowpea	0	0	100	0
Entumbane	Cowpea	0	33	67	0
Commercial	Cowpea	0	0	100	0

4. Discussion

Commercial seed germination performance was not distinct from grain sourced from the informal local markets as would be expected especially for germination and seed vigour. Even under its best performance in the experiment, it was way off the mark of the guaranteed germination percentage on the label (92%) by a minimum of 20%. Sometimes certified seed is overrated as there are context where farmers produced seed performed better compared to seed that is formally produced [11]. But from the research results, harnessing certified legume seed would be the most prudent decision to go in tandem with the nation's endeavour to commercialise smallholder agricultural sector and attain food and nutrition security. In wheat which is a self pollinated crop, the average yield productivity of certified wheat variety was observed to be 22.5% higher than uncertified seeds [12]. Moreover farmers using certified wheat seed used less seed per unit area, had more income and straw compared to those using unicertified seed. [12]. The poor performance of legume seed is not an anomaly since production, multiplication and supply in Zimbabwe is done outside a legally sanctioned system for quality assurance [8]. The magnitude of the differences obtained in commercial seed is very is however a cause for concern.

Informal market sourced sowing material exhibited a superior vigour in comparison to formal market sourced seed. Vigorous seeds emerge quickly from the soil and have a competitive advantage over weeds, efficiently utilise growth factors, show resilience to adverse abiotic factors and maintain yield potential [13]. This ultimately ensures food security once the crop reaches harvest maturity.

All the planting material regardless of source was infected, at various levels. A cause of concern as seed borne diseases reduces germination and percentage normal seedlings resulting in severely reduced yields. Seed-borne diseases often strike early in the growth of a plant causing poor crop establishment and reduced plant vigour which results in lower yields [14]. Moreover, a disease free seed is the foundation of healthy plants, a necessary condition for good yields [15]. Good quality seed can increase farmer productivity by 20% to 30% [16].

4.1. Conclusion

Commercial sourced seed did not exhibit superiority from informal market sourced seed, and all the planting material performed below minimum quality standards. With that, supply of labelled legume seed is not enough as a measure to elevate the productivity of legumes in Zimbabwe. This is against the background that seed production is completely free from government certification scheme, no inspection is needed at field or tagging from any other agency because the functions are performed by the producers themselves. For smallholder farmers to attain food and nutrition security there is need to legally sanction the quality control of such crops. Without such drastic measures, small-scale farmers remain challenged in their endeavour to attain satisfactory legume yield and food security as long as they are not protected from acquisition of poor quality seed.

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Conflict of Interest and Financial Disclosure Statement

None.

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