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Research Article

Production Practices, Postharvest Handling, and Quality of Cowpea Seed Used by Farmers in Makueni and Taita Taveta Counties in Kenya

Mary W. Njonjo, James W. Muthomi, and Agnes W. Mwang'ombe

Department of Plant Science and Crop Protection, University of Nairobi, P.O Box 29053-00625, Nairobi, Kenya

Correspondence should be addressed to Mary W. Njonjo; wanjikunjonjo2015@gmail.com

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Over 80% of farmers in the developing countries use seeds from the informal seed supply that is of unknown quality status with low physical purity, reduced vigour, and contamination with seed-borne pathogens. A survey involving 114 farmers was conducted in Makueni and Taita counties using a semistructured questionnaire to determine cowpea production practices. Forty-seven cowpea seed samples were collected from farmers, and thirty-four were collected from markets and analysed for physical and physiological quality. The data from the questionnaire were analysed using SPSS package. Majority, over 76% of farmers used farm-saved seeds and intercropped cowpea with cereals (56%). The common storage container was polythene bags (56%), and farmers did not treat the seeds. The seed was below the recommended purity standard of 98%. In Taita, farm-saved and market-sourced seeds met the recommended 75% germination at 82.7% and 76.8%, respectively. Even though the germination standard was met, seeds were of low physical purity and reduced vigour. Farmers should be enlightened on recommended production practices, methods of harvesting, and postharvest handling practices to reduce seed quality loss during storage and maximize production.

1. Introduction

Cowpea is an annual or biannual grain legume ranked among the topmost important legumes in the world, second in Africa and third in Kenya [1, 2]. It is suitable for sub-Saharan Africa due to its ability to grow in adverse climatic conditions where other legumes cannot flourish well. In Kenya, 85% of its production area is in the arid and semiarid areas of the former Eastern province and the rest is in Nyanza and Central and Western regions [3, 4].

Cowpea is mainly intercropped with cereals and hence contributes to soil fertility and sustainability in complex cropping systems in drylands through nitrogen fixation. It is adapted to dry and low fertility conditions where it still produces leaves even though not to its optimal ability under such conditions [5]. Two of the varieties released in Kenya at Katumani in earlier years are Machakos 66 (M66) and Katumani 80 (K80) both of which are dual purpose, are drought tolerant, give yield range of 1.3–1.5 t/ha, and are adapted to altitudes above 1,300 m and below 1,300 m, respectively [6]. Low yields are significant attribute of production estimates, particularly in Africa where 240–300 kg/ha are often realized [2].

Studies by the Ministry of Agriculture, Livestock and Fisheries in Kenya reported a decrease in yield per hectare despite an increase in the land area under cowpea. This could be attributed to, among other factors, low quality in terms of physical, physiological, genetic, and seed health qualities [7, 8]. Cowpea farmers are only willing to buy small amounts of seeds once and recycle them in the subsequent seasons and years. Therefore, it is uneconomical for seed companies to distribute small amounts of seeds over long distances in the rural areas, and hence certified seeds do not reach the farmers [6].

Continuous recycling of seeds leads to loss of quality over time and eventually results in poor grain yields [9].

Quality of the seeds is determined by the genotype of the parent material, as it determines the response of the plant to abiotic and biotic stresses and ultimately determines the yield potential. Quality of seeds ensures establishment of optimum crop stand which directly affects yields [10]. Seed quality is affected by many aspects in its production such as seed source, production practices and management, cropping system, methods of harvesting, and postharvest handling. Therefore, this study was carried out to determine the production practices, postharvest handling, and quality of seeds used by farmers in Makueni and Taita counties in Kenya.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted in Wote and Makindu subcounties of Makueni County and in Mwatate subcounty of Taita Taveta County. Wote subcounty lies in lower midland subzone IV (LM4) and receives a bimodal rainfall with the long rains occurring between March and April and the short rains occurring between November and December. It receives rainfall of 800–1200 mm per year with cool temperatures ranging from 20.2°C to 24.6°C. Makindu and Mwatate subcounties lie at lower midland subzone V (LM 5). The areas experience bimodal rainfall patterns with the long rains between March and May and the short rains between November and December. An average annual rainfall of 157–1200 mm is received in these areas while mean temperature varies at 18–25°C [11].

2.2. Determination of Cowpea Seed Production Practices. A survey involving 114 farmers was conducted using a semistructured questionnaire during the 2016 short rains. Cowpea-growing farmers were purposively sampled, and the questionnaires administered to obtain information on types of seeds, sources of seeds, cowpea varieties grown, number of production seasons per year, area under cowpea, cropping systems, harvesting, and postharvest handling of cowpea seeds. Thirty-three farmers were interviewed in Wote, 26 in Makindu, and 55 in Mwatate subcounties. From each farmer interviewed, at least 500 g of cowpea seed sample was obtained for physical and physiological quality analysis. Thirty-four cowpea seed samples were also collected by random sampling in three major markets within the respective areas of study, namely, Mwachabo, Makindu, and Wote markets. The sample size was determined using the following formula:

$$n = \frac{N}{1 + N\,(e)2}, \tag{1}$$

where n is the size of the sample and N is the population size and assumptions of the formula are 95% confidence interval, $P = 0.5$, and error limit $(e) = 0.1$ [12].

2.3. Determination of Physical Purity. The cowpea seed samples were analyzed for physical purity according to the International Seed Testing Association [13]. Purity test was done on four replicates of 100 g each. Each of the samples was separated into pure seeds, other variety seeds, other crop seeds, weed seeds, discolored/shrivelled seeds, and inert matter on a separating board with the aid of separating knife and magnifying lens. The weight of each fraction was taken, and the percentage of each component was calculated as follows:

$$\text{component (\%)} = \frac{\text{weight of each component (g)}}{\text{weight of total test sample (100 g)}} \times 100. \tag{2}$$

2.4. Determination of Germination and Vigour. Four hundred seeds of each sample were divided into four replicates of 100 seeds each. The seeds were surface sterilized in 2% sodium hypochlorite for four minutes and then washed in distilled water three times. The seeds were planted in sterile humid chambers lined with three layers of moist blotting papers. The seeds were covered with additional two layers of moist blotting paper and incubated at room temperature. Germination was assessed on the 5th, 7th, and 9th day. On the 9th day, data on the number of normal seedlings, abnormal seedlings, infected seedlings, and dead, hard, and mouldy seeds in addition to shoot and root length were taken. The data were used to calculate germination indices which included germination percentage, germination index and germination rate index, and seedling vigour index [13–15] as follows:

$$\begin{aligned} \text{germination (\%)} &= \frac{\text{no. of emerged seedlings at the final count}}{\text{total number of seeds planted}} \times 100, \\ \text{germination rate (GR)} &= \frac{\sum (Nx)(\text{DAS})}{\text{total number of seedlings that emerged at the last count}}, \end{aligned} \tag{3}$$

where Nx is the number of seedlings that emerged on day x after planting and DAS is the day after planting. The germination rate index is as follows:

$$\text{germination rate index} = \frac{\text{GP}}{\text{GI}}. \tag{4}$$

The seedling length was assessed by randomly selecting 10 normal seedlings from each replication, and the root length was measured from the point of attachment to the seed to the root tip, while the shoot length was measured from the point of attachment to the seed to the shoot tip [16].

The average shoot and tip length were computed by dividing both lengths by 10:

$$\text{vigor index} = \text{germination (\%)} \times \text{seedling length}. \quad (5)$$

2.5. Statistical Data Analysis. The survey data were analysed using SPSS Statistical Software version 20 to determine the percentage frequency of the respondents and the respective production frequencies. The data obtained from purity and physiological quality analysis were subjected to analysis of variance using GENSTAT© statistical package to determine the significant differences between sample means and means separated using Fisher's protected least significant differences (LSD) at $P \leq 5\%$.

3. Results

3.1. Cowpea Production Practices in Makueni and Taita Taveta Counties. Up to 76% of farmers in Wote were using uncertified cowpea seeds, which was almost three times of the percentage of farmers using certified seeds. In Makindu, all the respondents were producing cowpea from uncertified seeds, while in Mwatate, a significant number of farmers were producing cowpea from certified seeds (75%) (Figure 1).

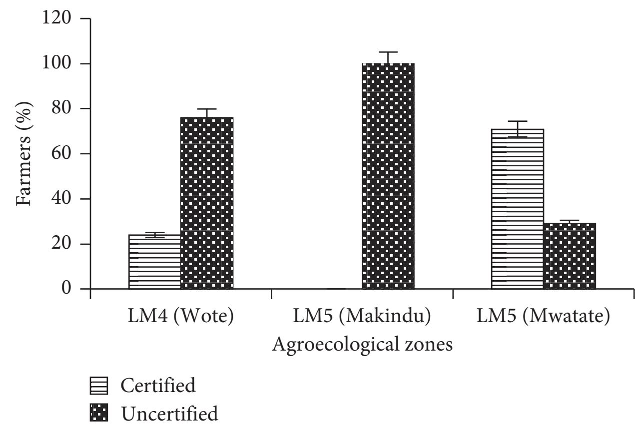

Figure 1: Percentage of farmers using certified and uncertified cowpea seeds in various AEZ in Makueni and Taita Taveta counties during the 2016 short rains.

There was a significant difference in the number of farmers who were using uncertified farm-saved seeds, and it was highest in Mwatate which was more than twice the use in Wote. Use of uncertified seeds from the market was significantly higher in Wote at 63% (Figure 2).

Percentage of farmers using seeds borrowed or bought from other farmers was significantly higher in Makindu at 17.6% and Mwatate at 5%. A few farmers in Makindu had ever used certified seeds from CBO/NGO. There was a significant difference in the use of certified seeds from the Agrovet among the three areas whereby Mwatate had the highest percentage of farmers who sourced their seeds from the Agrovet which was more than thrice the farmers from Wote and none of them sourced for seeds from the Agrovet in the Makindu area. Access of seeds from research institutions was significantly higher in difference in farmers from Wote at 66.7% followed by Mwatate at 6.7% (Figure 2).

Recycling of cowpea seeds was a common practice in each of the three areas of study. Across the three regions, the highest mean percentage of farmers were recycling seeds for 2-3 seasons with Wote having the highest followed by Mwatate, and in Makindu, it was twice less those in Wote. The percentage of farmers using seeds for a season was almost equal across the sites at 24%. A few farmers recycled seeds for more than 10 seasons (Table 1).

Land area under cowpea in Wote and Mwatate was 0.25 acres at 88% and 82%, respectively. In Makindu, most of the respondents (53%) had 2–4 acres of land under cowpea. Only 9% of farmers grew cowpea on more than 4 acres of land in Makindu (Figure 3).

Mixed cropping was significantly different across Wote, Makindu, and Mwatate at 84%, 67%, and 56%, respectively. Preference of monocropping was significantly different in the three sites and had an inverse relationship with the mixed cropping system such that the pure stands were highest in Mwatate followed by Makindu and Wote at 44%, 34%, and 16%, respectively (Figure 4).

During the 2015 short rains, the highest percentage of farmers obtained cowpea yields of 201–500 kg/ha with the highest yields in Wote followed by Makindu. Percentage of farmers in Wote and Makindu who obtained these yields was up to five times compared to those in Mwatate. A considerable percentage of farmers from Mwatate (26.9%) got no harvest during this season followed by Wote (20%) and Makindu (8.8%). It was also noted that across the areas, none of the respondents harvested over 500 kg/ha of cowpea (Table 2).

During the 2016 long rains, the highest mean percentage of farmers (20.5%) had a yield range of 201–500 kg/ha followed by those who obtained yields at <10 kg/ha (17.7%). There was low yield during the short rains than during long rains. During the 2016 long rains, the highest yield was 201–200 kg/ha in Wote as reported by 20% of farmers and 32.4% in Makindu unlike in Mwatate where most of the farmers (40%) obtained less than 10 kg/ha. Higher maximum yields of over 500 kg/ha were obtained during the long rains in Wote and Mwatate at 12% and 1.8%, respectively (Table 2).

Physical hitting was the main method of threshing by farmers in all the three study sites, and the harvested grains were sundried by majority of the farmers at 96%, 97.1%, and 85.7% in Wote, Makindu, and Mwatate, respectively. The main methods of storing cowpea grains were on house racks, in granaries, and in the kitchen (Table 3). Across the three areas, most of the farmers were using house racks and granaries as their places of storage. House racks were most popular in Taita (74.5%) followed by Wote (24%) and Makindu (14.7%). Use of granary for storage was most popular in Makindu used by 85.3% of the farmers followed by Wote (76%) and was least used in Taita (23.5%). Storage of harvested cowpea in the kitchen was only employed in Taita by 2% of respondents (Table 3).

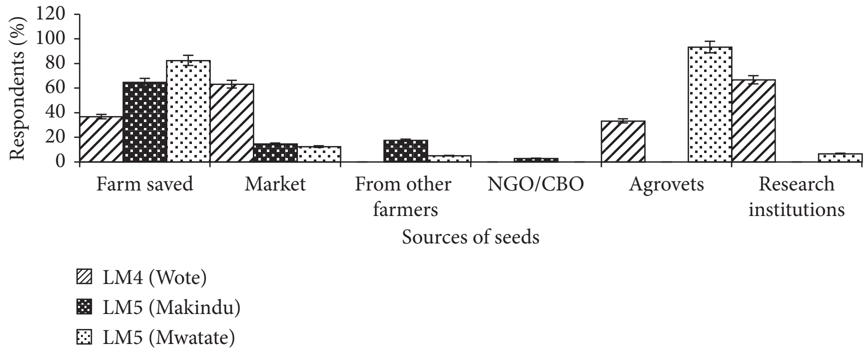

Figure 2: Percentage of farmers obtaining cowpea seeds from different sources in various agroecological zones in Makueni and Taita Taveta during the 2016 long rains.

Table 1: Percentage of farmers using cowpea seeds for indicated seasons in various subcounties in Makueni and Taita Taveta during the 2016 long rains.

Seasons	LM4 (Wote)	LM5 (Makindu)	LM5 (Mwatate)	Mean
One	22.2	25.0	25.0	24.0
2-3	55.6	18.8	37.5	37.3
4–8	11.1	12.5	29.2	17.6
>10	0.0	6.3	4.2	3.5

LM4: lower midland zone IV; LM5: Lower midland zone V.

Five types of containers were used for storage of cowpea seeds which included nylon sacs, gunny bags, plastic containers, pots, and reed baskets. The most popular storage container was the nylon sacks mostly used in Makindu (91.2%) followed by Wote (64%) and Mwatate (55.8%). The second most used storage container was the plastic containers at 20% and 28.8% in Wote and Mwatate, respectively, and was not being used at all in Makindu. Use of gunny bags was relatively similar in the three areas as they were at 8.8%, 8%, and 3.8% in Makindu, Wote, and Mwatate, respectively. Plastic bags, pots, and reed baskets were not used at all in Makindu as they heavily relied on plastic sacks and gunny bags (Table 3). Methods of seed treatment used varied from place to place which included pirimiphos-methyl (Actellic Super®), malathion 2% + permethrin 0.3 w/w (Scanner Super®), ash, and others such as paraffin, oil, and smoke. The most popularly used product for seed treatment was the Actellic Super® whose use was highest in Wote (95%) followed by Makindu and Mwatate at 57.6% and 55.9%, respectively.

The second most used product was ash which was used in Makindu (42.4%) and Mwatate (29.4%). Scanner Super® was only used in Mwatate (9.1%), while ash was only used in Makindu (42.4%) and Mwatate (29.4%). Other products such as smoking, oil, and paraffin wereused in Wote by only 5% of the respondents (Table 3).

3.2. Effect of Seed Source on the Cowpea Physical Purity. The mean purity percentage of the farm-saved and market-sourced seeds in the various agroecological zones was at 73.7% and 84.7%, respectively. Purity in the farm-saved seeds was significantly different between Wote (61.6%), which was the least, and the other areas, Mwatate (82.1%) and Makindu (79.3%), which were the highest and not significantly different. The percentage of other crop seeds and other cowpea varieties was similar, whereby Mwatate had the highest which was significantly different from that of the other two areas (Table 4).

Percentage of insect-damaged seeds was significantly different across the three areas of study with Wote having the highest percentage (33.6%) followed by Makindu and Mwatate at 15.9% and 6.7%, respectively. The percentage composition of shrivelled seeds and inert matter was not significantly different across the three areas of study. Percentage purity of market-sourced seeds was highest in Makindu and Wote at 91.2% and 90% which was significantly different from that of Mwatate (80.2%). Percentage composition of other variety seeds and other crop seeds was not significantly different across the three areas. Composition of insect-damaged seeds and inert matter was significantly different between Wote, which had the highest percentage at 13.2% and 2.3%, respectively, and the other two areas, whereas the percentage composition of shrivelled seeds was highest in Wote (1.2%) which was significantly different from that of the other two regions (Table 4).

3.3. Effect of Seed Source on Cowpea Germination. The mean germination percentage of farm-saved and market-sourced seeds was at 68% and 76%, respectively. In farm-saved seeds, the highest germination percentage was in Mwatate (86.6%) which was significantly different from the one in Wote (61.1%) and Makindu (61.2%). The germination rate of farm-saved seeds was highest in Mwatate (38.1%) which was significantly different from that of Wote and Makindu. Percentage of normal seedlings was not significantly different among seeds across the three areas. Farm-saved seeds from Mwatate had the highest percentage of abnormal seedlings (52%) and hard seeds (3%) which was significantly different from that of the seeds from the other two areas (Table 5).

Germination percentage of seeds sourced from the market varied across the regions. Seeds from Mwatate had

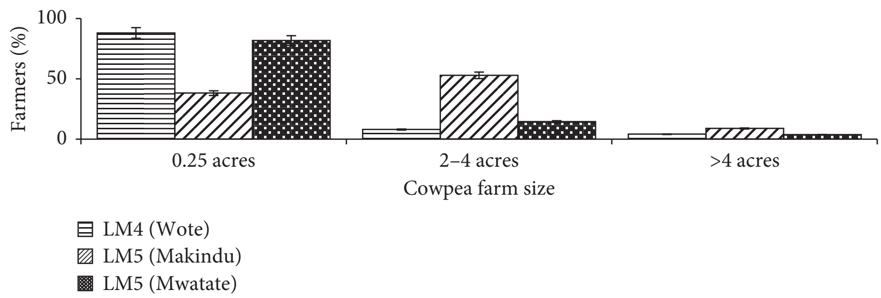

Figure 3: Percentage of farmers growing cowpea seeds in various farm sizes in various agroecological zones in Makueni and Taita Taveta during the 2016 short rains.

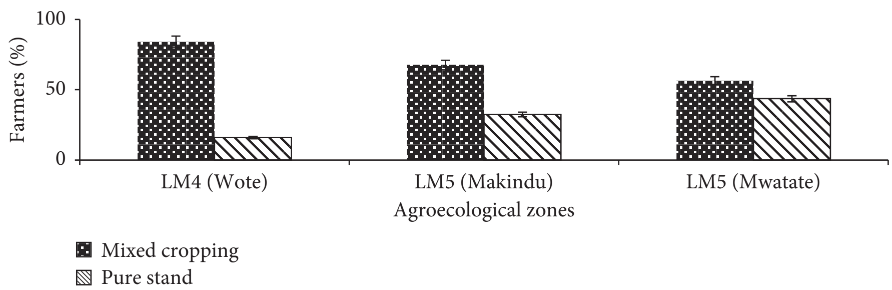

Figure 4: Percentage of farmers growing cowpea on pure stand and by mixed cropping in various agroecological zones in Makueni and Taita Taveta during the 2016 short rains.

Table 2: Percentage of farmers and the corresponding production levels during the 2015 short rains and 2016 long rains in various agroecological zones in Makueni and Taita Taveta.

Production level (Kg/ha)	LM4 (Wote)	LM5 (Makindu)	LM5 (Mwatate)	Mean
2015 short rains				
0	20.0	8.8	26.9	18.6
<10	12.0	8.8	38.5	19.8
10–50	0.0	17.6	9.6	9.1
51–100	12.0	17.6	3.8	11.1
101–200	8.0	5.9	5.8	6.6
201–500	44.0	41.2	9.6	31.6
>500	0.0	0.0	0.0	—
2016 long rains				
0	0.0	5.9	27.3	11.1
<10	8.0	11.8	40.0	19.9
10–50	8.0	32.4	12.7	17.7
51–100	12.0	8.8	7.3	9.4
101–200	0.0	8.8	0.0	2.9
201–500	20.0	32.4	9.1	20.5
>500	12.0	0.0	1.8	4.6

LM4: lower midland zone IV; LM5: lower midland zone V.

the highest germination percentage (80.5%) which varied significantly with the seeds from Wote and Makindu at 73.7% and 67.1%, respectively. The highest germination rate was on the seeds from Mwatate (35.6%) which was significantly different from that of seeds from Wote (29.4%) and Makindu (26.6%). Percentage of normal seedlings was highest in seeds from Mwatate (18%) which was significantly different from that of the seeds from Wote and Makindu both at 10%. Percentage of abnormal seedlings was highest in Wote and Makindu at 51% and 54%, respectively, and was significantly different from that of the seeds from Mwatate (36%), while hard seed composition was highest in seeds from Wote which was also significantly different with the seeds from the other two areas (Table 5).

The percentage of infected seedlings on farm-saved and market-sourced seeds was 14.4% and 10.6%, respectively. In farm-saved seeds, the highest percentage of infected seedlings was in seeds from Mwatate (19%) which was significantly different from that of with the seeds from the

Table 3: Percentage of farmers using various postharvest handling practices of cowpea seeds in various agroecological zones in Makueni and Taita Taveta during the 2016 long rains.

Methods of threshing	LM4 (Wote)	LM5 (Makindu)	LM5 (Mwatate)
Physical hitting	100.0	100.0	97.9
Removal by hand	0.0	0.0	2.1
Methods of drying			
Sun-drying after harvesting	96.0	97.1	85.7
Sun-drying before harvesting	4.0	2.9	12.2
Storage place			
House racks	24.0	14.7	74.5
Granary	76.0	85.3	23.5
Kitchen	0.0	0.0	2.0
Storage containers			
Nylon bags	64.0	91.2	55.8
Gunny bags	8.0	8.8	3.8
Plastic containers	20.0	0.0	28.8
Pots	4.0	0.0	7.7
Reed baskets	4.0	0.0	3.8
Treatment before storage			
Pirimiphos-methyl	95.0	57.6	55.9
Malathion 2% + permethrin 0.3 w/w	0.0	0.0	9.1
Ash	0.0	42.4	29.4
Others (paraffin, oil, smoking)	5.0	0.0	0.0

LM4: lower midland zone IV; LM5: lower midland zone V.

Table 4: Percentage of physical purity components of cowpea seeds obtained from Wote, Makindu and Mwatate in various agroecological zones.

Agro-ecological zone	Pure seeds	Other variety	Other crops	Insect damaged	Inert matter	Shrivelled
Farm saved						
LM5 (Mwatate)	82.1a	7.9a	1.1a	6.7c	1.5a	1.5a
LM5 (Makindu)	79.3a	2.0b	0.4b	15.9b	2.1a	0.7a
LM4 (Wote)	61.6b	1.1b	0.3b	33.6a	2.0a	1.5a
Mean	73.7	2.8	0.5	20.3	2.0	1.1
LSD ($p < 0.05$)	17.3	4.4	1.0	16.4	1.2	2.1
CV (%)	29.8	198.3	264.8	102.8	80.5	241.3
Market sourced						
LM5 (Makindu)	91.2a	0.8a	0.3a	5.5b	1.3b	0.9b
LM4 (Wote)	90.0a	3.7a	0.4a	4.6b	1.1b	1.2a
LM5 (Mwatate)	80.2b	2.3a	0.7a	13.2a	2.3a	1.1b
Mean	84.7	2.3	0.5	9.6	1.8	1.2
LSD ($p < 0.05$)	14.2	4.5	0.9	14.9	1.0	0.9
CV (%)	19.2	219.6	195.2	177.4	61.4	86.3

Means with different letters are significantly different ($p < 0.05$) with Fisher's multiple range tests. LSD = least significant difference; CV = coefficient of variance; LM4: lower midland zone IV; LM5: lower midland zone V.

other two areas, both at 12.7%. Percentage composition of mouldy and dead seeds was not significantly different across the three agroecological zones. In market-sourced seeds, the highest composition of infected seeds was on seeds collected from Mwatate and Wote at 12.4% and 13.3%, respectively, which was significantly different with the seeds from Makindu. The mouldy seeds composition varied significantly across the three agroecological zones with Makindu having the highest (25.3%) followed by Wote and Mwatate at 13.8% and 5.6%, respectively, whereas there was no significant difference in the dead seed composition across the three agroecological zones (Table 6).

3.4. Effect of Seed Source on Vigour of Cowpea Seeds. The mean seedling length in farm-saved and market-sourced seeds was 10.7 cm and 9.6 cm, respectively. Seeds from Mwatate and Makindu had the highest and were not significantly different while Wote had the least which was not significantly different with the ones from Makindu. The market-sourced seeds from Mwatate and Wote had the highest and were significantly different from the ones from Makindu. The mean dry weight of seedlings in farm-saved and market-sourced seeds was 13.2 g and 12.8 g, respectively. In the farm-saved seeds, dry weight of seedlings from Mwatate and Makindu was the highest and significantly different from that of the ones from Wote. In market-

Table 5: Percentage viability of farm-saved and market-sourced seeds from different agro ecological zones in Makueni and Taita Taveta.

Agroecological zone	Germination (%)	Germination rate	Normal seedlings	Abnormal seedlings	Hard seeds
Farm saved					
LM5 (Mwatate)	86.6a	38.1a	16.2a	52.3a	3.1a
LM4 (Wote)	61.2b	25.7b	15.1a	33.7b	1.3b
LM 5 (Makindu)	61.1b	25.6b	15.2a	33.7b	1.3b
Mean	68.0	29.0	15.5	38.8	1.7
LSD ($p < 0.05$)	20.1	8.2	10.7	13.7	2.7
CV (%)	37.6	36.2	88.0	44.9	196.7
Market sourced					
LM5 (Mwatate)	80.5a	35.6a	18.1a	35.5b	1.3b
LM4 (Wote)	73.7b	29.4b	9.8b	50.8a	2.4a
LM 5 (Makindu)	67.1b	26.6b	10.4b	54.0a	1.6b
Mean	76.0	32.3	14.5	43.0	1.6
LSD ($p < 0.05$)	14.0	6.7	14.8	19.4	2.4
CV (%)	21.0	23.8	116.1	51.5	170.2

Means with different letters are significantly different ($p < 0.05$) with Fisher's multiple range tests; LSD = least significant difference; CV = coefficient of variance.

Table 6: Percentage of infected, mouldy, and dead seeds in farm-saved and market-sourced seeds in different agroecological zones in Makueni and Taita Taveta.

Agroecological zone	Infected seedlings	Mouldy seeds	Dead seeds
Farm saved			
LM5 (Mwatate)	19.0a	6.4a	4.4a
LM4 (Wote)	12.7b	11.6a	17.9a
LM 5 (Makindu)	12.7b	10.8a	17.8a
Mean	14.4	9.9	13.4
LSD ($p < 0.05$)	10.3	8.8	14.9
CV (%)	91.7	112.6	143.6
Market sourced			
LM5 (Mwatate)	12.4a	5.6c	6.6a
LM4 (Wote)	13.3a	13.8b	10.3a
LM 5 (Makindu)	3.0b	25.3a	6.0a
Mean	10.6	11.7	7.3
LSD ($p < 0.05$)	9.5	8.0	10.0
CV (%)	102.2	78.3	155.5

Means with different letters are significantly different ($p < 0.05$) with Fisher's multiple range tests. LSD = least significant difference; CV = coefficient of variance.

sourced seeds, seedlings from Mwatate and Wote were the highest and significantly different from the seeds from Makindu (Table 7).

The mean vigour index of farm-saved and market-sourced seeds was at 832 and 734, respectively. The vigour index of farm-saved seeds from Mwatate was the highest and significantly different from that of the seeds from Makindu and Wote which did not vary significantly. This is similar to the market-sourced seeds whereby Mwatate also recorded the highest vigour index and Makindu recorded the least (Table 7).

4. Discussion

4.1. Cowpea Seed Production and Postharvest Handling Practices. A majority of the farmers were using uncertified seeds of farm-saved origin with the dominant cropping system being the intercrop with cereals such as sorghum, maize, and pearl millet. The popularity of uncertified seeds of farm source origin in this study is in concurrence with the findings of Almekinders and Louwaars [17] who reported that in the developing countries, 60–100% of farmers obtain their seeds from the informal seed systems which are farm saved, market sourced, or exchange between farmers. Additionally, Wekundah [18] reported that in Africa, approximately 80% of the farmers use seeds from the informal seed system. Rubyogo et al. [19, 20] also found out that the own farm-saved seeds contribute to the highest proportion of the supply of the seeds in the informal seed system. The preference of uncertified seeds over the certified ones by farmers is because certified seeds are generally expensive and farmers are unwilling to buy them at a cost twice or more than that of the grain price [6, 21]. Contrastingly, McGuire and Sperling [10] reported market as the most common source of seeds used by farmers, sourcing seeds from the informal seed system. The larger proportion of the

Table 7: Vigour of farm-saved and market-sourced seeds from different agroecological zones in Makueni and Taita Taveta.

Agroecological zone	Seedling length (cm)	Seedling dry weight (g)	Vigour index
Farm saved			
LM5 (Mwatate)	12.4a	14.5a	1076.3a
LM5 (Makindu)	10.6ab	14.0a	763.0b
LM4 (Wote)	9.5b	12.0b	722.8b
Mean	10.7	13.2	832.0
LSD ($p < 0.05$)	3.7	2.6	362.5
CV (%)	44.3	21.8	55.5
Market sourced			
LM5 (Mwatate)	9.9a	13.4a	811.0a
LM5 (Makindu)	7.4b	9.9b	504.6b
LM4 (Wote)	10.4a	14.0a	746.6a
Mean	9.6	12.8	734.0
LSD ($p < 0.05$)	3.2	2.3	298.6
CV (%)	37.8	20.1	46.5

Means with different letters are significantly different ($p < 0.05$) with Fisher's multiple range tests. LSD = least significant difference, CV = coefficient of variance.

respondents was producing cowpea under farm size 0.25 ha. Similarly, Modu et al. [22] reported that most of the cowpea farmers grow cowpea in small scale with a farm size of less than 4 ha in Nigeria that revealed that the farmers growing cowpea had a total farm size of 2 ha. Asiwe [23] also found out that the area under cowpea was between 0.25 and 2.0 ha per farmer in a survey among cowpea farmers in South Africa. Similar findings were reported by Kimiti et al. [2] who reported the area under legume in some parts of Makueni County ranged from 1.1 to 1.5 ha. This is also consistent with the earlier findings of Muthamia and Kanampiu [4] and Muli and Saha [3], who reported that over 85% of the area under cowpea in Kenya is in the Eastern Province and the rest is in the Coast and Western and Central provinces. This is because cowpea production is still at the subsistence level and there is need to improve and minimize the effect of the constraints in its production [23].

Use of intercropping as the common production system in which cowpea is grown is consistent with the findings of Asiwe [23] which showed that intercropping along with mixed cropping of cowpeas along cereals was popular in South Africa. The use of this cropping system is an effort to avoid crop failure, optimization of available labour, efficient utilization of environmental resources, suppression of weed growth, decreasing of damage by pests, improvement of forage yield, and quality as well as improvement of soil fertility through nitrogen fixing by legumes [24–27]. However, there are findings that show that cumulative crop yields on the intercropping system are currently on decline due to erratic rains [11].

The short rains were cited as the less suitable cowpea season where a majority of the farmers realized yields of 201–500 kg/ha which was also characterized with a high percentage of farmers not realizing any yields as compared to the long rains. Cowpea produced in the areas of study is mostly dual purpose, but the intensity of use of leaves over the seeds varied from locality to locality. The characteristic low yields of 201–500 kg/ha in this study are in consistent with the findings of Kimiti et al. [2] who reported that the cowpea farming was characterized by low yields of 30–416 kg/ha which is extremely low as compared to the yield potential of 1200–1800 kg/ha. Karanja et al. [28, 29] ascribed these extremely low yields to inadequate farm input, low soil fertility, infestation by parasitic weeds such as Striga, and long dry spells during the season. Furthermore, Saidi et al. [30] observed that increase in cowpea harvesting at the leaf stage led to a decrease in grain yield and hence could result in less number of seeds. Cowpea use as a dual-purpose crop for its leaves and seeds in the areas of study with leaves being more popular is in agreement with the findings of Bubenheim et al. [31] and Kabuye and Ngugi [32] who reported that cowpea is produced due to its versatility in the use of its leaves and seeds. The production of cowpea for its leafy vegetables has markedly increased in the recent past as farmers nowadays prefer growth of drought-tolerant vegetables due to the current prevailing weather conditions in Africa as reported by Saidi et al. [33]. Cowpea leaves have been identified as one of the most important traditional vegetable in sub-Saharan Africa alongside amaranth, night shade, pumpkin leaves, and African spider plant [34–36]. They rank third among the top five leafy vegetables consumed in sub-Saharan Africa in terms of the quantity consumed [34]. Cowpea leaves are more popular than seeds in some areas because they are produced earlier and in large quantities than seeds as well as the protein content being said to be more than 15 times in leaves than in seeds [37].

Dominance of physical hitting of the cowpea as the common method of threshing in this study is consistent with the findings of Gómez [38] and Taruvinga et al. [39] who reported the threshing method by beating as popular among cowpea farmers. Popularity of nylon sacs, gunny bags, plastic containers, pots, and reed baskets as the storage containers in the areas of study is concurrent with the findings of Kimiywe [40], who among other postharvest storage containers cited use of storage pots, sacks, woven baskets, and drying methods such as hanging over fireplace, drying by smoking, and solar drying as popularly used containers and methods of drying. Recent studies in Nigeria showed that the traditionally preferred method of storage is use of polyethylene bags but pests have made them to turn to alternatives such as metal drums, Purdue-improved cowpea storage (PICS) bags, and double bags according to Moussa et al. [41]. According to Catholic Relief Services [42], use of plastic containers for cowpea storage is due to local availability and ability to reuse over the years although it can only store small quantities of seeds. Use of these multilayered plastic bags is reported to have resulted in the decrease in the use of storage insecticides from 40% to 6%. In contrast, not all bags are suitable for seed storage except hermatic bags since some bags such as plastic bags prevent air circulation while tightly woven polypropylene bags do not allow sufficient air circulation even though they are readily available in the market. Therefore, the best storage bags are of UV-stabilized polypropylene with special weave which allows for air circulation or jute bags [43]. Although these airtight storage techniques are available and suppress damage of cowpea storage pests such as weevils, the farmers persist in the use of low-quality storage bags [44].

Popular seed treatment was the use of compounds containing pirimiphos-methyl and malathion 2% + permethrin 0.3 w/w as active ingredients and others such as ash, paraffin, oil, and smoke. This is in agreement with the findings of Apuuli and Villet [45], who reported that ash is effective in control of damage of cowpea seeds in storage through restricting the movement of beetles among the seeds, hampering the oviposition, and interfering the immature stages of the storage pests through abrasion. Even though most farmers could have suggested that they use the mentioned insecticide, in actual sense, most of the farmers using farm-saved seeds are resource poor and so may be mostly using ash. Moreover, protection of storage seeds has become harder nowadays due to decreasing active pesticide-active ingredient and increasing pesticide resistance [46].

4.2. Effect of Cowpea Seed Source on Analytical Purity. The percentage pure seed composition of farm-saved and market-sourced seeds was at 73.7% and 84.7%, and therefore, both were below the recommended quality as they did not meet the minimum pure seed composition of 98% as recommended by ISTA. This finding is in agreement with ICARDA [47], who also found out that some of the samples (5%) collected from wheat farmers did not meet the minimum recommended rate in Ethiopia. Varietal purity of farm-saved seeds is reported to be compromised due to the storage practices used by the farmers in Ghana [48]. Additionally, no significant difference was reported in analytical purity analysis of farm-saved wheat seeds from different regions in Ethiopia [49]. The reduced percentage purity of the seed samples below the recommended rate could also be attributed to poor seed production practices such as failure to rogue out other varieties as well as less-than-optimum harvesting practices, shelling techniques, and storage conditions [50].

Insect-damaged seeds were the second highest composition with farm-saved seeds having a higher percentage which was more than twice the market-sourced and was above the recommended limit by ISTA [13]. This is in consistent with the earlier findings that showed that insect damage remains a major constraint in cowpea production in Africa and in other cowpea-growing areas [51–54]. Biemond et al. [55] also reported that a high level of damage of cowpea seeds by weevil, which is the major storage pest, was evident among farmers who used traditional storage methods such as polyethylene bags which was the popular storage method in the areas of study. Therefore, there is a positive correlation between the method of storage and the level of seed damage by insects.

Other variety component percentage was the third highest component with one region having a composition as high as 4.1% which was more than the minimum recommended rate by ISTA [13]. This was similar to reports by Hasan [56] who found out that farm-saved wheat seeds had relatively high levels of other crop seed contamination and therefore low pure seed component. The Ministry of Agriculture Livestock and Fisheries [7, 57] reported that it is not possible to completely remove all foreign seeds due to the high cost of sorting and selection. However, Bishaw et al. [58] reported that farmers do use local selection, treatment, cleaning, and storage to maintain the quality status of their farm-saved seeds. Additionally, seed storage heavily affects the plant quality [59].

4.3. Effect of Seed Source on Cowpea Germination. Farm-saved and market-sourced seeds from one of the agroecological zones achieved the minimum germination percentage of 75% and were significantly different from the other ones. Different agroecological zones experience different rainfall amount, temperature, and humidity [11]. Sales et al. [44] reported that the conditions in which the mother plant has been grown heavily influence the seed germination. Additionally, Matikiti et al. [60] reported that factors such as poor storage could result in attacks by bruchids and fungi causing the seeds not to germinate. Misangu et al. [61] also observed that seeds with higher incidence of damage by bruchids resulted in lower germination compared to disinfested seeds.

Abnormal seedlings and infected seeds are direct indicators of seeds heavily infected by seed-borne pathogens [62]. The higher percentage of these two aspects in farm-saved seeds varying among the different agroecological zones is similar to the findings of Icashahayo [47] who reported varying levels of pathogens in bean seeds obtained from different agroecological zones in Zimbambwe. Farmers tend to retain and recycle seeds for several seasons, hence leading to buildup of seed-borne pathogen inoculum which negatively affects seeds causing rampant cases of abnormalities in seedlings and postemergency mortality in seeds [16, 63].

A comparison of the performance of farm-saved and market-sourced seeds showed that there was no significant difference in normal and abnormal seedlings and mouldy and hard seeds while a significant difference was in infected seedlings with farm-saved seeds having the highest level of infection and dead seeds. The germination percentage and germination rate were not significantly different in the seeds from the two sources. Similarly, farm-saved and market-sourced seeds were not significantly different in germination which concurs with the report by Walker and Tripp [64] who reported no significant difference in germination of farm-saved cowpea and sorghum in Ghana and Zambia and those obtained from other sources which are informal.

4.4. Effect of Cowpea Seed Source on Seedling Vigour. The seedling vigour index using dry weight showed that there was a significant difference in the seedling vigour index of seed samples from the three different areas. The seedling vigour index of farm-saved seed samples was significantly different from that of the ones which were market sourced and had a higher seedling vigour index. This is in agreement with results by Bishaw et al. [58] who also reported similar findings while working on wheat from different areas in Ethiopia.

5. Conclusions and Recommendations

Despite the economic importance of cowpea crop, many farmers still use seeds from the informal seed systems and mainly the farm-saved seeds. These seeds are characterised by low purity, germination percentage, and seedling vigour. Storage pests are also a major challenge evidenced by the high composition of insect-damaged seeds and the low percentage of respondents applying seed treatment before storage. Farmers are still employing suboptimal postharvest handling practices such as storage containers, storage places, and seed treatment which negatively affect most aspects of seed quality. Farmers should therefore be strongly advised on the importance of replenishing their seed stock every often. They should also be trained on proper harvesting and postharvesting practices which also have considerable effect on seed quality in order to ensure optimum cowpea yield.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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References

[1] A. N. Awurum and D. N. Enyiukwi, "Evaluation of seed dressing potentials of phytochemicals from *Carica papaya* and *Piper guinense* on the germination of cowpea (*Vigna unguiculata* L. walp) seeds and the incidence of seed borne fungi," *Journal of Agricultural Science*, vol. 7, no. 1, pp. 29–35, 2013.

[2] J. M. Kimiti, D. W. Odee, and B. Vanlauwe, "Area under grain legume cultivation and problems faced by smallholder farmers in legume production in the semi-arid, Eastern Kenya," *Journal of Sustainable Development in Africa*, vol. 11, no. 4, pp. 305–315, 2009.

[3] M. B. Muli and H. M. Saha, "Participatory evaluation of cowpea cultivars for adaptation and yield performance in coastal Kenya," in *Proceedings of 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, pp. 267–272, Mombasa, Kenya, June 2000.

[4] J. G. N. Muthamia and F. K. Kanampiu, "On-farm cowpea evaluation in the marginal areas of eastern Kenya," in *Proceedings of the 5th KARI Scientific Conference, Focus on Agricultural Research for Sustainable Development in a Changing Economic Environment*, Kenya Agricultural Research Institute, Nairobi, Kenya, October 1996.

[5] M. Ayieko and D. Tschirley, *Enhancing Access and Utilization of Improved Seed for Food Security in Kenya*, Tegemeo Institute of Agricultural Policy and Development, Egerton University, Nakuru, Kenya, 2006.

[6] P. Kimani, D. K. Kamundia, R. D. Narla, and A. W. Mwang'ombe, "An integrated seed delivery system and seed research in Kenya: case studies of pigeon pea, onion and dry bean," *Seed Systems, Science and Policy in East and Central Africa*, vol. 73, 2014.

[7] Ministry of Agriculture Livestock and Fisheries, *Economic Review for Agriculture*, Ministry of Agriculture Livestock and Fisheries, Nairobi, Kenya, 2015.

[8] N. Louwaars, *Seeds of confusion: the impact of policies on seed systems*, Ph.D. Thesis, Wageningen University, Wageningen, Netherlands, 2007.

[9] P. Amaza, E. Udoh, T. Abdoulaye, and A. Kamara, "Analysis of technical efficiency among community-based seed producers in the savannas of Borno State, Nigeria," *Journal of Food, Agriculture & Environment*, vol. 8, no. 2, pp. 1073–1079, 2010.

[10] S. McGuire and L. Sperling, "Seed systems smallholder farmers use," *Food Security*, vol. 8, no. 1, pp. 179–195, 2016.

[11] R. Jaetzold, H. Schmidt, B. Hornetz, and C. Shisanya, *Farm Management Handbook of Kenya. Natural Conditions and Farm Information, Vol. II, Part C1—East Kenya*, Ministry of Agriculture, Nairobi, Kenya, 2nd edition, 2006.

[12] N. L. Leech, K. C. Barret, and G. A. Morgan, *SPSS for Intermediate Statistics: Use and Interpretation*, Psychology Press, London, UK, 2005.

[13] ISTA, *Handbook on Seed Health Testing*, ISTA, Zürich, Switzerland, 2015.

[14] A. A. Abdul-Baki and J. D. Anderson, "Vigor determination in soybean seed by multiple criteria1," *Crop Science*, vol. 13, no. 6, pp. 630–633, 1973.

[15] M. W. Njonjo, "Quality of cowpea seed used by farmers in Makueni and Taita Taveta Counties and its effect on crop performance," M.Sc. Thesis, University of Nairobi, Nairobi, Kenya, 2018.

[16] J. M. Omiti, H. A. Freeman, W. Kaguongo, and C. Bett, "Soil fertility maintenance in eastern Kenya. Current practices, constraints and opportunities, CARMASAK," ICRISAT, Patancheru, Hyderabad, 1999.

[17] C. J. Almekinders and N. P. Louwaars, "The importance of the farmers' seed systems in a functional national seed sector," *Journal of New Seeds*, vol. 4, no. 1-2, pp. 15–33, 2002.

[18] J. M. Wekundah, "Why informal seed sector is important in food security. African technology policy studies network," *Biotechnology Trust Africa*, no. 43, 2012.

[19] J. C. Rubyogo, L. Sperling, L. Nasirumbi, and S. Kasambala, "Developing seed systems with and for the marginalized: case of common beans (*Phaseolus vulgaris* L.) in east, central and southern Africa," in *Proceedings of Farmer First Revisited Conference*, vol. 1214, Sussex, UK, December 2007.

[20] J. C. Rubyogo, L. Sperling, and T. Assefa, "A new approach for facilitating farmers' access to bean seed," *LEISA Magazine*, vol. 23, no. 2, pp. 27–29, 2007.

[21] K. Oshone, S. Gebeyehu, and K. Tesfaye, "Assessment of common bean (*Phaseolus vulgaris* L) seed quality produced under different cropping systems by smallholder farmers in Eastern Ethiopia," *Africa Journal of Food, Agriculture Nutrition and Development*, vol. 14, no. 1, pp. 8566–8584, 2014.

[22] Y. Modu, A. J. Putai, and A. M. Petu-Ibikunle, "An economic analysis of cowpea production among women farmers in Askira/Uba local government area Borno State Nigeria," *African Journal of General Agriculture*, vol. 6, no. 1, pp. 7–17, 2010.

[23] J. A. N. Asiwe, "Insect mediated outcrossing and geneflow in cowpea (*Vigna unguiculata* (L.) Walp): implication for seed production and provision of containment structures for genetically transformed cowpea," *African Journal of Biotechnology*, vol. 8, no. 2, 2009.

[24] M. Dahmardeh, A. Ghanbari, B. A. Syahsar, and M. Ramrodi, "The role of intercropping maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) on yield and soil chemical properties," *African Journal of Agricultural Research*, vol. 5, no. 8, pp. 631–636, 2010.

[25] G. Keding, K. Weinberger, I. Swai, and H. Mndiga, *Diversity, Traits and Use of Traditional Vegetables in Tanzania*, AVRDC-World Vegetable Center, Tainan, Taiwan, 2007.

[26] B. S. Olisa, S. A. Ajayi, and S. R. Akande, "Physiological quality of seeds of promising African yam bean (*Sphenostylis stenocarpa* (hochst. Ex A. rich) harms) and pigeon pea (*Cajanus cajan* L. Mill sp.) landraces," *Research Journal of Seed Science*, vol. 3, no. 2, pp. 93–101, 2010.

[27] O. O. Olufajo and B. B. Singh, "Advances in cowpea cropping system research," in *Proceedings of the World Cowpea Conference III, Challenges and Opportunities for Enhancing Sustainable Cowpea Production*, pp. 267–277, IITA, Ibadan, Nigeria, September 2000.

[28] S. M. Karanja, A. M. Kibe, P. N. Karogo, and M. Mwangi, "Effect of intercrop population density and row orientation on growth and yields of sorghum—cowpea cropping systems in semi-arid Rongai, Kenya," *Journal of Agricultural Science*, vol. 6, no. 5, pp. 34–43, 2014.

[29] R. D. Katsaruware and I. O. Manyanhaire, "Maize–cowpea intercropping and weed suppression in leaf stripped and detasseled maize in Zimbabwe," *Electronic Journal of Environmental Agriculture and Food Chemistry*, vol. 8, no. 11, pp. 1218–1226, 2009.

[30] M. Saidi, M. Ngouajio, F. M. Itulya, and J. Ehlers, "Leaf harvesting initiation time and frequency affect biomass partitioning and yield of cowpea," *Crop Science*, vol. 47, no. 3, pp. 1159–1166, 2007.

[31] D. L. Bubenheim, C. A. Mitchell, and S. S. Nielsen, "Utility of cowpea foliage in a crop production system for space," in *Advances in New Crops*, J. Janick and J. E. Simon, Eds., pp. 535–538, Timber Press, Portland, OR, USA, 1990.

[32] S. C. Kabuye and W. G. Ngugi, *Nutritional and Medicinal Importance of Indigenous Food Plants. The Potential of Indigenous Foods*, USAID, Washington, DC, USA, 2001.

[33] M. Saidi, F. M. Itulya, J. N. Aguyoh, and P. M. Mshenga, "Yields and profitability of a dual–purpose sole cowpea and cowpea-maize intercrop as influenced by cowpea leaf harvesting frequency," *ARPN Journal of Agricultural and Biological Science*, vol. 5, no. 5, pp. 65–71, 2010.

[34] B. N. Ekesa, M. K. Walingo, and M. O. Abukutsa-Onyango, "Accessibility to and consumption of indigenous vegetables and fruits by rural households in Matungu Division, Western Kenya," *African Journal of Food, Agriculture, Nutrition and Development*, vol. 9, no. 8, 2009.

[35] B. T. Kiremire, E. Musinguzi, J. K. Kikafunda, and F. B. Lukwago, "Effects of vegetable drying techniques on nutrient content: a case study of south-western Uganda," *African Journal of Food, Agriculture, Nutrition and Development*, vol. 10, no. 5, pp. 2587–2600, 2010.

[36] M. Shaban, "Review on physiological aspects of seed deterioration," *International Journal of Crop Sciences*, vol. 6, no. 11, pp. 627–631, 2013.

[37] P. S. Mamiro, A. M. Mbwaga, D. P. Mamiro, A. W. Mwanri, and J. L. Kinabo, "Nutritional quality and utilization of local and improved cowpea varieties in some regions in Tanzania," *African Journal of Food, Agriculture, Nutrition and Development*, vol. 11, no. 1, pp. 4490–4506, 2011.

[38] C. Gómez, "Cowpea: post-harvest operations," in *PHO—Post-Harvest Compendium*, D. Mejía, Ed., Food and Agriculture Organization of the United Nations, Rome, Italy, 2004.

[39] C. Taruvinga, D. Mejia, and J. Sanz Alvarez, *Appropriate Seed and Grain Storage Systems for Small-Scale Farmers: Key Practices for DRR Implementers*, Food and Agriculture Organization, Rome, Italy, 2014.

[40] J. Kimiywe, "Food and nutrition security: challenges of post-harvest handling in Kenya," *Proceedings of the Nutrition Society*, vol. 74, no. 4, pp. 487–495, 2015.

[41] B. Moussa, J. Lowenberg-Deboer, J. Fulton, and K. Boys, "The economic impact of cowpea research in West and Central Africa: a regional impact assessment of improved cowpea storage technologies," *Journal of Stored Products Research*, vol. 47, no. 3, pp. 147–156, 2011.

[42] Catholic Relief Services (CRS), *Documenting and Socializing Lessons Learned from 7 OFDA Grants on Household Seed Storage*, CRS, Bujumbura, Burundi, 2013.

[43] I. F. Smith and P. Eyzaguirre, "African leafy vegetables: their role in the world health organization's global fruit and vegetables initiative," *African Journal of Food, Agriculture, Nutrition and Development*, vol. 7, pp. 1–9, 2007.

[44] N. M. Sales, F. Pérez-García, and F. A. O. Silveira, "Consistent variation in seed germination across an environmental gradient in a Neotropical savanna," *South African Journal of Botany*, vol. 87, pp. 129–133, 2013.

[45] J. K. K. Apuuli and M. H. Villet, "The use of wood ash for the protection of stored cowpea seed (*Vigna unguiculata* (L) walp.) against *Bruchidae* (*coleoptera*)," *African Entomology*, vol. 4, no. 1, pp. 97–99, 1996.

[46] F. H. Arthur, "Aerosols and contact insecticides as alternatives to methyl bromide in flour mills, food production facilities, and food warehouses," *Journal of Pest Science*, vol. 85, no. 3, pp. 323–329, 2012.

[47] International Center for Agricultural Research in the Dry Areas (ICARDA), *Catalogue of Field and Seed Standards (Cereals, Legumes, Oilseeds, Forages and Vegetables)*, ICARDA, Aleppo, Syria, 2002.

[48] H. M. Bortey, N. S. Olympio, and B. Banful, "Quality of farmer saved tomato seeds and its effects on fruit yield in Ghana," *Ghana Journal of Horticulture*, vol. 9, pp. 25–33, 2011.

[49] R. Ensermu, W. M. Mwangi, H. Verkuijl, M. Hasenna, and Z. Alemayehu, *Farmers' Wheat Seed Sources and Seed Management in Chilalo Awraja, Ethiopia*, CIMMYT; IAR, Mexico, MX, USA; Ethiopia, 1998.

[50] M. M. Greven, B. A. McKenzie, J. G. Hampton, M. J. Hill, J. R. Sedcole, and G. D. Hill, "Factors affecting quality in dwarf French bean (*Phaseolus vulgaris* L.) before harvest maturity," *Seed Science and Technology*, vol. 32, no. 3, pp. 797–811, 2007.

[51] E. Adipala, P. Nampala, J. Karungi, and P. Isubikalu, "A review on options for management of cowpea pests: experiences from Uganda. Biomedical and life sciences," *Integrated Pest Management Reviews*, vol. 5, no. 3, pp. 185–196, 2000.

[52] S. K. Asante, M. Tamo, L. E. N. Jackai, and L. E. N. Jackai, "Integrated management of cowpea insect pests using elite cultivars, date of planting and minimum insecticide application," *African Crop Science Journal*, vol. 9, no. 4, pp. 655–665, 2001.

[53] K. F. Egbadzor, M. Yeboah, S. K. Offei, K. Ofori, and E. Y. Danquah, "Farmers key production constraints and traits desired in cowpea in Ghana," *Journal of Agricultural Extension and Rural Development*, vol. 5, no. 1, pp. 14–20, 2013.

[54] J. H. J. R. Makoi, A. K. Belane, S. B. M. Chimphango, and F. D. Dakora, "Seed flavonoids and anthocyanins as markers of enhanced plant defence in nodulated cowpea (*Vigna unguiculata* L. Walp.)," *Field Crops Research*, vol. 118, no. 1, pp. 21–27, 2010.

[55] P. C. Biemond, T. J. Stomph, A. Kamara, T. Abdoulage, S. Hearne, and P. C. Struik, "Are investments in an informal seed systems for cowpeas a worthwhile endeavor?," *International Journal of Plant Production*, vol. 6, no. 3, pp. 367–386, 2012.

[56] B. M. A. Hasan, "A survey of wheat seed quality in Jordan," M.Sc. Thesis, University of Jordan, Amman, Jordan, 1995.

[57] P. J. Michael, M. J. Owen, and S. B. Powles, "Herbicide-resistant weed seeds contaminate grain sown in the western Australian grainbelt," *Weed Science*, vol. 58, no. 4, pp. 466–472, 2010.

[58] Z. Bishaw, P. C. Struik, and A. J. G. Van Gastel, "Farmers' seed sources and seed quality: 1. Physical and physiological quality," *Journal of Crop Improvement*, vol. 26, no. 5, pp. 655–692, 2012.

[59] A. Sanon, L. C. Dabiré-Binso, and N. M. Ba, "Triple-bagging of cowpeas within high density polyethylene bags to control the cowpea beetle *Callosobruchus maculatus* F. (*Coleoptera*: *Bruchidae*)," *Journal of Stored Products Research*, vol. 47, no. 3, pp. 210–215, 2011.

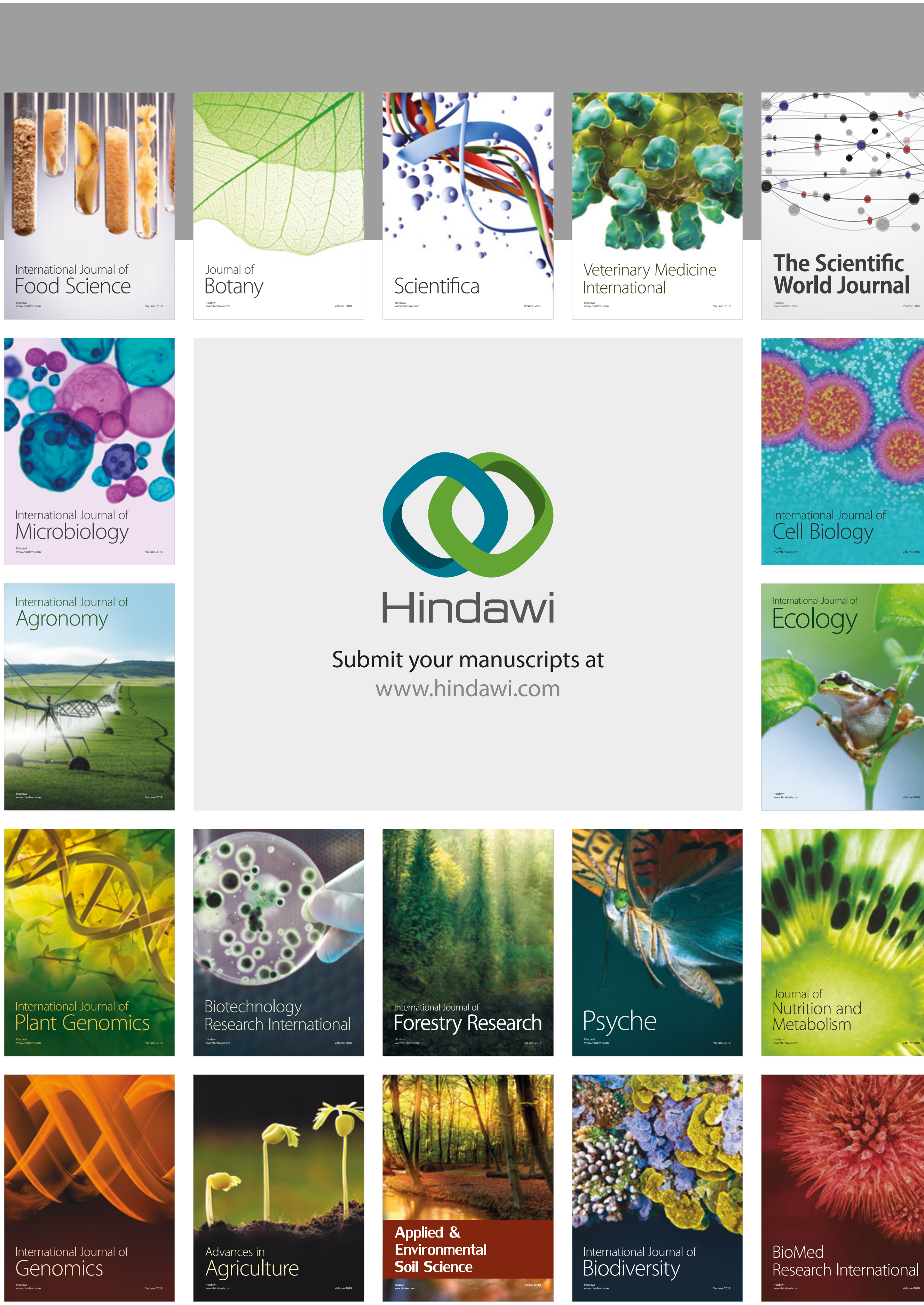
[60] A. Matikiti, Z. Chikwambi, C. Nyakanda, and A. B. Mashingaidze, "An overview of the agronomic production constraints to black-eyed bean cowpea type (*Vigna unguiculata* (L.) Walp) for leaf and grain utilization in Zimbabwe," *Journal of Crop Production*, vol. 1, no. 1, pp. 46–52, 2012.

[61] R. N. Misangu, M. S. Chipungahelo, S. O. W. M. Reuben, and L. S. Mulungu, "The effect of sowing bruchid damaged bean (*Phaseolus vulgaris*) seeds on germination, plant development and yields," *Journal of Entomology*, vol. 4, no. 4, pp. 337–340, 2007.

[62] D. Icishahayo, J. Sibiya, S. Dimbi, I. Madakadze, Manyangarrwa, and B. Chipidu, "Assessment of quality and health of field bean seed home saved by small holder farmers," *Africa Crop Science*, vol. 9, pp. 609–615, 2009.

[63] D. Icishahayo, E. Ngadze, A. B. Mashingaidze et al., "Effect of irrigation and planting date on common bean seed quality and health," *Africa Crop Science*, vol. 8, pp. 476–487, 2007.

[64] D. J. Walker and R. Tripp, "Seed management by small-scale farmers in Ghana and Zambia 207-215," in *Proceedings of the International Workshop on Seed Security for Food Security*, Food and Agriculture Organization, Rome, Italy, November-December 1997.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