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Contribution of Seed Quality to the Occurrence of Fungal and Bacterial Diseases of Farmer Produced Common Bean in Varied Agro-Climatic Zones of Western Kenya

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Abstract: Farmers often recycle farm saved bean seeds from previous harvest for planting in subsequent cropping seasons resulting in reduced quality and buildup of seed borne diseases. This study investigated the quality of bean seeds in western Kenya. Bean seeds saved by farmers for planting were collected from 110 farmers. The seed samples were subjected to quality analysis including physical purity, germination and contamination with seed borne pathogens. The bean seeds collected comprised of 13 different varieties with Rose coco (23%) and KK8 (22%) being the most popular. The purity of seeds was about 76% which is below the recommended purity standard of 95%. However, the seeds met the minimum germination standard of 80% although 12% of the seeds were discolored and shriveled. Seed samples from farmers participating in up-scaling technologies had significantly ($p \leq 0.05$) lower contamination with *Pseudomonas savastanoi* p.v. *phaseolicola* at 747 CFU/seed compared to 1241 CFU/seed for samples from non-participating farmers. *Fusarium solani* was the most common fungal pathogen contaminating almost all the seed samples. However, there were no significant differences in the level of seed infection with fungal pathogens. The results indicated that recycling of bean seeds from previous cropping seasons contributes to reduced physical, physiological and health quality of the seeds. This has a direct effect in terms of reduced crop establishment, high incidence of diseases and low productivity in the subsequent season. Therefore, there is need to create awareness among farmers on good agronomic practices and on use of disease-free seeds.

Keywords: Farm Saved Seed, *Phaseolus vulgaris*, Seed Quality, Seed Borne Diseases

1. Introduction

Common bean is the second most important food crop after maize in Kenya [1] [2] and is majorly cultivated as a source of food and income by small holder farmers [3] [4] [5]. Beans are rich in proteins, calcium, folic acid, dietary fiber and carbohydrates thereby contributing to food and nutritional security [6]. In Kenya, common beans are mainly grown in the highlands and midlands, with 75% of the annual production in Nyanza, Rift valley and Eastern regions with Western Kenya contributing 22% of the total national output [6]. Beans are mainly grown as an intercrop with cereals like maize, sorghum and millet, where the legumes are the minor crop while the cereals are the major crops [7]. Although many bean varieties are cultivated, most farmers prefer the large seeded varieties because of their tolerance to common diseases and preference by consumers [8] [9]. Bean is consumed by 100% of the population in Kenya and per capita consumption is estimated at 14 kg per year, but in western Kenya, it can be as high as 66 kg/yr [10] [6].

The output from bean production in western Kenya has however been on the decline due to several constraints. Majority of small holder farmers use farm saved seeds because of high cost, unavailability and lack of accessibility

of certified seeds [11] [12] [13] [14]. Like in other bean growing regions in Africa, farmers obtain seeds through the informal channels which include saving their own seeds from previous harvests, local exchanges and purchase from local markets [15] [16] [17]. Farm saved seeds are usually infected with seed borne pathogens and lack improved qualities such as tolerance or resistance to biotic and abiotic stresses. Many fungal and bacterial diseases of common bean are seed borne and therefore recycling of own farm saved seeds by farmers encourages buildup of pathogens in the seeds and soil which discourages breaking of disease cycles translating to low yields [18] [16] [19]. This has resulted in low productivity and increased poverty levels in the region [20]. Other common bean production constraints include diseases and pests, low soil fertility, unfavorable weather and lack of organic and inorganic inputs [19].

Fungi, bacteria and viruses are the major seed borne disease-causing pathogens of common bean in western Kenya [3] [4]. The most important foliage fungal diseases include anthracnose (*Colletotrichum lindemuthianum*), angular leaf spot (*Phaeoisariopsis griseola*), bean rust (*Uromyces appendiculatus)* and root rots (*Fusarium* spp., *Pythium* spp. *Macrophomina* sp. and *Rhizoctonia* sp.) while the major bacterial diseases are common bacterial blight (*Xanthomonas axonopodis* p.v. *phaseoli*) and halo blight (*Pseudomonas syringae* p.v. *phaseolica*). The major viral diseases include bean common mosaic virus (BCMV), *b*ean yellow mosaic virus (BYMV) and cucumber mosaic virus (CMV) [21] [22]. The objective of this study was therefore to assess the contribution of seed quality to the occurrence of fungal and bacterial diseases of common bean in western Kenya.

2. Materials and Methods

2.1. Description of the Study Area and Collection of Bean Seed Samples

Sampling of bean seeds from 110 farmers was carried out during the short rains cropping season of 2013 between October and December in different regions in the following six agro-ecological zones (AEZ) spread across seven Counties in western Kenya: Busia County (LM2, LM3), Bungoma County (LM2), Homabay County (LM1, LM2), Migori County (LM1), Nandi County (LH1, UM1), Siaya County (LM4) and Vihiga County (UM1) (Table 1). The regions covered in each AEZ were: Butula and Rongo (LM1), Busia and Rangwe (LM2), Teso north (LM 3), Bondo (LM4), Nandi south (LH1) and Vihiga (UM1). The study areas were selected based on intensity of legume production in the region. Approximately 0.5kg of common bean seed sample was collected from each of the 110 farmers. Ten seed samples, five from farmers participating in legume up-scaling projects and another five from non-participating farmers, were collected from each region. However, from Bondo, Nandi south and Vihiga where bean production was more intense, 20 samples were collected from each of the regions. The samples were stored at ambient temperature (23 ± 2°C) until laboratory analysis.

Table 1. *Characteristics of the agro-ecological zones where common bean seeds were sampled.*

AEZ	Altitude (m asl)	Annual rainfall (mm)	Average annual temperature (°C)	Description characteristics
LM1	1350 - 1500	1600 - 1800	21.1 - 22.0	Sugarcane zone
LM2	1350 - 1550	1350 - 1650	20.9 - 22.0	Marginal sugarcane zone
LM3	1200 - 1400	1200 - 1450	21.6 - 22.4	Cotton zone
LM4	1135 - 1200	600 - 1100	22.3 - 22.7	Maize, cotton, sisal
UM1	1500 - 2000	1540 - 1800	18.0 - 21.0	Coffee-tea zone, tea, maize
LH1	1950 - 2400	1600 - 2000	15.2 - 18.0	Tea-dairy zone

LM1 - low midland zone 1; LM2 - low midland zone 2; LM3 - low midland zone 3; LM4 - low midland zone 4; LH1 - low highland zone 1; UM1 - upper midland zone 1.
Source: Jaetzold *et al*., [23]

2.2. Determination of Physical and Varietal Purity of Bean Seeds

The bean seeds were physically examined to determine the physical composition and quality of the seeds following the procedure described by the International Seed Testing Association [24]. The seed samples were subjected to physical purity analysis to determine varietal purity, discoloration, presence of inert materials and weed seeds. Three replicates of 100g of each of the seed samples were separated using a knife blade on a purity board under good lighting into pure seeds, other crop seeds, other bean variety seeds, insect damaged seeds, weed seeds, discolored and shriveled seeds, and inert material (soil particles, stones and chaff). The different fractions were individually weighed and the percentage of each proportion determined.

2.3. Determination of Germination and Infection of Bean Seeds

Germination test was carried out following the procedure described by ISTA [24]. Three replicates of 100 seeds each were subjected to germination test. Three layers of sterile paper towels were wetted with sterile distilled water and five rows, each of ten seeds taken at random from a seed sample and placed evenly on the wet paper towels. Two layers of sterile paper towels were placed above the seeds, wet with sterile water and carefully rolled up. The rolled up sterile wet paper towels were incubated under humid conditions for 5 - 7 days. The test was carried out in triplicate. Data on the number of germinated seeds, normal seedlings, abnormal seedlings, mouldy seeds, dead seeds and seedlings showing infection was taken [24].

2.4. Determination of Bacterial Infection of Bean Seeds

Bacterial infection of bean seeds was determined by the dilution plate technique following procedures described by ISTA [25]. From each seed sample, 50g was extracted by suspending in 8.5% sterile saline solution containing 0.02% Tween 20 for 16-18 h at 5°C on a mechanical shaker (ROCKER 2D digital shaker, 0004003000, China). The saline solution was prepared by dissolving 8.5g sodium chloride (NaCl) in 1000mL distilled water and 0.2mL Tween 20 added. The solution was autoclaved for 15 minutes at 121°C and 15psi.

The number of seeds in 50g of seed was counted and the thousand seed weight (TSW) calculated as follows:

$$\text{Thousand seed weight (TSW)} = \left(\frac{\text{weight of seeds in 50g}}{\text{Number of seeds in 50g}}\right) \text{x}1000$$

The volume of saline used to extract bacteria from the seeds was equivalent to 1.0 x TSW (g). The extract was subjected to a 10-fold dilution series in sterile saline up to 10^2. Each dilution was plated in molten nutrient agar by pipetting 100µL of the extract onto sterile Petri dishes and then mixing with approximately 20mL of sterile molten nutrient agar cooled to 45°C. The plates were incubated at 28°C in an inverted position for 48 hours. The number of colonies typical of *Xanthomonas campestris* p.v. *phaseoli* and *Pseudomonas savastanoi* p.v. *phaseolicola* were counted for each dilution. The number of colony forming units (CFU) for each pathogen was calculated by multiplying the number of colonies by the dilution factor. The number of CFU per seed was calculated by dividing the calculated CFU by the number of seeds in 50g. Pure cultures of the resulting bacteria were prepared by sub-culturing single colonies on nutrient agar and identification was based on cultural characteristics (yellow mucoid convex colonies surrounded by a zone of hydrolysis characteristic of common bacterial blight pathogen (*Xanthomonas campestris* p.v. *phaseoli)* and cream colored colonies characteristic of halo blight pathogen (*Pseudomonas savastanoi* p.v. *phaseolicola*) [26]. Pathogenicity on susceptible bean seedlings was also carried out and characteristic symptoms of the pathogens observed.

2.5. Determination of Fungal Infection of the Bean Seeds

Fungal infection of bean seeds was determined by agar plate method [24], modified by amending the agar medium with 0.05g/L streptomycin sulphate and 13.45g/L sodium chloride to suppress growth of bacteria and seed germination, respectively [27]. Seeds were surface sterilized in 1.3% sodium hypochlorite for 3 minutes, rinsed in three changes of sterile distilled water and blot dried on sterile paper towel. Five seeds were plated on each plate containing amended potato dextrose agar medium. For each seed sample, fifteen seeds were plated and the plates incubated for 5-14 days at 22°C. The plates were examined for characteristic fungal colonies and the number of seeds infected with each fungal pathogen type was counted and the results expressed as a percentage of total seeds plated. Each fungal type isolated was sub-cultured on potato dextrose agar and the fungi were identified using morphological and cultural characteristics and conducting pathogenicity test on susceptible bean seedlings of the KK8 bean variety [28].

2.6. Data Analysis

All data were subjected to analysis of variance (ANOVA) using the PROC ANOVA procedure of Genstat version 15. Percentage data that were not normally distributed were transformed using arcsine transformation before analysis. Data on bacterial population was transformed to $\log_{10}$ (X+1) before analysis [29]. Differences among the treatments were compared using Tukey's test at 5% probability level.

3. Results

3.1. Purity and Germination of Bean Seeds

There was no significant ($P \geq 0.05$) difference in seed purity and germination rate between samples collected from farmers participating in legume up-scaling projects and non-participating farmers (Table 2). The mean purity of bean seed samples from the two categories of farmers was 74.1%. Seeds sampled from Busia (LM2) and Bondo (LM4) regions had the highest percentage of pure seeds while samples from Nandi south region (LH1) had the lowest with a correspondingly high proportion (15.8%) of discolored and shriveled seeds. However, there was a significant ($P \leq 0.05$) variation in the proportion of discolored/shriveled seeds among participating and non-participating farmers in Busia (LM2), Rangwe (LM2), Butula (LM1) and Nandi south (LH1) regions. The mean germination percentage for the two categories of farmers was 95.8%.

Table 2. *Percentage purity, germination and infection of common bean seeds collected from participating and non-participating farmers in legume up-scaling projects in various agro-ecological zones in western Kenya.*

AEZ	Region	Purity		Shriveled/ discolored		Germination		Infected seedlings	
Participating farmers									
LH1	Nandi south	62.9	fg	16.5	ab	92.5	b	8.6	ab
LM1	Butula	71.4	cde	13.2	bc	95.7	ab	10.6	a
LM1	Rongo	81.3	ab	8.7	ef	96.3	ab	9.5	ab
LM2	Busia	82.2	ab	6.8	ef	94.0	a	4.3	def
LM2	Rangwe	82.8	ab	12.3	cd	96.5	ab	2.7	f
LM3	Teso North	69.5	def	19.9	a	97.1	a	3.6	def

AEZ	Region	Purity		Shriveled/ discolored		Germination		Infected seedlings	
LM4	Bondo	86.9	a	7.7	ef	95.1	ab	11.2	ab
UM1	Sabatia	66.8	efg	12.7	bc	95.1	ab	5.8	cdef
Mean		75.5		12.2		95.3		7.0	
CV (%)		5.5		3.8		1.7		52.9	
Non-Participating farmers									
LH1	Nandi South	58.2	g	15.1	abc	96.9	a	5.7	bcde
LM1	Butula	78.3	abc	8.5	ef	95.2	ab	10.3	abc
LM1	Rongo	73.2	bcd	15.0	abc	96.7	a	7.0	abcde
LM2	Busia	84.6	a	5.0	f	97.7	a	3.1	ef
LM2	Rangwe	74.5	bcd	15.9	abc	94.0	ab	2.4	a
LM3	Teso north	66.0	efg	16.6	ab	93.9	ab	10.6	ab
LM4	Bondo	85.2	a	8.4	de	94.7	ab	8.1	abcd
UM1	Sabatia	61.3	g	12.1	bc	96.4	a	2.6	f
Mean		72.7		12.1		95.7		6.2	
CV (%)		5.5		3.8		1.7		52.9	

AEZ – agro-ecological zone; LM1 – lower midland zone 1; LM2 – lower midland zone 2; LM3 – lower midland zone 3; LM4 – lower midland zone 4; UM1 – upper midland zone 1; LH1 – lower highland zone 1; CV - Coefficient of variation; Means followed by the same letter(s) within columns are not significantly different.

3.2. Quality of Different Farm Saved Bean Variety Seeds

There were 13 different types of common bean varieties sampled from different regions in six agro-ecological zones in western Kenya (Table 5). Rose coco, KK8 and Zaire were the most common bean varieties grown by the farmers and accounted for 23%, 22% and 11%, respectively, of the samples. Seeds of varieties KK15, KK8 and GLP2 had the lowest levels of purity while varieties KK8 and KATX56 had the highest percentage of shriveled/discolored seeds of up to 16.8% and 17.2%, respectively. Variety KK8 also had the highest bacterial pathogen inoculum level of up to 1480 CFU/seed of *Pseudomonas savastanoi* pv. *phaseolicola* as well as the highest percentage of seeds infected with bean anthrachnose (*Colletotrichum lindemuthianum*). Seeds of variety GLP2 were not infected with halo blight (*Pseudomonas savastanoi* p.v. *phaseolicola*). However, seeds of variety KATB1 had the highest inoculum level of *Xanthomonas campestris* p.v. *phaseoli* of up to 789 CFU/seed while seeds of variety GLP2 and KK071 were not infected with the pathogen.

3.3. Bacterial Infection of Bean Seeds

Pseudomonas savastanoi p.v. *phaseolicola* (halo blight) and *Xanthomonas campestris* p.v. *phaseoli* (common bacterial blight) were the main bacterial pathogens isolated from the bean seed samples (Table 4). Seeds from farmers participating in legume up-scaling projects had lower levels of infection with *Pseudomonas savastanoi* p.v. *phaseolicola* and *Xanthomonas campestris* p.v. *phaseoli* at 747 and 283 CFU/seed, respectively, compared to samples from the non-participating farmers which had 1241 and 151 CFU/seed, respectively. Most of the seed samples had bacterial inoculum of 100 – 500 CFU/seed accounting for 23.5% of the samples for *Pseudomonas savastanoi* p.v. *phaseolicola* and 22.5% for *Xanthomonas campestris* p.v. *phaseoli*. All the seed samples from Bondo (LM4) were infected with *Pseudomonas savastanoi* p.v. *phaseolicola* while a third of the samples from Rangwe (LM2) had a high infection of over 3000 CFU/seed (Table 5). Samples from Butula (LM1) had the lowest seed infection with *Xanthomonas campestris* p.v. *phaseoli* but the bacterium was most prevalent in Bondo region. Only seeds from Sabatia region had high population (>2000 CFU/seed) of *Xanthomonas campestris* p.v. *phaseoli*.

Table 3. *Mean quality parameters for different varieties of common bean seed samples collected from farmers in western Kenya.*

Local name	Trade name	% of samples	Purity (%)	Discolored / shriveled (%)	Germination (%)	Halo blight (CFU/seed)	CBB (CFU/seed)	Anthracnose infected seeds (%)
Rose coco	Rose coco	23	70.0	12.0	94.0	1196	229	0.0
KK8	KK8	22	62.7	16.8	95.0	1480	213	2.4
Zaire	Zaire	11	88.2	8.0	97.0	437	30	1.2
Wairimu	Wairimu	8	79.0	12.9	93.0	175	111	0.8
KK15	KK15	5	58.0	8.3	96.0	398	489	0.0
Punda	Jessica	5	69.6	13.6	97.0	396	329	0.0
Yellow green	KATB1	3	85.2	5.2	95.0	1148	789	0.0
KATX56	KATX56	2	76.8	17.2	94.0	900	203	0.0
KK071	KK071	2	84.4	13.4	98.0	1028	0	0.0
Yellow beans	Small Yellow	2	74.9	12.4	99.0	54	52	1.7
Pocho	Canadian Wonder	2	85.5	7.2	96.0	544	15	0.0
GLP2	GLP2	1	65.8	13.5	99.0	0	0	0.0
Local varieties	Landrace	15	75.0	12.2	96.0	1447	199	1.9

CBB - Common bacterial blight; CFU – colony forming units

Table 4. *Level of seed contamination (CFU/seed) with Pseudomonas savastanoi p.v. phaseolicola and Xanthomonas campestris p.v. phaseoli in bean seed samples collected from farmers either participating or not participating in legume technologies up-scaling projects in different agro-ecological zones and regions in western Kenya.*

AEZ	Region	Participating farmers		Non-participating farmers	
		PSP	XAP	PSP	XAP
LH1	Nandi South	215 ef	242 ab	608 def	43 de
LM1	Butula	486 def	4 e	655 cde	51 de
LM1	Rongo	1203 bc	555 ab	567 cdef	306 bc
LM2	Busia	130 f	249 ab	500 cdef	317 bc
LM2	Rangwe	917 bcde	305 ab	1882 b	281 bcd
LM3	Teso North	708 def	355 bc	3603 a	17 e
LM4	Bondo	542 cdef	127 bcd	478 cdef	121 bcd
UM1	Sabatia	1775 bcd	428 bc	1634 b	69 cde
Mean		747	283	1241	151
CV (%)		62.7	96.4	62.7	96.4

AEZ – agro-ecological zone; LM1 – lower midland zone 1; LM2 – lower midland zone 2; LM3 – lower midland zone 3; LM4 – lower midland zone 4; UM1 – upper midland zone 1; LH1 – lower highland zone 1; CV - Coefficient of variation;. Means followed by the same letter(s) within columns are not significantly different; PSP- *Pseudomonas savastanoi* pv. *phaseolicola;* XAP - *Xanthomonas campestris* pv. *phaseoli.*

Table 5. *Percentage contamination (CFU/seed) of bean seed samples from different agro-ecological zones with Pseudomonas savastanoi p.v. phaseolicola and Xanthomonas axonopodis p.v. phaseolicola.*

AEZ	Region	Range of seed infection (CFU/seed)						
		Not infected	0 - 100	100-500	500-1000	1000 -2000	2000 -3000	>3000
Pseudomonas savastanoi p.v. *phaseolicola*								
LM1	Rongo	10.0	20.0	10.0	20.0	30.0	0.0	10.0
LM1	Butula	42.9	0.0	0.0	42.9	14.2	0.0	0.0
LM2	Rangwe	22.2	11.1	22.2	0.0	11.1	0.0	33.3
LM2	Busia	40.0	0.0	60.0	0.0	0.0	0.0	0.0
LM3	Teso North	18.2	16.7	0.0	0.0	9.1	18.2	16.7
LM4	Bondo	0.0	20.0	45.0	15.0	10.0	10.0	0.0
LH1	Nandi south	40.0	15.0	35.0	0.0	5.0	0.0	5.0
UM1	Sabatia	31.6	10.5	15.8	0.0	10.5	15.8	15.8
Mean		25.6	11.7	23.5	9.7	11.2	5.5	10.1
Xanthomonas axonopodis p.v. *phaseolicola*								
LM1	Rongo	40.0	10.0	20.0	10.0	20.0	0.0	0.0
LM1	Butula	85.7	0.0	14.3	0.0	0.0	0.0	0.0
LM2	Rangwe	44.4	22.2	11.1	22.2	0.0	0.0	0.0
LM2	Busia	20.0	20.0	40.0	20.0	0.0	0.0	0.0
LM3	Teso North	63.6	18.2	9.1	0.0	9.1	0.0	0.0
LM4	Bondo	20.0	35.0	40.0	5.0	0.0	0.0	0.0
LH1	Nandi south	50.0	5.0	35.0	10.0	0.0	0.0	0.0
UM1	Sabatia	57.9	21.1	10.5	0.0	5.3	5.3	0.0
Mean		47.7	16.4	22.5	8.4	4.3	0.7	0.0

AEZ – agro-ecological zone; LM1 – lower midland zone 1; LM2 – lower midland zone 2; LM3 – lower midland zone 3; LM4 – lower midland zone 4; UM1 – upper midland zone 1; LH1 – lower highland zone 1; CFU - colony forming units.

3.4. Incidence of Fungal Pathogens in Bean Seeds

Incidence of fungal pathogens in the bean seed samples significantly ($p \leq 0.05$) varied among the agro-ecological zones and regions (Table 6). Rangwe and Teso North had the highest percentage of infected seeds among participating farmers while Rongo and Teso North had the highest among non-participating farmers. Overall, there was a high percentage of infected seeds among farmers who were not participating in legume technologies up-scaling projects. The fungal pathogens isolated in decreasing incidence were: *Fusarium solani*, *Macrophomina* spp., *Rhizoctonia solani*, *Colletotrichum lindemuthianum* and *Phythium* spp. Overall, there was no significant ($P \leq 0.05$) difference in fungal infection between samples from farmers participating and those not participating in legume technologies up-scaling projects (Table 6). Seeds of variety KK8 had the highest infection with the anthrachnose (*Colletotrichum lindemuthianum* (Mean incidence = 2.4%) (Table 6).

Table 6. *Incidence (%) of fungal infection of common bean seeds collected from participating and non-participating farmers in different regions in western Kenya.*

AEZ	Region	Infected seeds (%)	*Fusarium*	*Colletotrichum*	*Rhizoctonia*	*Macrophomina*	*Pythium*
Participating farmers							
LH1	Nandi South	28.0 bcde	17.3 bcde	2.7 bc	4.7 ab	0.0 b	2.7 b
LM1	Butula	29.3 ab	26.5 ab	9.9 a	0.1 b	0.0 b	0.0 b
	Rongo	29.3 bcdef	24.0 ab	9.9 a	2.7 ab	0.0 b	0.1 b
LM2	Busia	13.3 h	13.3 bcde	0.0 c	0.0 b	0.0 b	0.0 b
	Rangwe	34.7 abcd	16.0 bcde	0.0 c	13.3 a	6.7 b	0.0 b
LM3	Teso North	33.3 bcde	25.6 abc	2.2 bc	0.0 b	0.0 b	0.0 b
LM4	Bondo	27.3 bcd	22.0 bcde	0.0 c	2.7 b	3.3 b	2.0 b
UM1	Sabatia	18.0 efgh	8.7 de	0.0 c	0.7 b	3.3 b	3.3 ab
Mean		27.6	19.2	1.8	3.0	1.7	1.0
Non-participating farmers							
LH1	Nandi South	30.0 bcde	20.7 bcde	2.0 bc	2.7 b	0.0 b	2.0 b
LM1	Butula	14.7 gh	10.7 cde	1.3 bc	2.7 bc	0.0 b	0.0 b
	Rongo	38.7 ab	26.7 abcd	4.0 bc	2.7 bc	0.0 b	5.3 a
LM2	Busia	32.2 abc	16.7 ab	0.2 c	0.0 b	31.6 a	0.0 b
	Rangwe	18.3 defgh	16.7 bcde	0.0 c	0.5 b	0.0 b	0.4 b
LM3	Teso North	53.3 a	37.3 a	4.0 c	1.3 b	46.7 a	0.0 b
LM4	Bondo	22.7 cdefgh	21.3 abcde	0.0 c	0.7 b	0.0 b	0.0 b
UM1	Sabatia	14.8 fgh	8.9 e	1.5 c	3.0 ab	0.0 b	0.0 b
Mean		28.1	20.9	1.6	1.7	9.8	1.0

AEZ – agro-ecological zone; LM1 – lower midland zone 1; LM2 – lower midland zone 2; LM3 – lower midland zone 3; LM4 – lower midland zone 4; UM1 – upper midland zone 1; LH1 – lower highland zone 1; CV - Coefficient of variation; Means followed by the same letter(s) within columns are not significantly different.

4. Discussion

Germination of common bean seeds was not influenced by the region or agro-ecological zone where the samples were collected. Germination rate was high and met the minimum germination standard of 80% [30]. This implies that farmers in western Kenya employed good pre and post-harvest handling practices like harvesting, threshing and storage, which resulted in high germination rate. In addition, it could have been that the seeds were freshly harvested and therefore had not been exposed to storage pests and pathogens which could lower the germination rate. There was however a significant variation in the number of germinated seedlings showing infection, discolored and shriveled seeds, and pure seeds from different regions and agro-ecological zones. Overall, the percentage of pure seeds was below the minimum standard set by the International Seed Testing Association of 95%. This observation was consistent with the findings by Oshone *et al*. [31], who reported variation in the proportion of pure seeds in common bean samples obtained from small-scale farmers from different agro-ecological zones in Ethiopia. The low percentage of seed purity can be attributed to lack of sorting, lack of use clean certified seeds by farmers or ignorance by the farmers in maintaining purity of the seeds.

The variation in seed discoloration and shriveling could be attributed to high prevalence of seed borne bean diseases in some agro-ecological zones compared to others probably due to weather conditions which favor disease development in a particular zone [13]. Seed discoloration and shriveling is an indicator of infection caused by the presence of inocula of seed borne pathogens present in the seeds [30] [12]. Mouldy and dead seeds together with diseased seedlings showing symptoms of infection can also be directly associated with the level of pathogen inoculum on the surface of the seed [12].

There was significant variation in the percentage of mouldy seeds, dead seeds and germinated seedlings showing infection in samples from the various agro-ecological zones. Seed samples from low highland zone one (LH1) and low midland zone three (LM3) had the highest percentage of samples with mouldy and dead seeds among participating and non-participating farmers, respectively. Infected seeds are usually the source of primary infection especially for bacterial diseases [32]. Bean seed production is affected by fungal and bacterial diseases which are seed borne. Healthy seed is therefore the most important agricultural input affecting yield levels of the crop [4].

There were 13 different trade names of bean varieties including landraces of the common bean seed samples collected from farmers in different regions and agro-ecological zones in western Kenya. KK8 and Rose coco were the most popular varieties among the farmers. The two varieties have been reported to be the most popular with farmers and consumers in Kenya because of their size and color [9]. Certain common bean varieties were only grown in specific regions. For instance, Punda (synonym Jessica) was only grown in Siaya and Bondo regions while the small yellow variety was only grown in Nandi south region. Differences in popularity of a variety could have been due to

regional preferences of food source and also market value of the bean variety in that region [3] [33] as well as variability in climatic and agronomic conditions [33]. Local varieties were also common among the farmers accounting for 15% of the bean seed samples collected. A previous study by Spilsbury *et al*. (10) reported that adoption of new bean varieties was low due to low market demand and lack of variety attributes demanded by the consumers. According to Wagara and Kimani [1], local varieties should therefore be embraced by seed companies and their good traits ought to be used to improve the preferred but susceptible varieties.

Various seed borne bacterial and fungal pathogens were isolated from the bean seeds sampled from farmers in different regions and agro-ecological zones. Oshone *et al*. [31] also isolated bacterial and fungal pathogens from bean seed samples from small-holder farmers in eastern Ethiopia. In the current study, *Xanthomonas campestris* pv. *phaseoli* and *Pseudomonas savastanoi* pv. *phaseolicola* were the major bacteria pathogens isolated from bean seeds. However, there was variation in the incidence of the two bacteria in different bean varieties with *Pseudomonas savastanoi* pv. *phaseolicola* being isolated in high frequency from KK8 and landrace varieties while *Xanthomonas campestris* pv. *phaseoli* was isolated in high frequency from KATB1 variety. The relatively high incidence of the two pathogens could be attributed to build up of pathogen inocula in the seeds due to planting of recycled farm saved seeds by the farmers. Certified seeds harbour less inocula of *Xanthomonas campestris* pv. *phaseoli* than farm saved seeds [17]. Similar studies by Makelo [13] and Gichangi *et al*. [34] also concluded that most small scale farmers in Kenya planted uncertified seeds saved from previous harvests, borrowed among themselves or purchased from local markets.

Xanthomonas campestris pv. *phaseoli*, the causative agent of common bacterial blight, is a major constraint in bean production in many countries and causes severe disease in regions characterized by high rainfall, humidity and temperature (25 - 35°C) with optimum development of the disease occurring at 28°C [35] [36]. Seeds which are the primary source of inocula for bacterial diseases [32], could therefore have been the main source of inocula for these pathogens. Survival of pathogens in soil or plant debris is influenced by geographical location, climate, cultural practices, host genotypes and pathogen strains [17].

Different fungal pathogens including *Fusarium solani, Rhizoctonia solani, Colletotrichum lindemuthianum, Macrophomina* and *Pythium* spp. were also isolated from the common bean seeds. *Fusarium solani* was the most common fungi isolated in high incidence in majority of the seed samples from different regions and agro-ecological zones. Diversity of fungal pathogens in bean seeds has also been reported in Zimbabwe [12]. Bean seeds in western Kenya were therefore a source of bacterial and fungal pathogens. Narayan and Ayodhya [37] concluded that bean seed production is affected by seed borne fungal and bacterial diseases. However, there was no significant variation in percentage of seeds infected by a particular fungus in samples collected from farmers participating in legume technologies up-scaling projects and non-participating farmers. It is therefore probable that farmers participating in the legume technologies up-scaling projects in western Kenya were not applying the knowledge gained as recommended.

5. Conclusion

Bean seeds sampled from western Kenya were infected by bacterial and fungal pathogens implying that the farm saved seeds planted by the farmers in subsequent seasons were unhealthy and could therefore have been the primary source of inocula for diseases. Bean farmers in western Kenya should therefore be trained on good agronomic practices like use of certified seeds instead of recycling farm-saved seeds which leads to accumulation of disease inocula and consequently higher disease incidence. Further research is recommended to determine suitability of common bean varieties to specific agro-ecological zones.

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