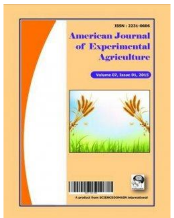

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Seed Maize (*Zea mays* L.) Quality Factors from Five Agro-ecological Zones in Ghana and Their Impact on Growth and Grain Yield

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This experiment was conducted in the field and laboratory to evaluate the impact of seed quality attributes on emergence, germination, growth and grain yield. Obatanpa (local maize) seeds produced under certified and farmer-saved seeds in five agro-ecological zones were collected for five agro-ecological zones were used. After the land was slashed by cutlass, ploughed and harrowed the experiment was done 2x5 factorial randomized complete block design with four replications at the spacing of 80x40 cm with three seeds per hill one seedling thinned later two weeks after planting. Seed quality parameters moisture content, purity analysis, germination, and fungus associations with the seeds were determined in the Pathology lab, Department of Crop and Soil sciences using randomized complete design (RCD) in three replications. Results from tests in the laboratory showed that seed moisture content, purity, germination, and fungus associations with the seeds were impact on emergence, growth and yields of maize. The certified seed system gave higher yields than farmer-saved seeds across the agro-ecological zones.

Keywords: Impact; seed quality; germination; growth and grain yield.

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1. INTRODUCTION

Maize (*Zea mays L.*) is one of the most important food crops world-wide and has the highest average yield per hectare. It is grown in most parts of the world over a wide range of environmental conditions[1]. Maize is the most important cereal food crop people in Africa [2]. It is the largest source of calories, followed by cassava and accounted for 22 to 25% of starchy diet consumption in the region [3]. Maize grain has greater nutritional value as it contains approximately 72% starch, 10% protein, 4% fat, 3% sugar, and 4% ash, supplying an energy density of 365 kcal/100 g. The world's average yield of maize, which is about 5.2 t/ha [4], and in Africa average maize yields are below 2 t/ha significantly below the US about 10 t/ha and South Africa averages 4.2 t/ha. The crop requires an average daily temperature of at least 20°C for adequate growth and development; the optimum temperature for growth and development ranges between 25-30°C; temperature above 35°C reduces yields [5]. The most suitable soil for maize is one with a good effective depth, favourable morphological properties, good internal drainage, and an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties. In Africa, almost half of the population is being considered for food insurance. To achieve food security, Africa must be able to grow sufficient food crops. Since most developing countries rely on their agricultural production for their food security, it follows that insecurity is mainly due to deficient agricultural production and low productivity. The main reason for this situation is the use of farmer-saved seeds and traditional farming. Most African countries still mainly depend on farmer-saved seeds in which about 80-90% of seeds come from these sectors.

Certified seeds are seeds that have passed field inspection and seed testing standards for varietal purity, which is the absence of certain other crop seeds, and certain diseases. In addition, most certified seed has been treated with a fungicide to control seed-borne and seedling diseases. In most cases, certified seed must exceed 90% germination [6]. However, farmer-saved seeds are seeds produced traditionally by farmers from their harvest to sow the following year [7]. The seeds are not inspected by public or private institutions [8]. Maize production in sub-Saharan Africa (SSA) is dominated by small-scale farmers who have land holdings from 0.3 to 0.5 ha [9]. The population of Ghana is around 24 million with 51% females and 49% males[10], who mainly live in the rural area. The agricultural sector provides about 60% of export earnings and economically supports 80% of the total population through farming, distribution of farm produce and provision of other related services [11]. Maize is the main staple food and represents the second largest commodity crop for Ghana after cocoa. Maize is cultivated throughout the country over a wide range of soils and ecological conditions. However, Guinea Savannah, Coastal Savannah, Transitional, Rainforest, and Semi-deciduous zones are the five major maize growing areas in Ghana. Around 70% of maize growers are smallholder farms [12]. An estimated 85-90% of the total maize seeds used by farmers in Ghana is produced by farmers themselves on their farms'. However, this system of seed production does not follow seed production procedures such as varietal purity, seed inspection, certification, moisture content, and appropriate storage conditions [13]. The productivity of maize in Ghana is still low, with an average of approximately 1.5 t/ha compared to the potential of 5.5 t/ha. Several reports have indicated that, the farmer-saved seeds do not achieve seed quality parameters [14,15]. However, limited research work has been done on maize seed quality and its effect on grain yield. Therefore, using good quality seeds can increase the yield potential of a crop and thus, it is the most an essential input to develop an agricultural product for a country such as Ghana. The research was carried out in order to evaluate the impact of seed quality parameters on germination, emergence, growth and grain yield of maize.

2. MATERIALS AND METHODS

The research had two parts; laboratory and field test. Seed purity analysis, germination tests, and seed borne fungi associated with the seeds were conducted at the Plant Pathology laboratory at the Crop and Soil Sciences Department (KNUST) during 2015 minor season. This investigation evaluated physical and physiological seed quality components of 30 seed lots of obatanpa maize variety collected from certified and farmer-saved seed systems from five agro-ecological zones of Ghana in June 2015. The five ecological zones were; Transitional, Guinea Savannah, Semi-Deciduous, Coastal Savannah, and Rainforest zones. From each ecological zone, three locations (villages) known for the production of maize were selected. From each location three to six farmers were selected and maize seed was collected from each. The seed samples were collected after the seeds had been harvested and processed in the same season of certified and farmer-saved seeds. In each zone three seed samples, one kilogram of each was taken from each of the seed growers. Each of the seed samples was labeled as name of the farmer, ecological zone, location, seed type, and date of collection.

2.1 Laboratory Analysis

2.1.1 Determination of maize seed moisture content

The moisture contents of the collected maize seed samples were determined using JOHN DEERE automatic moisture tester at the Insect laboratory, Department of Crop and Soil Sciences, KUNST, Kumasi. Three readings per sample were taken and the means were calculated.

2.1.2 Seed purity analysis

A sub-sample of the 1000 g maize seed of each sample was hands by visual examination into the following components; pure seed, broken seed, shriveled seed, discolored seed, and pest damaged seeds. The components were weighed using electronic weighing balance and their percentages by wet- weight bases calculated.

2.1.3 Isolation and identification of fungi associated with the maize seeds

One hundred maize seeds were selected at random from each sample of certified and farmer-saved seed systems and disinfected separately with 10% commercial bleach (1% chlorine) to get rid of superficially-borne organisms. Ten seeds were then plated on sterlized Petri dishes half-filled with PDA medium. This was done in the lamina flow to prevent contamination. Petri dishes were then set on a clean working table sterilized with ethanol in the transfer chamber in the Plant Pathology lab. After seven days fungal growth on maize samples was examined and identified under the compound microscope. The fungi identification was done with the help of identification manual [16].

2.1.4 Identification of location of fungi in maize seed

Randomly, 20 seeds were selected from pure seeds soaked in water for 24 h and then separated into embryos, endosperms, and cotyledons from each sample. The separated components were plated separately on PDA Petri dishes. After seven days, fungal growth on each part of maize seed samples was examined and identified as described above.

2.1.5 Germination test of maize seeds

Four hundred maize seeds were selected at random and counted from the well-mixed pure seed from certified and farmer-saved seeds. Trays filled with moistened sterilized river sand were used to sow the maize seed. Sown seeds were then left at the plant house for seven days after which seedlings were counted and sorted out into normal seedlings, abnormal seedlings, and dead seeds. Randomized complete design with four replications was used.

2.1.6 Seedling growth rate test

From each sample of pure seeds 25 seeds were selected and placed on sterilized filter paper moistened with 4ml distilled water inside a sterilized Petri dish. After 5-10, days counting and removal of the germinated seeds were done every 12 h. Germination was considered when the radical protrudes by 2-4 mm. Germination index [17] was calculated using $\sum(t*n)/\sum n$ where, n is the number of germinated seeds and t, the number of hours from the beginning of the germination test.

2.2 Field Trial Evaluations

2.2.1 Seedling emergence

Seedling emergences at two weeks after planting was counted form each plot and the percentage of each was calculated.

2.2.2 Growth analysis

Growth analysis at 20, 40, 60, 80 and 100 days after planting was recorded by measuring plant height (cm) and girth (cm) of randomly selected six plants from each plot.

2.2.3 Plant height

Plant height was measured using a measuring tape from the soil surface to the base of the tassel of six randomly taken plants from each plot at physiological maturity stage.

2.2.4 Number of kernels per ear

Kernels per ear was counted as the average number of kernels of six randomly taken ears from the central rows.

2.2.5 One thousand seeds weight

It was determined from 1000 seeds taken randomly from each plot and weighed (g) using sensitive weighing balance.

2.2.6 Grain yield (kg)

Grain yield per plot was measured using electronic balance and then adjusted to 12.5% moisture and converted to hectare basis.

3. RESULTS AND DISCUSSION

3.1 Moisture content of the maize seeds

The mean moisture content of seed samples from farmer-saved seed grower system *was* significantly ($p<0.05$) higher than seed samples from certified seed system across the ecological zones. However, there was no significant difference ($p>0.05$) within farmer-saved seed and certified seed grower systems throughout the zones. The highest moisture content was registered in farmer-saved seeds of Semi-deciduous (14.6%), followed by the Transitional (14.4%), and then Rainforest zones (14.3%). The lowest was recorded in Coastal Savannah and Guinea Savannah zones (14.1%) as presented in Fig. 1. The recorded difference may be come due to locations of production, climatic conditions, drying methods, storage conditions, and the duration of storage [17,18].

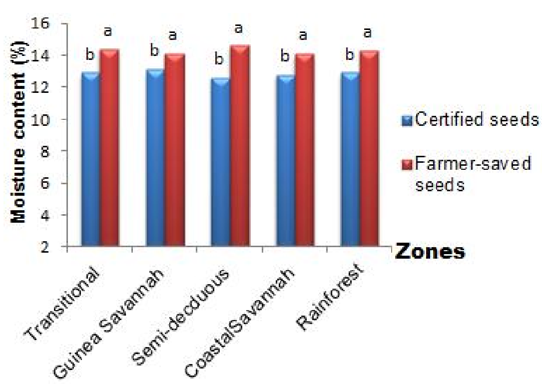

Fig. 1. Maize seed moisture contents from different zones

3.1.1 Seed purity analysis

Certified seed samples significantly ($p<0.05$) recorded the maximum seed purity values than farmer-saved seed samples across the study zones. The highest value was observed in Coastal Savannah Zone and the lowest was from Rainforest zone. Despite that, there was no significant difference ($p>0.05$) within certified seed systems across ecological zones and the same within farmer saved seeds but the seeds from Rainforest Zone was significantly different($p<0.05$) from them. Under certified seed system, the percentage purity were as follows the Coastal Savannah zone (95.10%), Semi-deciduous (94.57%), Transitional (94.53%), Guinea Savannah (94.13%), and Rainforest zones (93.73%) respectively. In farmer-saved seeds system the purity were, coastal Savannah (80.53%), Transitional (79.93%), Guinea Savannah (79.80%), Semi-deciduous (77.43%), and Coastal Savannah zones (74.4%) (Fig. 2).

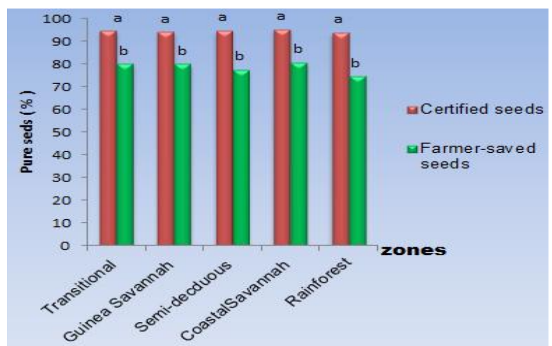

Fig. 2. Purity tests of certified and farmer-saved seeds from five agro-ecological zones of Ghana

3.1.2 Broken seeds

The maximum broken seed value (Fig. 3) was recorded under the farmer-saved seed systems across the agro-ecological zones. Although, certified seed system had significantly ($p<0.05$) lower broken seeds than farmer-saved seed systems across all zones there was no significant ($p>0.05$) variation within certified seed system across the zones. However, under farmer-saved seed, seeds from Transitional zone was significantly different ($p<0.05$) from Rainforest zone but similar to Coastal Savannah, Semi-deciduous, and Guinea Savannah zones.

3.1.3 Pest damaged seeds

There was no significance different ($p>0.05$) observed in pest damaged seeds under the certified seed grower systems of study zones. There was significant difference (p<0.05) across zones within the farmer-saved seeds. Rainforest zone recorded the highest value in pest damage seeds (6.0%) Fig. 4.

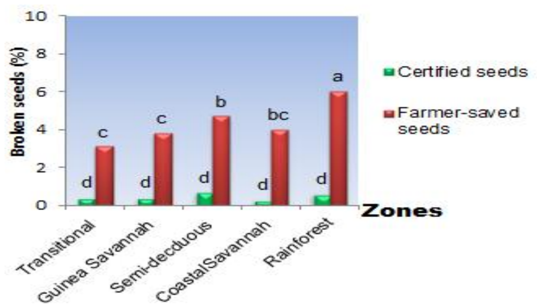

Fig. 3. Broken maize seeds under certified and farmer-saved seeds from different zones of Ghana

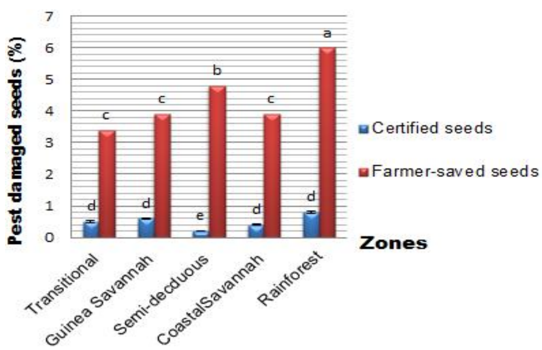

Fig. 4. Pest damaged maize seeds under certified and farmer-saved seeds from five agro-ecological zones of Ghana

The mean shriveled seed percent from certified grower system in Rainforest zone was significantly different (p<0.05) from Transitional, Guinea Savannah and Semi-deciduous zones but similar with Coastal Savannah, and Transitional zone that of farmer-saved seed (Fig. 5). There was significant difference (p<0.05) between certified and farmer-saved seeds across ecological zones. Delayed maturity due to environmental and disease stresses push the plant to early maturity and then causing shrivelled seeds [19].

3.2 Germination Tests

3.2.1 Normal seedlings

The mean normal seedling results out of four hundred (400) seeds from each sample was as follows, the Rainforest zone (85.2%), Guinea Savannah (84.9%), Transitional (84.2%), Coastal Savannah (83%), and Semi- deciduous zones (79.8%) Table 1. For the farmer-saved seed system, the Coastal Savannah zone produced the highest mean normal seedlings followed by Guinea Savannah, Transitional, Semi-deciduous, and Rain forest zones. There was Significant variation (p<0.05) between Certified and farmer-saved seeds across ecological zones (Table 1). According to Asfaw [20] seed quality is a right important factor that governs the early development and growth of agricultural crops. Sulewsk [21] also reported farmer-saved seeds recorded lower germination percentage as what was observed in the present study.

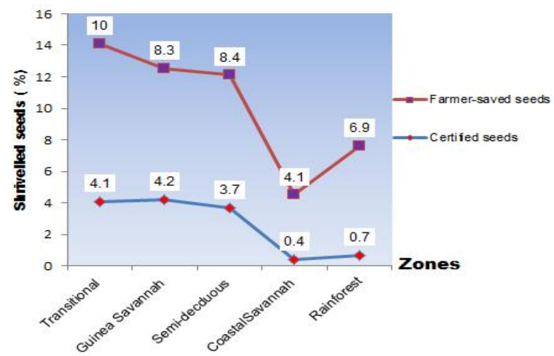

Fig. 5. Shrivelled maize seeds under certified and farmer-saved seeds from different zones of Ghana

3.2.2 Abnormal seedlings

The germination test showed that the farmer-saved seed system produced more abnormal seedlings than the certified seed system in all samples tested from all agro-ecological zones. There was significant difference (p<0.05) between certified and farmer-saved seeds systems across various zones. The highest values of abnormal seedlings were recorded in Semi-deciduous zone (20.2%), followed by Transitional (19.5%), Rainforest (19.4%), Guinea Savannah (18.9%) and then Coastal Savannah zones (17.9%). Under certified seed system, percent abnormal seedlings recorded were as follows; Semi-deciduous (13.4%), Costal Savannah (10.8%), Guinea Savannah (10.3%), Transitional (9.7%) and Rain Forest zone (9.6%) dead (Table 1). [22] reported that, 'germination and seedling vigor are severely affected if seed is stored at high temperature and relative humidity. According to [23] report mechanically damaged seed will result in seedlings that have no roots or shoots.

3.2.3 Dead seeds

The results in Table 1 indicate that, the farmer-saved seed system produced dead seeds than the certified seed system across the study zones. The value recorded in Guinea Savannah zone was lesser than Rainforest zone but similar with Semi-deciduous zone. There was significant difference (p<0.05) between certified and farmer-saved seeds across the ecological zones. Farmers do not store their seeds well and not treated; they may put them in polypropylene bags, jute sacks and hung on trees near their house. These practices expose the seeds to re-wetting, infested by pests and fungal diseases as a result the moisture contents increase and metabolic activities increase inside the seeds, the embryos die [24].

3.2.4 One hundred seed grain weight

The mean 100 seed grain weight under certified and farmers seed systems indicated that, there was significance difference (p<0.05) between the two seed grower systems across the agro-ecological zones. However, the farmer-saved seeds from the Transitional zone were the heaviest and followed by certified seeds from the same zone and the lowest value was recorded in Semi-deciduous farmer-saved seeds [22] (Table 1).

3.3 Fungi Associated with the Seeds

3.3.1 *Aspergillus flavus*

The incidence of *A. flavus* was recorded in all zones and in both seeds systems. *A. flavus* infection was generally higher in the farmer-saved seed system. The total value for the various zones showed that Guinea Savannah zone had the highest value (67%), followed by Coastal Savannah (60%), Semi-deciduous (57%), Transitional zone (53%), and Rainforest (30%) (Table 2). Farmers do not consider seed moisture content level during they are made harvesting. [25] showed that cracked seeds do not store as well as intact seeds and that fungi enter the seed through cracks in the seed coat.

3.3.2 *Aspergillus niger*

From the results (Table 2) that A: niger recorded the highest infection under certified seeds. The results were Rainforest zone (43%), Coastal Savannah (33%), Semi-deciduous (20%), Guinea Savannah (17%), and Transitional zones (10%). Exposure to increasing periods of high temperature during seed filling and high humidity can expose seeds for pathogen infections [26].

3.3.3 *Colletotrichum* sp

Colletotrichum species was also recorded in all zones and in both seed grower systems, but the highest infection was registered in the farmer saved- seed grower system (Table 2). Rainforest zone had the highest infection (23%) in farmer-saved seeds, followed by Guinea Savannah zone (17%). The Semi-deciduous, Coastal Savannah and Transitional zone recorded the same infection (13%) as indicated in Table 2.

3.3.4 *Penicillium sp*

This fungus was also recorded in both seed systems from all sampled zones, but the highest infection was observed in farmer-saved seed system. Infection in the Semi- deciduous was (33%), followed by the Coastal Savannah (10%), Transitional (10%), Rain forest (7%), and Guinea Savannah zones (3%) for farmer-saved seeds shown in (Table 2). Farmers do not harvest their maize at exact maturity time, this is also one factor to expose seeds for fungal development and then the fungi infected seeds become highly discolored [27].

3.3.5 *Curvularia* sp.

Curvurlaria species was recorded in the Transitional zone in both seed systems with 7% in certified seed system and 3% in the farmer-saved seed system. In the Semi-deciduous, Guinea Savannah and Coastal savannah zones it was found only on certified seed system. According to the test result indicated in Table 2, the following were recorded in Semi-deciduous (6%), Guinea Savannah (3%) and Coastal Savannah zones (3%). There is evidence that different environmental factors exposure on seeds during production can cause damage to seed parts as a results the variation in the incidence of fungi on seeds [28].

3.4 Growth and Yield Component Determinations

3.4.1 Seed emergence

The mean seed emergence after two weeks of planting, from five agro-ecological zones of Ghana planted in 2015 minor season indicated the seeds from certified seed growers had better

Table 1. Mean germination test of certified and farmer-saved seeds from five agro-ecological zones of Ghana

Ecological zones	Seed germination (%)						
	Types	NS	AS	DS	UG	HSWT(g)	GI
Transitional	CS	84.2a	9.7b	3.3c	2.6b	31.5ab	103a
	FS	63.8b	19.5a	9.3a	7.0a	34.4a	99.4a
Guinea Savannah	CS	84.9a	10.3b	3.0c	1.7b	27.1bc	92.9a
	FS	64.3b	18.9a	9.7a	7.2a	28.6bc	103.7a
Semi-deciduous	CS	79.8a	13.4b	4.7bc	2.3b	29.5ab	97.2a
	FS	61.6b	20.2a	9.7a	8.3a	23.7c	100.0a
Coastal Savannah	CS	83.0a	10.8b	4.1c	2.2b	27.5bc	97.6a
	FS	65.3b	17.9a	8.7ab	8.1a	29.9ab	95.8a
Rain forest	CS	85.2a	9.6b	2.9c	2.5b	30.4ab	103.1a
	FS	61.5b	19.4a	10.3a	8.8a	28.2bc	93.0a
CV (%)		5.2	12.5	5.9	6.7	11.9	7.2

NS=Normal seedlings, AS=abnormal seedlings, DS= Dead seeds, UG= Ungerminated seeds, HSWT= Hundred seeds weight, GI= Germination index, CS=certified seeds, FS= Farmer-saved seeds, Means followed by the same letters in column do not differ by Tukey test at 5% probability

Table 2. Mean frequency of infection of seed maize by fungi in certified and farmer saved seeds from five agro-ecological zones of Ghana

Ecological zones	Seed types	Mean fungal infection by zone (%)				
		AF	AN	CT	PC	CR
Transitional	CS	33d	10d	13b	10bc	7a
	FS	53ab	20c	13b	10bc	3b
Guinea Savannah	CS	30d	17cd	13b	13b	3b
	FS	67a	10d	17ab	3d	0
Semi-deciduous	CS	43c	20c	10bc	10bc	6a
	FS	57ab	3e	13b	33a	0
Coastal Savannah	CS	37cd	33b	10bc	3d	3b
	FS	60b	7d	13b	10bc	0c
Rain forest	CS	30d	43a	0c	3d	0c
	FS	30d	30b	23a	7cd	0c
CV (%)		8.7	6.9	12. 4	10.4	8.3

AF=Aspergillus flavus, AN=Aspergillus niger, CT=Colletotrichum sp. PC=Pencillium sp., CR=Curvularia sp., CS=certified seeds, FS= Farmer-saved seeds Means followed by the same letters in column do not differ by Tukey test at 5% probability

seedling emergence than farmers-saved seeds across all ecological zones. Although, there was significant difference ($p<0.05$) between certified and farmer-saved seeds (Table 3). The farmer-saved seeds showed poor crop stands on field. Reports have shown poor stand establishment caused by low seed quality and consequently, yield loss in maize [29].

3.4.2 Plant growth rate analysis 20 days after planting (DAP)

The plant growth rate analysis which took 20 DAP showed that there was a significant difference ($p<0.05$) between certified and farmer-saved seed system across and within the regions. However, there was no significant different ($p>0.05$) between the certified seeds across the zones. And also the same result as above under farmer-saved seeds across regions (Table 3). The variation in seeds, biological activities, such as germination, emergence, vigour, and growth affect the quality of seed when the seed is exposed to adverse weather condition during grain filling [25].

3.4.3 Plant growth rate analysis 40 days after planting

In this growth rate analysis also, the computed result indicated that, there was significant difference ($p<0.05$) between certified and farmer-saved seeds across the zones. There was no variation ($p>0.05$) recorded within the certified seeds and farmer-saved seeds across zones (Table 3). [30] reported growth rate increase when temperature is high and slow at low temperature.

3.4.4 Plant growth rate analysis 60 days after planting

The result was showed that, farmer-saved seeds from Transitional, Semi-deciduous and certified seed from Rainforest were significantly different at (p<0.05) from farmer-saved seeds in the Rainforest zone, but similar to certified seeds from Transitional, Guinea, and Coastal Savannah zones (Table 3).

3.4.5 Plant growth rate analysis 80 days after planting

The growth rate showed that, the growth rate at 80 DAP reduced to compare to 20 DAP, 40 DAP, and 60 DAP (Table 4). The farmer-saved seeds from Guinea Savannah zone was significantly different (p<0.05) from the certified seeds from Transitional, Semi-deciduous and Coastal Savanna zones. Nevertheless, similar with certified seeds from Transitional, Semi-deciduous, and Guinea Savannah and farmer-saved seed. In addition, both seed systems from Costal Savanna and Rainforest zones (Table 3).

3.4.6 Days to 50% tasselling

The study revealed that the farmer-saved seed systems from all ecological zones took longer days to tassel. However, there was significant difference (p<0.05) between farmers-saved and certified seeds across the various ecological zones but there was no significant difference (p>0.05) within farmers-saved seeds across zones. Nevertheless, mean days to tassel of the certified seed from Semi-deciduous and Coastal Savannah zones were significantly different (p<0.05) from Transitional but similar to that of Rainforest and Guinea Savannah zone (Table 4). Hayashi [31] also reported days to maize plant tassel when temperature was change during filed plantation.

3.4.7 Days to 50% silking

When compared certified to farmer-saved seed systems from the five agro-ecological zones of Ghana, the certified seeds took shorter days to silk than farmer-saved seeds across the agro-ecological zones. Although, there was significant difference (p<0.05) between certified and farmers-saved seeds across the study zones, there was no significant difference (p>0.05) between the certified seed systems across zones, and also the farmers-saved seeds too (Table 4). These are also similar situations as mentioned in the cased plant tassel above.

3.4.8 Plant girth

Mean plant girth measurement under certified seed system indicated that, the Rainforest zone was significantly different (p<0.05) from the Transitional, Guinea Savannah, Semi-deciduous, and Coastal Savannah zones. Under farmer-saved seed system, the Transitional and Semi-deciduous zones showed similar mean. In addition Coastal Savannah and Rainforest zones also recorded similar value, but significantly different (p<0.05) from the Guinea Savannah zone (Table 3).

3.4.9 Days to physiological maturity

Farmer-saved seeds matured earlier than the certified seeds across the zones. There was significant difference (p<0.05) between certified and farmer-saved seeds across zones except the Coastal Savannah zone. Variation was observed between certified seeds across zones and the farmer-saved seeds (Table 4). [32] reported that, the seed weight could affect the next plant physiology.

3.4.10 Grain per cob

The mean grain per cob analysis result displayed that, certified seed system from Semi-deciduous zone recorded the highest grain per cob (353), followed by Coastal Savannah (344), Guinea Savannah (332), Transitional (310), and Rainforest zones (248). Under the farmer-saved seed system, the Semi-deciduous zone (257), followed by Guinea Savannah (255), Rainforest (237), Transitional (230), and then Coastal Savannah zones (201). However, there was significant difference (p<0.05) between certified and farmer-saved seed systems across the agro-ecological zones (Table 4).

3.4.11 One hundred (100) seeds grain weight

It was realized that the certified and farmer-saved seeds from the Transitional and Guinea Savannah zones were significantly different (p<0.05) from the Coastal Savannah and Rainforest zones. There was no significant difference (P>0.05) between certified and farmers-saved seeds within agro-ecological zones (Table 3). [22] also reported that, the grain

Table 3. Mean of plant growth rate analysis at different day after planting from certified and farmer saved seed systems from five agro-ecological zones of Ghana in 2015 minor season at KNUST

Ecological zones	Types	SE (%)	20 DAP	40 DAP	60 DAP	80 DAP	PG(cm)
Transitional	CS	92.01a	34.83a	81.08a	52.17ab	9.25b	15.58ab
	FS	78.12b	25.00b	68.58b	62.83a	15.50ab	15.57ab
Guinea Savannah	CS	93.06a	35.58a	81.58a	51.92ab	17.08ab	15.56ab
	FS	74.65b	27.08b	66.92b	51.83ab	21.33a	16.23a
Semi-deciduous	CS	92.01a	36.08a	80.67a	51.67ab	9.42b	15.98ab
	FS	73.26b	26.67b	68.83b	64.67a	12.67ab	15.92ab
Coastal Savannah	CS	89.93a	33.33a	81.33a	58.67ab	13.00ab	15.31ab
	FS	71.18b	27.08b	68.83b	54.33ab	15.42ab	14.45b
Rain Forest	CS	92.01a	34.33a	81.33a	60.17a	9.58b	16.35a
	FS	75.35b	27.67b	73.67b	46.08b	18.08ab	14.97ab
CV (%)		12.7	13	10.5	11.6	8.7	11.9

DAP=Day after planting, PG= Plant girth in cent metre CS=certified seeds, FS= Farmer-saved seeds. Means followed by the same letters in column do not differ by Tukey test at 5% probability

Table 4. Mean analysis of maize plant maturity from certified and farmers saved seed system from five agro-ecological zones of Ghana planted in 2015 minor season

Ecological zones	Types	DT (%)	DS (%)	DPM	G/C	100 GwT	Y/ha (kg)
Transitional	CS	50.4c	61.4b	104.2b	230cd	34.3a	559.1b
	FS	55.0a	65.2a	106.5a	301abc	34.1a	390.5c
Guinea Savannah	CS	51.3bc	61.9b	103.9b	255bcd	33.6a	664.1a
	FS	55.6a	65.8a	106.1a	332ab	33.0a	456.1c
Semi-deciduous	CS	52.1b	62.3b	104.1b	257bcd	32.8a	576.8b
	FS	55.6a	66.0a	106.1a	353a	27.5b	405.9c
Coastal Savannah	CS	51.8b	61.9b	102.6c	201d	27.3b	597.3b
	FS	55.2a	65.4a	106.2a	344a	26.8b	423.0c
Rain forest	CS	51.1b	62.0b	104.1b	237cd	26.7b	586.0b
	FS	55.0a	65.8a	106.2a	248cd	24.9b	419.0bc
CV (%)		2.6	3	8.1	14.3	12.8	15.4

E=seedling emergence, DT= days to 50 % tasselling, DS= days to 50 % silking, DPM=days to plant maturity, G/C= grain per cob, Y/ha=yields per hectare, CS=certified seeds, FS= Farmer-saved seed. Means followed by the same letters in column do not differ by Tukey test at 5% probability.

seed weight plays a major role in the process of germination and it is usually associated with seedling vigour, which is very important for future crop plants. Sulewska and Hanna [33] also reported that there was impact of grain seed weight on vigour, crop establishments, and productivity.

3.4.12 Grain yield of maize

The mean grain yield of certified seed systems gave higher yield than the farmer-saved seed systems across all zones. There was significant variation ($p<0.05$) between certified and farmer-saved seeds across all the ecological zones (Table 4). Ragasa [12] also reported certified seed was yielder than farmer-saved seeds.

4. CONCLUSIONS

The results from tests in the laboratory showed that seed moisture content, analytical purity, germination, and fungi associated were different between certified and farmer-saved seed systems across the ecological zones. Certified seed system showed better performance in all the seed quality parameters. In addition, the certified seed systems gave higher yield than the farmer-saved seed systems across the zones. To increase maize yield in the country, certified seed should be available to the farmers and also strengthen farmers' capacity in seed production and postharvest handling. However, further study of the variety across different locations and under farmer conditions are recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ranum P, Peña-Rosas JP, Garcia-Casal MN. Global maize production, utilization, and consumption. Annals of the New York Academy of Sciences. 2014;1312(1):105-112.
2. Westengen OT, et al. Modern maize varieties going local in the semi-arid zone in Tanzania. BMC Evolutionary Biology. 2014;14(1):1.
3. Smale M, Byerlee D, Jayne T. Maize revolutions in sub-Saharan Africa. Springer; 2013.
4. Huang J, et al. Effect of maize-legume intercropping on soil nitrate and ammonium accumulation. Journal of Food, Agriculture and Environment. 2011;9(3&4): 416-419.
5. Mearns LO, Rosenzweig C, Goldberg R. The effect of changes in daily and interannual climatic variability on CERES-Wheat: A sensitivity study. Climatic Change. 1996;32(3):257-292.
6. Dogbe W, et al. A comparative analysis of the agronomic characteristics and economic benefits of using certified seed and farmer saved seed of rice *(Oryza sativa L)* atdifferent nutrient management regimes: Evidence from on-farm testing in the Guinea Savannah rice growing ecologies of Ghana. African Journal of Agricultural Research. 2014;9(43):3215-3225.
7. Biemond P, et al. Health of farmer-saved maize seed in north-east Nigeria. European Journal of Plant Pathology. 2013;137(3):563-572.
8. Asamoah JF. Seed-borne fungi of farmer-saved rice *(Oryza sativa L.)* seeds from inland valleys of three Districts in Ashanti Region of Ghana and their management; 2012.
9. Byerlee D, Heisey PW. Evolution of the African maize economy. Africa's Emerging Maize Revolution. 1997;9-22.
10. Espinoza LMC, et al. Variations of invasive Salmonella infections by population size in Asante Akim North Municipal, Ghana. Clinical Infectious Diseases. 2016;62(S1): 17-22.
11. Siddik MNA, et al. Assessing smallholder farming and poverty in post-conflict-Sierra Leone. Journal of Finance. 2015;3(1):156-166.
12. Ragasa C, Chapoto A, Kolavalli S. Maize productivity in Ghana. Intl Food Policy Res Inst. 2014;5.
13. Msuya D, Stefano J. Responses of maize (*Zea mays*) seed germination capacity and vigour to seed selection based on size of cob and selective threshing. World J Agr Sci. 2010;6:683-688.
14. Basra AS. Seed quality: Basic mechanisms and agricultural implications. Food Products Press; 1995.
15. Powell AA, Matthews S, Oliveira MDA. Seed quality in grain legumes. Advances in Applied Biology; 1984.
16. Barnett HL, Hunter BB. Illustrated genera of imperfect fungi. APS press Minnesota. 1998;3340.
17. Mills J. Quality of stored cereals, in cereal grain quality. Springer. 1996;441-478.
18. Arendt EK, Zannini E. 2 - maizes, in cereal grains for the food and beverage industries, Arendt EK, Zannini E, Editors. Woodhead Publishing. 2013;67-115.
19. Asfaw A, et al. Farmers' common bean variety and seed management in the face of drought and climate instability in southern Ethiopia. Scientific Research and Essays. 2013;8(22):1022-1037.
20. Fu Y-B, Ahmed Z, Diederichsen A. Towards a better monitoring of seed ageing under *ex situ* seed conservation. Conservation Physiology. 2015;3(1): cov026.
21. Kansaki KJ. Assessment of postharvest losses of maize in the Sissala East and West Districts of the Upper West Region of Ghana; 2015.
22. Sulewska H, et al. Seed size effect on yield quantity and quality of maize (Zea mays L.) cultivated in South East Baltic region. Zemdirbyste-Agriculture. 2014;101(1):35-40.
23. Melo LD, et al. Physiological and physical quality of seeds from peanut seeds and plants under the influence of fertilizer and biostimulant. American Journal of Plant Sciences. 2015;6(9):1594.
24. Akowuah JO, et al. Effects of practices of maize farmers and traders in Ghana on contamination of maize by aflatoxins: Case study of Ejura-Sekyeredumase Municipality. African Journal of Microbiology Research. 2015;9(25):1658-1666.

25. Copeland LO, McDonald M. Principles of seed science and technology. Springer Science & Business Media; 2012.
26. Egli D, et al. Air temperature during seed filling and soybean seed germination and vigor. Crop Science. 2005;45(4):1329-1335.
27. Jiang W-B, et al. Brassinosteroid regulates seed size and shape in Arabidopsis. Plant Physiology. 2013;162(4):1965-1977.
28. Cocolin L, et al. Culture independent methods to assess the diversity and dynamics of microbiota during food fermentation. International Journal of Food Microbiology. 2013;167(1):29-43.
29. Cruz-Garcia F, et al. Seed deterioration and respiration as related to DNA metabolism in germinating maize. Seed Science and Technology. 1995;23(2):477-486.
30. Turley NE, et al. Contemporary evolution of plant growth rate following experimental removal of herbivores. The American Naturalist. 2013;181(S1):S21-S34.
31. Hayashi T, et al. Barrenness and changes in tassel development and flowering habit of hybrid maize associated with low air temperatures. Plant Production Science. 2015;18(1):93-98.
32. Ambika S, Manonmani V, Somasundaram G. Review on effect of seed size on seedling vigour and seed yield. Res. J. Seed Sci. 2014;7:31-38.
33. Kalton RR, Barker RE, Welty RE. *S*eed production. Cool-Season Forage Grasses. (Coolseasonforag). 1996;383-411.

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