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A SURVEY OF ON-FARM SEED PRODUCTION PRACTICES OF SORGHUM (*Sorghum bicolor* L. Moench) IN BOMET DISTRICT OF KENYA

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ABSTRACT

Sorghum (*Sorghum bicolor* L. Moench) is one of the important cereal crops utilized worldwide for human food, animal feed and to a lesser extent as a raw material in commercial food industries. The crop is a strategic commodity for food security, particularly in harsh environments. In Kenya, sorghum is an important crop consumed in some parts of the country as a staple food. It is also a major source of income to small-scale farmers who are its major growers. In the past, its cultivation was concentrated in the medium and low altitude areas of Kenya. However, with the increase in improved varieties, sorghum cultivation has spread to the cold semi-arid highlands. Sorghum production in Bomet District of Kenya is low. Agronomic, socio-economic and varietal constraints usually affect the production of sorghum. In this study, it was assumed that use of low quality seed was among the factors leading to the low productivity of sorghum in Bomet District. Therefore, a survey was carried out in Bomet District of Kenya with the objective of identifying the constraints to on-farm sorghum seed production. A total of 100 farmers were interviewed using structured questionnaires. The survey focused on a wide range of seed management issues. From the descriptive analysis it was concluded that sorghum grain yield obtained by farmers in the previous season were low as compared to the documented research sorghum yield potential. The major constraints to on-farm sorghum seed production included poor seed source; lack of socio-economic resources; poor crop husbandry; poor post-harvest handling of seed; damage by weeds, pests and diseases; and lack of marketing incentives. Regression analysis showed that only sorghum farm size (as partitioned by farmers) significantly ($P \leq 0.05$) affected sorghum grain yield in the district. Therefore, there is need to have high yielding varieties which will compensate for the ever diminishing farm sizes and land sub-division. In addition, there is need to assess the quality of sorghum seeds planted by farmers to determine the effect of such seeds on sorghum production. There is also need to improve the farmers' agronomic practices on sorghum production especially in relation to fertilizer application. An economic analysis to find out the profitability of purchasing inputs in sorghum production is required. An investigation on pests and diseases affecting sorghum production is also needed. Finally, extension services should be given to farmers and the prices of farm inputs subsidized.

Key words: survey, constraints, production, seed quality

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INTRODUCTION

There is a dearth of information about the informal on-farm seed production system in Sub-Saharan Africa. While the informal seed sector is responsible for providing more than 90% of the seed produced in most countries, only recently has it been recognized as the major system for seed supply in Sub-Saharan Africa [1]. In particular, the majority of small-scale farmers in Sub-Saharan Africa use on-farm produced and saved seed but unfortunately the quality of local seed is usually poor [2,3]. This is true in Bomet District of Kenya as the use of farm recycled and poor quality seed has been identified as a threat to food security [4].

Bomet District of Kenya relies heavily on the agriculture sector as a base for the overall economic mainstay of the inhabitants [4]. The sector is the main source of income and employment for about 70-80% of the population [4]. Any effort to transform the economy in the District must therefore start with improving the sector to make it profitable to the farmers. Two main ways of increasing crop production are increasing the area under production and raising farm productivity by use of improved production technologies [5].

Agricultural production in the lower zones of Bomet District is constrained by moderately harsh environmental conditions which include prolonged drought or unreliable rainfall [6]. The Kenyan government recognizes the importance of drought-tolerant crops like sorghum in alleviating food insecurity [7].

To increase the sorghum production in the District, several varieties and technologies have been generated through agricultural research and disseminated to the farmers by agricultural extension workers. However, sorghum production in the District has been marked by farmers reducing the portion of their farms set aside for crop production. For instance, between the years 1993-1995, the land allocated by farmers for sorghum production in the District ranged between 201.3-572 ha but between the years 2003-2005 the area under sorghum production in the district reduced to 145-160 ha [4, 8]. Similarly, the yield output also decreased from about 101,400 kg/ha in the years 1993-1995 to about 66,000 kg/ha in the years 2003-2005 [4, 8]. There was need to know why farmers lost the motivation to venture into the production of sorghum despite the drought-resistance properties found in the crop. One of the possible reasons for this loss of motivation by farmers could be the decline in average yield per hectare with time (years) obtained from the cultivation of the crop [8].

There exists a significant gap between farmers sorghum seed yield production levels of about 0.5 t ha^{-1} and research potential sorghum seed yield of ≥4 t ha^{-1} [9, 10]. Diverse management practices and complex socio-cultural factors usually contribute to this variation [11]. This study was carried out to identify constraints to on-farm sorghum seed production.

The release of sorghum improved varieties accompanied by agronomic package for optimal yield can be well adopted if farmer circumstances have been identified and integrated in technology development [5, 11]. To improve the quality of on-farm

produced seed, an understanding of traditional seed production systems is therefore essential and can be accomplished through participatory research and in-depth analysis of the present informal seed supply systems [12].

Understanding the seed system can be done by assessing current activities involving the sector; sources of traditional and/or improved varieties; seed production problems; status of seed availability; seed processing situation; seed storage methods and problems; seed marketing strategies; roles and participation of research and extension services; and participatory approaches used in variety development. It was on this basis that this study was initiated in Bomet District of Kenya.

METHODOLOGY

Survey area

Bomet District of Kenya is sub-divided into six divisions, thirty-eight locations and one hundred and nine sub-locations [4]. The District receives rainfall throughout the year with the long rains occurring from March to May and the short rains from August to October [4]. Apart from November and December, all the months have mean rainfall of between 1100 mm and 1500 mm. The mean monthly temperature is 18 ^{0}C [4]. The coldest months are July and August with monthly temperatures of 17.6 ^{0}C and 19.8 ^{0}C respectively [4]. The district is divided into three agro-ecological zones. These are the Lower Highland, Upper Midland and Upper Highland [4]. The general altitude varies between 1800m asl in the south and 3000m asl in the north [4].

Data collection

A survey was carried out in the months of September and October 2005 using a formal questionnaire. The questionnaire covered the socio-economic and traditional practices of on-farm sorghum seed production. In each of the following four divisions (Longisa, Bomet central, Sigor and Siongiroi) 17 farmers were interviewed. In two divisions (Mutarakwa and Ndanai), 16 farmers were interviewed from each division.
In every division of the district, a random selection method was used to identify farmers to be interviewed. The agriculture extension officers from the Ministry of Agriculture facilitated the survey by personally taking the surveyor to individual farmers' homes and helping in the sampling of the farmers to be interviewed. This was very helpful because of the language barrier and the requirement of obtaining a representative sample.

Data analysis

Information obtained from the questionnaire was coded on a numerical scale and entered into a spreadsheet. Descriptive statistics and regression analysis using SPSS version 12.0.1 were later carried out on the data. Descriptive statistics involved using the frequencies command to determine percentiles, measures of central tendency (mean, median, and mode), measures of dispersion (range, standard deviation and variance) and drawing of bar charts.

The regression analysis had the model described below.
$Yi = \mu + S_j - F_k - P_l + G_m + e$
Where:
Yi= Yield observation (tones per hectare)
μ = constant
S_j = Size of sorghum farms (hectares)
F_k = Fertilizer application rate (tones per hectare)
P_l = Planting sorghum seed rate as used by farmers
G_m = local market grain price per 2kg
e = Error

RESULTS

1.1 Seed source

Of all the farmers interviewed, 98% depended on the informal seed supply sector for their seed. The remaining two percent relied on the formal seed supply sector. About 69% saved their own seed for planting in the next season while 24% borrowed from their neighbours (Table 1). Five percent of the respondents bought grains from the market and used it as seed (Table 1).

About, 92% farmers preferred planting local varieties to improved varieties. The local varieties mentioned were Ochutti, Andiwo, and Obamo. Five percent of the farmers' interviewed preferred planting improved sorghum varieties while three percent preferred planting both local and improved varieties. The improved varieties known and planted by farmers' were Serena and Seredo. These improved varieties are not recommended to be grown in such an agro-ecological zone because they are not cold tolerant. The recommended variety (E 1291) developed by Kenya Agriculture Research Institute (KARI) was unknown to farmers. Table 2 shows the reasons given by farmers for the preference of local to improved sorghum varieties.

Of the farmers interviewed, 77% preferred a variety that would take 6 months (as maize) to maturity. This is because traditionally farmers' plant maize and sorghum at the same period. A late maturing variety was preferred because it was safer from bird predation than an early maturing variety.

Majority (82%) of the farmers did not plant certified seeds because they are not easily available to them. Only eight percent of the farmers sometimes accessed certified seed.

Farmers did not have a predetermined number of years for which they save their seeds before renewal (Table 3). It is not common for farmers to renew their seeds except if something unexpected happens such as poor yields or crop failure. In such adversities, farmers usually consumed all their produce and afterwards got seeds from another source. Farmers saved part of their harvest every year.

1.2 Crop husbandry

Of the farmers interviewed, 66% did not use any fertilizers during the crop production (Table 4). Those farmers who applied Diammonium Phosphate (DAP) fertilizers at planting did not top dress their crop with nitrogenous fertilizers like Calcium Ammonium Nitrate (CAN) as required for the production of good quality seed and better yields.

In comparison with the recommended seed rate of 7-10 kg ha^{-1} [13], 42% of the farmers interviewed used an optimum seed rate of about 6-10 kg ha^{-1}. This recommended seed rate was applicable when the planting method involved drilling seeds in lines. High seed rates of more than 10 kg ha^{-1} as practiced by 29% of the farmers interviewed can lead to over-population of the crop during its early stage resulting into poor quality seedlings at emergence. Over-population usually increases the intra-plant competition for nutrients, water and sunlight. Seed rates depend on the method of planting used. Broadcasting of seed as practiced by 30% could lead to uneven germination of seeds since the covering of the seeds after sowing is not usually uniform. Observations carried out during the survey showed that when broadcasting method was used, thinning was not done by farmers but plants were exposed to intra-specific competition and only surviving plants would give some yield.

Of the farmers interviewed, 66% did not harvest their seed separately from grain (Table 5). Of the 34% farmers who identified their seed from their farms, only 19% continuously selected their seed crop from the seedling stage. Otherwise, about 81% of the farmers selected their seed either at harvest or after harvest (Table 5).

1.3 Availability of socio-economic resources

Of all farmers interviewed, 27% never went to school meaning, that their knowledge on sorghum production was most probably through experience. Out of the 68% of farmers who claimed to be informed on sorghum production, about 43% obtained the information from an extension service providers. This would be a possible reason for the numerous poor crop husbandry practices reported earlier.

About 81% of the farmers were small scale self-employed in agricultural production. This portrayed the probability of low-income status of the farmers (Table 6). Fertilizers were readily available to 75% of the farmers interviewed while pesticides were available to 81% of the farmers interviewed even though both were not being used effectively (Table 6). Credit facilities were not available to the majority (95%). Some farmers did not access credit since they were unwilling to offer security for it or lacked security. It was noted that most sorghum farm sizes were too small to be financially viable.

1.4 Handling of seed from harvest to storage

The majority (98%) of the farmers threshed their seed from panicles by beating with sticks or rubbing the panicles on a hard surface (Table 7). Both methods cause mechanical damage to the seed (seeds are broken in the process) hence reducing the

seed quality. Many farmers harvest the panicles after the crop has attained harvest maturity as measured by the change of colour of the panicles (i.e. to brown or white depending on the variety) and then the panicles are dried in direct sunlight. After selection, majority of the farmers stored their seeds separate from grains where special precautions were taken to avoid infestations by pests. About 88.6% of the farmers stored their seed at the fireplace on the kitchen roof ceilings (Table 7). The farmers believed that the smoke from the fireplace protects the seed from storage pest and disease attack even more than the use of commercial pesticides.

1.5 Weeds, pests and diseases

The most (81%) stubborn pests of sorghum production were birds (Table 8). Improved varieties were more prone to birds attack due to their reduced tannin content making them sweet in taste than local varieties. Their earliness to maturity could have been another possible reason for the susceptibility of improved variety to bird damage.

Black jacks, macdonald eye and grasses (mainly the couch grass) constituted the most common weeds encountered by farmers (Table 8). Other weeds mentioned by farmers included pigweed, Mexican marigold and Chinese lantern.

About five percent of the farmers reported problems related to diseases. Diseases mentioned included honey dew, head smuts, leaf rusts and leaf blight. The majority of the farmers were not conversant with diseases affecting their crop.

1.6 Marketing incentives

All the farmers interviewed acknowledged the adaptability of the crop in the region but its production was constrained by lack of its marketability. It was found out that the price offered for sorghum (Ksh. $25kg^{-1}$) was very low as compared to that of maize (Ksh. $35kg^{-1}$).

1.7 Farm sizes

Farm sizes were quite variable. Of the farmers interviewed, 27% allocated ≤0.05 ha of land to sorghum production in the previous season (Figure 1). Only three percent allocated more than 0.3ha for sorghum production (Figure 1). The average sorghum farm size was 0.15ha.

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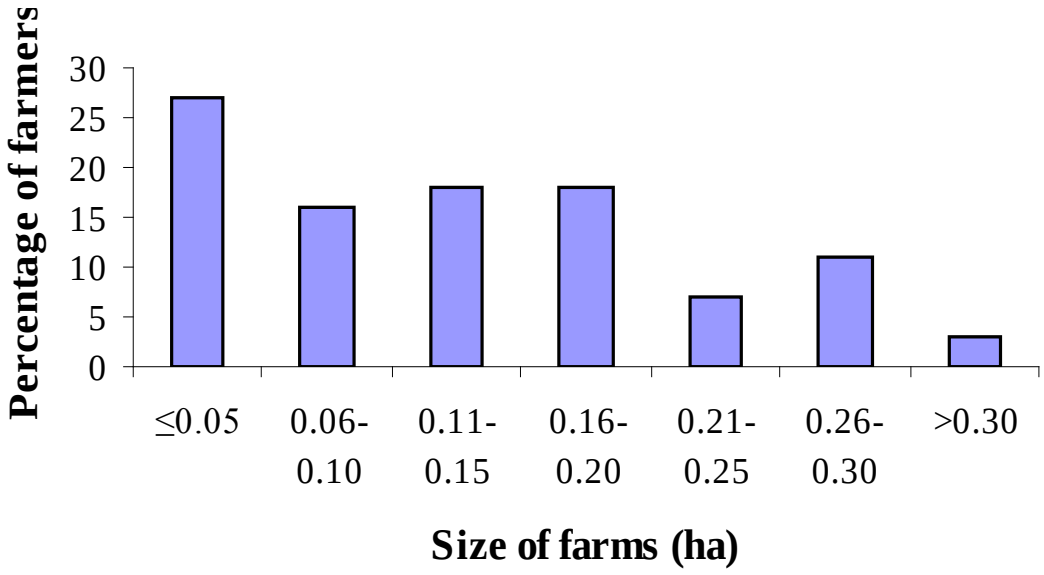

Figure 1: Percentage of farmers and farm sizes in hectares (ha) allocated by them

1.8 Grain yield attained by farmers

Most (92%) farmers had sorghum seed yield ranging from 0.5 to 2.5 t ha^{-1} (Figure 2). The mean yield was 1.3t ha^{-1}. This yield is low as compared to the research potential yield (≥4 t ha^{-1}). About eight percent of farmers attained the potential grain yield of 4 t ha^{-1}.

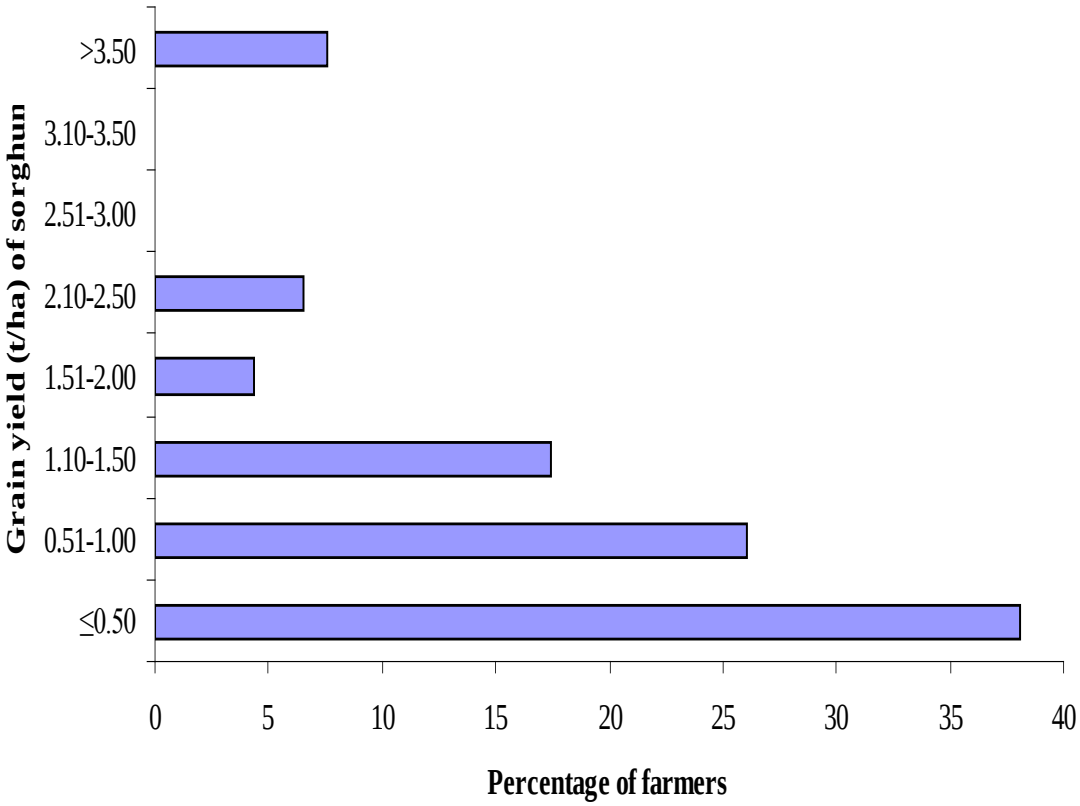

Figure 2: Grain yield in tones/hectares (t/ha) attained by farmers in Bomet District

The combination of all factors (yield, sorghum farm sizes, fertilizer application rate, sorghum seed rate and local market grain price/2kg) tested in the regression model significantly ($P \leq 0.05$) affected the sorghum grain yield attained by farmers in Bomet District. The combination of all factors entered in the regression model contributed up to 23.5% ($r^2 = 0.235$) of the factors that affected grain yield obtained by farmers.

From the regression analysis, only the size of the field portioned for sorghum cultivation significantly ($P \leq 0.05$) affected sorghum grain yield attained by farmers. There was a weak positive relationship between yield and field size as shown in Figure 3. All other tested variables did not significantly ($P \leq 0.05$) affect sorghum grain yield attained by farmers.

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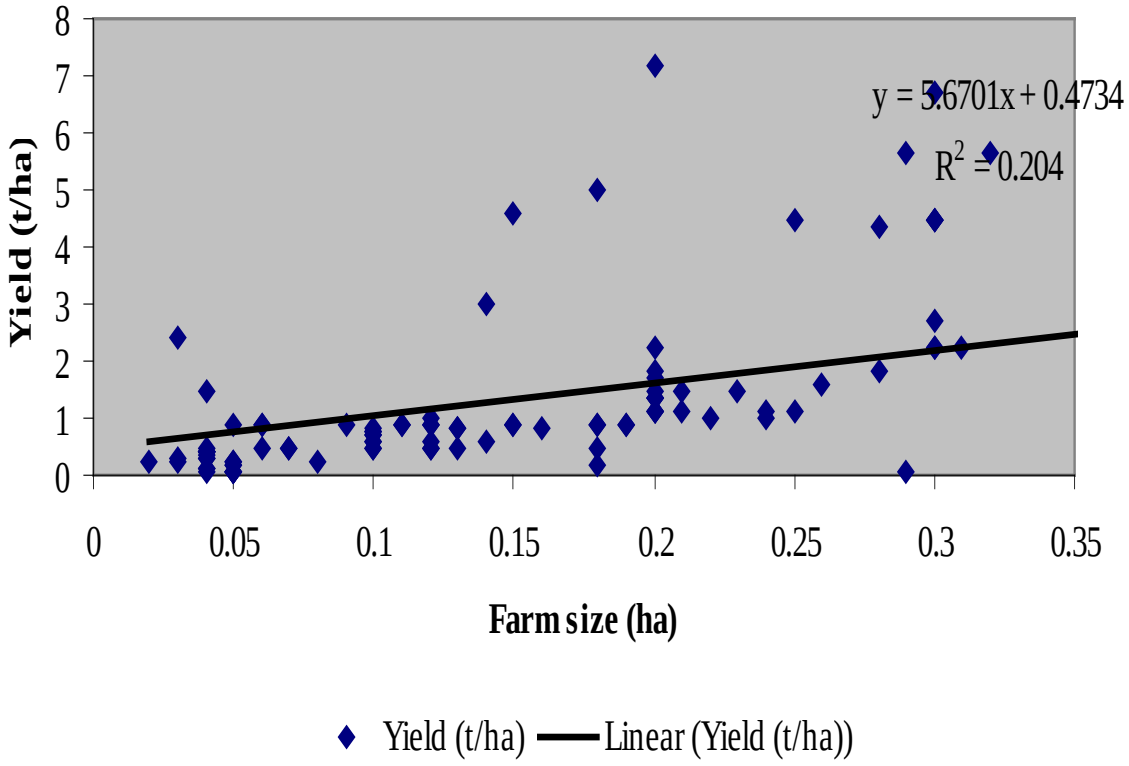

Figure 3: The relationship between yield in tones/hectares (t/ha) and size of land in hectares (ha) portioned for sorghum production by farmers in Bomet District.

DISCUSSION

Use of poor quality seed is one of the constraints to sorghum production in Bomet District. The result that 98% of the farmers rely on the informal seed supply sources agrees with the findings of others [1, 14]. The informal seed system includes methods such as retaining seed on-farm from previous harvests to plant the following season and farmer-to-farmer seed exchange net works [15]. Results of this study show that own saved seed contributes the largest proportion of the informal seed sector. This is in agreement with the report that approximated that 80% of the farmers save their own seeds for planting the next season [2]. The requirement of cash in the formal seed supply systems has been frequently viewed as a drawback [16]. Therefore, acquisition of inputs through non-cash alternatives as it is in the informal sector is preferred by small-scale farmers who have cash deficiencies. About 23.4% of the farmers saved and selected seed from the previous season for planting for more than four seasons (years). This is in contrast with the agronomic standard given by KARI which

discourages farmers from continual use of seed that has been recycled for more than four generations (seasons) [13]. The use of such seed will lead to the degeneration of a variety because a weaker progeny would be generated from these inferior quality seed.

Poor on-farm seed management in relation to fertilizer application and choice of variety to plant is another identified constraint to sorghum seed production in Bomet District. The results that 66% of the farmers interviewed did not apply fertilizers in their sorghum farms agrees with other findings [17] whereby it was reported that many small scale farmers in Sub-Saharan Africa do not apply fertilizers to their farms. This is attributed to the fact that sorghum is often grown under marginal rainfall conditions and fertilizer prices are unfavourably high in relation to sorghum grain price. This practice of using little or no fertilizer may affect both seed quality and yield of the crop negatively [18]. Nutrient stress during plant development (especially at seed filling) has been reported to result in seeds of poor quality because less food reserves are channeled to the developing seed [19, 20].

Both phosphatic and nitrogenous fertilizers are essential for the growth of sorghum plant [21]. Nitrogen fertilizers need to be used together with phosphates since nitrogen plays a complementary role in the uptake of phosphorous [21]. When phosphorous acts independently the yield and seed quality become lower. Phosphorous is essential in supplying phosphates which plays a role in energy storage and transfer within plants and is also an important structural component [22]. Nitrogen is used largely in the synthesis of proteins and is part of the chlorophyll molecule [22]. The 34% farmers in Bomet District that apply fertilizers during their seed production only used DAP.

Improved high-yielding varieties have been ignored by majority of farmers for various reasons. Farmers' preference for local varieties (*Ochutti, Andiwo,*and *Obamo*) as compared to improved varieties is attributed to the duration they take to mature. Since maize is a major staple food in the region and is usually intercropped with sorghum, most farmers prefer a sorghum variety that would take the same duration in the field like maize. The main reason for this decision is to protect the crop from high incidences of bird damage. More so, the local varieties have a hard endosperm and are bitter in taste hence undergo less bird damage as compared to the improved varieties which have a soft endosperm [5]. The local varieties that are low in tannin content are the white sorghums but unfortunately, they are highly prone to birds' damage hence reducing the yield [5]. From the survey findings, it seems that the main advantages of the improved varieties over the local varieties are early maturity and high yielding. These advantages are however weighed down by the high susceptibility of the improved varieties to bird damage. They mature early when other types are not ready in the fields and also few farmers venture in growing them. However, many farmers will prefer a variety whose yield is stable [12, 23]. It appears that if improved varieties were made resistant to bird attack, they would compliment local varieties. There is need to breed varieties similar to local types but high yielding.

Sorghum seed production in Bomet District is constrained by lack of socio-economic resources. The gap between the formal and informal seed supply systems can be bridged by the extension service or agricultural credit institutions [24]. Extension officers should play a crucial role in training farmers in on-farm seed production. The latest sorghum variety E 1291 is a technology developed by KARI breeders. It is a variety that is adapted to cold semi-arid regions like Bomet District. However, the variety has not been adopted by farmers because it is not well known. This implied that there was need to effectively popularize the improved variety to the farmers by raising awareness on the merits of the improved varieties so as to increase their adoption by farmers [25]. The fact that 84% of the interviewed farmers could not afford farm inputs may lead to the production of poor seed quality and yield of the crop because many soil nutrients have become depleted in many parts of the country. Seeds produced under conditions of low soil fertility usually express poor germination and vigour [26]. Failure to control pests and diseases could also have serious implications on the quality of farm saved seeds.

Sorghum seed production in Bomet District is constrained by poor post-harvest handling of seed. The majority of farmers threshed their seed from panicles by beating with sticks or rubbing the panicle on a hard surface like a rough stone. This contributes to high mechanical damage due to the breaking of seeds into small pieces hence reducing the seed quality [27]. When seeds within a seed lot are broken into pieces, the embryos are damaged hence reducing the germination capacity of the seeds. More so, the practice of drying sorghum panicles in direct sunlight by farmers in Bomet District might lead to reduced seed quality. It was found out that when seeds were dried at high temperatures, loss of vigour and viability was very rapid [28].

Lack of marketing incentives was cited by all interviewed farmers as a major constraint of sorghum production. It was reported that the supply of sorghum in Bomet District local markets was low at that particular time due to low production as most farmers opted for maize [6]. This was due to the good prices prevailing in the market as compared to sorghums'. The crops' low demand could also be attributed to the fact that its versatility as a food and feed crop is still unknown to many. Kenya Agricultural Research Institute, in collaboration with the Ministry of Agriculture, is educating farmers on sorghum utilization and therefore it is expected that its demand will soon increase.

CONCLUSION AND RECOMMENDATIONS

Estimates by farmers indicated that the mean grain yield was 1.3t ha^{-1} which is low as compared to the potential research yield of 4 t ha^{-1} [9, 10]. This low sorghum grain yield could have been caused by some constraints to production identified in this study, for example, poor agronomic practices like low use (or none use) of fertilizers, poor varietal choice; use of low quality seed, lack of cash to buy inputs, lack of marketing incentives, lack of technical advice and crop infestation by weeds, pests (especially birds) and diseases.

Although the allocation of small areas to sorghum production has been cited as a cause for low sorghum seed production in Bomet District, the results revealed that the farmers' grain yield of 1.3t ha^{-1} was low as compared to research grain yield potential of 4 t ha^{-1}. It can be concluded that, sorghum seed production may effectively be increased by raising farm productivity using improved production technologies.

Increase in sorghum seed production in Bomet District can be realized by subsidizing the farm inputs to enable their affordability by farmers, popularizing the improved variety E1291 to the farmers, improving farmers' agronomic practices on sorghum seed production and assessing the quality of sorghum seeds planted by farmers so as to determine whether seeds sown by farmers affect the crops' production. More so, this study recommends that plant pathologists, entomologists and breeders help farmers to manage sorghum pests and diseases by developing varieties resistant to such pests and disease. Also, economists should analyze the profitability of purchasing farm inputs (fertilizers, certified seed and pesticides) in sorghum seed production. Finally, agriculture extension officers are encouraged to provide their services on sorghum seed production to farmers.

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Table 1: Percentage of farmers' using seeds from different sources in Bomet District

Seed source	Percentage of farmers' N=100
Own saved	69.0
Neighbours	24.0
Market	5.0
Certified	2.0

Table 2: Reasons for the preference of local to improved sorghum varieties by farmers in Bomet District

Reason	Percentage of farmers' N=92
Less susceptible to bird attack (except the white seeded)	60.5
Good food quality (good taste)	20.4
High yielding	19.0
Early Maturity	3.0

Table 3: Length of time that farmers' have saved their seeds

Number of years	Percentage of farmers' N=100
1	11.7
2	19.5
3	29.9
4	15.6
>4	23.4

Table 4: Percentage of farmers' who use fertilizers, the type and the rate

Fertilizer use	**Percentage of farmers' N=100**
Yes (DAP)	34.0
No	66.0
Fertilizer rate (Kg ha^{-1})	
<50	9.0
50-100	15.0
110-150	10.0
0.00	66.0

Table 5: Harvesting of seed and seed selection criteria as practiced by farmers in Bomet District

Variable Description	Percentage of farmers N = 100
Harvest of seed	
If the farmer harvests seed separately from grain	
Yes	34.0
No	66.0
when do you select the crop for your seed	
Pre-harvest	19.0
During harvest	30.0
Post harvest	51.0
Sorting criteria of seed at harvest	
Panicle size and colour	53.6
Panicle size	21.4
Panicle size, disease and pest free	2.4
Panicle size, disease and pest free and colour	20.2
Others	2.4

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Table 6: Sources of incomes to farmers, farm input availability and affordability by farmers in Bomet District

Variable Description	Percentage of farmers N = 100
Income source	
Self employed (Agric)	81.0
Self employed (Non-agric)	14.0
Salaried (Agric)	2.0
Salaried (non-agric)	3.0
Affordability of inputs	
Yes	16.0
No	84.0
Availability of inputs	
(i) Fertilizers:	
Always	75.0
Sometimes	4.0
Never	21.0
(ii) Pesticides:	
Always	81.0
Sometimes	4.0
Never	15.0

Table 7: Seed extraction, drying and storage methods as practiced by farmers in Bomet District

Variable Description	Percentage of farmers N = 100
Seed extraction method (from panicles)	
Hand shelling	2.0
Rubbing panicle on a rough stone	2.0
Beating with stick	96.0
Method of seed drying	
In direct sunlight	100.0
In shade	0.0
Storage of seed	
Roof ceiling and at fireplace	82.9
Gunny bags in granary	6.8
Gunny bag in granary	4.5
Gunny bag, at a fireplace in the roof ceiling	5.7

Table 8: Weeds, pests and diseases affecting sorghum production in Bomet District

Variable Description	Percentage of farmers N = 100
Problems experienced	
Pest	63.0
Diseases	5.0
Others	32 0
Common pests	
Birds	81.0
Beetles	11.0
Weevils (during storage)	29.0
Great grain borer (during storage)	15.5
Shoot fly	33.0
Stalk borer	23.0
Types of weeds	
Black jacks	75.0
Grasses	52.0
Macdonald eye	65.0

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