International Scholarly Research Network
ISRN Agronomy
Volume 2012, Article ID 153412, 7 pages
doi:10.5402/2012/153412

Research Article

Constraints to On-Farm Maize (*Zea mays* L.) Seed Production in Western Kenya: Plant Growth and Yield

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Received 12 April 2012; Accepted 18 June 2012

Academic Editors: J. Hatfield, G. C. Heathman, and M. A. Taboada

Studies have shown that that about 85% of maize farmers in Western Kenya plant local varieties with about 80% using own farm-saved seeds. The production system is characterized by late harvesting, heavy *striga* infestation, use of local varieties, and low-soil fertility. The objective of this study was to test an on-farm seed production system which would help improve yield and quality of farm saved seeds. The trials were set up in a factorial design fitted as random complete block design. There were 3 factors each at 2 levels: time of harvest, variety choice, and fertilizer application. Fertilizer application led to an 88% increase in yield, 54% increase in number of seeds per cob, and 14% increase in 100-seed weight. Fertilizer application also led to an increase in seed vigour and viability. Yield differences between the 2 varieties were not significant. The correlation between 100-seed weight and seed vigour was significant showing that heavy seeds were more vigourous. Nitrogen application was therefore recommended for increasing yields and for producing vigourous seeds but should be done with caution to avoid lodging as witnessed. This study also noted that farmers are rational and their decisions are usually based on strong economic considerations.

1. Introduction

Maize (*Zea mays* L.) is the most important cereal in Kenya and acts as the staple food for over 90% of the population [1]. The national food security in Kenya is often pegged to availability of adequate supplies of maize to meet domestic food demands. About 1.6 million hectares are under maize annually, 80% of which is owned by smallholder farmers [2]. Despite the development of high-yielding varieties and improved cultivation methods, Kenya has to attain self-sufficiency in production of the crop [3].

An estimated 80% of the total maize seeds used by farmers in Western Kenya is produced by farmers themselves through on-farm seed production [4]. However, on-farm seed production has been neglected by breeders, researchers, and policy makers [5, 6]. This system of seed production appears to neglect some quality aspects [7]. The risk of declining seed quality and yield is therefore imminent. Several reports indicate that the quality of local seeds is not always optimal [8, 9].

In a study conducted in Western Kenya, the current practices of on-farm seed production were described [10]. Priority problems that farmers face during seed production were identified as follows: late harvesting, *Striga* infestation, and low-soil fertility. Majority of farmers in Siaya and Busia districts do not apply fertilizers thus leading to nutrient stress. This situation is made worse by the fact the soils in this region are deficient in major nutrients such as nitrogen, due to continuous cultivation. This not only affects seed quality adversely [11], but also seriously reduces yields. Farmers often delay harvesting their crops until they are completely dry (harvest maturity) and this could expose the seeds to adverse conditions that aggravate deterioration. Maximum seed quality is generally regarded to be attained at physiological maturity and not at harvest maturity [12]. Witchweed (*Striga hermonthica*), a parasitic weed, remains another great challenge to farmers, sometimes leading to complete yield loss of maize in the affected farm [13].

On-farm and on-station trials were therefore conducted in order to investigate these problems in a farmer participatory approach. The objective of the study was to improve on-farm seed production system by incorporating aspects of scientific plant breeding and seed production techniques of the formal seed sector into the informal sector. Specifically, the study aimed at improving the yields and quality of farm-saved seeds. The need to understand the current practices of on-farm seed production in W. Kenya necessitated the undertaking of a survey.

2. Materials and Methods

2.1. Study Area. The experiment was carried out in Siaya and Busia Districts of Western Kenya. Busia District receives a mean annual rainfall of 1500 mm in 2 seasons a year. The annual mean maximum temperature ranges from 26° to 30°C and the annual mean minimum temperature varies between 14° and 18°C. The altitude varies from 1130 to1375 m a.s.l. [14]. The district has 4 agro-ecological zones—LM_1–LM_4. Siaya district gets a bimodal average annual rainfall of 800 to1600 mm. The mean temperature is 21°C. The altitude ranges from 1140 to 1400 m a.s.l. The district has 5 agro-ecological zones—LM_1–LM_5 [15].

2.2. Survey. A formal questionnaire type survey were carried out where a total of two hundred farmers was interviewed, one hundred from each district. A nonrandom purposive selection method was used to identify the farmers to be interviewed.

2.3. Field Experiments. On-farm trials were carried out in seven farmers' fields in the following divisions of Busia and Siaya districts during the long rain season of 2003: Nambale, Butula, Matayos, and Funyula in Busia and Uranga, Yala and Ukwala in Siaya district. The trials were repeated in Yala, and Uranga during the short rains of the same year. An on-station trial was conducted in Siaya Farmers' Training Center (FTC) in both seasons. The trials were set up in a farmer participatory approach for technology adaptation and dissemination among farmers or farmer groups [16].

The trials were set up as a 2^3 factorial fitted in a randomized complete block design (RCBD) with 3 replicates. The factors included variety choice, fertilizer application, and time of harvesting giving 8 treatment combinations. The performance of the farmer's variety was compared with that of Kakamega *Striga* Tolerant Population (KSTP '94) for tolerance to *Striga*. The farmer varieties were *Rachar, Nyamula, Msamaria, Nambanane,* and *Ebuganda*.

The different trials had different local varieties as preferred by the farmer. At planting, half the plots were fertilized at 60 kg N and 60 kg P per hectare using the fertilizer 23 : 23 : 0. The same plots were later top dressed, with Urea (46% N) at 100 kg N per hectare. The other plots were not fertilized. Harvesting was done at 2 stages: physiological maturity (PM) and harvest maturity (HM). The plot size was 3.75 × 3 m and the plants had a spacing of 75 cm × 30 cm, giving 5 rows per plot each with 10 plants. Paths of 0.5 m and 1.0 m were left between the plots in a block and between the blocks, respectively. Data was collected on plant height, *Striga* effect score on a scale of 1–9 [17], *Striga* population, lodging severity on a score of 1–9 and yield.

2.4. Data Analysis. The effect of variety, fertilizer application and time of harvesting was tested by analysis of variance using the general linear model of SPSS. Treatment means were compared by using the LSD test while location means were compared by using DMRT. A combined across-locations and seasons analysis of variance was also done [18]. Correlation analysis was conducted where Pearson's correlation coefficients were used to determine correlation between yield, seed vigour, and morphological characters such as plant height. A benefit: cost analysis was done to assess the economic value of treatments. To assess the costs and benefits associated with different treatments, the partial budget technique as described by CIMMYT [19] was applied on the yield results. Economic analysis was done using the prevailing market prices for inputs at planting and for outputs at the time the crop was harvested.

3. Results and Discussion

3.1. Survey Results

3.1.1. Seed Sources, Varieties Grown, and Their Attributes. Table 1 shows that about 80% of the farmers save their own seed for planting the next season while a small proportion depend on neighbours, market, and formal seed sector. This proportion of farm-saved seeds is confirmed in other reports [4, 20, 21].

Apart from seed being cheap and available on time, farmers reported that financial constraints could not allow them to purchase certified seeds (Table 2). Unlike own saved-seeds farmers reported that certified seed requires a lot of inputs for good performance. Most farmers do not use inputs mainly due to financial constraints and even in the face of all these stresses, local varieties give acceptable yields as compared to improved varieties which perform poorly under conditions of stress. Farmers indicated that the yields could be low but were more interested in their stability over seasons (Table 2).

While 76% of farmers had information about improved varieties and their management, only 22% grew them. About 85% of the farmers plant local landraces. Table 3 shows that farmers considered the main advantages of planting local landraces as good grain yield and early maturity. The results of this study show that most farmers plant more than one local variety which is an important strategy of risk avoidance. Local varieties generally harbour wide genetic variation and the planting of such germplasm results in heterogeneity which leads to less than highest obtainable yield potential but can contribute significantly to yield stability [22]. Farmers prefer yield stability to highest obtainable yield in line with their policy of risk avoidance [5, 23, 24] as shown in Table 2. Unlike improved varieties, most local varieties are

Table 1: Percentage of farmers using seeds from different sources.

Source	Percent of farmers (n = 200)
Own seed	78
Certified seeds	18
Market	9
Neighbours	3

Table 2: Percentage of farmers giving various reasons for use of own seed.

Reason	Percent of farmers (n = 154)
Lack of cash to buy certified seeds	27.3
Cheap and readily available	20.1
Good performance of own seed	14.9
Security of seed stock	12.3
Low input requirement	11.0
Yield stability	9.7
Early maturity	1.9
Pest resistance	1.3
Others	5.6

Table 3: Preferences of farmers for varieties and their attributes.

Attribute	Percent of farmers	
	Local landraces (n = 162)	Improved varieties (n = 27)
Good grain yield	44.7	79.1
Early maturing	44.0	16.7
Good grain/food quality	29.8	12.5
Drought resistance	15.6	4.2
Low-input requirement	12.8	
Good marketability	6.4	
Pest and disease resistance	3.5	
Good storage potential	2.1	
Lodging resistance	1.4	
Striga resistance	0.7	

tolerant to most stresses and will yield even under the most unfavourable conditions.

High yield is perceived as the main advantage for growing improved varieties. Next is early maturity. Suitability for food preparation is also important for farmers (Table 3). Of those who grew improved varieties, about thirty-five percent of them also grew local varieties. The most common local varieties include *Rachar, Spindi/Nyamula, Oking, Ebuganda, Nyalewekwar, Ababari, Purple,* and *Msamaria*. However, one variety may be known by different local names in different places.

The reasons as to why most farmers do not plant improved varieties were based on their perceived poor grain yield and pest and disease susceptibility, as shown in Table 4.

3.1.2. Seed Production Agronomic Practices. Generally the management of the crop is poor and this could also compromise both the yields and seed quality. Most farmers do not use agricultural inputs such as fertilizers. There is no standard seed rate used by farmers and most farmers do not have information about recommended spacing (Table 5).

Table 4: Percentage of farmers giving undesirable attributes of improved varieties.

Attribute	Percent of farmers (n = 27)
Poor grain yield	42.8
Pest susceptibility	33.3
Disease susceptibility	23.8
Rotting	9.5
Poor food quality (poor cooking ability)	9.5
High-input requirement	4.8

Seeds produced under conditions of low-soil fertility may express poor germination and vigour [11]. Nutrient stress during mother plant development and at seed fill is generally associated with reduced seed quality of the progeny [8]. Most farmers do not control pests and diseases. Failure to control pests and diseases may have serious implications on the quality of farm-saved seeds and the performance of subsequent crops. This is clearly evident in this study where thirty one percent of farm-saved seeds collected from farmers had fungal infections observed during a germination test. The physiological quality was also sometimes poor with 10% of the collected samples having germination capacity of less than 10% which is the minimum germination required by the formal sector for maize. Control of fungal infection in the field by systemic fungicide sprays and other cultural practices for example, removing diseased plants leads to seeds of improved germination and field emergence [25]. Insect populations should as much as possible be controlled during crop production since their build up during crop growth may extend to storage [26].

Apart from causing yield loss, the high *Striga* infestation observed in the study area might also affect the quality of on-farm produced seeds. The seeds may be poorly filled and hence of poor vigour since very little food reserves are channeled to the developing seed.

3.2. Effect of Variety, Fertilizer Application, and Time of Harvest on Plant Growth, Yield, and Seed Quality

3.2.1. Plant Height. Plant height is an important characteristic in on-farm seed production as it is among the criteria used for seed selection by farmers. Farmers believe the taller the plant, the higher the seed quality, and the higher the yield produced [10]. Plant height was significantly increased by fertilizer application (Table 6). Differences due to variety were, however, not significant.

The correlation between plant height and seed vigour (data not shown) was only significant at Uranga in the second season thereby showing that taller plants may sometimes produce vigorous seeds than shorter ones. The low plant height in unfertilized plots is in line with the findings of Ulger et al. [27] and Gungula [28] that nutrient

Table 5: Use of agricultural inputs, knowledge about recommended spacing, roguing, and pest and disease control.

Response	Percent of farmers ($n = 200$)	
	Yes	No
Uses agricultural inputs	44.0	56.0
Has information on recommended spacing	42.5	57.5
Controls pests	21.4	78.6
Controls diseases	19.5	80.5
Does rouging	35.7	64.3

Table 6: Plant height (cm) in Western Kenya.

Variety	Plant height (cm)		
	With fertilizer	Without fertilizer	Difference
Local	192.7	172.0	20.7^{ns}
KSTP '94	189.0	126.0	63.0**
Difference	3.7^{ns}	46.0*	
Mean	169.9		
SE	5.2		
CV (%)	10.7		

ns, *, **, and *** indicate statistically non significant ($P \geq 0.05$), significant at $0.01 \leq P < 0.05$, $0.001 \leq P < 0.01$ and $P < 0.001$.

Table 7: *Striga* effect rating in a maize field in Western Kenya on a score of 1–9.

Variety	*Striga* effect score		
	With fertilizer	Without fertilizer	Difference
Local	1.7	3.3	-1.7^{ns}
KSTP '94	3.0	4.7	-1.7^{ns}
Difference	-1.3^{ns}	-1.3^{ns}	
Mean	3.2		
SE	0.4		
CV (%)	42.4		

ns, indicate statistically non significant ($P \geq 0.05$).

availability, especially N, could determine plant vegetative development. Bittenbender et al. [29] reported significant reduction in plant growth parameters when the soil was deficient in some notable nutrients. In addition to nutrient stress, differences in plant height can also be caused by *Striga* infestation and varietal differences. Varieties susceptible to *Striga* have reduced growth leading to short plants [30]. These two authors reported that plants with higher ear height were less damaged by *Striga*. Although ear height was not considered in the present study, it is expected that plant height has a similar effect since the former and latter are related. The relationship between ear height and *Striga* damage is however not clear and needs to be studied as it can form a basis for seed selection for tolerance to *Striga*.

3.2.2. Effect of Striga. Based on a *Striga* effect score, *Rachar* and KSTP did not show any significant differences (Table 7). Similar findings were made by Odongo and Abayo [30] who found no significant differences between the two varieties in their tolerance to *Striga*. The 2 varieties were therefore recommended for farmers in *Striga* infested areas since they were found to be more tolerant to *Striga* than other improved hybrid maize varieties.

Fertilizer application led to a reduction in the population of *Striga* (data not shown). Though this observation confirms that of Oswald et al. [31], that with declining levels of N, the build-up of *Striga hermonthica* increases, the differences were not significant.

Table 8: Lodging score in Yala division of Western Kenya.

Variety	Lodging score		
	With fertilizer	Without fertilizer	Difference
Local	10.0	1.3	8.7***
KSTP '94	10.7	3.3	7.3***
Difference	-0.7^{ns}	-2.0^{ns}	
Mean	6.3		
SE	0.4		
CV (%)	19.2		

3.2.3. Lodging. The significant differences between plots with and without fertilizer on lodging (Table 8), are in agreement with observations made in a study by Timmerman and Brolley [32] who found that plots with high soil nitrogen had more lodging than plots with low soil nitrogen. Excessive nitrogen application should therefore be avoided. Varietal differences could not be assessed as significant on lodging. Varietal differences on lodging are mainly determined by rooting and stem strength with some varieties having stronger stems than others.

In addition, lodging could also be caused by *Striga* infestation as reported by Sallah and Afribeh [33]. In this study the authors reported that *Striga* infestation increased lodging by 136.9%. In the present study, it is however difficult to isolate the effects of lodging due to nitrogen application and those due to *Striga* infestation which was also present in the fields.

3.2.4. Yield and Yield Components. Fertilizer application led to a significant increase in yield/ha ($P \leq 0.001$). On average, grain yield was 88% higher in fertilized plots compared to unfertilized plots (Table 4). However, the differences between the local landraces and KSTP were not significant. Varietal, fertilizer and seasonal effects on 100-seed weight were highly significant across the locations ($P \leq 0.001$). Yield reductions as high as 68% for local landraces and 74% for KSTP were recorded in the first season.

The higher grain yields of maize with fertilizer in this study were similar to the results of Akintunde et al. [34]. Higher nitrogen content facilitates better photosynthetic activity and higher partitioning of dry matter to ears [27]. In addition to nutrient stress, reductions in grain yield and ear weight could also be caused by *Striga* infestation [33]. This can principally be attributed to competition for nutrients thereby leading to nutrient stress.

Table 9: Yield and some yield components of various treatments in Western.

Treatment	Yield and yield components			
	Mean yield (kg/ha)	No. of seeds/cob	100-seed weight (g)	No. of rows/cob
Local variety without fertilizer	2040	212	30	9.9
Local variety with fertilizer	3697	314	33.8	10.2
KSTP without fertilizer	1805	222	26.7	10.5
KSTP with fertilizer	3462	356	30.5	11.6
Mean	2751	276	30.2	10.5
SE	113.4	6.9	0.5	0.1
LSD (0.05)	317.2	19.2	1.3	0.3

Table 10: Economic analysis of various treatment combinations in Western Kenya.

Variable (ha^{-1})	Costs (Ksh) by treatment combination			
	Local variety		KSTP	
	With fertilizer (A)	Without Fertilizer (B)	With fertilizer (C)	Without fertilizer (D)
Yield (kg/ha)	3697.30	2039.73	3461.62	1805.05
Gross field benefit	49297	27196	46155	24067
Land preparation	3,600	3,600	3,600	3,600
Cost of seed	600[a]	600[a]	1,200	1,200
Cost of fertilizer	6,503	0	6,503	0
Cost of weeding	3,840	3,840	3,840	3,840
Cost of empty bags	1,150	600	1,100	525
Total variable costs	15,693	8,640	16,243	9,165
Net benefit	33,604	18,556	29,912	14,902
Benefit: cost ratio	2.14	2.15	1.84	1.62

[a]The cost of seed for the local variety was taken as the price of maize price plus the storage costs.

Seeds produced with fertilizer had higher seed weight than those without (Table 9). This supports the findings of Kanzikwera et al. [35] who reported that nitrogen application significantly increased 100-seed weight, emergence, and seedling vigour in true potato seeds (TPS). The increase in vigour and emergence can be explained by the well-known fact that heavy seeds contain more food reserves than light seeds and have the capacity to nourish the embryo longer during germination [36].

In this study, the correlation between 100 seed weight and vigour was significant in some locations (data not shown). Similar correlation was reported by Vaughan et al. [37] in Soya bean. Similarly, Perry [38] reported that weight among mature cereal seeds might affect some aspects of seed quality. Seed weight itself is sometimes considered a component of seed quality because it can be correlated with seed and seedling performance. Fertilizer application increases photosynthates being channeled to the developing seed thereby making it more vigorous. Farmers who intend to use own seeds in the following season should therefore practice proper crop husbandry such as timely harvesting and application of appropriate nitrogen levels in order to increase the proportion of large and heavy seeds [39]. However, fertilizer application led to a significant increase in lodging ($P \leq 0.001$).

3.2.5. Seed Quality. This study showed that maximum seed vigour was attained at harvest maturity (HM) and not at physiological maturity (PM). Maximum viability was also attained at HM and not at PM. Fertilizer application led to a significant increase in seed vigour and viability (data not shown).

3.3. Economic Analysis on the Adoption of Improved Variety and Inorganic Fertilizer. An economic analysis carried out shows that producing the local varieties with fertilizer had the highest gross field and net benefit with the improved variety (KSTP) produced without fertilizer having the lowest (Table 10).

Surprisingly, the local varieties produced without fertilizer had the highest benefit: cost ratio. This means that the benefits derived from fertilizer application were very low and hence it was not cost effective. The inefficiency can be attributed to several factors. The broad or "blanket" recommendations used in this study that assume homogeneity of farming conditions may not always give good results and may have led to low diffusion of fertilizer technologies [40]. The low economic benefits derived from the use of fertilizers in farmers' fields can also be attributed to the fact that farmers in Western Kenya are aware of the need to apply Nitrogen and phosphorus fertilizers but the costs are prohibitive [41] and hence they apply lower rates of inorganic fertilizers than is usually considered economically optimal [42]. Additionally, improper fertilizer application practices such as poor fertilizer placement may reduce its economic returns. For example, some farmers place phosphatic fertilizers on the soil instead of working it into the soil. This reduces its effectiveness due to its low mobility. The fixation of P by aluminum and iron oxides [43] may also negate its benefits.

The higher benefit: cost ratio recorded by local varieties as compared to KSTP both produced without fertilizer lends support to the observation that the local varieties are adapted to local conditions and are of low-input requirement and as reported by farmers during the survey (Table 3). They therefore perform better under these conditions than most improved varieties. It may therefore seem that this is a major consideration in the choice of varieties by farmers. The choice of varieties by farmers is therefore founded on strong economic considerations in addition to other factors.

3.4. Farmer Cultural Practice Analysis. Statistical and economic analysis can never replace farmer assessment and adoption behaviour unless the farmers are convinced of the benefits of the technology without a lot of extra resource input [44]. Through farmer participation in the execution of trials, it was evident that farmers realized the importance of using fertilizers in maize production. The conventional wisdom in the area is that inorganic fertilizers hurt the soil [45]. The farmers were therefore willing and ready to adopt the use of fertilizers but were not fully convinced of the capacity of KSTP to tolerate *Striga* as compared to the local landraces. In addition, farmers found KSTP '94 less appealing due to its small grain size. Farmers usually prefer large grain sized varieties.

4. Conclusion

Though on-farm seed production appears to have its constraints that lead to reduced yield and quality of farm-saved seeds, it also has its strengths such as the presence of local varieties which are able to perform well under conditions of stress. Such aspects need to be retained while incorporating others from the formal seed sector such as timely harvesting and fertilizer application. Fertilizer application led to an increase in yield and yield components as well as seed quality and its optimal use is therefore recommended. However, nitrogen fertilizer applications should be done with caution especially on fertile soils to avoid lodging. This study also noted that farmers are rational and their decisions are usually based on strong economic considerations.

Acknowledgments

The authors acknowledge with thanks the kind financial assistance from the Rockefeller Foundation through Forum for Agricultural Resource Husbandry (FORUM) to carry out this study. Thanks are also due to participating farmers in Siaya and Busia Districts for allowing the authors to use their farms for the study and sharing their knowledge and ideas. Logistical support by Moi University is also greatly acknowledged.

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