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Genetic biodiversity assessment and local seed systems of maize landraces among smallholder farmers in Western Kenya

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Abstract Maize is the main staple food in Kenya and adoption rates for improved varieties is high. Smallholder farmers grow over 75% of the maize crop in Kenya. Breeders consider that some local varieties hold potential value for local adaptation and other useful traits. Many farmers in western Kenya use local maize landraces although documentation indicating genetic diversity of these maize types has not been done. The objective of this study was to assess the genetic diversity of these local maize landraces and to document the existing local seed systems of the same in four western Kenya districts. A total of 285 randomly selected farmers from four western Kenya districts were interviewed using a questionnaire. Both primary and secondary data is used. Four maize landraces were found in this region. Eighty percent and sixty five percent of farmers in Siaya and Busia districts respectively planted only these maize types, whereas Bungoma and Kakamega each had 32% and 20% respectively. These local maize types covered more than half of the total maize area in Siaya and Busia districts. The interviewees had a well defined local maize seed system. In conclusion there are four types of indigenous maize types of economic importance in western Kenya with well defined seed conservation systems. It is recommended that communities in the lower potential areas of Siaya and Busia districts be considered as sites for improved on-farm seed conservation programmes. Also, any anticipated introduction of genetically modified maize into this region should be done under carefully considered guidelines to minimize the risk of contaminating these maize types.

Key words: Conservation, cropping systems, genetic diversity, seed systems, *Zea mays*

Résumé Le maïs est le principal aliment préféré au Kenya et l'effort fournit pour améliorer les variétés est plus beaucoup. Les petits agriculteurs augmentent plus de 75 % de production des mais au Kenya. Les producteurs considèrent que quelques variétés locales possèdent de valeurs potentielles pour l'adaptation locale et autres caractéristiques essentielles. Beaucoup d'agriculteurs d'Ouest du Kenya utilisent le mais local même si les littératures qui parlent de diversités génétique de ce type de mais ne sont pas encore fait. L'objectif de cette étude était de décider la diversité génétique de ces mais variété locales et de documenter le système local de semence existant de la même variété (race locale) dans les 4 districts de l'ouest du Kenya. Un total de 285 échantillons forme d'agriculteurs sélectionnés de 4 districts de l'Ouest du Kenya étaient interviewé en utilisant un questionnaire. Les données primaires et secondaires étaient utilisées. Quatre mais variétés locales étaient découvert dans cette région. 80% et 65% d'agriculteurs de districts de Siya et de Busia plantaient respectivement ces types de mais seulement, par contre Bugoma et Kakamega avait respectivement chacun 32% et 20%. Ces types de mais local couvraient plus que la moitie de l'étendue totale de mais dans les districts de Siaya et de Busia. Les interviewes avaient un bon système de semence de mais local bien défini. En conclusion, il y a 4 types de mais local d'importance économique d'Ouest du Kenya avec un bon système de conservation des semences bien défini. Il est recommande que les communautés dans les milieux a faible possibilité de district de Siaya et de Busia soient considérés comme les sites pour améliorer le programme de conservation des semences agricoles. Aussi, tout introduction anticipe de mais génétiquement modifie dans cette région devrait être fait avec beaucoup de soins selon les lignes directrices pour minimiser les risques de contamination de ces types de mais.

Key words: Conservation, systems de cultures, diversité génétique, systems de graines, *Zea mays*

Introduction

Maize is an important staple food crop in Kenya with an annual production of 3.68 million tons (FAOSTAT, 2002). Production takes place both under smallholder (80%) and large-scale (20%) farming systems. Like other developing countries, adoption of improved cereal seed varieties is significant especially in the uniform and high potential areas (Dalrymple, 1986a). The share of the formal seed sector in the total seed supply rarely exceeds 10% in most cereal staple food crops in developing countries (Helsey, 1990). The formal seed sector is associated with improved maize varieties unlike the local landraces.

Pests, diseases and weeds such as stem borers, armyworms, maize streak virus, ear and head smut, grey leaf spot and striga weeds lower maize production per unit of land. Attack of maize crop by stem borers is consistently cited as a major constraint to maize production in many Kenyan maize growing areas (De Groote, 2002). An estimated 15 - 30% yield losses occur due to damage by these stem-borers including *Chillo partellus, C. orichalcociliellus, Busseola fusca, Eldama saccharina* (Mwangi and Ely, 2001).

Conventional methods of stem borer control which employ chemicals or bio-pesticides sprays including those based on *Bacillus thuringiensis* (Bt), have not always been effective due to challenges of timing these applications and the resulting difficulties in eradicating this pest once it has infested the crops. Few farmers use these control techniques. Introducing genetically modified stem-borer resistant Bt maize is one of the few effective approaches used to control the pest.

Maize originates from Central America and some well adapted landraces can be found in East Africa which were introduced in the sixteenth and eighteenth centuries by the Portuguese and English settlers respectively. (Harrison, 1970). These pools formed the basis of the first modern maize varieties bred in Kenya (Stabinsky and Sarno 2001) and are a vital source of genetic diversity for breeding locally adapted varieties. Information documenting the range of genetic diversity of these maize landraces in Kenya is lacking. Kenya's predominantly smallholder agriculture makes it hard to ensure non-contamination of landraces with Bt genes, once released.

In developed countries, the risk of GM crops has been assessed using case studies and models of gene-flow (Bellon and Risopoulos, 2001; Brush 1995; Di-Giovanni *et al*., 1995). Most of these studies have been done in temperate regions where the complexities of agro-ecosystems are less than those in tropical countries like Kenya. Most of these studies were carried out in the Americas where the agricultural systems lack traditional landraces that have long history of cultivation and are maintained by traditional seed saving practices. Limited information from studies in Mexico showed that maize pollen is desiccation intolerant and isolation distance can be a useful tool for controlling gene flow via pollination in research scale plantings (Luna, 2001). This study aimed at determining the genetic biodiversity and local seed systems of traditional maize landraces in four districts of western Kenya. The specific objectives of this study were to assess the genetic biodiversity of maize landraces and to document their existing local seed systems among farmers in western Kenya. This information will assist in formulating policies to determine the introduction of genetically modified bt stalk borer resistant maize in this region.

Materials and methods

The study was conducted in four smallholder highly populated districts of western Kenya i.e. Siaya, Busia, Bungoma and Kakamega, located around latitude 0.25^{o}S and longitude 33.5^{o}E. The altitude ranges from 1000-1500 metres above sea level. The weather is hot and sub-humid and the area receives a bimodal pattern of annual rainfall with the peaks in April for long rains and October for the short rains. It receives an annual rainfall of 1000-2000mm and this is erratic in some zones. Annual average temperature fluctuates between 15-30^{o}C with a mean annual temperature of 21^{o}C. The population density in this region is over 380 people per square kilometre (Nation Team, 2000) and subsistence agriculture is the major activity..

A total of 285 randomly selected farmers were interviewed in four districts of western Kenya over a period of 21 days. Those interviewed were selected from across the agro-ecological zones in each study districts. Questionnaires with structured, semi-structured and open ended questions were used. Both primary and secondary data were used. Data obtained from the questionnaire survey was analysed using the Statistical Package for Social Scientists (SPSS 12.0.1 for windows) program and descriptive statistics obtained.

Results

The four most prevalent indigenous varieties were found to be as follows: '*nyamuula*', a small yellow kernel, yellow cobbed maize variety which is highly prevalent in Siaya district; '*rachar*', a white kernel, white/red cobbed small sized maize type; '*samaria*', a medium sized white kernel/ white cobbed maize type found prevalently in Siaya and Busia distrricts, '*namba nane*', a large white kernel/white cobbed type found prevalently in Bungoma and Kakamega and characterized by a typical eight lines per cob of this maize.

The four most prevalent indigenous varieties are as follows and have the listed characteristics as in Table 1. Farmers in this area highly value their own indigenous maize varieties. The results obtained indicate that the area planted with local maize landraces and improved hybrid varieties varied strongly between the four districts.

Majority of farmers planted local maize landraces in two out of the four study districts. Kakamega district had the largest percentage of farmers who have planted both the local and improved maize types (58%) as indicated in Table 2. Local maize varieties covered more than half of the total maize area among the interviewed farmers in Siaya and Busia districts.

A total of 85% of the farmers interviewed grew some local maize landraces whereas 15% grew only improved maize varieties. Farmers prefer local maize varieties because of their early maturity, drought tolerance, low input tolerance, cheap/affordable seed and their culinary qualities. Table 3 shows why farmers value local maize varieties Farmers in the study district are resource poor and thus prefer to use their own available farm saved seed due to lack of money. Early maturity of these local maize types also makes them popular among the farmers interviewed.

Table 4 shows the percentage of farmers who rely on farm saved maize seed from previous harvest for next years' crop. Siaya district had the highest number of farmers who rely on own saved seed (85%). Percentage of farmers who use own saved seed in Busia, Bungoma and Kakamega Districts is 78, 36 and 25 respectively. Kakamega has the least due to the fact that most maize farmers in this district are aware of the advantages of hybrid maize and use it. The predictable and favourable weather in Kakamega district could also be a contributing factor to the high adoption levels of improved maize varieties. However, most farmers in this district set aside a portion of their farms to plant local maize types because of cheap seed and early maturity. Table 4 also shows the farmers initial seed source. Mother in laws were the main seed providers in Siaya (60%), and Busia (56%) districts. However in Bungoma and Kakamega district, this source of seed accounted for less than 50% of the respondents.

The most common method of paying for seed for those farmers who bought their seed was by paying cash. The price for one kilogram of seed maize ranged from USD 0.4 – 0.8.

The criteria used to select seed maize from the maize food grain include: cob-size - bigger cobs preferred, seed color - uniform seed color on cob preferred, uniformity of seed as arranged on the cob, good/uniform grain filling i.e. cobs with no shrivelled grains, and cobs that are free from pest/disease infestation. Seed maize selected to be

Table 1. Types and Characteristics of the preferred local maize landraces.

Local name	Grain colour	Cob colour	Grain size	District prevalent
'Nyamuula'	Yellow	Yellow	Small	Siaya
'Rachar'	White	Red/white	Small	Siaya
'Samaria'	White	White	Medium	Siaya/Busia
'Namba nane'	White or mixed colors	White	Large	Bungoma/Kakamega

Table 2. Percentages of local and improved maize varieties planted by farms in four districts of western Kenya.

Variety planted	District			
	Siaya	Busia	Bungoma	Kakamega
Local Maize	80	65	32	20
Local and Improved	14	32	22	58
Improved Variety	06	03	46	22

Table 3. Reasons why farmers preferred local maize landraces.

Reason	% of respondents who ranked this 1st
Cheap/affordable	42
Early Maturity	21
Assured/Guaranteed harvest even under unpredictable weather	14
Better yields with limited use of inorganic fertilizers and other inputs (low input tolerance)	8
Better storage potential and less insect infestation in storage	8
Better grain taste	7

Table 4. Percent of farmers who use own farm saved seed and where initial seed was obtained from.

District	% farmers who use own saved seed	% farmers who obtained initial local var. seed from:			
		Mother in law	Neighbours	Market	Others
Siaya	85[a]	60[a]	22	16	2
Busia	78[a]	56[a]	32	8	4
Bungoma	36[b]	48[b]	19	22	11
Kakamega	25[b]	45[b]	20	25	10

Table 5. Percent of farmers who use various seed storage methods.

No.	Method	Percent
1.	Hanging above the fire place in the kitchen	47.4
2.	Storage in earthen pots	17.6
3.	Storage in plastic or sisal gunny bags	15.8
4.	Storage in plastic containers	12.6
5.	Others	6.6

conserved for the next planting season is stored separately from the rest of the food maize grain. The recorded seed conservation methods are outlined in Table 5.

Discussions

Maize is known to evolve with tolerance to low input supply and drought tolerance (Poehlman, 1964). Four different local maize types were identified in this study. *Nyamuula* and *Rachar* were found to be prevalent in Siaya and Busia districts whereas *Samaria* and *Namba nane* were common in Bungoma and Kakamega districts. Each maize landrace is preferred either for early maturity, low input tolerance, or culinary qualities eg superior taste and better keeping quality. Given that rainfall in parts of this study area are erratic, many small-scale farmers especially in the LM1 zones of Siaya and Busia were found to prefer the local maize landraces whose maturity is guaranteed with minimal rainfall. This is in agreement with Poehlman. The Farmers in this districts are also resource poor. Although most farmers were found to apply some criteria to select seed for the next planting, the level of specialisation varied strongly. Seed was more often selected after harvest by selection of corn ears and stored separately. Over 75% of the farmers interviewed in Siaya and Busia districts were found to use own farm saved seed, differing significantly from those farmers in Bungoma and Kakamega where 38% and 25% farmers respectively used own farm saved seed (Table 4). In Bungoma and Kakamega districts, the few farmers who grow local maize landraces preferred to buy the seed from local markets at a cost of USD 0.4 – 0.8 per kilogram of seed whereas the rest selected and kept their own maize seed. Besides buying seed from the local market, receiving seed from mother-in-law and seed exchange with neighbors were the other seed exchange mechanisms noted in this study. The mother in law was found to play a major role of handing over seed to the daughter in law or her own daughters possibly because of the culture of the people in these districts. Also, in this community, most farm work is carried out by the women and children. Possible reasons for seed exchange mechanisms could be for seed renewal, a necessary practice to avoid high level of inbreeding leading to depressed yields. Some of the noted seed exchange could also be due to superior crop performance. Local seed systems in Equador indicate that the farmers' own seed has the advantage of being cheap, of known quality, and of being readily available (Crissman and Uquillas,1989). When the farmers in Equador did not save seed, when the seed was degenerated or when the farmers want to plant a new variety, they have to look for other seed sources. When the local seed supply is reliable (in timely availability, price and quality), small-scale farmers are likely to consume or sell their own seed especially when the market prices are high. Loss of seed due to disasters or general poverty is also an important factor in the use of off farm seed sources, particularly among resource poor farmers. Studies on the role of farmers in bean plant breeding program in Rwanda among resource poor farmers indicated that 90% of the common bean seed used for planting was obtained mainly from the food grain market. Sperling and Loevinsohn, 1993). Seed production could be more specialized when seed is produced in separate plots, which can be encountered in situations where seed is difficult to store e.g. in the case of sweet potatoes. It could also be produced off season to avoid a long storage season e.g. soybean (Linnemann and Simonsma, 1987), or sweet potato (Rao, 1993).

Time, method and criteria of selection interact with the genetic composition of the variety or variety mixtures-earlier selection and more intense selection pressure increase the opportunity of adaptation to environment and preferences. Reports on production and selection practices demonstrate the presence of capable breeders-selectors in the farming communities. Rice farmers in Nigeria were found to harvest seed rice from the centre of the field to maintain purity (Richards, 1985), sorghum farmers in central Nigeria were found to select heads for seed from a range of plant types (Harlan, 1975). Farmers seed selection in combination with production under local conditions has created local cultivars with valuable adaptation to specific local environmental conditions such as day-length adaptation of sorghum cultivars in Nigeria (Curtis, 1968) and the drought tolerance of maize varieties of North America (Collins 1914). Selection of healthy looking large maize ears and seed is likely to favour seed vigor.

Local seed sources, other than the farmers' own seed, have the advantage that the variety or mixture is usually known to be adapted to the respective agroecological and socio-economic conditions of a given area. Moreover, such seed is usually available and can often be obtained without involvement of cash i.e. through barter, gift or loan. Farmers with good seed production practices may have the reputation as reliable seed suppliers in the local community. Such farmers may also be important sources of new varieties and knowledge about their adaptability to the local conditions. Traditional seed producing areas can be a source of healthy and vigorous seed to replace degenerated seed stocks. In our study, farmer to farmer seed exchange mechanisms were mostly based on the traditional social network of mothers passing local maize seed to their daughters or daughter in law. A similar seed exchange mechanism was found to be an effective way of diffusing new irish potato seed varieties in Kenya (MacArthur, 1989).

A significant percentage of farmers in Siaya and Busia districts use own farm saved local maize seed. The difference between these two districts was found not to be significant as indicated in Table 4. However for Bungoma and Kakamega districts, the percentage of farmers using their own farm saved seeds was not significant. Both Bungoma and Kakamega are significantly different from Siaya and Busia (Table 4). Almekinders (1994) reported the lack of systematic information on informal seed sector but reiterated the existence of many observations and reports in literature which confirm the importance and potential of local seed systems among small-holders. Farmers' seed production, handling and selection system in this study were found to be well developed and mainly a domain of the women whereby mothers and mother-in-laws pass on local maize seed to their daughters or their daughter-in-laws. It should be noted that the existing seed exchange mechanisms could often adequately supply seed and diffuse genetic material within the respective agro-eco-zones.

Special seed storage practices such as hanging above the fire place, storage in earthen pots mixed with ashes, storage in plastic or sisal gunny bags while mixed with ashes were found to be common in this study. This demonstrates the farmers' awareness and capability to produce 'good' quality seed. Hanging seed above the fire place provides an environment which is unsuitable for insect infestation, hence next seasons seed is guaranteed. Ashes also do interfere with the porous nature of insect epidermis hence seed is likely to stay insect free till planting time. Storage in plastic containers or gunny bags helps to reduce light intensity of the seed storage environment ensuring that the seed stays in a quiescence state for a long period.

Insect pests are a major threat to seed conserved for the next season. The use of ashes, hanging the seed above the fire place in a smoke filled environment are strategies to minimize insect infestation in stored seed. The preferred ash was that obtained from burning cow dung. Other methods of attempting to keep the seed free of insect infestation were found e.g. mixing seed maize with cement or mixing seed with crushed carbon obtained from dry cell batteries. These two methods however need precautions since dry cell battery carbon is highly toxic to human and animals and should be handled with care. Left over seed mixed with cement or battery mixture cannot be used as food grain the way other preserved seed maize can.

Conclusions and recommendations

In conclusion, there are four distinct types of maize landraces in western Kenya. it can be recognized that the farmers knowledge and capacity to conserve genetic diversity of local maize landraces plays an important role in the continuation of the process of crop evolution. Farmers highly value local maize landraces in because of their low input requirement, early maturity and drought tolerance. It is recommended that the existing local maize landraces be conserved both at the National Gene bank level and that farmers be empowered to effectively carry out on farm seed conservation. Also local maize seed supply for the small scale farmers can be improved through strengthening of the existing seed systems by training the women involved in better seed handling techniques. It is evident that the farmers in western Kenya highly value their local maize types. There is therefore a need to carefully consider possible contamination of the maize landraces into this region by introduction of genetically modified Bt stem borer resistant maize into this area. Carefully outlined guidelines to minimise the high risk of contaminating the locally adapted local landraces need to be put in place.

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