

IFAR SPONSORED PROJECT PROGRESS REPORT

**MODELLING GENEFLOW TO ASSESS RISK TO
BIODIVERSITY IN TRADITIONAL CROPPING SYSTEMS
OF MAIZE IN KENYA**

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Modelling Geneflow to Assess Risk to Biodiversity in Traditional Cropping Systems in Western Kenya.

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Abstract

Maize production in Kenya takes place under both smallholder and largescale farming systems. The use of local landraces/traditional maize varieties is still a practiced among smallholder maize growers in many parts of Kenya. Maize is wind pollinated with long dispersion distances and preventing contamination to maintain varietal purity is a major challenge. The distribution of diversity among local landraces is unknown and the geneflow within the cultivars has not been documented. This study sought to find out the distribution of diversity among local maize landraces in four districts of western Kenya situated between longitude 34°E and 35°E, and between latitude 0°30'N and 1°S, with an altitude range from 900-1500 meters above sea level. Distribution of diversity among local maize landraces was assessed by a survey to determine components of traditional maize production systems in western Kenya. A total of 285 farmers were interviewed using a questionnaire. Farmers' seed production strategies including storage, and exchange were documented. 38 germplasm samples were collected from the four districts and grown at two sites in this region for assessment of genetic diversification/characterization using IBPGR/CIMMYT descriptor list of 1995. Variation in vegetative, ear, tassel, and kernel descriptors was determined in representative sets of these collected landraces. Experiments were designed to measure geneflow and the

impact of various factors contributing to gene flow under field conditions using dominant morphological markers (xenia effects). The results from these experiments will be used to develop models to forecast rates of gene flow under varying conditions in the farmers' fields and hence develop guidelines to minimize risk to contamination of traditional maize cultivars. Four broad cultivars were identified and collected for characterization in this study. These were 'nyamuula' – a small to medium sized maize type with a white cob and yellow kernels, 'rachar' - a small to medium sized maize type with white or red cobs and white kernels, 'samaria', - a medium sized maize type with white kernels on a white cob, and 'namba nane' – a medium to large size maize type with a white cob and white kernels which has characteristic 8 lines per cob of maize. Variation in eleven descriptors was determined and their minimum, maximum, SD, and CV determined using SPSS computer statistical program. Plant height had a CV of 24.82% with the shortest variety measuring 68 cm and the tallest variety 218 cm. Days to flowering had a CV of 9.51% with the earliest variety flowering after 48 days after planting and the latest variety 65 days after planting. CV for ear leaf length was determined as 11.29 whereas CV for leaf width was 12.39. It can thus be noted that there is distinct variation among the collected maize germplasm which can be used in crop improvement programs, and thus should be protected against dilution/contamination. Gene flow studies should be carried out to the end so as to develop models to forecast rates of gene flow under farmers' fields and to develop guidelines to minimize risk to biodiversity in traditional cropping systems of maize in Kenya.

Introduction

Maize is an important staple food crop in sub-Saharan Africa. Recent FAO reports indicate that 24 sub-Saharan countries face food shortage emergencies, and that millions of people in these countries still rely on food aid for survival (Africa Harvest, 2004). Maize production takes place under both small-holder and large-scale farming systems in this region. In Kenya, small-holders account for 75 - 80% of the total production. Although improved maize varieties dominate in the high potential zones, around a quarter of the farmers especially in the central highlands, eastern, coastal areas, and western parts

of Kenya use local landraces/traditional varieties of maize. Maize is wind pollinated with long dispersion distances, and preventing contamination to maintain varietal purity is a major challenge. The degree of cross pollination is influenced by a number of factors such as wind direction and speed, weather conditions at flowering time, pollen viability, abundance of insect pollinators etc. However, the distribution of diversity among the local traditional landraces has been unknown and the degree of gene flow within the cultivars has not been documented. This study aimed at finding out the distribution and diversity of traditional maize landraces in 4 districts of western Kenya i.e. Siaya, Busia, Bungoma, and Kakamega. These 4 districts of Kenya are highly populated with an average population density of over 350 people per square kilometer. The only form of survival is agriculture which is done at subsistence level because the residents are resource poor. Rainfall pattern in most of this area is erratic often having long delays and frequently failing altogether. Maize is the staple food for this region and thus a vital crop. Due to the rising population pressure on arable land in Kenya, maize production is moving to marginal agriculture areas. This is an area of agrarian-ecological concern because in these marginal maize production areas, maize stalk borer (*Buseola fuscica*) is a major pest accounting for losses of up to 30%. *Bacillus thuringensis* (bt) maize is one of the few approaches to control this pest. CIMMYT, under the Insect Resistant Maize for Africa (IRMA) Project in partnership with Kenya Agricultural Research Institute (KARI) and International Centre for Insect Physiology and Ecology (ICIPE), are developing transgenic maize resistant to this major insect pest using gene constructs. Maize is a highly domesticated crop whose wild relatives (teosinte etc) occur only in Central America, so gene flow leading to weediness is not a significant risk in Africa. However, there are general concerns over contamination of these well adapted traditional maize landraces that have been developed since the introduction of *zea mays* species in this region. These traditional maize landraces are a vital source of genetic diversity for breeding locally adapted varieties and should be conserved. Dilution/contamination of these maize landraces by bt maize might lead to loss of important germ-plasm. Traditional maize collections that have not been systematically characterized can contain duplicated accessions or too many unique/rare types (Steiner and Poklemba 1994). In the characterization part of this study we characterized a collection of the 40 accessions

based on 20 vegetative and agronomic characters. The objective was to try to establish association between varieties and to select the outstanding traditional maize varieties with better yields. For this purpose, Cluster Analysis (CA) which is an effective tool to screen germplasm and to classify accessions according to their degree of similarity (Peeters and Martinelli, 1989; Ordas et al. 1994; Smith et al. 1995) was used.

The specific objectives of this research were as follows:

- To determine the components of traditional maize production systems in 4 districts of western Kenya
- To determine the genetic variability in traditional varieties of maize in this region
- To determine the degree of gene flow between maize varieties
- To develop a risk assessment model for the introduction of novel maize varieties into traditional production systems

The main focus of this research was to determine the gene flow and assess the risk of introducing transgenic maize varieties into traditional cropping systems of maize in western Kenya.

Justification

Maize is an important staple food crop in Kenya. Maize production takes place under both small-holder and large-scale farming systems in this region. In Kenya, small-holders account for 75 - 80% of the total production. Although improved maize varieties dominate in the high potential zones, around a quarter of the farmers especially in the central highlands, eastern, coastal areas, and western parts of Kenya use local landraces/traditional varieties of maize. Maize is wind pollinated with long dispersion distances, and preventing contamination to maintain varietal purity is a major challenge. The degree of cross pollination is influenced by a number of factors such as wind direction and speed, weather conditions at flowering time, pollen viability, abundance of insect pollinators etc. However, the distribution of diversity among the local traditional landraces has been unknown and the degree of geneflow within the cultivars has not been documented. This study aimed at finding out the distribution and diversity of traditional maize landraces in 4 districts of western Kenya i.e. Siaya, Busia, Bungoma, and Kakamega. These 4 districts of Kenya are highly populated with an average population

density of over 350 people per square kilometer. The only form of survival is agriculture which is done at subsistence level because the residents are resource poor. Rainfall pattern in most of this area is erratic often having long delays and frequently failing altogether. Maize is the staple food for this region and thus a vital crop. Documenting the variation in the available indigenous maize varieties will help implement crop improvement programs and avoid dilution/contamination of these landraces. It will also help draw guidelines on how to introduce genetically modified maize into the country without risking contamination of these landraces.

Materials and Methods

The Survey

The methodology involved documentation of the range of maize production systems in the region and the seed production strategies used by farmers including details of farmers' handling, sampling, storage and exchange of seed. Potential sources of gene flow in the field including the nature of cropping systems weather patterns, distance between plantings, maturity differences for the various maize landraces, abundance and type of insect pollinators were also recorded. A questionnaire with structured and semi-structured questions was used to interview a total of 300 farmers from the four districts under this study i.e. Siaya, Busia, Bungoma and Kakamega. Both primary data (from the interviewees) and secondary data (from the respective District Agricultural Offices) were used in this exercise. Data obtained from questionnaire survey was analyzed using the Statistical Package for Social Scientists (SPSS 12.0.1 for windows) program and descriptive statistics obtained.

Germplasm Collection and Characterisation

Germplasm of traditional maize varieties from four districts in western Kenya were collected for characterisation and conservation purposes by the team from Moi University and National Genebank of Kenya Muguga. 38 samples of the collected traditional maize varieties were grown at Siaya FTC (34⁰30'E, 0⁰25'N, 1150 m asl) and Western University College (WEUCO) farm (35⁰E, 0⁰20'N, 1450 m asl) for characterization and assessment

of genetic diversity using appropriate morphological markers according to CIMMYT/IBPGR (1995) list of maize descriptors and Kenya National Genebank guidelines. Pots of 3x3 m were planted with each accession with a spacing of 75x50cm inter-row and between plant spacing. Plots were fertilized with 200kg/ha of P₂O₅ and top-dressed after 4 weeks with 200kg/ha of N on 2 occasions of 100kg each at 1 week interval. Weeds were controlled by three hand weedings. Field evaluations were carried out in 20 plants from the middle rows in each plot. Eleven vegetative and reproductive characters were evaluated by the time of writing this report (Table 1). Twelve other (reproductive and post-harvest) characters are still being evaluated since the crop has not yet fully matured. Two replicates of each traditional variety were planted at these trial sites. The Siaya FTC and WEUCO experimental sites were planted concurrently expecting to take advantage of the short rains of September to January. However, there was a prolonged dry spell in Kakamega resulting in poor germination. This site had to be abandoned and thus only data from the Siaya FTC site was collected and used for characterization. Data collection started from the third week after planting. At a later time, assessment of genetic diversity of these traditional maize varieties using biochemical (protein and isozyme) and molecular markers (subject to availability of specific markers) will be done. The following descriptors were recorded seedling vigor, days to 50% flowering, midrib color of third leaf counted from the flag leaf, plant height, stem color, number of basal tillers, plant uniformity, total number of leaves per plant after flowering, ear leaf length, ear leaf width, and number of leaves above the uppermost ear. Not all the descriptors listed could be recorded because by the time of compiling this report, this exercise is still going on as the crop has not yet matured. Seed descriptors will be recorded after harvesting has been done.

Pollen Longevity Studies

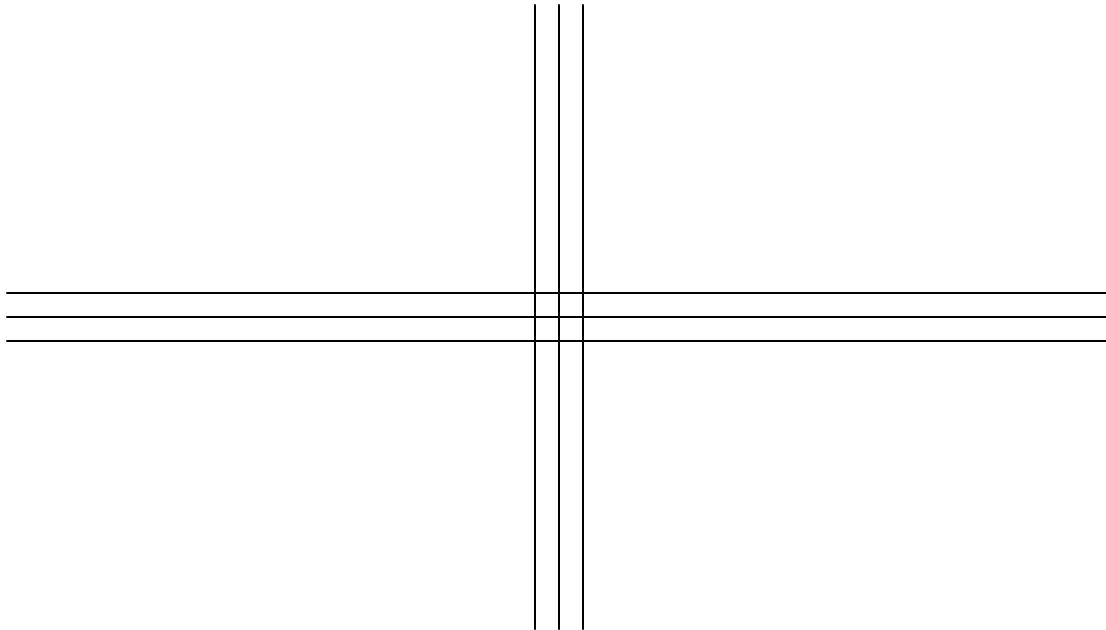
Field station experiments to measure pollen longevity under ambient atmospheric conditions of the target regions were designed and set up at Siaya FTC and WEUCO farms. These studies were designed to measure how long pollen of three different maize types can survive under ambient temperatures in the two locations in Western Kenya. Pollen was to be collected at the onset of dehiscence and its survival in the ambient

conditions assessed by visual scoring, viability testing and measuring the seed set after controlled pollination of the ear heads. Pollen from each of the different maize types was to be exposed to ambient environmental conditions for 0, 15, 30, and 45 minutes and then used to pollinate different plots. Seed set in each of the plots was to be assessed to note how long pollen can stay viable in this environment. Three maize varieties 'Musamaria', 'KSTP', and a stable yellow variety were obtained from KARI/CIMMYT project in Nairobi and used in this study. Initial laboratory tests indicated fair germination of seeds from these varieties. However, field experiments were a failure at this time because 'KSTP' and 'Musamaria' seeds showed very poor germination. This study will however be done in February 2005 at the onset of long rains in this region using better quality seed with the same design.

Gene flow Studies

The degree of gene flow in the target environment was to be measured from the rate of inter-crossing between the selected genotypes in experiments designed to investigate the impact of various factors (e.g. isolation, seasonal variation in atmospheric conditions) that are known to influence the rate of gene flow. Two maize varieties of different colors and same maturity period were planted with the aim of measuring their rate of intercrossing. 3 lines of the white maize variety were planted in a length of 140 meters in a North-South orientation. Another 3 lines (140 meters long) of the same white maize variety were planted on the same plot in an East-West orientation, such that they intercepted in the middle. At the portion where these 6 lines intercepted, a stable yellow colored maize variety was planted to act as a source of yellow pollen (see sketch below). Gene flow was to be assessed at seed filling stage by harvesting and assessing the rate of intercrossing between white and yellow maize via xenia effect. These gene flow experiments were set up in Siaya FTC and WEUCO farm. . Initial laboratory tests indicated fair germination of seeds from these varieties. However, field experiments were a failure at this time because 'KSTP' and 'Musamaria' seeds showed very poor germination. These experiments too will be repeated in February 2005 at these same sites at the onset of long rains at these sites using better quality seed.

Fig. 1 Sketch Showing Experimental Design for the Geneflow Studies Experiment



Results Obtained

The results presented in this report cover the survey work, germplasm collection and characterization.

The Survey

In a period of 21 days, a total of 285 farmers were interviewed in the four districts of western Kenya, Siaya, Busia, Bungoma and Kakamega. All the interviewees were maize growers and they all happened to have either local maize varieties, improved maize varieties or both. The overall average family/household size among the interviewees was found to be seven (i.e. 2 adults and five children). Labor for farm work is mainly supplied by these family members. The average family farm size in the 4 districts was documented as 1.4 hectares. Of the farmers interviewed 20% had also rented some other piece of land (0.1 – 1.0 ha) in the neighborhood where they had also planted maize. Maize is planted twice in a calendar year in this region and the maturation period ranged from 3 – 5 months. Other crops grown in the region include beans, sorghum, sugar-cane, finger

millet, sweet potatoes, bananas, avocados, and assorted vegetable crops for domestic consumption. Table 1 shows the number of farmers interviewed per district, gender distribution, age, and marital status.

Table 1. No. of farmers interviewed Gender distribution, age and marital status

District	N Interviewed	% Gender		% in Age-group (Yrs)			Marital Status (% of farmers:)			
		Male	Female	<30	30-45	>45	Single	Married	Widow	Widower
Siaya	89	39	50	21	30	38	8	33	31	6
Busia	99	36	63	30	27	43	10	70	17	3
Bungoma	50	19	31	10	16	24	3	41	5	1
Kakamega	47	18	29	25	21	54	10	70	17	3
TOTAL	285	112	173							

Preferred Maize varieties

Several maize varieties are preferred in the different districts for various reasons. The five most prevalent indigenous varieties are as follows and have the listed characteristics as in Table 2.

Table 2. Types and Characteristics of the preferred local maize varieties

Local Name	Grain color	Cob color	Grain size	District prevalent
'Nyamuula'	Yellow	Yellow	Small	Siaya
'Rachar'	White	Red/white	Small	Siaya
'Samarina'	White	White	Medium	Siaya/Busia
'Namba nane'	White or mixed colors	White	Large	Bungoma/Kakamega
'Ugandan Composite'	White	White	Medium-Large	Busia/Bungoma

Farmers in this area highly value their own indigenous maize varieties. Responding to why they value these varieties, they gave the following reasons as shown in Table 3 below.

Table 3. Reasons why farmers prefer local maize varieties

Reason	No. of respondents who ranked this 1 st
Cheap/Affordable since I have limited cash	113

Early Maturity of maize variety	60
Assured/Guaranteed harvest even under unpredictable weather	32
Better yields with limited use of inorganic fertilizers & other inputs	23
Better storage potential and less insect infestation in storage	22
Better grain taste	20
Drought tolerance	15
TOTAL	285

The four most common maize insect pests in this area which attack maize crop while still in the field are stalk borer, termites, moles, and quelea birds.

Maize seed production, handling and storage systems used by farmers.

Table 4 shows the percentage of farmers who rely on own farm saved maize seed from previous harvest for next years' crop. Siaya District has the highest number of farmers who rely on own farm saved seed. Kakamega has the least due to the fact that most maize farmers in this district are highly aware of the advantages of hybrid maize and use it. However, most farmers in this district do set aside a portion of their farms to plant indigenous maize types because the seed is cheaper and due to early maturity of these varieties. The table also shows where the farmers got their initial seeds from.

Table 4. Percentage 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:			
		Parents	Neighbors	Market	Others
Siaya	85	60	22	16	2
Busia	78	56	32	8	4
Bungoma	36	48	19	22	11
Kakamega	25	45	20	25	10

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 30 – 60 shillings. The farmers awareness of advantages of modern hybrid maize varieties was as shown in Table 5.

Table 5. Farmers Perception of advantages of improved maize varieties

District	%Farmers perception of advantages of improved maize varieties		
	Good	Medium	Poor
Siaya	15	30	55
Busia	35	36	29
Bungoma	62	31	9
Kakamega	73	21	6

Seed storage systems

10% of the interviewees harvest their seed maize separately from the rest of the grain crop. The criteria used to select seed maize from the rest include:

- Cob-size - bigger cobs preferred
- Seed color - uniform seed color on cob preferred
- Uniformity of seed arrangement on the cob
- Good/uniform grain filling i. e. cobs with no shriveled grains
- Cobs that are free from pest/disease infestation

Seed maize is selected immediately after harvesting and is stored separately from the rest of the grain crop for food. Seed storage methods were outlined as below in Table 6.

Table 6. Methods of Maize Seed Storage by farmers in western Kenya

	Method	n = no. of respondents
1	Hanging above the fire place in the kitchen	127
2	Storage in earthen pots	46
3	Storage in plastic or sisal gunny bags	42
4	Storage in plastic containers	33
5	Others	17
		265

Control of Storage Pests

All farmers ensure that seed is thoroughly dried before storage. The following 5 methods were recorded as practiced by farmers to control storage pests in their seed maize:

- Mix seed maize with ash obtained from burning cow dung
- Smoking cobs above fire place

- Mix seed with kerosene
- Mix seed with cement
- Mix seed with crushed carbon obtained from radio/torch dry cell (batteries)

Potential Sources of gene flow in the fields

98% of the farmers interviewed indicated that they do not mix any two or more maize varieties in the same plot. All different maize varieties are grown as pure stands thus minimizing gene flow from one maize type to another. 95% of all the farms visited had crops inter-planted with the maize crop. The intercrops were beans, sorghum, groundnuts, finger millet etc. The most prevalent intercrop pattern was alternate rows of maize and the respective intercrop. The distance between neighbors maize fields ranged from 6 – 30 meters, since the entire study area is predominantly a high population small scale area. Hedges, fences, windbreaks were common in all the four districts. These are planted as a tradition to demarcate borders of farms from one neighbor to another. No special care is taken by any of the interviewees to prevent contamination and maintain maize varietal purity. Insect pollinators cited include bees (few), and butterflies (very few) in these areas.

Germplasm Collection and Characterization

Germplasm Collection

A total of 38 different maize samples were collected from various places within the four districts. The field collection trip was planned such that the accessions were collected from the farmers fields just after maturity, immediately before harvest. Passport data for every collected sample was documented and the collections were then taken for drying, processing and conservation at the National genebank of Kenya at Muguga. These were given accession numbers and then issued to Moi University for planting and characterization at the two field experimental sites in Siaya FTC and WEUCO farm in Kakamega. The list of the accessions collected and used in the characterization study is appended in this report as Appendix 2.

Germplasm Characterization

Eleven descriptors were recorded using the IBPGR/CIMMYT (1993) list. Not all the listed descriptors could be recorded because the crop is still in the field by the time of writing this report. Only seedling and plant vegetative/pre-harvest data have been recorded as of now (Table 7).

Table 7. Evaluated characteristics in each one of the 38 indigenous maize germplasm as per CIMMYT/IBPGR and Kenya National gene-bank requirements and the ones considered in the multivariate analysis.

Code for character	Parameter measured
PREHARVEST	
SVig	Seedling vigor – visual measurement recorded 3 wks after emergence of seedlings. (1 – V. Strong, 2 – Strong, 3 – Average, 4 – Weak, 5 – V. Weak)
Dfl	Days to 50% flowering – counted as no. of days from planting to when 50% of plants have extended silk.
Mrcol	Midrib color – midrib color of the third leaf counted from the flag leaf downwards taken during or shortly after flowering
Ht	Plant height – mean height of a plant row measured in cm from ground level to the tip of the head taken after flowering, before ripening.
Col	Stem color - Indicate up to three stem colors in the order of frequency. Observed between the two topmost ears. 1.Green, 2.Sun-red, 3.Red, 4.Purple, 5.Brown
Til	Basal tillers – Average no. of basal tillers at maturity without counting the stem
PUnif	Plot uniformity - consider phenotypic appearances
Lea	Total number of leaves per plant after flowering
Llen	Leaf length (cm) From ligule to apex. Measure the leaf which subtends the uppermost ear. After flowering.
Lwid	Leaf width (cm). Same leaf as above. Mid-way along its length
Lear	Number of leaves above the uppermost ear including ear leaf. Counted on at least 20 representative plants. After milk stage.

The germplasm showed a fairly distinct range of variability in plant height (63 – 218 cm), ear leaf length (50 – 85cm), days to flowering (48 – 67), ear leaf width (6 – 11cm), and

seedling vigor (1 – 4). This indicates the possibility of exploiting this variation for varietal improvements of these local maize types. High coefficient of variation (CV) was observed for plant height (24.91%), followed by ear leaf length (11.29%), days to 50% flowering (9.51%), ear leaf width (12.39%), and seedling vigor (9.51%). Wide diversity in agronomic traits have been reported among other crops (amaranthus genotypes) and several genotypes identified which appear to carry favorable agronomic traits of immediate use in cultivar improvement (Wu et al, 2000). The indigenous maize germplasm being characterized are highly valued for traits such as drought tolerance and good yields with low level inputs. These traits can be improved upon to give better yielding, fast maturing maize varieties suited for these areas. However, these germplasm is contaminated by the introduction of genetically modified maize in this region. Such introduction will hamper improvement programs of maize in this western Kenya region. Table 8 shows a statistical summary of quantitative morphological pre-harvest characters which were recorded for the 38 accessions. The table shows the mean, minimum, maximum, standard deviation, and the coefficient of variation (CV).

Table 8. Summary of quantitative morphological characters of Indigenous maize accessions obtained from 4 western Kenyan Districts

Trait	No.	Minimum	Maximum	Mean	S	CV
Plant height (cm)	38	63	218	122.39	30.38	24.91
Ear leaf length (cm)	38	50	85	70.63	7.91	11.29
Days to flowering	38	48	67	55.42	5.27	9.51
Ear leaf width (cm)	38	6	11	8.94	1.11	12.39
Seedling vigor (5 – 1)	38	4	1	2.71	0.83	30.82
No. of leaves above ear	38	4	6.5	5.48	0.53	9.83

Table 9. Grouping maize entries for the different biometric and qualitative traits.

Trait	Range	Germplasm lines
Plant Height [Ht] (cm)	<100	32,52,79,71,86,60,89,88,62
	101-120	61,70,67,57,63,50,76,81,65
	>120	85,55,72,80,58,83,66,59,64,87,84,77,78,82,53,51,56,74,54,75
Days to flowering [Dfl]	<50	64,74
	51-55	32,75,79,54,73,53,63,81,71,83,88,70,71,83,88,70,78,58,85,57,82,76,50,87,65,51,86,60,59
	>55	66,77,80,55,72,89,52,62,56,84
Leaf length [Llen] (cm)	<68	88,62,86,57,71,89,52,70,84,64,77,51,60,61,54,81,65
	69-79	79,53,32,50,75,80,87,73,78,56,66,55,63,76
	>80	74,83,59,82,72,85,67
Tillers [Til]	0	32,50,51,52,53,54,55,57,61,62,63,67,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,89
	1-2	60,64,56,70,88,59,66,75,58,65,87
Stem color [Col]	Green	53,32,82,76,77,87,63,81,57,58,54,79,89,84,71,66,52,59,88,60,61,67
	Sun-Red	78,52,75,51,83,85,55,56,74
	Red	65,70,64
	Purple	50,73,86,80,62,72
Seedling vigor [SVig]	V.Strong	87,78,58
	Strong	74,55,70,80,88,54,86,75,81,63,50
	Average	60,72,64,61,56,62,85,83,66,71,89,79,65,73,76,32,53,67
	Weak	59,84,52,57,77,82
Leaf Midrib color [Mrcol]	White	53,32,82,76,77,87,78,65,75,89,84,71,66,51,86,83,54,85,80,64,72,67
	Dark-Green	50,63,73,81,57,52,58,79,59,88,70,62,55,56,61,60,74
Plant Uniformity [PUnif]	V.Uniform	58,54,72,67
	Uniform	53,82,76,50,77,63,73,78,57,65,89,84,66,83,59,88,85,62,56,64,74
	Un-uniform	32,87,81,52,75,71,51,86,80,70,55,61,60
No. of leaves [Lea]	8-10	60,64,62,71
	11-12	53,81,57,52,79,51,86,54,88,61,74,32,82,50,77,76,87,63,73,65,58,89,66,83,59,85,80,55,56,72,67
	13-14	84,88,70,67
Leaf width [Lwid]	<7.5	86,88,70,67
	7.6-9.0	32,82,77,78,86,57,52,65,75,79,89,84,71,66,51,54,80,62,56,61,64,60,74
	>9.1	53,76,50,87,63,73,58,83,59,85,55,72
Leaves above ear [Lear]	<4.5	89,66,88,67
	5-6	53,32,82,76,50,77,87,63,73,78,81,57,52,65,58,75,79,84,71,51,86,83,54,64
	>6	59,81,85,80,70,62,55,56,61,72,60,74

Discussions

(a) The Survey results

All the farmers interviewed were growing either local maize varieties only or both local varieties and hybrids. Many of these farmers were noted to typically use own farm saved seeds from previous harvest as seed for the next crop (Table 4). For Siaya district, the percentage of farmers who save own seed was as high as 85% whereas Kakamega had the lowest with 25%. Initial seed was noted to be passed on from one generation to the next as mother in laws pass on such seed to their daughter in laws who in turn pass it on to the next generation. Local seed saving activities on the farms were found to be a domain of women. Farmers prefer local maize varieties because they are resource poor, This is illustrated in Table 3 where 115 respondents out of 285 rank limited finances as the main reason why they save own seed. This seed is also preferred because of early maturity. Since farmers in these districts have small farm sizes, then maize harvests do not last until next harvest leaving a gap when there is not available food grain in the farm. Therefore, early maturing local maize varieties are treasured since they fill in this gap of food shortage as compared to late maturing improved maize varieties. Other reasons for preferring local varieties are as listed in Table 3.

Farmers in Siaya and Busia districts have very poor perception of the advantages of improved maize varieties as shown in Table 5. This explains why there is such a large percentage of farmers who use own farm saved seed seeds. It should, however, be noted that the farmers interviewed practice farming for subsistence and not commercial. Growing of improved varieties usually gives better yields.

(b) Genetic variation in local maize varieties/characterization trials

A total of 5 distinct types of local maize varieties were identified as shown in Table 2. “Nyamuula” a yellow kernel type of maize was prevalent in Siaya district and so was “Rachar” a white kernel type. “Samaria” was found mainly in Siaya and Busia districts. Siaya was noted to be a district rich in biodiversity of indigenous maize varieties. “Namba nane” was predominantly found in Kakamega and Bungoma districts. In these

districts farmers perception on the use of hybrid maize varieties was very high. Table 8 shows the parameters which were found to be more variable among the maize types found in the four districts. The variation provides a rich source of traits which can be used for improving maize varieties in the region.

Conclusion

From the completed part of this study, it can be concluded that among the four districts Siaya has a rich biodiversity of local maize germplasm. The local varieties are highly regarded by the farmers because of their adaptability to the local conditions. Therefore, any efforts towards conserving the local varieties will ensure preservation of a rich source of maize germplasm.

Description of conference participation planned

Have plans to present a paper on initial research survey findings at the 1st Annual Moi University Conference (15-16th February 2005) entitled **“Documentation Of Maize Production Systems In Western Kenya With A View To Assess Risk To Biodiversity On Introducing Genetically Modified Maize”**

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Appendices

Appendix 1. Sample Of Questionnaire Used For The Field Interview

MOI UNIVERSITY, FACULTY OF AGRICULTURE IN COLLABORATION WITH IFAR/IPGRI-KENYA.

Questionnaire for farming systems survey

QUESTIONNAIRE TO DOCUMENT MAIZE PRODUCTION SYSTEMS IN 4 DISTRICTS IN WESTERN KENYA REGION AND MAIZE SEED PRODUCTION/ STORAGE STRATEGIES IN THIS REGION.

Name of Interviewer.....
Date of interview.....
Questionnaire no.

A. IDENTIFICATION

1. Name of respondent:..... Gender: M/F.....Age.....
2. Marital Status: Single/Married/Widow/Widower/Separated.....
3. District (Siaya/Busia/Bungoma/Kakamega):.....
4. Division:.....
5. Location:.....
6. Village:.....
7. AgroEcological Zone:.....
Soil-type:.....
Rainfall:.....
Topography: (Steep/gentle slope/flat).....

B. SOCIO-ECONOMIC AND GENDER ISSUES

8. Position of the respondent in the household:.....
9. Type of household (Female headed/Male headed):.....
10. Highest education level of the respondent (if any):.....
11. Occupation of the respondent: (a) Current:.....
(b) Previous:.....
12. Type of Farmer (resident/ non-resident):.....
13. Languages spoken:.....
14. Family size (number of people in household):.....
15. Family Structure (Residents): (a) No. of male adults:.....
(b) No. of female adults:.....
(c) Children between 8 - 18 years:.....
16. Source of labour (household/hired/both):.....
17. Total Farm Size.....
18. Land Ownership (with title deed/without title deed/other=specify):.....
19. Land Under Maize (Acres):.....
20. Other Crops Grown (crop/acreage): (a).....
(b).....
(c).....
(d)
21. Have you rented another pieces of land in this same district? (Yes/No):.....
22. If Yes, what crops have you planted on the rented land?.....
23. Who makes decision on land use (Male/female/both):.....
24. Farming experience (years):.....

C. DOCUMENTATION OF RANGE OF MAIZE PRODUCTION SYSTEMS

25. Total area Under Maize Crop:
 - (a) Large-scale (over 5 ha).....
 - (b) Med-scale (2 - 5 ha).....
 - (c) Small-scale (Under 2 ha).....
26. Types of Maize crop grown (Hybrid/ Local Variety):

Maize Variety	Proportion of Total Maize	How long have you grown this variety.	Reason for planting(code 1)	Problems experienced (code 2)	Yield per Acre

Code 1

- 1=Good grain yield
- 2=Good straw yield
- 3=Good grain quality
- 4=Good grain taste

Code 2

- 1=No problem
- 2=Poor grain yield
- 3=Poor straw yield
- 4=Poor grain taste

- 5=Good marketability
- 6=Good storage potential
- 7=Disease resistant
- 8=Drought tolerant
- 9=Pest resistant
- 10=Others (specify)

- 5=Poor marketability
- 6=Poor storage potential
- 7=Disease susceptibility
- 8=Drought intolerance
- 9=Pest susceptibility
- 10=Others (specify)

27. How long does maize take to mature in long rain season?.....
28. How long does maize take to mature in short rain season?.....
29. Name the common maize **diseases** & extent of attack(Mild/serious/very serious).
And how do you control them?

- (a).....
- (b).....
- (c).....

30. Name the common maize **pests** & extent of attack (mild/serious/very serious) **And** how do you control them?

- (a).....
- (b).....
- (c).....

31. Name the serious maize **weeds** & extent of attack (mild/serious/very serious) **And** how do you control them?

- (a).....
- (b).....
- (c).....

E. MAIZE SEED PRODUCTION, HANDLING, AND STORAGE STRATEGIES USED BY FARMERS.

1. Source of seed for current Maize crop:
- (a) Own Farm saved seed (Yes/No).....
 If Yes, where did you get initial seed?
 - (b) From neighbor (bought or exchanged):.....
 If from neighbor where did neighbor initially get seed from?.....
 - (c) Relatives (from same village/different village/region).....
 - (d) Bought from market (local/regional).....
 - (e) Bought From local seed stockist:.....
 - (f) Others (specify):.....

2. Which source of seed do you prefer?.....
- Why do you prefer this seed source?.....
 - How far do you travel to obtain your seed?.....
 - How do your neighbors source their seed?
 - Are there changes in seed sourcing habits in recent years? Yes/No
 - If yes, what's the change?

3. What is the most common method of paying for seed (where applicable)
- (a) gift
 - (b) barter (specify commodity)

- (c) seed exchange
 - (d) labour exchange
 - (e) cash money. (Price per kg?)
 - (f) others (specify)
4. Awareness among farmers about advantages of modern varieties?
 - (a) good
 - (b) medium
 - (c) Poor
 5. What do farmers see as the main advantage or disadvantage of their current seed source?.....
 - (a) Quantity (too small or too big)
 - (b) Availability (runs out before all farmers can get seed)
 - (c) Seeds do not arrive on time
 - (d) Price (too expensive)
 - (e) Lack of credit
 - (f) Poor quality of seed
 - (g) Inappropriate varieties (agronomic or consumption properties)
 - (h) Unavailable complementary inputs eg fertilizers, etc.
 - (i) No information on cultural practices
 - (j) Source of seed is too far away

F. SEED STORAGE

1. Do you harvest seed maize differently from the rest of the maize crop? **Yes/No...**
2. What criteria do you use in you maize seed selection?
(Cob-size/Color/Shape/Pest-Disease resistance, others (specify)
3. How long before planting do you select your seed maize from the rest of the crop?
.....
4. Do you store your seed separate from your food grains? (**Yes/No**).....
If Yes, How?.....
5. How do you control storage pests for your stored seed maize?.....
6. In an ordinary year are you able to save sufficient seed to plant desired area at the recommended densities?.....
7. Do you usually have excess seed maize? (Yes/No)
- If Yes, what do you do with it?
8. If own farm saved seed, how do you treat the seed to ensure it keeps well until next planting season?:.....
.....
9. Do you select your own seed while still in the field? (Yes/No).....
If Yes, how do you do the selection?
Do you select a section of the field? Yes/No.....
Do you select plants? Yes/No.....
Do you select ears? Yes/No.....
Do you select the grains? Yes/No.....

10. For which characteristics do you select? Earliness/High Yields/Cob-size/Disease tolerance/Pest tolerance/weed tolerance/ Others,specify.....

G. POTENTIAL SOURCES OF GENE FLOW IN THE FIELD.

1. Nature of cropping systems:

- (a) Is maize grown as a pure stand or is it intercropped with other crops(specify)
- (b) If purestand, is only one variety planted or a mixture of varieties mixed together?
- (c) If maize varieties are mixed, how may varieties/hybrids be mixed i.e. in what proportions?
- (d) Is any specific pattern of planting followed in the varietal mixtures? E.g. no. of rows of each variety?
- (e) If inter cropped, what is the proportion of maize to other crops in the same field?
- (f) Is any specific pattern of planting followed in the intercropped fields? E.g lay out, no. of rows of each crop.etc)
- (g) Approx. distance between neighboring maize fields?.....
- (h) Presence of hedges, wind-breaks, border plantings around maize plots? Yes/No?

2. Phenology and Weather

- (a) Time of planting?.....
- (b) Time of flowering?
- (c) Flowering duration (days)?
- (d) Any special care taken (if any) to prevent contamination and maintain varietal purity?
- (e)Time to maturity?
- (f)Mean temperature, relative humidity and precipitation during flowering time ?
- (g) Mean wind speed and wind direction?

3 Types of insect pollinators cited: Type and abundance (1,2,3,4)

- (a) Bees (Yes/No):..... Abundance:.....
- (b) Butterflies Yes/No):..... Abundance:.....
- (d) Others (specify):..... Abundance:.....
..... Abundance:.....
..... Abundance:.....
..... Abundance:.....

(1 = very few; 2 = few; 3 = many; 4 = very many)

Appendix 2. List of Accessions obtained from genebank of Kenya and used for characterization

Sample No.	Gene-Bank No.	No. of Seeds issued	Seed weight (gm)
1	046850	240	99
2	046851	240	77
3	046852	240	82
4	046853	240	73
5	046854	240	74
6	046855	240	67
7	046856	240	53
8	046857	240	57
9	046858	240	62
10	046859	240	73
11	046860	240	51
12	046861	240	49
13	046862	240	63
14	046863	240	48
15	046864	240	73
16	046865	185	71
17	046866	240	71
18	046867	240	89
19	046870	240	82
20	046871	240	79
21	046872	240	48
22	046873	240	49
23	046874	240	86
24	046875	240	67
25	046876	240	79
26	046877	240	81
27	046878	240	98

28	046879	240	82
29	046880	240	86
30	046881	240	118
31	046882	240	139
32	046883	240	141
33	046884	240	96
34	046885	240	94
35	046886	240	108
36	046887	240	76
37	046888	240	99
38	046889	240	105