African Journal of Agricultural Research Vol. 7(17), pp. 2701-2712, 5 May, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.488
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Dynamics of on-farm management of potato (*Solanum tuberosum*) cultivars in Central Kenya

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Accepted 7 December, 2011

Studies to understand the dynamic nature of farmers' management of potato and assess the extent of genetic erosion and farmers' perceptions of genetic erosion in potato were conducted in Kiambu West district in 2006. A stratified random sampling procedure was used to draw a sample of 302 farmers for the study. Majority of the farmers interviewed obtained seeds from informal sources. Farmers identified 29 varieties which were once widely grown in the study area. Of these, only 9 are still grown while another 11 have been introduced. The most commonly grown varieties were Zangi (69.4%), Tigoni (41.4%), Thima Thuti (30.8%) and Karuse (20.9%). Twenty cultivars including Amin, Anett, Cardinal, Feldeslohn, Gituru, Kiraya, Kibururu, Kenya Baraka, Kenya Dhamana, Karora Iguru, Maritta, Mirka, Njae, Njine, Patrones, Romano, Roslin Bvumbwe, Roslin Gucha, Suzanna and Furaha were the most affected by genetic erosion. The most important causes for abandonment of varieties were low yields, rapid greening, susceptibility to late blight, strong dormancy, sensitivity to drought, and susceptibility to bacterial wilt, susceptibility to potato tuber moth, poor storability and poor cooking quality. The emergence of new and better varieties, lack of markets and lack of seed were the three most cited non-varietal reasons for abandoning varieties. Farmers were not bothered by the loss of varieties. When comparing varieties currently cultivated to formerly available varieties, a genetic erosion of 31.0% was computed suggesting that genetic loss has occurred in the study area. Results of this study suggested that it is necessary to initiate collection, characterization and conservation studies of potato varieties across the country. There is also the need for awareness creation on the importance of potato genetic resources and their conservation.

Key words: Conservation, genetic erosion, farmers' perceptions, Kenya, potato, seed sources, *Solanum tuberosum*, variety abandonment.

INTRODUCTION

The continuing need for improved crops to cope with new environmental and changing consumer demands creates a constant requirement for genetic diversity, but the pool of natural diversity is shrinking with time largely, because of the negative actions of humans (Guarino, 1999). The loss of genetic diversity results in increasing vulnerability of crops to changing abiotic and biotic stresses and threatens global food security (Hawkes et al., 2000). The concept of genetic erosion in agriculture can be applied at three different levels of integration: at crop level as an impoverishment in the assemblage of crops used in agriculture, at the level of varieties of a specific crop or at the level of alleles (van de Wouw et al., 2009).

The present threats to biodiversity from genetic erosion and extinction were recognized by the Convention on Biological Diversity's (CBD's) Global Strategy for Plant Conservation (CBD, 2002) which in Target 9 called for conservation of 70% of the genetic diversity of crops and other major socioeconomically valuable plant species. Further, the 2010 biodiversity target committed the parties 'to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and

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national levels as a contribution to poverty alleviation and to the benefit of all life on earth'. From the dawn of modern plant breeding, there has been apprehension that replacement of traditional crop varieties with improved varieties poses a risk to biological diversity (Harlan, 1975; Vellve, 1993). It has previously been suggested that plant breeding is a strong force in the reduction of genetic diversity' (Gepts, 2006), and introduction of modern cultivars has been cited as evidence of genetic erosion (Bennett, 1973). It is however, unclear to what extent the onset of modern breeding efforts has really affected diversity levels in crops (van de Wouw et al., 2009). Frankel and Bennett (1970) referred to such a decrease in crop diversity as genetic erosion (GE). The traditional perception of genetic erosion is that of the loss of a stable and diverse set of locally adapted landraces resulting from the adoption of a small number of modern varieties (Hawkes, 1983; Brush, 1999). On the basis of this perspective, genetic erosion is considered to be the disappearance of named varieties in the regions where they were previously grown (for example, Hammer et al., 1996).

Maxted and Guarino (2006) defined genetic erosion as the permanent reduction in richness (or evenness) of common local alleles, or the loss of combinations of alleles over time in a defined area. Brown (2008) defined genetic erosion as a process that refers to a change in genetic diversity over time, and considered it to be difficult to specify in an index or indicator since monitoring changes in the rate of genetic erosion strictly requires a direct comparable if not identical measures of the state of a system at several points in time. More recently, van de Wouw (2009) reviewed the concept of genetic erosion and concluded that genetic erosion as reflected in a reduction of allelic evenness and richness appears to be the most useful definition, but has to be viewed in conjunction with events at variety level. To date, there is no simple technique available that can adequately measure the genetic erosion of crop diversity. This is partly attributable to the huge data requirements needed to cover all the disciplines involved (for example, agronomy, plant protection, genetics, population biology, ecology, economics, sociology, ethno-botany), and the paucity of time series data on landraces. The dynamic nature of crop evolution, whereby genetic diversity is added and lost from plant populations through time (Wood and Lenne, 1997; Brush, 1999; Tunstall et al., 2001) also complicated the study of genetic erosion. There is also a dearth of information on the selection and maintenance of landraces by traditional farmers (Zeven, 2002). According to Wood and Lenne (1997) and Brush (1999), information on the conservation and use of genetic diversity in traditional agricultural systems remain largely empirical and anecdotal. Therefore, most of the available information regarding genetic diversity of landraces is not consistent and/or not adequately explored.

The degree of genetic erosion faced by a particular crop in a certain region over time can be estimated using a number of approaches including making comparisons between the number of species/cultivars still in use by farmers at the present time and those found in previous studies or interviewing farmers about varieties that used to be grown in a particular area (van de Wouw et al., 2009). The latter approach has been applied to estimate the extent of GE in wheat (Teklu and Hammer, 2006; Tsegaye and Berg, 2007), sorghum (Mekbib, 2007) and cassava (Willemen et al., 2007).

There is, however, little information on the level of genetic erosion of potato in Kenya. This is despite the fact that the crop has been grown in the country since the late nineteenth century (Durr and Lorenzl, 1980). In a study on evaluation, choice and use of potato varieties in Kenya, Crissman (1989) reported that some older varieties had been rejected by farmers, but no attempt was made to estimate the extent of genetic erosion. The objectives of this study were to: i) understand the dynamic nature of farmers' management of potato; and ii) assess the extent of genetic erosion (GE) and farmers' perceptions of genetic erosion in Kiambu West district in Kenya.

MATERIALS AND METHODS

Study area

The study was done in three divisions: Limuru, Ndeiya and Tigoni of Kiambu West district in central province of Kenya between February and March, 2006. The altitude in the study area varies between 1800 and 3000 m above sea level. Agroecological zones include Upper Highland (UH_0 to UH_2), Lower Highlands (LH_1 to LH_5) and Upper Midlands (UM_3, UM_5 and UM_6). The district borders, Lari district to the North, Naivasha district to the West, Kikuyu and Kajiado districts to the South and Kiambu East district towards the east. The farming system of the study area is a typical crop-based mixed, crop–livestock mixed production. Production is rain-fed with most households growing a number of crop types and varieties. The three divisions are readily accessible to markets.

Sampling procedures

Kiambu West district was purposively chosen as the study area because of; (i) its importance in potato production; (ii) its long history of growing potatoes hence, has ideal sites for study on farm GE; (iii) the diverse cropping systems; (iv) the area has been exposed to market forces and other externalities that influence on-farm diversity of potato; and (v) its proximity to the Kenya Agricultural Research Institute (KARI) Tigoni Research Centre, which permits access to many varieties since this is the institute mandated with potato variety development in the country.

Farmers were selected using stratified sampling techniques whereby the three major potato growing locations in each division were chosen and within each location, farmers were selected at random from a list of potato-growers obtained from the local agricultural extension offices across all locations and sub-locations within a division.

Questionnaire development

Information about varieties grown in 1989 was obtained from secondary literature and key informant interviews. The key informant interviews were conducted with special potato knowledge holders in the farming community and involved interviewing agricultural extension officers, key farmers, potato traders and market vendors in the target area. A questionnaire was then formulated based on information from the key informant interviews and secondary literature. The questionnaire captured information on i) farmer's seed sources, ii) identification and naming of varieties, iii) varieties grown, iv) varieties no longer grown and the reasons for not growing them, and v) farmers' perception on genetic erosion. The questionnaire was pretested with 15 farmers in each of the three divisions and then revised accordingly. The final version consisted of both open-ended and closed questions.

Field survey

Interviews were conducted in farmers' potato fields to permit cross-checking of their answers with field observations where applicable. A total of 302 farmers comprising 100 farmers from Limuru, 110 from Ndeiya and 92 from Tigoni division, respectively, were interviewed. Enumerators were drawn from extension personnel from the Ministry of Agriculture and the KARI-Tigoni Research Centre. The interviews were conducted either in the national language (Kiswahili) or the local language (Kikuyu), depending on the language competencies of the respondents.

Data analysis

Survey data was analyzed using descriptive statistics, data explorations and cross-tabulations based on the Statistical Package for Social Scientists (SSPS) version 16 computer software. Pearson chi-square (χ^2) tests were used to determine whether there were significant associations between variables at $p \leq 0.10$ (Steel et al., 1997). The extent of genetic erosion, expressed as loss of potato cultivars grown by farmers was computed as the ratio of the number of varieties currently available to their former number using two parameters; genetic erosion and genetic integrity as indicated by Hammer et al.(1996) but as modified by Mekbib (2007). Genetic erosion (GE) = 100% - Genetic Integrity (GI). Genetic integrity (GI) = $C_{2006}/C_{1989} \times 100$, where C_{2006} is the number of varieties grown by farmers in 2006 (the year the survey was conducted) and C_{1989} is the number of varieties grown by farmers in 1989. The year, 1989 was chosen for comparison because there was a documented evidence of many of the varieties that were grown in this area during that time (Crissman, 1989) while the year 2006 was the year when the survey was done. In using names of potato cultivars as a proxy indicator for diversity in the study area, consideration was made of the following factors: (i) potato is clonally propagated and genetic integrity is maintained over relatively long periods of time, and (ii) the community members in the study area belonging to the same ethnic group share a common history, and have similar socio-economic and cultural environments. The farming system and cropping patterns are also fairly similar thus; information shared concerning crop species and cultivar names, most likely, remains consistent. It was therefore, assumed that names of potato cultivars identified by farmers could be used as a proxy indicator for genetic diversity within the species.

RESULTS

Farmer attributes

The characteristics of the potato farmers interviewed are presented in Table 1. Majority of the farmers surveyed in the three divisions were females (67.5%). Most of the farmers surveyed were 30 to 50 years (36.1%) and over 51 years old (60.3%). The farmers had stayed in the respective areas for relatively long periods, with most of them having been resident in their divisions for over 20 years (57.0%). Average farm sizes were generally small with 37.1% of the farmers owning less than 1 acre and 36.8% owning 1 to 5 acres. Only 1.3% of the farmers had acreages greater than 20 acres. On the average, most of the farmers were experienced in potato growing with 41.1% of the farmers having grown the crop for over 20 years and 29.5% having grown the crop for between 16 and 20 years. Only 0.7% of the farmers had grown the crop for periods ranging from 1 to 5 years.

Sources of seed

Table 2 lists the sources of potato seed identified by farmers. Only 23, 8.2 and 13.2% of the farmers in Limuru, Ndeiya and Tigoni, respectively, obtained seeds from sources likely to produce high quality seed such as seed growers and research institutions. Use of own seed saved from previous harvest was the most important source of seed for farmers in all the divisions. The second most important source of seed in all the three divisions was the market while neighbours comprised the third most important source of seed. In nearly all the cases (95%), only small sized tubers were saved as seed. None of the farmers interviewed had a specialized plot for seed production purposes.

Varieties known and planted by farmers

Details about farmers' knowledge and awareness of varieties are presented in Table 3 and were generally similar across the three divisions. Seventeen of the 40 varieties named by farmers had local names with 13 of them being in the local dialect. All the farmers' given names referred to dominant criteria such as morphological characteristics, productive capacity, an important person or event that coincided with the time the variety was introduced, the person who introduced the cultivar and similarity with other cultivars.

Except for older varieties such as Amin, Gituru, Kiraya, Mirka, Njine, Njae, Patrones and Roslin Gucha, 32 other varieties were known by more than 69.9% of the respondents. None of the respondents had grown or knew anyone growing some 20 varieties (Amin, Anett, Cardinal, Feldeslohn, Furaha, Gituru, Kenya Baraka, Kenya Dhamana, Karora Iguru, Kibururu, Kiraya, Maritta, Mirka, Njae, Njine, Patrones, Roslin Bvumbwe, Roslin Tana, Romano and Suzanna) that had been previously grown in the survey area in the past five years prior to the survey. The varieties known by respondents ranged from

Table 1. Farmer characteristics in the three divisions surveyed (percentage of respondents).

Attribute	Limuru (n = 100)	Ndeiya (n = 110)	Tigoni (n = 92)	Total (n = 302)
Sex				
Male	35.0	30.9	31.5	32.5
Female	65.0	69.1	68.5	67.5
Age				
18-29 years	6.0	4.5	0.0	3.6
30-50 years	36.0	35.5	37.0	36.1
Over 50 years	58.0	60.0	63.0	60.3
Period of stay				
11-15 years	14.0	16.4	16.3	15.6
16-20 years	24.0	30.9	27.2	27.5
Over 20 years	62.0	52.7	56.5	57.0
Farm size				
< 1 acre	9.0	32.7	72.8	37.1
1-5 acres	36.0	45.5	27.2	36.8
6-10 acres	26.0	19.1	0.0	15.6
11-20 acres	25.0	2.7	0.0	9.3
Over 20 acres<	4.0	0.0	0.0	1.3
Household size				
1-2 persons	10.0	9.1	7.6	8.9
3-5 persons	59.0	48.2	60.9	55.6
Over 5 persons	31.0	42.7	31.5	35.4
Experience in potato growing				
1-5 years	2.0	0.0	0.0	0.7
6-10 years	12.0	7.3	8.7	9.3
11-15 years	15.0	19.1	25.0	19.5
16-20 years	33.0	26.4	29.3	29.5
Over 20 years	38.0	47.3	37.0	41.1

T**able 2.** Sources of seed for potato farmers in Limuru, Ndeiya and Tigoni (in percentage).

Division	Sources of seed (%)[a]				
	Own seeds	Market	Neighbour	Traders	Seed grower/research
Limuru (n = 100)	100	57.0	47.0	6.0	23.0
Ndeiya (n = 110)	100	76.4	32.7	1.8	8.2
Tigoni (n = 92)	100	79.3	34.8	0.0	13.0
Total (n = 302)	100	70.9	38.1	2.6	14.6

[a] Multiple responses possible.

23 to 40. Table 4 shows that about 42% of the farmers knew 35 to 40 varieties while 38.1% were familiar with 31 to 35 varieties. Approximately 19.0% of the farmers knew 26 to 30 varieties. Table 4 also shows that older farmers tended to know more varieties. The longer the growing period of potatoes the more the varieties a farmer tended to know (Table 5). About ninety eight percent of the farmers who had grown potatoes for over 20 years knew 35 to 40 varieties. None of the farmers who had grown potatoes for less than 6 years could identify more than 30 varieties. The number of varieties planted by farmers since the beginning cultivation of potatoes ranged from

Table 3. Farmers' knowledge and awareness of varieties (percentage of respondents).

Variety	Known by farmer				Planted by farmer or person known to the farmer			
	Limuru (n = 100)	Ndeiya (n = 110)	Tigoni (n = 92)	Total (n = 302)	Limuru (n = 100)	Ndeiya (n = 110)	Tigoni (n = 92)	Total (n = 302)
Roslin Gucha	40.0	50.0	50.0	46.7	0.0	0.0	0.0	0.0
Feldeslohn	69.0	73.6	66.3	69.9	0.0	0.0	0.0	0.0
Njine[abc]	41.0	59.1	48.9	50.0	0.0	0.0	0.0	0.0
Mukori[abc]	100	100	100	100	31.0	25.5	26.1	27.5
Desiree	100	100	100	100	100	100	100	100
Nyayo[ae]	100	100	100	100	100	100	100	100
Kerr's Pink	100	100	100	100	61.0	48.2	48.9	52.6
Maritta	94.0	93.6	93.5	93.7	0.0	0.0	0.0	0.0
Anett	100	100	100	100	0.0	0.0	0.0	0.0
Kenya Baraka	100	100	100	100	0.0	0.0	0.0	0.0
Roslin Tana	100	100	98.9	99.7	31.0	22.7	22.8	25.5
Njae[abc]	41.0	38.2	31.5	37.1	0.0	0.0	0.0	0.0
Suzanna[ae]	76.0	71.8	63.0	70.5	0.0	0.0	0.0	0.0
Arka	93.0	97.3	95.7	95.4	24.0	40.9	30.4	32.1
Dutch Robijn	100	100	100	100	100	100	100	100
Roslin Bvumbwe	98.0	92.7	91.3	94.0	0.0	0.0	0.0	0.0
Cardinal	95.0	92.7	91.3	93.0	0.0	0.0	0.0	0.0
Gituru[abc]	48.0	47.3	37.0	44.4	0.0	0.0	0.0	0.0
Amin[ae]	59.0	70.0	57.6	62.6	0.0	0.0	0.0	0.0
Kiraya[abc]	64.0	50.0	44.6	53.0	0.0	0.0	0.0	0.0
Kihoro[abc]	100	100	100	100	61.0	48.2	48.9	52.6
Kibururu[abc]	100	100	100	100	0.0	0.0	0.0	0.0
Karora –Iguru[abc]	98.0	92.7	91.3	94.0	0.0	0.0	0.0	0.0
Tana Kimande[abc]	99.0	100	100	99.7	100	100	100	100
Tigoni	100	100	100	100	100	100	100	100
Asante	100	100	100	100	100	100	100	100
Karuse[abe]	100	100	100	100	100	100	100	100
Thima Thuti[abd]	100	100	100	100	100	100	100	100
Kenya Dhamana	98.0	100	100	99.3	0.0	0.0	0.0	0.0
Furaha	100	100	100	100	0.0	0.0	0.0	0.0
Zangi[ae]	100	100	100	100	100	100	100	100
Kenya Sifa	100	100	100	100	56.0	66.4	56.5	59.9
Kenya Mavuno	100	100	100	100	100	100	100	100
Kenya Karibu	100	100	100	100	86.0	89.1	79.3	85.1
Romano	98.0	99.1	91.3	96.4	0.0	0.0	0.0	0.0
Roslin Eburu (B53)	98.0	100	100	99.3	2.0	0.0	0.0	0.7
Meru Mugaruru[abfg]	99.0	100	100	99.7	39.0	51.8	51.1	47.4
Ndera Mwana[abd]	100	100	100	100	100	100	100	100
Mirka	34.0	42.7	31.5	36.4	0.0	0.0	0.0	0.0
Patrones	30.0	39.1	28.3	32.8	0.0	0.0	0.0	0.0

a- refers to local name given by farmers; b- refers to name in the local dialect-Kikuyu; c- refers to a morphological characteristics; d- refers to productive capacity, e- refers to an important person/event that coincided with introduction of the variety; f- refers to the person who introduced the cultivar and g- refers to morphological similarity with another cultivar.

11 to 17. Most of them had planted between 15 to16 varieties (Table 6). There was no relationship between the number of varieties known by a farmer and the number of varieties they had ever planted ($r^2 = -0.58$, $p = 0.316$). On the average, majority of the farmers had planted two varieties (83.4%) during the survey (Table 6). None of the farmers surveyed had planted more than 3 varieties.

Table 4. Relationship between age of farmer and number of varieties known (percentage of respondents).

Number of varieties known	Age of farmer			
	18-29 years (n = 11)	30-50 years (n = 109)	Over 51 years (n = 182)	Total (n = 302)
20-25	0.0	2.8	0.5	1.3
26-30	72.7	28.4	9.3	18.5
31-35	27.3	51.4	30.8	38.1
35-40	0.0	17.4	59.3	42.1
Total	100	100	100	100

Table 5. Relationship between experience in potato growing and number of varieties known (percentage of respondents).

Number of varieties known	Experience in growing potatoes (years)					
	1-5 (n = 2)	6-10 (n = 28)	11-15 (n = 59)	16-20 (n = 89)	20< (n = 124)	Total (n = 302)
20-25	50.0	10.7	0.0	0.0	0.0	1.3
26-30	50.0	75.0	57.6	0.0	0.0	18.5
31-35	0.0	14.3	42.4	94.4	1.6	38.1
35-40	0.0	0.0	0.0	5.6	98.4	42.1

Table 6. Number of varieties planted by a farmer or person known to farmer, number of varieties currently planted by the farmers and characteristics used to distinguish varieties (percentage of respondents).

Variety	Division			
	Limuru (n = 100)	Ndeiya (n = 110)	Tigoni (n = 92)	Total (n = 302)
Number of varieties planted by farmers since the beginning of potato growth				
10-12	14.0	10.9	20.7	14.9
15-16	85.0	89.1	79.3	84.8
17-18	1.0	0.0	0.0	0.3
Number of varieties currently planted by farmers				
One	0	0	0	0
Two	82.0	83.6	84.8	83.4
Three	18.0	16.4	15.2	16.6
Characteristics used to distinguish varieties				
Tubers	79.0	75.5	78.3	77.5
Foliage	13.0	11.8	5.4	10.3
Tubers + foliage	8.0	12.7	16.3	12.3

Identification of varieties

There was no difference in the characteristics farmers used by farmers to distinguish varieties across the three divisions (χ^2 = 5.903; d.f = 4; p = 0.207). Varieties were mainly distinguished according to tuber characteristics across the three divisions. Table 6 shows that the use of tuber characteristics (77.5%) was the most common method employed by farmers to distinguish varieties. Foliage characteristics were used by only 10.3% of the farmers while 12.3% indicated that they used both tuber and foliage characteristics to identify varieties. Tuber attributes included the shape, skin colour and sprout characteristics while foliage characteristics mainly

Table 7. Varieties grown by farmers in the three divisions surveyed (percentage of respondents).

[1]Variety	Tuber skin colour	Proportion of farmers growing (%)		
		Limuru (n = 100)	Ndeiya (n = 110)	Tigoni (n = 92)
Tigoni	White	67.0	16.8	42.1
Zangi	Red	82.0	65.4	62.1
Karuse	Red	0.0	38.3	23.2
Meru	Red	0.0	6.5	8.4
Nyayo	White	17.0	5.6	15.8
Ndera Mwana	Red	2.0	39.3	16.8
Asante	Red	0.0	9.3	15.8
Tana Kimande	White	3.0	4.7	1.1
Thima Thuti	White	48.0	22.4	22.1
Dutch Robijn	Red	0.0	5.6	10.5

[1]All farmers grew more than one variety.

Table 8. Reasons cited by farmers for abandoning eight of the most commonly abandoned varieties (percentage of respondents).

[a]Reason	Tigoni n = 501	Nyayo n = 783	Desiree n = 582	Roslin tana n = 78	Tana kimande n = 381	Anett n = 42	Roslin eburu (B53) n = 27	Dutch robjin n = 309
Rapid greening	29.3	10.0	-	16.7	-	-	14.8	-
Low yields	32.7	32.4	33.3	26.9	33.1	33.3	18.5	33.3
Susceptible to late blight disease	25.3	26.6	22.9	16.7	3.4	33.3	-	19.4
Strong dormancy	0.6	0.8	24.9	-	26.0	16.7	25.9	-
Sensitive to drought conditions	-	0.9	2.7	10.3	1.6	-	33.3	7.8
Long maturity period	-	-	-	-	24.1	-	-	-
Susceptible to bacterial disease	8.2	19.8	16.0	1.3	9.2	2.4	-	26.2
Susceptible to moth infestation	3.8	4.0	0.2	-	2.6	14.3	-	13.6
Poor storability	-	5.6	-	28.2	-	-	-	-
Poor cooking qualities	-	-	-	-	-	-	7.4	-

a Multiple answers possible.

consisted of the flower colour and nature of the foliage.

Predominant varieties and number of varieties grown

During the survey period, only ten varieties were found in farmers' fields (Table 7). The most common varieties across the three divisions were Zangi (69.4%), Tigoni (41.4%), Thima Thuti (30.8%) and Karuse (20.9%). Only three of the ten varieties (Tigoni, Dutch Robijn and Asante) were improved varieties developed by the Kenyan potato programme.

The varieties grown as indicated by the respondents differed significantly across the divisions. Varieties Asante, Dutch Robijn, Karuse, Meru and Ndera Mwana were common in Ndeiya and Tigoni but not in Limuru. Varieties like Thima Thuti, Tigoni and Zangi were grown across the three divisions but tended to be more common in Limuru. Nyayo was more common in Limuru and Tigoni than in Ndeiya. There was no clear pattern for farmers' preference for either red or white skinned varieties across the three divisions.

Variety abandonment

Reasons for variety abandonment

Farmers reported that they had rejected some varieties and replaced them with others. Reasons for rejection were grouped into two: varietal reasons and non-varietal reasons.

Varietal reasons: Farmers cited eight reasons as being the most important in rejection of varieties (Table 8). These included: rapid greening; low yields, susceptibility to late blight, strong dormancy, sensitivity to drought conditions, long maturity period, susceptibility to bacterial wilt, susceptibility to tuber moth, poor storability, and poor cooking qualities. The reason for rejecting a variety was

Table 9. Non-varietal reasons cited by farmers for abandoning varieties (in percentage).

Reason	Limuru (n = 100)			Ndeiya (n = 110)			Tigoni (n = 92)			Total (n = 302)		
	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3
Better varieties came	61.0	4.0	35.0	55.5	5.5	39.1	56.5	14.1	29.3	57.6	7.6	34.8
Poor markets	11.0	69.0	20.0	20.9	43.6	35.5	4.3	64.1	31.5	12.6	58.3	29.1
Lack of seeds	28.0	27.0	45.0	23.6	50.9	25.5	39.1	21.7	39.1	29.8	34.1	35.1

Multiple responses possible.

Table 10. Method for variety abandonment used by farmers (percentage of respondents).

Method for variety abandonment	Limuru (n = 100)	Ndeiya (n = 110)	Tigoni (n = 92)	Total (n = 302)
Consume or sell all seed	97.3	98.9	98.6	98.3
Leave seed to deteriorate and throw away	2.7	1.1	1.4	1.7

dependent on the variety itself, although, many of the varieties were rejected for similar reasons. Most of the farmers who rejected variety Tigoni cited low yields (32.7%), rapid greening (29.3%) and susceptibility to late blight (25.3%) as the most important reasons for rejecting it. Nyayo was rejected because of low yields (34.2%), susceptibility to late blight (26.6%) and susceptibility to bacterial wilt (19.8%). Desiree was rejected for low yields (33.3%), strong dormancy (24.9%) and susceptibility to late blight (22.9%). Roslin Tana was rejected because of low yields (26.9%), rapid greening (16.7%) and susceptibility to late blight (16.7%). The most important reasons for rejecting Tana Kimande were low yields (33.1%), strong dormancy (26.0%) and long maturity period (24.1%). Anett was rejected because of low yields (33.3%), susceptibility to late blight (33.3) and strong dormancy (16.7%). Roslin Eburu was rejected because of low yields (27.8%), sensitivity to drought (22.2%) and rapid greening (22.2%). Dutch Robijn was rejected because of low yields (33.0%), susceptibility to bacterial wilt (26.2%) and late blight susceptibility (19.4%). None of the farmers interviewed reported that they rejected any variety due to small sized tubers.

Most of the farmers indicated that discarding of an older variety will only occur after the older and new varieties have been grown together for several seasons, permitting comparison. During the observation period, the acreage of the older varieties will be progressively reduced in favor of the new variety. Non-varietal reasons: Majority of the farmers ranked the displacement of older varieties by new varieties as the number one reason (57.6%) for rejecting varieties while 12.6% regarded poor markets as the second most important reason for rejecting a variety (Table 9). Lack of seed was considered the second most important reason for rejecting a variety by 29.8 % of the farmers. The reasons for rejecting the varieties did not differ significantly between the divisions.

Method of variety abandonment

Majority of the farmers surveyed (97.3%) indicated that the principal method they used to discard a variety was to either sell or consume all the tubers of the variety to be discarded (Table 10). A small proportion of the farmers (2.7%) indicated that they left the seeds of the variety to be discarded to deteriorate during storage, after which the material was thrown away.

Perceived losses of cultivars and quantification of genetic erosion

From an initial 29 varieties grown in 1989 in the study area, a total of 20 varieties were no longer grown by farmers as of the year 2006. Another 11 varieties (Asante, Furaha, Karuse, Kenya Karibu, Kenya Mavuno, Kenya Sifa, Mugaruru, Ndera Mwana, Thima Thuti, Tigoni and Zangi) had been introduced in farmers' fields bringing the total

Table 11. Reasons why farmers do not care about loss of varieties (percentage of respondents).

Reason	Limuru (n = 100)			Ndeiya (n = 110)			Tigoni (n = 92)			Total (n = 302)		
	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3
Better varieties came	69.0	3.0	11.0	64.5	5.5	20.0	84.8	1.1	6.5	72.2	3.3	12.9
Poor markets	8.0	27.0	45.0	2.7	43.6	43.6	0.0	35.9	58.7	3.6	35.8	48.7
Lack of seeds	8.0	55.0	19.0	22.7	40.9	26.4	9.8	57.6	29.3	13.9	50.7	24.8

Multiple responses possible; ranking scale 1-3, where 1-most important, 2-second most important and 3 is least important.

number of cultivated varieties in the survey area in 2006 to 20. All the varieties that were introduced after 1989 were still being grown to some degree by farmers. Thus, the GI is 69.0% while the GE was 31.0%.

Farmer's perception of genetic erosion

There were differences in farmers perceptions about loss of varieties across the three divisions ($\chi^2 = 4.773$; d.f = 2; $p = 0.092$). A very high proportion of the farmers that surveyed (89.7%) were not bothered by the loss of varieties. Majority of the farmers ranked the appearance of higher yielding varieties (72.2%) followed by the preference of newer varieties by the market (13.9%) as the most important reasons for not caring about the disappearance of the varieties ($\chi\chi^2 = 25.940$; d.f = 6; $p = 0.001$) (Table 11). Lack of seeds was ranked third (3.6 %).

DISCUSSION

This study found potato farmers to be ageing lot with most of them aged over 50 years. The implication of this finding is that the ageing farmers participated prominently in potato farming production in the study area, while a large proportion of the young and able bodied men might have migrated to the urban centers in search of more lucrative jobs. This is a negative influence not only on conservation of potato varieties but also on the sustainability of potato farming with potentially negative effects on food security situation of Kenya. It is important that the youths are encouraged to take up potato farming through appropriate incentives and policy measures.

Most studies have pointed out that yield is the most important criterion for the choice of a variety by a farmer (Heisey and Brennan, 1991). When the yields of a particular variety decline because of degeneration, farmers needed to replenish their seed stocks to restore the yields (Lung'aho et al., 2007). In the absence of sources of good quality seed, farmers may prefer to change a variety and plant a different variety that has high yields rather than a variety that is considered good but low yielding due to diseases. Thus, varietal composition in the informal seed system is dynamic. Over time, varieties are lost and new ones are introduced from elsewhere (Louette et al., 1997). Commonly, improved varieties are incorporated into the informal system (Almekinders et al., 1994), a process that is known as creolization (Bellon and Risopoulos, 2001). These creolized varieties are often given local names, becoming part of what farmers consider to be their local varieties. Majority of farmers in this study sourced their seed from informal seed sources. Studies from elsewhere (Cromwell, 1990; Ndjeunga et al., 2000) reported farmer-to-farmer seed exchange to be an effective means of exchanging seed and a means of diffusing new varieties to small holder farmers. Farmer seed systems should therefore be strengthened so that they can provide local farmers with seeds of varieties that they require. Sustainable seed supply amongst farmers can be achieved by supporting local seed networks, injection of clean seeds and capacity building.

Other than varieties officially named by the Kenyan potato programme or those introduced into the country with distinct names, many of the other names of varieties known in the survey area are derived from the local dialect - Kikuyu. Examples include Ndera Mwana, Kibururu, Gituru, Karora Iguru, Kiraya, Kihoro, Thima Thuti and Mukori.

Both the factors related to variety and non-varietal characteristics influenced the degree to which varieties were replaced or abandoned by farmers. The cultivar characteristics included susceptibility to diseases and pests, agronomic performance and postharvest attributes while non-varietal characteristics that influenced abandonment of varieties by farmers included lack of seed, appearance of newer or better varieties and poor market for the older varieties. Results of this study showed that farmers have a logical preference for cultivars that produce higher yields and explains why

Zangi, Tigoni and Thima Thuti and Karuse were most commonly grown varieties. Similar observations were made by Crissman (1989). The fact that many farmers would not grow the varieties that have disappeared even if good quality seed was offered to them suggests that farmers attach little value to lost varieties. This observation has serious implications on the conservation of local potato germplasm and calls for deliberate efforts to conserve germplasm that is in danger of getting lost.

The findings of our study are in agreement with those of FAO (1988) who reported that the main cause of GE in crops, as reported by most countries, was the replacement of farmer varieties by improved varieties. The results however, differ from those of Mekbib (2007) who reported that for sorghum, the most important reasons for variety loss were reduced benefit from the abandoned varieties, drought, reduced land size and introduction of other food crops. With respect to GE, our results are different from those of Mekbib (2007) who found that there was no genetic erosion of sorghum in the centre of diversity in Ethiopia and those of Hermadez (1993) who disproved GE of maize in Mexico in the centre of diversity.

As has been previously pointed out (Quiros et al., 1990; Rao et al., 2002), the use of variety names to represent genetic diversity requires some precaution. It is possible that the same cultivar might be known by different names in different localities. Conversely, cultivars with different morphological and physiological characteristics might be called by the same name. The former type is commonly encountered when dealing with different ethnic groups (Tsegaye, 1991). The latter type of misclassification can arise when farmers use only one trait (for example, tuber skin colour) to distinguish between local varieties and disregard the other differences. Folk taxonomy exercised by traditional seed experts usually involves a hierarchy of classification criteria that combines various traits. For instance, Rao et al. (2002) identified three elements used in naming rice varieties (basic name, root name and a descriptor). Similarly, Tsehaye (2004) documented successive levels used by farmers to refine the classification of finger millet landraces (first inflorescence morphology, secondly, seed colour classes, then agronomic, and finally end-use characteristics).

Farmers' knowledge of their cultivars is reported to be fairly consistent. Teshome et al. (1997) examined sorghum landraces and confirmed that the landraces named by farmers were distinct plant populations, while Quiros et al. (1990) studied Andean potato varieties and found a high level of agreement between folk variety names and genetic distinctness identified by molecular markers. Similarly, diversity studies using DNA in taro cultivars (Caillon et al., 2004) revealed that each cultivar named by farmers corresponded to a separate genotype. Work by Lung'aho et al. (2011) which analyzed some of the potato cultivars mentioned in the present study demonstrated that the cultivars studied were indeed distinct from each other.

Data on the loss of varieties may provide a good indicator of loss diversity particularly, if accompanied by data on genetic distances. Diversity could even increase if newer or improved varieties are genetically more heterogeneous than older varieties or if they offer traits that are not present in older varieties (Wood and Lenne, 1997; Louette and Smale, 2000). Under such circumstances, the disappearance of named varieties may not be sufficient proof that loss of diversity has occurred.

The nature of the informal seed system makes the designation of discrete entities somewhat difficult (Cromwell, 1990; Almekinders et al., 1994; Louette et al., 1997) and local names may not necessarily reflect the genetic history of crops. Different names may be given to identical varieties and conversely, a single name may apply to heterogeneous material (Crissman, 1989; Jarvis et al., 2008). In such cases, DNA-marker techniques have provided tools for directly measuring genetic diversity hence, testing for occurrence of genetic erosion (Almanza-Pinzon et al., 2003).

Although, viruses will not usually kill the crop, their presence can result in reduced yields (Lung'aho et al., 2007) and the abandonment of the affected variety by farmers. Assessment of virus infection, cleaning of infected cultivars and providing local farmers with clean seed has been suggested as one way of maintaining potato diversity among growers (Clausen et al., 2005). It is however, doubtful if these systems would work with commercially oriented farmers since most of the farmers interviewed indicated that they would not grow such varieties as it would be difficult to market them and some may not be as high yielding as newer varieties. However, this may be an option for farmers practicing subsistence potato production.

Conclusions

Results of this study showed that loss of varieties has occurred with 20 of the 40 varieties encountered in this study being most affected by genetic erosion. The main reason for abandoning varieties was a decline in utility derived from a variety, with low yields and susceptibility to a host of biotic and abiotic stresses being rated as the most important reasons for abandoning a variety. The study also revealed that farmers were not concerned about loss of varieties. This may mean that they are unaware of the dangers of losing varieties or that they are aware but do not consider the threat to be significant. There is, therefore, the need for awareness creation on the importance of potato genetic resources and their conservation. There is also an urgent need to collect and preserve existing varieties as a reduction in their number has already taken place and it is only a matter of time before more varieties are lost.

ACKNOWLEGEMENTS

The authors are grateful to agricultural extension personnel who assisted during the field survey. The cooperation of farmers in the study area is highly appreciated. The valuable comments on the earlier version of the manuscript by an anonymous reviewer are appreciated. This study was financed by the Kenya Agricultural Productivity Project (KAPP).

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