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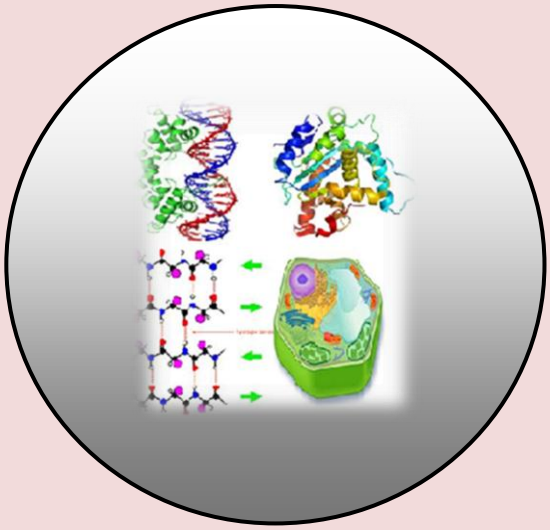

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RESEARCH PAPER

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Diagnostic Assessment of on-farm Diversity and Management of Yams Landraces in Ethiopia

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ABSTRACT

Yam (Dioscorea spp.) is one of the most important food security and economical crop in tropical Africa. In Ethiopia, it has been cultivated in densely populated and high rainfall areas to fill seasonal food and economic gaps. To assess the diversity, management and spatial distribution of yam landraces in major growing areas, a survey was conducted on 240 households from seven districts of Southwest Ethiopia. Data were collected from different sites through the application of participatory research appraisal tools and analyzed by SPSS statistical software. The results revealed a total of 38 farmers named landraces were identified on farm. The number of landraces maintained on individual farmers' varies from one to six with mean and standard deviation of 2.78 and 1.08, respectively. The lowest number was observed in Seka chekorsa and the highest in Kersa districts in the Jimma Zone. From the household interviews, 76(31.71%), 49 (20.40%) and 29 (12.10%) of farmers' replied that they select and collect materials from their family, local market and own gardens, respectively. The remaining 86(35.83%) of the farmers' collected planting material from different sources. The type and the number of landraces to plant, farmers' decision on the selection of landraces are mainly affected by environmental factors, the knowledge of the crop, market and stake demands. Most of the landraces (60.53%) had limited abundance and uneven distribution and only a few (39.47%) grew dominantly. Based on the above results, farmers' indigenous knowledge, socio-cultural process and cultural practices affect the diversity, distribution and managements of yam diversity in Southwest Ethiopia. The result of this study is also crucial for develop conservation strategy and to maximize efforts for breeding of the crop in the country.
Keywords: Distribution, Food Security, Indigenous Knowledge, Landrace and Yam.

INTRODUCTION

Yam (*Dioscorea* spp.) is a crop of major economic and socio cultural importance for a wide range of smallholder households in sub-Saharan Africa [Mignouna et al., 2002]. It is the fourth most important tuber crop in the world after potatoes [*Solanum tuberosum* (L.)], cassava (*Manihot esculenta* Crantz) and sweet potatoes [*Ipomoea batatas* (L.) pori.] [Loko et al., 2013]. The genus *Dioscorea* comprises over 600 species [Jayasurya, 1984, Wilkin, 1998, Mulualem and Mohammed, 2012]. Of these, only ten of them are cultivated for human food for millions of people in tropical and sub-tropical regions [Hahn and Hozio, 1993, Dansi, Dantsey and Mvodouhè, 2013, Sesay et al., 2013].

Although, yams are cultivated in most tropical countries, West Africa alone produces over 95% of the world's output [FAOSTAT, 2006, FAO, 2010]. Guinea yam (*D. cayenensis* and *D. rotundata* complex) is the most important species and represents about 97% of the total production in West Africa [Mignouna and Dansi, 2003, Demuyakor et al., 2013] with considerable varietal and genetic diversity due to the continuous process of domestication from related wild species of *D. abyssinica* [Edwards, 1991] reported *Dioscorea* species are widely adapted in Ethiopia as cultivated and wild relatives. It is also believed that *D. abyssinica* is native to Ethiopia and currently distributed in tropical Africa [Rehm and Espig, 1991, Hildebrand, 2003]. In line with this, *D. abyssinica* Hochst and *D. praehensilis* Benth are believed to be among the wild species that are ancestors of cultivated African species [Terauchi, et al., 1992, Hahn, 1995, Dumont et al., 2005]. Besides, 23 indigenous yam types belonging to at least four *Dioscorea* species are widely distributed in Southwest Ethiopia [Hildebrand et al., 2002]. In this regards, Ethiopia is an important center of origin of yam diversity that can constitute a useful source of materials for breeding and conservation of the crop [Zeven and De Wet, 1982, Abebe et al., 2012].

In Ethiopia, yams are hardly known by the scientific community before 1984 famine, however, different yam species are grown and widely distributed in major growing areas of South, Southwestern and Western parts in complex farming systems [Mulualem, 2012] and there has been no systematic way to study on diversity, distribution and management of the crop [Tamiru, 2006] [Miege and Demesew, 1997] have described eleven *Dioscorea* species cultivated in the country. Furthermore, several *Dioscorea* species might have their origin in Ethiopia as well [Vavilov, 1951, Halar, 1969] [Edwards, 1991] also reported *D. bulbifera* (aerial yam), *D. alata* (water yam), *D. cayenensis* and *D. rotundata* Complex (*Dioscoreaceae*) are grown in Ethiopia for food, medicinal use and to fill economic gaps during the off season.

These reports further confirmed that yam is widely cultivated as subsistence farming in different areas of the country. Moreover, there is a large puddle of landraces which are expected to be found within the existing yam diversity in Southwestern and Western Ethiopia [Norman et al., 1995], which is yet to be studied before. Besides, the diversity, distribution and management of yam landraces throughout agro-ecological zones have never been assessed; the ethno-botanical data, agronomic and culinary attributes of landraces have also not been documented for use by scientific research and development program in the country; and that has limited researchers' to access yam genetic resources in the country [Hildebrand et al., 2002]. Cognizant of these facts, strategic assessment of existing genetic diversity and management of yams at country level is expected to have significant importance to develop conservation plan and to address the existing problems on yam genetic resources in an affordable and sustainable way. Hence, this study was designed to assess the diversity, distribution, and management of yam landraces based on farmers' indigenous knowledge in Southwestern Ethiopia.

Methodology

Description of the study areas

The study was conducted in major yam growing areas of Jimma, Sheka and Bench-maji zones, which are the main yam production areas in Ethiopia. Accordingly, five districts namely, Manna, Dedo, Shebe-sombo, Seka-chekorsa and Kersa from Jimma zone and two districts namely Sheko and Yeki from Bench-maji and Sheka zones were selected (Figure 1). These areas were selected for study based on strong tradition in cultivating and domesticating various yam landraces with wide genetic base (Hildebrand, 2003; and Demissew et al., 2003), high production potential and long history on production and management system of yam with farmers' traditional knowledge (Miege and Demissew, 1997).

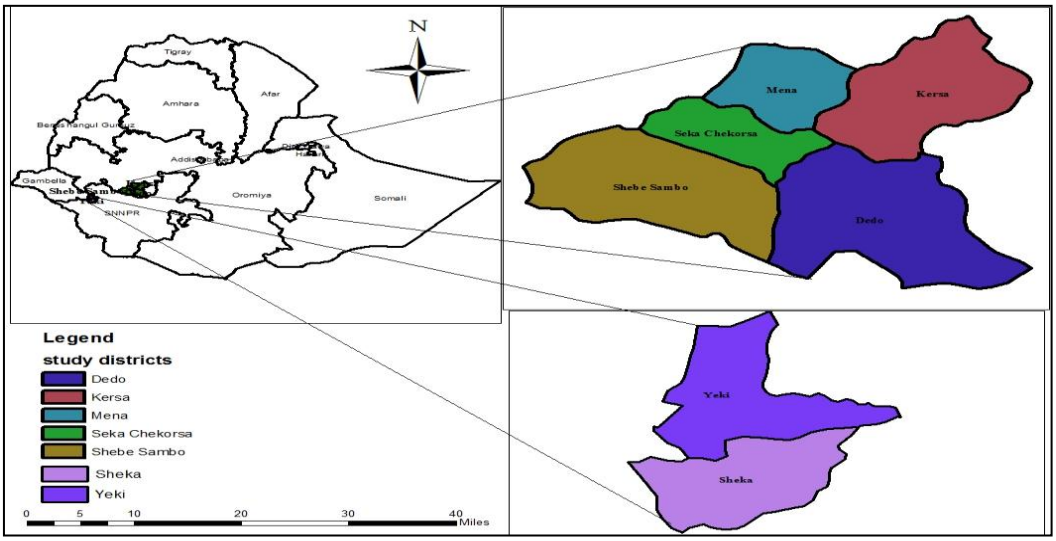

Figure 1. Districts of study area in Southwest Ethiopia.

Questionnaire design, sampling, and data collection

A semi-structured questionnaire, transect walks, and field visits (home gardens, cultivated fields) key informants and focus group discussions were used to collect information from selected farmers. Data gathered from transect walks, field visits and key informants were used to provision and confirm the information obtained from the semi-structured questionnaire. From each district, on average 34 farmers, 15 to 20 yam producers, 10 key informants and five DAs were sampled from different social groups for individual interviews, group and key informants' discussions. In total, 240 farmers were interviewed using the semi-structured questionnaire and key informants discussions. Through the semi-structured questionnaire, household information, farm size covered by yam, farm size, the number of landraces in each district, the local name of existed landraces, selection, management, agronomic practices, use value, and the time of maturity were gathered. Each landrace was properly evaluated based on, extent of the production, distribution, degree of consumption, cultural and medicinal importance, sex type, and contribution to household income. Other PRA tools used to gather information included the distribution and variability within the landraces were collected.

Data analysis

Quantitative and qualitative social survey data collected were coded and analyzed using IBM Statistical Package for Social Science (SPSS) software, version 21.0[28].

Cross-tabulation tables were constructed, and descriptive statistics were generated to summarize data from the questionnaires. To make statistical inferences, descriptive statistics, frequencies and percentages were conducted to analyze relationships between variables. Simpson's diversity index was computed to estimate diversity of landraces (evenness and richness) in all the districts. Simpson's index (K) mainly measures the probability that two individuals randomly selected from a single belong to the same category [Simpson, 1949] and hence, as K increases, the diversity decreases. Therefore, it transformed as 1-K with values ranging from 0 to 1. The index was computed for all districts using the function:

$(1\text{-}k)= \sum(n/N)^2 = \sum(n(n\text{-}1)/(N(N\text{-}1)$

Where (1-k) = Simpson's diversity index

N= the total number of households assessed in each district

n= the number of households where a landraces was found.

Shannon diversity index (H') was considered to assess the diversity of landraces by using the number and evenness of the landraces. The index is defined as:

$$H' = -\sum_{i=1}^{S} pi\ ln\ pi$$

Where S= the number of landraces, p=the proportion of landraces i relative to the total number of landraces (S/N) and ln=logarithm to base e.

The Shannon weaver index values (H') can range from 0 to ~ 4.6 using the natural log (versus $\log_{10}$). A value near 0 indicated that every species in the sample are the same. Conversely, a value near 4.6 indicated the numbers of individuals are evenly distributed between the species [Hennink and Zeven, 1991]. Although, Shannon's index takes in to account evenness of the abundance of landraces, evenness can be calculated separately as a measure of the observed diversity to the maximum diversity. For calculating the evenness of the landraces, the Pielou's evenness index (E) was used [Pielou, 1966]. It is defined by the function:

$E=H'/\ln s$

Where, H' is Shannon diversity index and S referring to the number of landraces described in each district [Vikrant and Pawan, 2014]. High evenness resulting from all landraces having equal abundance is normally is equated with high diversity [Magurran, 1988]. Differentiation of diversity estimates how different and similar habitats in terms of diversity of category under consideration. This can be achieved by doing similarity measure of pair of sites, as is the case with Sørenson's similarity index. In this study, the index was computed based on the presence and or absence of landraces to estimate landrace similarity between pairs of districts as follow:

Sorenson's Similarity index = $\frac{2S}{(Sa+Sb)}$

Where, S= the number of landraces common to both districts, Sa= the number of landraces in district A and Sb= the number of landraces in district B.

HH=House holds

RESULTS AND DISCUSSION

The level of landrace diversity

Farmers identify different landraces by their descriptors with different names for management decisions. They described their landraces in various ways and characters used to separate landraces. The number of farmer named landraces in the farming communities are the first indicator of the diversity at a given location [Bhuwon et al., 2012]. In this study farmers' identified 38 known yam landraces (Table 2, Figure 2). Of these four landraces, (*liyan, offea, welmeka* and *woko*) belongs to well definite species of aerial yam and are recognized based on the differences of bulbils shape, color, size and surface texture. Moreover, one species called *badaye* belongs to *Dioscorea alata* basically identified by early maturity and a square vine with tubers varying in shape, and flesh color (white, creamy yellow or purple). Nevertheless, these characters not give the impression to provide reliable means of identification, as they tend to differ within a landrace.

Table 1. Sociodemographic characteristics of the farmers in the study areas.

Districts	No. of HH interview	No. of landraces	Sex		Mean age of farmers	Mean family size	Mean farm size (ha)	Mean elevation
			Male	Female				
Dedo	38.0	15	28	10.0	55.08	8.00	1.63	1873
Kersa	42.0	10	30.0	12.0	47.83	6.19	0.86	1750
Manna	35.0	17	28.0	7.0	47.46	6.08	1.47	1889
Seka-chekorsa	30.0	10	27.0	3.0	51.67	6.80	1.44	1785
Shebe-sombo	31.0	14	23.0	8.0	52.35	6.90	1.40	1622
Sheko	32.0	13	22.0	10.0	45.62	6.43	1.13	1725
Yeki	32.0	11	24.0	8.0	50.11	6.80	1.51	1306
Total	240.0	90.0	182.0	58.0	350.12	47.20	9.44	
Mean	34.3	12.86	26.0	8.28	50.01	6.74	1.35	1707.1

From all tested districts, Manna and Dedo exhibited high richness, and have less diversity due to comparatively lower number of unique landraces. The lowest number of landraces, least diverse and none of which was unique were observed in Kersa and Seka chekorsa, districts.

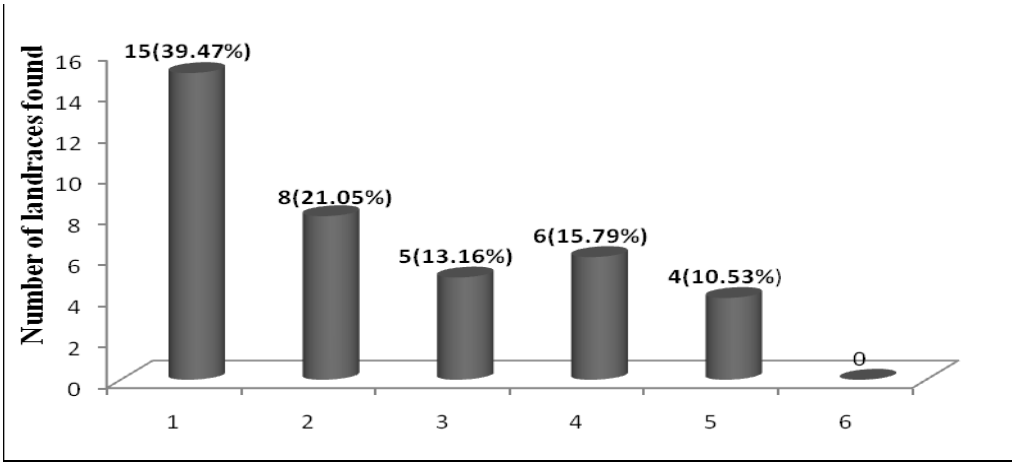

Figure 2. Number of landraces in different districts.

Table 2. Yam landraces recorded in the tested districts of Jimma, Sheka and Bench maji zones and numbers where they were encountered.

No	Name of landraces	Districts							Total
		Dedo	Kersa	Manna	Seka chekorsa	Shebe sombo	Sheko	Yeki	
1	Afra	-	2	2	-	1	3	-	8
2	Anchiro	13	18	8	8	8	-	-	55
3	Badaye	1	-	-	-	-	18	21	40
4	Badenseye	-	-	-	-	-	-	2	2
5	Baki boye	2	-	1	-	-	1	2	6
6	Bambuche	1	-	4		1	-	-	6
7	Banda	-	-	-	-	-	4	3	7
8	Bola boye	-	-	-	-	2	-	-	2
9	Bori boye	-	-	-	-	-	3	-	3
10	Chebesha	-	-	-	-	-	5	1	6
11	Dakuy	-	-	-	-	-	2	4	6
12	Dapo	-		2	-	-	-	-	2
13	Dartho	13	6	1	5	7	-	-	32
14	Doni	-	-	-	-	-	4	20	24
15	Erkabea	-	-	-	-	-	-	2	2
16	Feda	4	-	-	2	-	-	-	6
17	Geano boye	2	17	8	7	7	-	-	41
18	Gesa boye	-	-	-	-	2	-	-	2
19	Goshitea	12	7	4	6	3	-	-	32
20	Gurshume	14	6	2	-	5	-	-	27
21	Hati boye	-	10	2	1	1	-	-	14
22	Karakachi**	-	-	-	-	-	7	-	7
23	Kerta boye	6	-	-	2	1	-	-	9
24	Liyan*	-	-		-	-	-	9	9
25	Mecha boye	3	-	2	-	-	-	-	5
26	Offea*	-	18	4	6	4	-	-	32
27	Pada	2	-	3	2	-	-	-	7
28	Sesa**	1	-	1	-	-	-	-	2
29	Torebea	-	-	-	-	-	4	-	4
30	Tsedeboye	-	-	-	-	-	2	-	2
31	Wadela boye	-	2	2	1	3	-	-	8
32	Woko*	-	-	-	-	-	3	13	16
33	Washinea	-	-	-	-	-	-	7	7
34	Wayera	6	-	-	-	-	-	-	6
35	Welmeka*	-	3	7	-	2		-	12
36	Zankur	-	-	-	-	-	6	-	6
37	Zatemera	-	-	3	-	-	-	-	3
38	Zawera	4	-	-	-	-	-	-	4

* = Aerial yams, ** = wild yams,

The other landraces are hardly identified as a species or group of species. Furthermore, wild yams widely referred named as *sasa* and *karakachi* were identified in forest areas of Manna and Sheko districts by having typically big thorns on the surface of vine and underground tuber. In all districts, the number of landraces on individual farmer's fields ranged from one to six with mean and standard deviation of 2.78 and 1.08, respectively. The number of yam landraces per districts was summarized in Table 3. From all districts, relatively large number of farms having five or more landraces was found in Manna, Shebe sombo and Seka chekorsa districts. Most of the farmers who were visited in these districts were residing relatively in lower altitudes (Table 1).

Table 3.Variation in the number of yam landraces planted per farm across the tested districts of Southwest Ethiopia.

No. of landraces	Dedo	Kersa	Manna	Seka chekorsa	Shebe sombo	Sheko	Yeki	Total
1	3.0	0.0	5.0	5.0	3.0	2.0	8.0	26.0
2	22.0	6.0	16.0	6.0	14.0	7.0	6.0	77.0
3	10.0	27.0	7.0	13.0	5.0	15.0	12.0	89.0
4	3.0	8.0	3.0	4.0	5.0	8.0	6.0	37.0
5	0.0	1.0	4.0	0.0	0.0	0.0	0.0	5.0
6	0.0	0.0	0.0	2.0	4.0	0.0	0.0	6.0
Total	**38.0**	**42.0**	**35.0**	**30.0**	**31.0**	**32.0**	**32.0**	**240**
Mean	**9.5**	**10.5**	**7.0**	**6.0**	**6.2**	**8.0**	**8.0**	**34.28**

Table 4. Yam landrace diversity in the various districts of Jimma, Sheka and Bench maji zones of Southwest Ethiopia, expressed as richness, Simpson (1-K) and Shannon (*H'*) diversity indices and Evenness.

Districts	Richness	% of the total*	No. of unique landrace	1-K	*H'*	Evenness
Dedo	15	39.47	2	0.90	1.71	0.631
Kersa	10	26.31	0	0.84	2.30	0.998
Manna	17	44.73	2	0.84	1.66	0.585
Seka chekorsa	10	26.31	0	0.74	1.57	0.681
Shebe sombo	14	36.84	2	0.74	1.61	0.610
Sheko	13	34.21	5	0.80	1.69	0.658
Yeki	11	28.94	4	0.84	1.48	0.617

*Calculated on the basis of 38 yam landraces throughout the tested districts

To analyze the similarity and associations between districts, Sørenson's similarity index was intended for all possible pairs of districts combinations based on the presence and absence of yam landraces. The overall similarity of districts ranges from 0.00 to 0.39. Shebe sombo, Seka chekorsa and Kersa were similar districts. Furthermore, Dedo and Sheko, Yeki and Manna were also similar districts. In other hands, Yeki and Seka chekorsa, Sheko and Manna and Sheko and Kersa were the dissimilarly districts.

Table 5. Sørenson's similarity estimates of yam landrace diversity between different districts of Jimma, Sheka and Bench maji zones of Southwest Ethiopia.

Districts	Dedo	Kersa	Manna	Seka chekorsa	Shebe sombo	Sheko	Yeki
Dedo	**1.00**						
Kersa	0.20	**1.00**					
Manna	0.31	0.37	**1.00**				
Seka chekorsa	0.28	0.35	0.27	**1.00**			
Shebe sombo	0.25	0.39	0.33	0.35	**1.00**		
Sheko	0.07	0.04	0.03	0.00	0.00	**1.00**	
Yeki	0.07	0.05	0.07	0.05	0.00	0.29	**1.00**

The results highly expressed the geographical differences between the districts. This is true for similar and dissimilar districts. Similar districts belong to the same boundary and have possibilities to share genetic materials between farmers; however, districts not bounded by the same boundary had different landraces. However, the association hardly follow similar tendency, as the most similar districts of Dedo and Sheko, Yeki and Manna were also among those located far apart. In line with this, similar trends were observed in regard to similarity and dissimilarity of yam landraces from results of on yams in Southern Ethiopia.

Selection, cultivation and management of yam landraces

Farmers shape the distribution and degree of genetic diversity of landraces directly, through selection, and indirectly through management of different factors [40]. In the present study, the result of farmers' evaluation indicated that there were many important practices carried out by farmers' concerning selection, cultivation and management of yam landraces. Although, selection of landraces can go on throughout the year by observation, intensive selection and planting of the selected material was done during the main rainy season. From the household interviews, 76(31.71%), 49(20.40%) and 29(12.10%) of farmers' replied that they select and collect planting materials from their family, local market and own gardens, respectively (Table 6).

In all tested districts, yam was cultivated on annual cycle of planting in the farmers' field. It also varied between districts and zones. For example, about 45.45% and 22.72% of farmers' in Jimma zone planting was done in October and November respectively. Likewise, there were the same trends in Sheko and Yeki districts. In these districts, 96.87% and 85.00% of farmers' were planted in November and October (Figure 3). There is similar tendency with respect to the time of planting of yams in other tested districts of Southwest Ethiopia. The result of this study was similar to the work of Tamiru, 2006 who reported that the main time of planting of yams in Southern Ethiopia is in October. Although, in South and Southwest Ethiopia, yam planting is done in November and October (dry season), the seedling actively grow up at the onset of rain (March and April). Farmers have their own reason to plant yams in October and November, mainly, to break dormancy, lack of storage facility after harvest and reduce the cost of planting materials were the few of them. Furthermore, 76(31.71%), 49(20.4%) and 29 (12.10%) of the farmers get planting material from their family, local market and own gardens respectively and planted yam on ridges along the rows.

Table 6. Major sources of the planting materials for field planting of yam as reported by farmers in Jimma, Sheka and Bench maji zones of Southwest Ethiopia.

Criteria	Number of households	Proportion of farmers' (%)
Gifted from family	76	31.70
Local market	49	20.40
Neighbors	29	12.10
Own harvest + Gifted from family	28	11.70
Local market + Neighbors	22	9.20
Own harvest	14	5.80
Neighbors + Gifted from family	6	2.50
Local market + Neighbors + Exchange of seeds	4	1.70
Local market + Neighbors + Own harvest+ Gifted from family	4	1.70
Local market + Exchange of seeds	3	1.30
Local market + Gifted from family	2	0.80
Exchange of seeds	1	0.40
Neighbors + Local market + Gifted from family	1	0.40
Exchange of seeds + Own harvest + Gifted from family	1	0.40

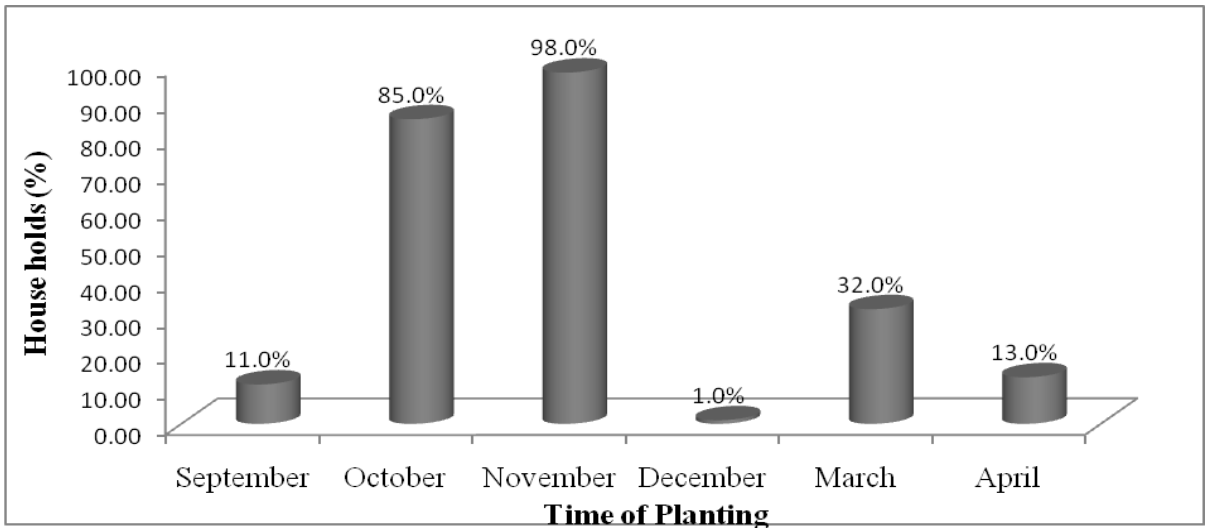

Figure 3. Critical time of yam planting and percentage of households in Jimma, Sheka and Bench maji zones of Southwest Ethiopia.

Production of yam is severely constrained by the cost and availability of healthy seed during the time of planting. In all surveyed districts, there was no formal seed supply system for yam nor do farmers specialize in the production of yam planting materials. Besides, there are no extension services to support farmers to produce yam tuber seed. In the present study, 76(31.71%), 49(20.4%) and 29(12.10%) of the farmers get planting material from their family, local market and own gardens respectively and planted yam on ridges along the rows.

Intercropping of field crops are important to maximize yields, avoid lodging, improve soil fertility, efficiently utilize their farmlands, reduce risk, and make advantage of variations in times of maturity among individual crops helps to stagger harvesting [Deribe et al., 2002].

Nevertheless, the results of this study on yam had contrary with this information. From the overall surveyed, 97.8% of the farms yam established mono cropping. Most farmers in the area believed that, intercropping reduces the tuber yield and difficult to apply different management practices during the entire growing stages of yam. Besides, in Southwest Ethiopia, farmers have similar belief that recurrent visit on yam fields are not appreciated. This might be due to, farmers' in the study areas have long tradition on regularity entrance to yam fields reduce the tuber yield severely, thus, mono cropping is the appropriate option for yam cultivation in the areas. On the contrary, in some districts, farmers intercrop yams with cereals and high value crops such as maize [*Zea mays* (L.)], sweet potato [*Ipomoea batatas* (L.) Lam.] and coffee [*Coffeaarabica* (L.)]. Farmers explained that intercropping different species/varieties of field crops helped them to minimize damage caused by pest and diseases. The mix of species and varieties served as a buffer for certain pest and disease problems. Most of the respondents agreed that such constraints to crop production such as frost, weeds, insect pest and disease did not damage all varieties when planted as intercrop. Increasing diversity did not reduce all diseases and pests, but promoted diversity thereby reducing risks and resulting in yield stability. Based on the above results, traditional management of yam genetic resources that are based on use and preference values could be useful for choosing conservation strategies pertinent to target yam species in a given ago-ecological conditions [Afio, 2006]. Yam is mainly cultivated along rows of stakes, except the wild yam where the tubers are brought from surrounding forests. In the present study, about 57.9% of the farmers used any materials as a stake to support yam during the entire growing period. In some locality, however, farmers used dried coffee as stake, the remaining famers used a combination of different materials to support yam for production. Stacking commences after one months of planting when the vine became 15-30cm in its height. Early staking is important to get high tuber yield, it is highly correlated with the time of planting. In the present study, 47.6% of the farmers use stake at planting and the remaining 52.4% used stake after two months of planting. This result is similar with the work of [Ogah, 2013] who reported that staking at planting gave the highest grain and tuber yields on African yam beans. Farmers applied different staking methods, in the present study, 86.20%, 2.10% and 8.30% of the farmers encountered a single stake, fence and combination of both respectively, however, few farmers (3.4%) used fence as a stake to support many plants simultaneously. According to farmers and following [8Sesay et al., 2013], who described, producing diversity of yam landraces at household level is seem as a risk minimizing strategy. The available lands for exploitation are not homogeneous (structure, fertility, moisture content, etc.) and landraces also differ in terms of adaptability to climate variability. In the present study, farmers planted different landraces on their farms. The early, medium and late maturing types usually occupies the same farm as a mixture. On average, 72.517% of the farmers' preferred the late maturing landraces, 21.40% selected medium maturing and the remaining 6.09% of the farmers selected early maturing landraces, based on organoleptic taste of the boiled yam. According to farmers interviewed, early maturing landraces had high amount of water after boiling, no taste, poor color and quality after cooking. In regarding to the total yield, 61.2%, 24.30% and 14.50% of the farmers selected the late, medium and early maturing yam landraces, respectively. Farmers preferred early maturing landraces to get early harvest during seasonal food shortage in the area when other crops are still in the field. Thus, the early maturing landraces are used to fill seasonal gap in food supply. Besides, the first harvest of the early maturing landraces satisfies farmers' food needs after the long period of scarcity, the second harvest serves to get yield and collect tuber (seed) for the next planting period.

So it is necessary for farmers to plant the late maturing landraces to ensure food security during the dry season and reduce the cost of the seed during the time of planting. Late maturing landraces are only harvested once, with the large roots being used for consumption and the small ones as seed roots for the next crop. Farmers choose their landraces in taking into account factors that may significantly influence not only the yield, but also their management practices (time for planting, conditions and duration of the storage, seed practices, the availability of seed roots and roots for consumption and sales) over the whole year. Farmers define their objectives in selecting and maintaining the different types (two harvests for early maturing and one harvest for late maturing) and the number of landraces that ensures the food security in the household throughout the year, while, several constraints contributed to the reduction of the yield. These include: climatic and agricultural risks, the high costs of seed roots, loss of landraces, lack of fertile land, and reduction of labor capacity of the farmer [Afio, 2006]. The use of inorganic fertilizer reduces the quality of the pounded yam and contributes to the loss of the organoleptic quality. Taking this into consideration, 15% and 10% of the farmers used manure and compost for yam production and the remaining 75% of the farmers hardly used any available fertilizer for yam production.

Table 7. Criteria used by farmers in the study areas for timing of harvest.

Harvest criteria	Proportion of farmers' (%)
Yellowing of leaves, flowering and seed development	15.10
Yellowing of leaves and soil cracking	13.80
Flowering, seed development and soil cracking	10.90
Yellowing of leaves	9.20
Yellowing of leaves and count from the time of planting	8.40
Yellowing of leaves and digging and checking the tuber	5.00
Wilting of vine	4.20
Count from the time of planting, flowering and seed development	4.00
Count from the time of planting	3.80
Flowering and seed development	3.80
Yellowing of leaves and wilting of vine	3.80
Wilting of vine, flowering, seed development and soil cracking	3.30
Digging and checking the tuber	2.50
Soil cracking	2.50
Digging and checking the tuber and count from the time of planting	2.50
Digging and checking the tuber, flowering and seed development	1.70
Count from the time of planting, yellowing of leaves and soil cracking	1.30
Flowering, seed development, yellowing of leaves and soil cracking	0.80
Count from the time of planting + soil cracking	0.80
Wilting of vine, flowering and seed development	0.80
Wilting of vine, digging and checking the tuber, flowering and seed development	0.80
Wilting of vine and count from the time of planting	0.40
Yellowing of leaves, digging and checking the tuber and flowering and seed development	0.40

Yam harvesting is a labour intensive operation that involves standing, bending, squatting, and sometimes sitting on the ground depending on the size of the mound, size of tubers or depth of tuber penetration [Onwueme and Charles, 1994]. Besides, many tubers also get deformed during their entire growth as a result of obstacles they encounter. This is taken into consideration by the farmers, 112(46.67%) of the farmers selected early maturing landraces for ease of harvesting. In the late maturing landraces, the tuber penetrates deep in to the soil and harvesting is tedious, as a result, 27(11.25%) of the farmers preferred late maturing landraces. The remaining 101(42.20%) farmers selected medium maturing type. There are similar trends in respect to the times of harvesting in the study areas. The late maturing landraces are harvested once at maturity (full of senescence), whereas the early maturing types are harvested twice and in some cases three times. In the present study, 85% and 98% of farmers planted in October and November, double harvest involved in between the second week of June to end of July. This is achieved by careful digging and removing of the soil to free the tubers, which are then, cut 15cm from their point of attachment of the vine. The roots are then, covered with the soil and the plant is left to form more tubers in different directions. Single harvesting requires less effort as tubers are harvested at the end of the growing season. In all surveyed areas, farmers are experienced with regard to minimizing the load of harvesting operation by manage or bending up the tuber at early growth stage.

In some districts, farmers used plastic sheet with hole and level under the surface of the tuber to grow horizontally. The lateral roots of the tubers easily penetrate into the soil through the hole of plastic sheet to absorb mineral nutrients from the soil for the functioning of the plant. This is also important to reduce the labour cost during the time of harvesting. Farmers are knowledgeable about maturity indices of yam. In most districts, farmers used flower development, soil cracking and counting days from the time of planting are the main signals to estimate the time of harvesting (once, twice and three times) (Table 7). The aim is to get more yield and quality tuber in first and second harvest, respectively.

During the entire growing period of the crop, no diseases and pests were observed; as a result farmers did not evaluate the susceptibility and resistance of landraces to diseases and insect pests. However, during the dry season and onset of rainy season, some larvae of yam beetle were observed in the area (personal communication with farmers in the study areas). In all districts, farmers' selection criterion varied and highly depended on the needs of individual farmers and the availability of planting material. In general, farming communities in major yam producing areas of Southwest Ethiopia managed their cropping systems employing a range of indigenous skills. Weed reduces the quality and the quantity of yield of yam, especially when the plant is at early stage. In the present study, *Biden pilosa, Tufo, Cuscuta, Kelo* (adayababa), *Dobi, Zaban, Muja, Serdo* and *Amarantus* are the major weed species that affect the yield of yams in Southwest Ethiopia. This taken in to account 51 (21.2%), 127(52.9%) and 55 (22.9%) of farmers weed their farm lands twice, three times and four times respectively. Hand weeding, early land preparation, plough the land during the dry season, soil burning, application of mulch and combine application of these practices are the best options that were used by farmers to reduce the effect of weeds in the area. Generally, the socio-cultural contexts shape the roles of different individuals or groups within a household or community [Arua, 1981, Brydon, 1981, Uzozie, 1981, Bellon and Risopoulos, 2001]. These socially determined roles affect farmers' knowledge, actions and access to resources regarding the maintenance of crop diversity (Jarvis et al. 2000). Thus, study on the relevance of socio-cultural factors on on-farm crop diversity is important to understand how the social maintenance mechanism of yam diversity in Ethiopia might be enhanced.

CONCLUSION

The result of the present study gives a good indicator on the structure of on farm based diversity, distribution, management and future genetic intervention on yams in Southwest Ethiopia. In this study, farmers place on yam is articulated in its continued cultivation despite the lack of any form of support from agricultural experts and researchers. Besides, yam is still an important for food security and major economic importance crop as compared to other root and tuber crops in all tested districts. Thus, it needs a great effort for research and development program to maximize the use of the existing diversity to meet their food and livelihood security through broadening the knowledge base of the crop. Management of yam diversity is mainly done by farmers. However, little is known about how farmers truly manage yam diversity, even though the management and use of agricultural biodiversity is an important national policy issue. Therefore, analyses of different socio cultural, economic and agronomic factors could play a significant role in yam diversity management in Southwest Ethiopia. The use of local landraces has valuable impact to study the diversity of the crop in traditional farming system. Hence, the indigenous knowledge of yam and local landraces must be collected, analyzed and properly documented for use to enhance the research and development program in the country. Conservation and use of yam genetic resources are an important aspect for sustainable utilization of genetic diversity. To do so, understanding the extent and distribution of diversity within and between species through molecular and bio- chemical characterizations are vital for clarification of synonymies and identification of duplicates for conservation and development of a participatory varietal selection of yam in Southwest Ethiopia.

Abbreviations

CSA: Central Statistical Agency, Ethiopia; DA: Development Agent; FAO: Food and Agricultural Organization of the United Nations; FAOSTAT: Food and Agriculture Organization of the United Nations, statistical Data base; JARC: Jimma Agricultural Research Center; SNNPRS: Southern Nations Nationalities and People's, Regional State; SPSS: Statistical Package for Social Sciences; SZFEDD: Sheka Zone Finance and Economic Department.

Authors' contributions

TM carried out the field work and drafted the manuscript. FM conceived the study, followed up the field work and drafted the manuscript. SH participated in designing of the study and proof reading of the manuscript. EG proof reading of the manuscript. All authors read and approved the final manuscript.

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