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Analysis of the Phenotypic Diversity Within Cultivated Potato Varieties in Ethiopia at Three Locations

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ABSTRACT

The phenotypic diversity of 25 potato varieties was analyzed at three distinct locations in the Amhara region of Ethiopia with the main objective of determining the diversity present among them based on 11 quantitative and 18 qualitative morphological characteristics. The field experiment was laid out in a 5 × 5 balanced lattice design with six replications. The results of analysis of variance indicated highly significant ($P < 0.01$) differences among varieties for all 11 quantitative characteristics considered. Furthermore, analysis of the average taxonomic genetic distance based on 18 qualitative characteristics using the Euclidean distance function revealed considerable divergence among the studied varieties. Accordingly, the genetic distance value ranged from 0.24 between Tolcha and Wochecha, European commercial varieties, to 0.72 between the farmer's variety Ater Abeba and the improved variety Zengena. The 25 varieties were grouped into three main clusters based on the distance matrix following the hierarchical agglomerative clustering method known as UPGMA (unweighted pair group method with arithmetic mean). Cluster I, which was the largest, contained 18 varieties followed by clusters II and III, with 3 and 4 varieties, respectively. Thus, this study revealed the presence of sufficient phenotypic diversity among varieties in the country that can be exploited for germplasm enhancement.

Keywords: potato, phenotypic diversity, variety, location

INTRODUCTION

Genetic diversity is the state of all the variety of genes that exist in a particular variety or species and as such it plays a vital role for a successful breeding program and in enabling breeders to respond sustainably to the diversified goals of plant breeding and the dynamic demands of humans for either food or nonfood agricultural products (Haydar *et al*., 2007). Moreover, genetic diversity is essential to study the taxonomic relationships present among germplasms and also to identify the sources of genes for a particular trait from the existing germplasms (Haydar *et al*., 2007; Arslanoglu *et al*., 2011) and to sort out parental lines with complementary features that can enhance breeding progress (Cartea *et al*., 2002; Saljoghianpour *et al*., 2007). Genetic gains are also more likely to be significant if the diversity and level of genetic variability of desirable traits is sufficient (Biswas *et al*., 2008). Therefore, knowledge of the genetic diversity present within existing germplasm is crucial for effective utilization of genetic resources by plant breeders (Martins *et al*., 2006). Genetic diversity analysis of genotypes can be carried out using various

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procedures with morphological characterization being the earliest (Smith and Smith, 1989). This system relies on the recording and description of phenotypic and agronomic characteristic that cover the leaf, floral parts and the yield and yield component attributes. In potato, morphological characterization techniques have been used in the taxonomic classification of cultivated and wild species (Hawkes, 1994), the characterization of local genotypes (Arslanoglu *et al*., 2011), and the evaluation of genetic diversity among cultivars (Ahmadizadeh and Felenji, 2011). Potato is a widely grown tuber crop in the highlands of Ethiopia and is a staple food crop of highland residents of the Amhara national regional state in Ethiopia (Tesfaye and Yigzaw, 2008). Moreover, it is an important source of income as a cash crop to the large number of people dwelling in these areas (Central Agricultural Census Commission, 2003). In view of its dietary and income-generating role to the community, the research system in Ethiopia has released over 30 varieties during the past three decades of research. These varieties are different from each other with regard to useful attributes such as maturity time, post-harvest quality, yielding ability and growth habit, among others. It has been postulated that commercial varieties are an important genetic resource for the breeding program because of their many useful attributes. Nevertheless, optimal use of the divergence at hand entails a systematic evaluation of these genetic resources. The commercial potato varieties released by the research system and local cultivars in the hands of farmers for quite long periods in Ethiopia, however, were not systematically evaluated for their diversity. Hence, there is a critical gap of information related to the genetic diversity of the potato germplasm in the country. The current study was thus carried out with the main objective of evaluating the phenotypic diversity or relationships among 18 improved or commercial potato varieties, 3 elite clones and 4 farmer's cultivars based on morphological and agronomic characteristics in three distinct major potato production areas in the Amhara region of Ethiopia.

MATERIALS AND METHODS

Genetic material

In total, 25 varieties consisting of 18 improved varieties, 4 farmer's cultivars and 3 advanced genotypes were tested.

Description of study area

Climatic data were sourced from the Ethiopian Meteorological Agency branch at Bair dar while soil analysis was undertaken at the Adet Agricultural Research Center Soil and Water Research Department. The three districts in which the experiment was undertaken were Adet, Merawi and Debretabor. Adet is positioned at 11°16′32″ N and 37°29′30″ E. It has a red brown Nitosol soil. The Merawi experimental site is located at 11°30′0″ N and 37°0′0″ E. The soil is a heavy clay-textured red Nitosol. Debretabor is a cool highland area located at 11°51′0″ N and 38°1′0″ E and has a soil type classified as a Luvisol. The rainy season at these sites extends from May through October and does not limit crops with a growing period ranging from 120 to 150 d (Tesfaye *et al*., 2012). Hence, crops grown in these areas complete their crop cycle without requiring any kind of moisture supplement. Details of the soil pH, cation exchange capacity (CEC), organic matter (OM) content, available N, P, K, texture, precipitation, sunshine hours, altitude, rainfall and maximum and minimum air temperatures of these sites are provided in Tables 1 and 2.

Experimental de sign and procedures

The experiments were laid out in a 5 × 5 balanced lattice design. A total of 40 well sprouted seed tubers of the 25 varieties were planted on a gross plot size of 9 m^2 at an inter-row spacing of 0.75 m and intra-row spacing of 0.3 m. Following the specific fertilizer recommendations developed for each location, the plants at Adet and

Table 1 Physicochemical properties of soils at the three experimental sites.

Experiment Site	Altitude (m)	Soil physical and chemical properties						
		Soil pH	Total N (%)	Available P (ppm)	Available K ($Cmol^{+}.\ kg^{-1}$)	CEC (Meq per 100 g)	Organic matter (%)	Texture
Adet	2,240	5.20	0.44	7.17	0.781	30.62	1.69	Heavy clay
Merawi	1,960	5.00	0.19	8.70	0.768	26.00	2.75	Heavy clay
Debretabor	2,706	4.94	0.20	17.18	0.339	31.74	3.00	Clay

Data analyzed by Adet Agricultural Research Center Soil and Water Research Department.

Table 2 Total rainfall, minimum and maximum air temperature, relative humidity and sunshine hours at the experimental sites during the 2011 cropping season.

Site	Cropping months	Total rainfall (mm)	Air temperature (°C)		Relative humidity (%)	Sunshine (h)
			Min.	Max.		
Adet	May–October	1, 124.3	10–18.1	24.2–27.9	54–80	4.6–8.4
Merawi	May–October	1, 585.4	12.1–15	24.4–28.7	68–74	8.3–11
Debretabor	May–October	1, 488.1	9–15.2	18.9–23.5	54–83	2.9–7.8

Source: Ethiopian Meteorological Agency branch at Bair dar. Min. = Minimum, Max. = Maximum.

Merawi were fertilized at the rates of 81 and 69 $kg.ha^{-1}$ for N and P_2O_5, respectively, while those at Debretabor were fertilized at the rates of 108 and 69 $kg.ha^{-1}$ for N and P_2O_5, respectively. All plots at the three sites were sprayed twice with the fungicide Mancozeb (65% wettable powder) at the rate of 3 $kg.ha^{-1}$ as soon as symptoms were observed, to protect the plants from the late blight leaf disease. All remaining husbandry practices were carried out as recommended.

Data collection

Data on 11 quantitative and 18 qualitative characteristics related to the leaf, stem, flower and tuber morphological characteristics and yield and yield components were recorded from all experiments at the three locations. The 11 quantitative characteristics collected were: days to 50% flowering, days to maturity, number of primary stems, plant height at flowering, leaf length, leaflet length, leaflet width, leaflet length-to-width ratio, tuber number per hill, average tuber weight and marketable tuber yield. The quantitative data were collected from the central 16 plants of each replicate. The 18 qualitative morphological characteristics collected were: leaf dissection, leaf insertion, leaf green color intensity, leaf midrib pigmentation, growth habit, predominant flower color, secondary flower color, secondary flower color distribution, degree of flowering, duration of flowering, corolla shape, predominant skin color, secondary skin color, secondary color distribution, tuber skin type, predominant flesh color, general tuber shape and depth of tuber eyes. All these qualitative characters were recorded from a randomly selected 10 plants of each variety planted at each location. The characters were described according to the morphological descriptors of potato published by the International Board for Plant Genetic Resources (Huamán *et al*., 1977).

Data analysis

Both quantitative and descriptive statistical analyses were carried out. Considering the inherent characteristics of these two data categories in terms of stability across environments and their distinct weaknesses and strengths in typifying varieties phenotypically, separate analyses were carried out on each data group. The 11 quantitative data, which varied in value with the environment, were subjected to simple analysis of variance using the SAS statistical computer package (Version 9.2; SAS Institute, 2010). Thus, these environmentally unstable characters that showed high genotype variation through an environmental interaction were not used for both the genetic distance and cluster analysis of varieties, but instead were only used for the purpose of agronomic evaluation across the environment. On the other hand, the 18 stable, qualitative characteristics were used to compute the genetic distance matrix as well as for cluster analysis. For this reason, they were first converted into a binary data matrix (present = 1 and absent = 0, for each phenotypic class evaluated within each trait) following the classification system of Stevens (1966). Consequently, traits with only two categories of description were converted simply into a binary score while those traits with more than two category classes such as color, shape, growth habit were converted into a binary matrix against each category of that particular class. Corolla shape, for example, has three categories: semistellate, pentagonal and stellate. Accordingly, a variety with a semi-stellate corolla shape was scored as 1 against CS1 (semi-stellate) and 0 for both CS2 (pentagonal flower shape) and CS3 (stellate flower shape category). Finally, the “average” taxonomic genetic distance was computed using the Euclidian distance function in Equation 1:

$$E_{ij} = [\Sigma_k (n^{-1})(X_{ki} - X_{kj})^2]^{1/2} \qquad (1)$$

where (E_{ij}) is the average genetic distance of individuals *i* and *j* with morphological traits *k*.

The Euclidian distance of p variables was then computed as the square root of the sum of squared differences between the coordinates of each variable of the two observations. Then, cluster analysis was carried using the agglomerative hierarchical method known as UPGMA (unweighted pair-group method with arithmetic mean) on the generated distance matrix to examine the resemblance and grouping of genotypes using the NCSS statistical software (Version 2.0; NCSS, LLC, Kaysville, UT, USA).

RESULTS AND DISSCUSSION

Analysis of variance of quantitative characteristics

The results of the separate analysis of variance of the 11 quantitative characteristics at each location are provided in Tables 3, 4 and 5 and reveal that the 25 potato varieties differed significantly (P < 0.01) in all the characters considered indicating the presence of notable phenotypic variability among them.

Accordingly, days to flowering at Adet, Merawi and Debretabor ranged from 30 d for Hunde to 46 d for Jalene and Guasa (Table 3), from 27 d for Awash, Challa and Ater Abeba to 39 d for Agere (Table 4) and from 30 d for Wochecha to 44 d for Belete, Aba Adamu, Jalene and Guasa (Table 5), respectively. Likewise, days to maturity of these varieties ranged from 84 d for Awash to 104 d for Menagesha at Adet, from 88 d for Sisay to 113 d for Menagesha at Merawi and from 95 d for Awash to 112 d for Jalene at Debretabor. These results clearly showed significant (P < 0.01) differences among varieties over the indicated characteristics on the one hand and the influence of climatic conditions under each set of environments on days to flowering and maturity on the other hand.

The shortest and longest leaf length (LL) at Adet and Merawi was recorded from Zengena and Challa, respectively, (Tables 3 and 4). At Debretabor, LL ranged between 21.5 cm for Wochecha and 27 cm for the variety Challa.

Table 3 Mean results of 11 quantitative data of 25 varieties at Adet experiment station, 2011.

Variety	DF(d)	DM(d)	LL (cm)	LLL (cm)	LLW (cm)	LLWR	SN	PH (cm)	TN	TW (g)	MTY ($t.ha^{-1}$)
Menagesha	32.17^{gh}	104.00^{a}	22.65^{defg}	7.31^{ef}	4.21^{efgh}	1.75^{bcd}	3.8^{cdefg}	60.6^{efgh}	8.0^{i}	73.8^{abc}	24.49^{def}
Gera	33.67^{efg}	88.83^{ef}	24.99^{abcde}	7.89^{bcde}	4.64^{bcdef}	1.73^{bcd}	4.2^{cde}	64.5^{cdefg}	13.3^{cdef}	48.3^{fghi}	27.68^{cdef}
Challa	31.67^{hi}	98.33^{bc}	27.06^{a}	8.60^{abc}	5.10^{abcd}	1.69^{bcdef}	3.8^{cdefg}	71.6^{bcd}	12.8^{defg}	60.3^{bcdefgh}	32.41^{abc}
CIP-395096.2	35.50^{de}	100.33^{ab}	23.32^{bcdefg}	7.77^{bcde}	4.68^{bcdef}	1.66^{bcdef}	3.2^{efgh}	65.1^{cdef}	11.3^{efghi}	61.6^{bcdefg}	28.38^{cde}
Wochecha	33.83^{efg}	99.17^{b}	22.83^{defg}	7.51^{de}	4.50^{defg}	1.68^{bcdef}	2.5^{h}	44.9^{ij}	8.3^{hi}	58.3^{cdefgh}	20.32^{fg}
Awash	34.00^{efg}	83.67^{g}	21.67^{efg}	7.82^{bcde}	5.21^{abc}	1.50^{ef}	4.0^{cdef}	45.8^{ij}	9.7^{fghi}	48.9^{fghi}	16.81^{g}
Gorebella	31.67^{hi}	100.50^{ab}	22.57^{efg}	7.44^{ef}	4.83^{abcde}	1.54^{def}	4.7^{c}	72.3^{bc}	11.2^{efghi}	69.0^{bcd}	31.44^{abcd}
Zengena	35.67^{cde}	93.50^{d}	20.47^{g}	6.49^{f}	3.68^{h}	1.77^{abcd}	4.2^{cde}	92.7^{a}	11.7^{efghi}	56.8^{defgh}	26.23^{cdef}
Hunde	30.17^{i}	98.00^{bc}	23.02^{cdefg}	7.31^{ef}	4.98^{abcd}	1.47^{f}	3.0^{fgh}	56.4^{fgh}	14.3^{bcde}	45.6^{ghi}	25.86^{cdef}
Agere	40.17^{b}	104.17^{a}	21.35^{fg}	7.28^{ef}	3.89^{gh}	1.88^{ab}	4.3^{cd}	70.6^{bcd}	13.5^{bcdef}	45.8^{ghi}	22.50^{efg}
Shenkolla	33.67^{efg}	94.00^{cd}	26.26^{abc}	7.84^{bcde}	4.60^{cdef}	1.71^{bcde}	3.0^{fgh}	76.9^{b}	9.2^{ghi}	75.6^{ab}	27.08^{cdef}
Belete	34.33^{ef}	101.50^{ab}	25.96^{abcd}	8.01^{abcde}	4.82^{abcde}	1.66^{bcdef}	2.5^{h}	66.0^{cde}	11.0^{efghi}	85.1^{a}	36.00^{ab}
Ater Abeba	31.00^{hi}	99.33^{b}	22.27^{efg}	7.26^{ef}	4.47^{defg}	1.64^{def}	6.3^{b}	55.8^{gh}	16.8^{abc}	40.2^{i}	26.99^{cdef}
CIP-392640.524	34.33^{ef}	93.17^{de}	26.38^{ab}	7.51^{de}	4.08^{fgh}	1.69^{bcdef}	5.8^{b}	57.9^{efgh}	11.7^{efghi}	56.1^{defghi}	25.99^{cdef}
Gudene	36.33^{cd}	87.67^{f}	22.31^{efg}	7.63^{cde}	4.67^{bcdef}	1.64^{def}	8.0^{a}	66.7^{cde}	12.2^{efgh}	57.9^{defgh}	26.32^{cdef}
Bulle	32.83^{fgh}	101.50^{ab}	24.72^{abcdef}	7.59^{cde}	4.46^{defg}	1.86^{abc}	4.0^{cdef}	57.6^{efgh}	11.2^{efghi}	49.8^{efghi}	22.73^{efg}
Gabisa	34.00^{efg}	90.00^{def}	23.76^{abcdefg}	8.92^{a}	5.24^{abc}	1.71^{bcde}	3.2^{efgh}	52.3^{hi}	11.5^{efghi}	54.2^{defghi}	25.23^{cdef}
Tolcha	33.67^{efg}	98.33^{bc}	21.66^{efg}	7.49^{e}	4.59^{cdef}	1.64^{def}	2.5^{h}	42.0^{j}	8.0^{i}	64.0^{bcdef}	20.63^{fg}
Aba Adamu	37.50^{c}	99.17^{b}	22.77^{defg}	8.71^{ab}	5.35^{ab}	1.64^{def}	3.2^{efgh}	51.9^{hi}	10.2^{fghi}	65.6^{bcde}	27.8^{cdef}
Marachare	31.33^{hi}	99.50^{b}	24.31^{abcdef}	7.61^{cde}	4.82^{abcde}	1.59^{def}	3.5^{defgh}	51.8^{hi}	19.3^{a}	44.2^{hi}	32.43^{abc}
Sisay	35.67^{cde}	91.33^{def}	24.21^{abcdef}	8.55^{abcd}	5.47^{a}	1.57^{def}	2.8^{gh}	56.8^{fgh}	13.7^{bcdef}	48.3^{fghi}	26.22^{cdef}
Ararsa	32.33^{gh}	91.17^{def}	26.46^{ab}	7.82^{bcde}	4.04^{fgh}	1.96^{a}	4.5^{cd}	60.6^{efgh}	10.5^{efghi}	58.6^{cdefgh}	25.72^{cdef}
Jalene	45.67^{a}	98.17^{bc}	22.22^{efg}	7.68^{bcde}	4.57^{cdef}	1.68^{bcdef}	5.8^{b}	61.6^{efg}	16.7^{abcd}	49.2^{fghi}	31.14^{bcd}
Guasa	45.67^{a}	99.00^{b}	22.23^{efg}	7.79^{bcde}	4.41^{defg}	1.77^{abcd}	4.7^{c}	63.2^{defg}	17.3^{ab}	55.8^{defghi}	38.52^{a}
CIP-396004.337	34.50^{def}	98.00^{bc}	24.84^{abcde}	8.06^{abcde}	4.72^{bcdef}	1.71^{bcde}	4.7^{c}	60.2^{efgh}	12.0^{efghi}	67.5^{bcd}	31.76^{abcd}

DF = Days to flowering; DM = Days to maturity; LL = Leaf length; LLL = Leaflet length; LLW = Leaflet width; LLWR = Leaflet length-to-width ratio; SN = Stem number; PH = Plant height; TN = Tuber number; TW = Tuber weight; MTY = Marketable tuber yield.

Mean values in the same column with the same lowercase superscript letter are not significantly different at ($P < 0.01$).

Table 4 Mean results of 11quantitative data of 25 varieties at Merawi experiment station, 2011.

Variety	DF (d)	DM (d)	LL (cm)	LLL (cm)	LLW (cm)	LLWR	SN -	PH (cm)	TN	TW (g)	MTY ($t.ha^{-1}$)
Menagesha	28.5^{ghij}	113.0^{a}	16.6^{fg}	5.9^{i}	4.2^{hij}	1.4^{bc}	3.7^{cdef}	53.0^{cdef}	8.7^{defgh}	76.5^{cdefg}	26.45^{fgh}
Gera	30.8^{defgh}	98.0^{fg}	21.2^{abc}	7.0^{defg}	5.0^{defg}	1.4^{bc}	3.8^{cdef}	64.0^{b}	12.2^{bcd}	61.5^{ghijk}	32.83^{def}
Challa	27.2^{ij}	102.0^{bcdefg}	23.1^{a}	8.2^{ab}	5.6^{abc}	1.5^{bc}	3.5^{cdef}	66.0^{ab}	12.3^{bc}	74.0^{cdefgh}	37.96^{bcde}
CIP-395096.2	30.8^{defgh}	106.3^{abcde}	17.8^{def}	6.6^{efghi}	4.8^{efgh}	1.4^{bc}	3.8^{cdef}	54.1^{cdef}	10.5^{bcdef}	65.7^{fghij}	28.06^{fg}
Wochecha	30.5^{defgh}	105.2^{bcdef}	19.1^{cde}	7.1^{def}	4.9^{defg}	1.4^{bc}	2.5^{f}	40.5^{h}	6.3^{gh}	84.3^{bcde}	20.39^{ghi}
Awash	28.3^{ghij}	88.8^{i}	16.9^{ef}	6.7^{efghi}	4.9^{defg}	1.4^{bc}	3.3^{cdef}	41.5^{gh}	7.8^{fgh}	52.2^{jkl}	17.16^{hi}
Gorebella	27.0^{j}	104.5^{bcdef}	18.5^{def}	6.7^{efghi}	4.8^{efgh}	1.4^{bc}	4.3^{bc}	67.6^{ab}	11.0^{bcdef}	95.5^{b}	42.76^{abc}
Zengena	31.0^{defg}	95.8^{gh}	14.6^{g}	6.2^{hi}	4.5^{fghij}	1.4^{bc}	4.2^{cd}	73.2^{a}	11.2^{bcdef}	65.8^{fghij}	29.84^{defg}
Hunde	27.5^{ij}	104.0^{bcdef}	20.0^{bcd}	7.3^{cde}	5.5^{bcd}	1.3^{c}	3.3^{cdef}	55.9^{cde}	13.3^{b}	71.2^{defghi}	39.47^{abcd}
Agere	39.2^{a}	109.3^{ab}	18.7^{def}	7.1^{def}	4.0^{j}	1.8^{a}	4.0^{cde}	53.7^{cdef}	12.8^{bc}	57.0^{hijkl}	24.95^{fgh}
Shenkolla	32.8^{cde}	100.0^{efg}	21.6^{ab}	7.2^{cde}	4.6^{efghi}	1.6^{b}	3.0^{cdef}	61.1^{bc}	8.0^{fgh}	90.3^{bc}	30.82^{def}
Belete	32.3^{cdef}	105.5^{bcde}	22.4^{a}	7.9^{bc}	5.1^{cdef}	1.6^{b}	3.0^{cdef}	60.2^{bcd}	10.3^{bcdef}	113.0^{a}	48.03^{a}
Ater Abeba	27.3^{ij}	102.2^{bcdefg}	18.6^{def}	6.0^{hi}	4.2^{hij}	1.4^{bc}	5.5^{b}	52.5^{def}	19.2^{a}	44.2^{l}	33.55^{cdef}
CIP-392640.524	31.8^{def}	100.5^{defg}	19.2^{bcde}	7.1^{def}	4.9^{defg}	1.4^{bc}	3.5^{cdef}	51.4^{ef}	7.8^{fgh}	83.8^{bcde}	27.92^{fg}
Gudene	33.3^{cd}	91.3^{hi}	18.2^{def}	6.8^{efgh}	5.1^{cdef}	1.3^{c}	6.8^{a}	60.9^{bc}	10.5^{bcdef}	61.5^{ghijk}	26.57^{fgh}
Bulle	31.2^{defg}	107.0^{abcde}	18.5^{def}	6.4^{fghi}	4.4^{ghij}	1.5^{bc}	4.0^{cde}	54.8^{cdef}	10.3^{bcdef}	61.5^{ghijk}	24.56^{fgh}
Gabisa	33.0^{cd}	88.8^{i}	19.4^{bcd}	8.7^{a}	6.1^{a}	1.4^{bc}	3.2^{cdef}	51.5^{ef}	11.7^{bcde}	62.5^{ghijk}	31.68^{def}
Tolcha	30.0^{efghi}	106.3^{abcde}	19.9^{bcd}	7.2^{cde}	4.9^{defg}	1.5^{bc}	2.7^{ef}	41.6^{gh}	5.7^{h}	76.5^{cdefg}	14.83^{i}
Aba Adamu	35.0^{bc}	100.8^{cdefg}	19.6^{bcd}	8.2^{ab}	6.0^{ab}	1.4^{bc}	2.8^{def}	48.2^{efg}	8.5^{efgh}	82.8^{bcde}	29.14^{efg}
Marachare	28.0^{hij}	106.3^{abcde}	19.9^{bcd}	7.7^{bcd}	5.5^{bcd}	1.4^{bc}	3.3^{cdef}	51.0^{ef}	13.3^{b}	69.2^{efghij}	38.50^{bcde}
Sisay	29.7^{fghij}	87.7^{i}	18.4^{def}	7.2^{cde}	5.2^{cde}	1.4^{bc}	3.2^{cdef}	50.3^{ef}	12.3^{bc}	48.5^{kl}	25.62^{fgh}
Ararsa	28.8^{ghij}	89.3^{hi}	22.4^{a}	6.3^{ghi}	4.1^{ij}	1.5^{bc}	4.3^{bc}	54.6^{cdef}	13.2^{b}	54.7^{ijkl}	28.90^{efg}
Jalene	36.8^{ab}	106.7^{abcde}	17.9^{def}	7.1^{def}	4.7^{efgh}	1.5^{bc}	4.0^{cde}	53.7^{cdef}	13.0^{b}	68.2^{efghij}	38.14^{bcde}
Guasa	36.0^{b}	108.2^{abc}	19.4^{bcd}	7.3^{cde}	5.0^{defg}	1.5^{bc}	3.5^{cdef}	53.3^{cdef}	12.5^{bc}	81.7^{bcdef}	43.25^{ab}
CIP-396004.337	31.0^{defg}	107.5^{abcd}	19.8^{bcd}	7.2^{cde}	5.2^{cde}	1.4^{bc}	3.5^{cdef}	47.3^{fgh}	9.3^{cdefg}	87.7^{bcd}	32.76^{def}
Mean	31.12	101.4	19.25	7.07	4.92	1.44	3.71	54.47	10.87	71.59	30.96
CV%	5.27	4.11	7.07	6.41	7.25	6.21	20.43	8.52	18.73	13.59	18.13
LSD	2.23	5.67	1.85	0.62	0.49	0.12	1.03	6.32	2.77	13.24	7.63

DF = Days to flowering; DM = Days to maturity; LL = Leaf length; LLL = Leaflet length; LLW = Leaflet width; LLWR = Leaflet length-to-width ratio; SN = Stem number; PH = Plant height; TN = Tuber number; TW = Tuber weight; MTY = Marketable tuber yield.

Mean values in the same column with the same lowercase superscript letter are not significantly different at ($P < 0.01$).

Table 5 Mean results of 11 quantitative data of 25 varieties at Debretabor experiment station, 2011.

Variety	DF (d)	DM (d)	LL (cm)	LLL (cm)	LLW (cm)	LLWR	SN	PH (cm)	TN	TW (g)	MTY (t.ha^{-1})
Menagesha	34.7^{fgh}	106.5^{abc}	22.8^{cde}	6.7^{hij}	4.4^{fg}	1.5^{cd}	2.3^{abcd}	47.8^{bcd}	7.3^{ef}	82.7^{bcde}	25.69^{defg}
Gera	38.7^{cdef}	104.3^{abc}	23.7^{bcde}	6.9^{ghij}	4.6^{defg}	1.5^{cd}	2.3^{abcd}	49.7^{abc}	10.3^{de}	70.4^{defgh}	31.69^{abcde}
Challa	37.5^{def}	104.5^{abc}	27.0^{a}	7.7^{abcde}	4.6^{defg}	1.7^{ab}	2.3^{abcd}	45.4^{bcdefg}	10.0^{de}	71.9^{defg}	31.80^{abcde}
CIP-395096.2	40.2^{abcde}	101.0^{abc}	22.2^{ed}	7.0^{efghi}	4.9^{cdef}	1.4^{de}	2.5^{abc}	46.8^{bcdef}	12.5^{abcd}	57.7^{fghij}	30.85^{bcde}
Wochecha	30.2^{h}	110.7^{a}	21.5^{e}	7.0^{efghi}	4.5^{efg}	1.6^{bc}	1.5^{d}	27.5^{j}	6.0^{f}	69.3^{efgh}	17.71^{g}
Awash	38.3^{cdef}	95.0^{c}	23.5^{bcde}	7.4^{bcdef}	5.5^{ab}	1.3^{e}	2.2^{abcd}	31.8^{ij}	9.2^{def}	61.3^{fghij}	17.53^{g}
Gorebella	42^{abcd}	106.3^{abc}	23.7^{bcde}	6.4^{ij}	4.6^{defg}	1.4^{de}	2.3^{abcd}	51.3^{abc}	10.5^{de}	93.5^{b}	39.96^{a}
Zengena	41.0^{abcd}	109.2^{a}	21.8^{e}	7.1^{defghi}	5.1^{abcd}	1.4^{de}	2.5^{abc}	56.8^{a}	10.7^{cde}	67.2^{efgh}	31.85^{abcde}
Hunde	37.3^{def}	106.0^{abc}	24.6^{bcd}	7.0^{efghi}	5.0^{bcde}	1.4^{de}	2.3^{abcd}	44.0^{cdefg}	15.0^{ab}	48.1^{ij}	30.29^{bcde}
Agere	41.2^{abcd}	110.0^{a}	23.4^{bcde}	7.7^{abcde}	4.2^{gh}	18^{a}	2.2^{abcd}	47.0^{bcdef}	15.7^{a}	47.5^{j}	26.95^{cdef}
Shenkolla	40.0^{abcde}	100.2^{abc}	27.0^{a}	7.3^{cdefg}	4.6^{defg}	1.6^{bc}	1.8^{bcd}	52.3^{ab}	6.3^{f}	111.5^{a}	32.07^{abcde}
Belete	44.2^{a}	107.0^{ab}	24.9^{abc}	7.9^{abc}	4.9^{cdef}	1.6^{bc}	2.3^{abcd}	52.8^{ab}	10.3^{de}	90.2^{bc}	37.52^{ab}
Ater Abeba	37.3^{def}	109.2^{a}	22.5^{ed}	6.4^{ij}	3.8^{h}	1.7^{ab}	3.0^{a}	43.7^{cdefg}	15.5^{a}	46.9^{j}	30.79^{bcde}
CIP-392640.524	38.5^{cdef}	107.5^{ab}	23.5^{bcde}	7.2^{cdefgh}	4.8^{cdef}	1.5^{cd}	1.7^{cd}	39.7^{efgh}	7.5^{ef}	74.2^{cdef}	23.36^{efg}
Gudene	43.0^{abc}	103.2^{abc}	22.2^{ed}	7.0^{efghi}	4.9^{cdef}	1.4^{de}	2.7^{ab}	49.3^{abc}	11.0^{cd}	60.6^{fghij}	27.18^{cdef}
Bulle	35.5^{efg}	100.5^{abc}	23.4^{bcde}	6.4^{ij}	3.7^{h}	1.7^{ab}	2.2^{abcd}	38.2^{ghi}	11.0^{cd}	53.3^{ghij}	24.27^{efg}
Gabisa	40.8^{abcd}	106.3^{abc}	24.5^{bcd}	8.1^{a}	5.5^{ab}	1.5^{cd}	2.0^{bcd}	43.9^{cdefg}	10.3^{de}	81.6^{bcde}	34.63^{abcd}
Tolcha	31.3^{gh}	109.2^{a}	23.6^{bcde}	7.0^{efghi}	4.5^{efg}	1.5^{cd}	1.7^{cd}	33.7^{hij}	6.7^{f}	82.2^{bcde}	20.16^{fg}
Aba Adamu	44.2^{a}	107.5^{ab}	23.8^{bcde}	8.1^{a}	5.6^{a}	1.5^{cd}	1.7^{cd}	40.4^{defgh}	10.3^{de}	70.1^{defgh}	26.95^{cdef}
Marachare	35.5^{efg}	102.8^{abc}	24.4^{bcd}	7.0^{efghi}	4.9^{cdef}	1.4^{de}	2.2^{abcd}	39.3^{fgh}	14.0^{abc}	52.8^{hij}	30.89^{bcde}
Sisay	38.8^{bcdef}	97.0^{bc}	25.4^{ab}	8.0^{ab}	5.5^{ab}	1.5^{cd}	2.0^{bcd}	40.5^{defgh}	12.5^{abcd}	60.6^{fghij}	30.74^{bcde}
Ararsa	38.8^{bcdef}	104.7^{abc}	25.2^{abc}	6.3^{j}	3.8^{h}	1.7^{ab}	2.3^{abcd}	46.4^{bcdef}	10.7^{cde}	60.9^{fghij}	26.92^{cdef}
Jalene	44.4^{a}	111.5^{a}	22.8^{cde}	7.9^{abc}	5.5^{abc}	1.5^{cd}	2.3^{abcd}	47.5^{bcde}	11.8^{bcd}	66.5^{efghi}	36.77^{ab}
Guasa	43.8^{ab}	109.5^{a}	21.6^{e}	7.8^{abcd}	5.1^{abcd}	1.5^{cd}	2.3^{abcd}	46.1^{bcdefg}	11.7^{cd}	68.1^{efgh}	35.11^{abc}
CIP-396004.337	35.5^{efg}	106.7^{abc}	23.7^{bcde}	6.9^{ghij}	4.7^{defg}	1.5^{cd}	2.0^{bcd}	45.6^{bcdefg}	9.2^{def}	88.4^{bcd}	34.43^{abcd}
Mean	38.92	105.45	23.70	7.20	4.75	1.53	2.19	44.29	10.64	69.43	29.44
CV%	7.44	6.23	5.55	5.60	6.64	5.69	22.88	10.11	18.49	15.42	17.15
LSD	3.94	8.95	1.79	0.55	0.43	0.12	0.68	6.32	2.68	14.60	6.88

DF = Days to flowering; DM = Days to maturity; LL = Leaf length; LLL = Leaflet length; LLW = Leaflet width; LLWR = Leaflet length-to-width ratio; SN = Stem number; PH = Plant height; TN = Tuber number; TW = Tuber weight; MTY = Marketable tuber yield.

Mean values in the same column with the same lowercase superscript letter are not significantly different at ($P < 0.01$).

Leaflet length (LLL) varied from 6.49 cm (Zengena) to 8.92 cm (Gabisa), from 5.9 cm (Menagesha) to 8.7 cm (Gabisa) and from 6.3 cm (Ararsa) to 8.1 cm (Gabisa) at Adet, Merawi and Debretabor, respectively (Tables 3, 4 and 5).

The leaflet width of varieties (LLW) at the Adet, Merawi and Debretabor sites ranged from 3.68 cm (Zengena) to 5.47 cm (Sisay), 4 cm (Agere) to 6.1 cm (Gabisa) and 3.7 cm (Bulle) to 5.6 cm (Aba Adamu), respectively (Tables 3, 4 and 5). Significant ($P < 0.01$) variation in the leaflet length-to-width ratio (LLWR) was observed among the varieties and ranged from 1.47 (Hunde) to 1.96 (Ararsa) at Adet, 1.3 (Hunde) to 1.8 (Agere) at Merawi and 1.3 (Awash) to 1.8 for Agere at Debretabor (Tables 3, 4 and 5).

The number of main stems per plant (SN) of varieties ranged between 2.5 (for Tolcha, Wochecha and Belete) to 8 (Gudene) at Adet, 2.5 for Wochecha to 6.8 for Gudene at Merawi and 1.5 for Wochecha to 3 for Ater Abeba at the Debretabor site (Tables 3, 4 and 5). The tallest plant heights (PH) at Adet (92.7 cm), Merawi (73.2 cm) and Debretabor (56.8 cm) were all recorded for Zengena. On the other hand, the shortest PH value at Adet (42 cm) was recorded for the variety Tolcha, while at Merawi (40.5 cm) and Debretabor (27.5 cm) it was recorded for Wochecha (Tables 3, 4 and 5).

These results clearly indicated the variability in tested varieties with regard to PH, LL, LLL and LLWR as well as the sizeable effects of climatic variables on the size and growth rate of plants. Certainly the plant growth rate was higher under warmer conditions than in cooler areas as reported elsewhere (Struik (2007).

At Adet, the greatest number of tubers per plant (TN) of 19.3 was obtained from Marachare while the farmer's cultivar (Ater Abeba) produced the greatest numbers at Merawi and Debretabor (Tables 3, 4 and 5). The heaviest tuber weight (TW) at Adet and Merawi was produced by the variety Belete while at Debretabor it was produced by Shenkolla. In contrast the lowest weight tubers at all three sites were harvested from Ater Abeba (Tables 3, 4 and 5).

The highest marketable tuber yields (MTYs) of 38.52 $t.ha^{-1}$ at Adet, 48.03 $t.ha^{-1}$ at Merawi and 39.96 $t.ha^{-1}$ at Debretabor were obtained from Guasa, Belete and Gorebella, respectively. In contrast, the lowest MTYs at all the three sites were harvested from Ater Abeba which had the earliest maturity date and an umbrella canopy leaf arrangement (Tables 3, 4 and 5). This was in agreement with reports made elsewhere that early maturing varieties will have a shorter photosynthetically active green leaf period on the one hand and an umbrella type leaf arrangement that shades the lower leaves from receiving direct sunlight for photosynthesis resulting in photosynthate competition from the sink organ on the other (Houghland *et. al*., 1961, Gray and Hughes (1978), Cole (1980), Munzert (1987). Arslanoglu *et al*. (2011) reported similar genetic variability in the plant height, main stem number and maturity date among 146 local potato genotypes in Turkey. Likewise, Haydar *et al.* (2007) reported phenotypic variability of 30 potato varieties grown in Bangladesh with regard to their plant height, number of leaves per plant, tuber number per plant, tuber weight per plant (tuber yield) and fresh weight per plant. A study on the phenotypic diversity in 31 potato genotypes by Mondal *et al.* (2007) also reported the presence of significant phenotypic diversity and genetic divergence in the plant height, number of stems per plant, number of tubers per plant, tuber weight per plant and dry-matter content among the studied genotypes. Similarly, Tairo *et al*. (2008) reported the observation of significant differences in the number of roots per plant, weight of roots and the fresh weight per plant and dry matter content in a collection comprising germplasm from 136 sweet potato varieties evaluated in Tanzania for two season using morphological characteristics. Similar phenotypic variability was also reported in pepper (Yayeh and Zeven, 1997), sorghum (Amsalu and Endashaw, 2000) and hazelnut

(Ferreira *et al*., 2010). The results of the quantitative morphological trait divergence observed among the 25 potato varieties in the current study were in agreement with these earlier reports made on different crops. These results imply the presence of considerable phenotypic variability among the germplasm in the country that can be of use in a germplasm enhancement program if complemented with information related to their heritability, genetic and phenotypic correlation and genetic advance value estimates. Moreover, the inherent drawbacks of morphological characters associated with high genotype × environment variability or low consistency of quantitative characteristics were clearly noted in the current study and this corroborated earlier reports describing quantitative characteristic as poor descriptors in typifying varieties. The effects of climatic variables on these traits were clearly reflected in the number of plant days to flowering and maturity, stem number, plant height, tuber weight and marketable tuber yield at the different sites. Early flowering and maturity dates were observed at the warmer sites than at the cool Debretabor site. The maturity time was extended by a week and more at the Merawi and Debretabor sites and this resulted in higher marketable tuber yields as expected (Tables 4 and 5).

Genetic distance analysis

The numeric data on the qualitative characteristics converted into a binary matrix were subjected to computation of genetic distance using a Euclidian distance analysis procedure. This distance matrix in turn was used to construct a dendrogram to graphically present the association and divergence of evaluated varieties. The lowest genetic distance of 0.27 or the highest similarity distance of 0.73 was observed between Tolcha and Wochecha (Table 6). These varieties were commercial varieties introduced to Ethiopia in 1980 following the poor harvest from long-cycle cereal crops in order to mitigate the effect of a food deficit from the main season harvest. These varieties do display very similar growth habit, flower color, days to maturity day, leaf length, leaflet length, leaflet width and leaflet length-to-width ratios as shown in Tables 3, 4 and 5. Thus, these two varieties probably have closely related parents or sports. In the same way, the second lowest genetic distance was observed between the two improved varieties of Guasa and Jalene. These varieties are progenies of the same parental line and thus have a common genetic background. They have very similar growth habit, flower color, leaf characteristics as a whole, flowering and maturity periods. This, however, is not the rule for tetrasomic potato varieties in which alleles occur in fours resulting in a highly heterozygous crop unlike the diploids where only two alleles occur at a locus (Gebhardt, 2007). Practical evidence for this fact was clearly observed from the genetic distance of the varieties Awash and Sisay that have common parents but differ in flower color, plant height, and tuber yield among other characteristics as seen in Tables 3, 4 and 5. Conversely, the highest genetic distance value of 0.72 was observed between the farmer's cultivar Ater Abeba and the improved variety Gorebella. Gorebella also had the next highest genetic distance value of 0.64 with the other farmer's cultivar Agere (Table 6).

Cluster analysis

The dendrogram produced from the distance matrix clustered the 25 varieties into three main clusters (Figure 1). The first cluster (cluster I) contained only two varieties—Bulle and Challa. The second cluster (cluster II) contained the largest number (18) of varieties and the third cluster (cluster III) contained four varieties—Menagesha, CIP-395096.2, Gorebella and Belete. The separately placed singleton was Ater Abeba. Cluster II had four sub-clusters each containing a different number of varieties. The first sub-cluster contained five varieties, (CIP-392640.524, Zengena, Marachare, Hunde and Awash), the second sub-cluster contained two varieties (Ararsa and Sisay), the third sub-cluster contained six

Table 6 Genetic distance between the 25 potato genotypes based on morphological characters.

Variety	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Menagesha																								
Gera	0.56																							
Challa	0.62	0.58																						
CIP-395096.2	0.49	0.58	0.61																					
Wochecha	0.60	0.49	0.56	0.53																				
Awash	0.67	0.53	0.59	0.53	0.51																			
Gorebella	0.59	0.64	0.51	0.43	0.56	0.49																		
Zengena	0.62	0.51	0.58	0.54	0.56	0.53	0.51																	
Hunde	0.62	0.61	0.61	0.54	0.56	0.41	0.58	0.58																
Agere	0.65	0.51	0.64	0.61	0.56	0.59	0.67	0.64	0.54															
Shenkolla	0.64	0.45	0.62	0.56	0.54	0.47	0.65	0.53	0.56	0.49														
Belete	0.61	0.56	0.53	0.49	0.54	0.64	0.45	0.59	0.65	0.56	0.58													
Ater Abeba	0.65	0.64	0.61	0.67	0.65	0.65	0.64	0.72	0.61	0.64	0.68	0.65												
CIP-392640.524	0.67	0.53	0.59	0.56	0.58	0.54	0.59	0.41	0.59	0.65	0.51	0.61	0.68											
Gudene	0.68	0.47	0.54	0.64	0.53	0.53	0.58	0.51	0.58	0.51	0.45	0.56	0.64	0.56										
Bulle	0.61	0.59	0.49	0.59	0.61	0.61	0.59	0.59	0.62	0.68	0.64	0.64	0.56	0.54	0.62									
Gabisa	0.68	0.58	0.61	0.67	0.45	0.56	0.61	0.54	0.58	0.51	0.49	0.53	0.69	0.59	0.47	0.62								
Tolcha	0.62	0.51	0.61	0.54	0.24	0.49	0.54	0.58	0.58	0.54	0.56	0.56	0.67	0.62	0.51	0.62	0.47							
Aba Adamu	0.59	0.43	0.61	0.54	0.45	0.53	0.58	0.54	0.61	0.43	0.41	0.53	0.67	0.59	0.38	0.65	0.47	0.43						
Marachare	0.54	0.49	0.56	0.62	0.54	0.51	0.65	0.53	0.45	0.59	0.54	0.67	0.65	0.54	0.53	0.54	0.59	0.56	0.56					
Sisay	0.64	0.53	0.49	0.59	0.58	0.54	0.62	0.65	0.56	0.56	0.47	0.51	0.62	0.58	0.56	0.61	0.56	0.62	0.53	0.58				
Ararsa	0.59	0.58	0.51	0.61	0.56	0.56	0.51	0.54	0.64	0.61	0.62	0.49	0.67	0.56	0.58	0.62	0.51	0.61	0.58	0.62	0.49			
Jalene	0.64	0.53	0.53	0.59	0.47	0.51	0.53	0.49	0.59	0.49	0.51	0.51	0.68	0.58	0.49	0.64	0.41	0.49	0.49	0.54	0.58	0.49		
Guasa	0.61	0.56	0.45	0.49	0.47	0.51	0.45	0.59	0.59	0.53	0.54	0.47	0.65	0.67	0.59	0.61	0.53	0.49	0.53	0.61	0.51	0.49	0.38	
CIP-396004.337	0.62	0.51	0.54	0.61	0.36	0.53	0.61	0.58	0.54	0.51	0.53	0.56	0.64	0.59	0.51	0.62	0.38	0.43	0.43	0.56	0.45	0.51	0.49	0.53

varieties (Guasa, Jalene, CIP-396004.337, Gabisa, Tolcha and Wochecha) and the fifth sub-cluster had five varieties (Agere, Aba Adamu, Gudene, Shenkolla and Gera).

Characteristics of cluster I varieties

This cluster contained three varieties (Bulle, Challa and Ater Abeba) which can be identified by a profuse flower with medium duration of stay, strongly dissected leaves, erect growth habit and obtuse leaf insertion. However, while Bulle and Challa had a semi-stellate corolla shape with leaves having red-brown pigment midribs and a predominantly yellow tuber skin, with a purplish-black secondary tuber skin confined to their eyes, Ater Abeba had a pentagonal corolla shape, a light purple flower, green leaves and round tubers with a purplish-red tuber skin spectacled with white-cream secondary color, a partially netted skin type, yellow-cream flesh and deep eye tubers.

Cluster II varieties characteristics

Sub-cluster I

The five varieties in the first sub-cluster were typified by an erect growth habit, light green leaves and a light purple flower in all varieties, with white acumen secondary flower color distributed on both surfaces, a strongly dissected leaf with brown pigment midribs and a predominantly white tuber flesh and a shallow eye in three of the four varieties in the group, Zengen was the exception with regard to leaf dissection, Awash with regard to midrib pigmentation and CIP-392640.524 deviated from the rest in its eye depth and flesh color. As seen in Figure 1, these

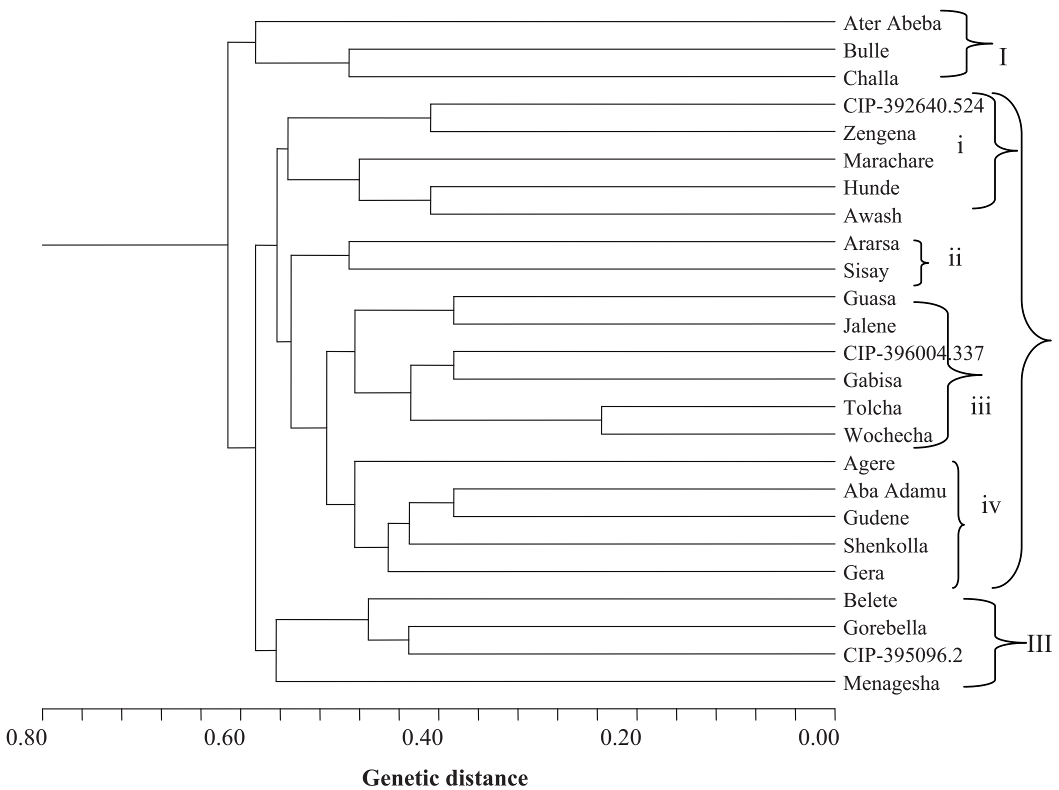

Figure 1 Dendrogram depicting the interrelationship between 25 potato genotypes constructed based on 18 morphological characters using unweighted pair group method with arithmetic mean with a 0.58 genetic distance as a cut-off point.

five varieties have two mini-clusters within the sub-cluster. Phenotypically, it is quite difficult to distinguish between Hunde and Marachare despite their separate registration in the list of nationally released varieties (Ministry of Agriculture and Rural Development, 2008). On the other hand, the varieties Marachare and Awash have a pedigree linkage to each other. Thus, the mini-sub grouping among these three varieties might probably be attributed to their genetic proximity or ancestral closeness.

Sub-cluster II

The two varieties under this sub-cluster were characterized by an erect growth habit, semi-stellate corolla shape, short flowering duration, obtuse leaf insertion, light green leaf color and an oblong tuber shape and smooth skin type, with a tuber skin with secondary color confined to their eyes and a predominantly white-fleshed tuber.

Sub-cluster III

The six varieties of this sub-cluster were identified by their medium leaf dissection, equal obtuse and acute leaf insertion and green and light green leaf color, a semi-stellate corolla shape, white flowers and a moderate degree of flowering (except for CIP-396006.337 where the flowering was profuse), with an erect growth habit, and four varieties having a predominantly white flesh while the other two had white flesh characteristics. The linkage within this sub-cluster clearly followed both pedigree proximity and phenotypic proximity as Guasa and Jalene are sister line varieties derived from the same parents. The closeness between Tolcha and Wochecha as described earlier by their genetic distance followed their phenotypic resemblance which shed some doubt on their origin from either a common parent or one is a sport of the other thus necessitating further investigation at the DNA level with primers covering a wide area of the genome. This condition that was observed between Tolcha and Wochecha and Marachare and Hunde in sub-cluster I of this same cluster II clearly follows the description made according to the method of morphological characterization by Sneath and Sokal (1973) who described a morphological characterization system as a method of classification that generally relies upon the overall phenotypic resemblance or differences judged from the phenotype of the organism without any implication as to their relationship by ancestry. Along the same line, van Eck (2007) emphasized the importance of realizing that phenotypic variation may not have a heritable basis at all, for in many cases, severe phenotypic differences are observed despite any lack of genetic variation. On the contrary close linkage is noticeable among some of the genetically distant varieties which goes against the hypothesis of van Eck (2007) but favors Sneath and Sokal (1973) with their morphological method of characterization. Presumably, the linkage observed between such genetically distant varieties might be the result of the breeders favoring certain phenotypic types such as an erect growth habit, a smooth skin type and intermediate maturity.

Sub-cluster IV

Varieties in this sub-cluster were characterized by an erect growth habit (except for the semi-erect Agere), obtuse leaf insertion generally, with Agre and Shenkolla having a light green leaf while Gera, Aba Adamu and Gudene had a green leaf and white tuber skin (except for Gudene that was yellow), a flaky skin type (except for Agere with a heavy netted skin) and a white tuber flesh color in all varieties of the group. Like in the earlier groups, Agere linked at a distance pertaining to the differences it exhibited in growth habit, leaf color and tuber skin type, among others.

Cluster III varieties characteristics

These varieties had an erect growth habit with intense green leaves, a semi-stellate corolla shape, predominantly white fleshed tubers and a purplish secondary skin color and equally divided obtuse leaves with acute insertion. Menagesha and CIP-395096.2 were further associated with each other by their scattered secondary tuber skin color distribution.

In a similar work carried out on 146 locally collected potato varieties from Turkey, Arslanoglu *et al.* (2011) reported their clustering into 27 groups based on 12 qualitative and 3 quantitative phenotypic characteristics. Tairo *et al*. (2008) found 136 sweet potato genotypes were clustered into two groups based solely on six qualitative characteristics. The narrow cluster groups observed in the current study presumably were attributed to the small number and common origin from the International Potato Center.

CONCLUSION

The selected, environmentally stable, qualitative characteristics employed in this study classified the 25 varieties studied into three main groups and one singleton as judged by their phenotypic resemblance or differences without any implication on their relationship by ancestry. Thus, morphological characterization could be efficiently used to characterize varieties if those plant characteristics were consistent across varying environments and were carefully recorded. Most of these characteristics were controlled by simply heritable genetic factors, as in those varieties with desirable flesh color, tuber shape and eye depth. The difference observed between Marachare and Hunde and between Tolcha and Wochecha in the current study are a manifestation of the method's reliance on phenotypic resemblance or divergence without any implications on their relationship by ancestry. Thus, complementing this system with DNA fingerprinting techniques could help solve doubts emanating from the phenotypic evaluation system. It is also reasonable to suggest the inclusion of phenotypic diversity analysis work supported with heritability, phenotypic and genotypic correlation, and genetic advance value estimates so that there is reliable selection of divergent parental varieties for the germplasm enhancement program in the country.

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