Berhan International Research Journal of Science and Humanities (BIRJSH), 2018, 2(1), 156-173
Journal homepage: www.dbu.edu.et ISSN:2414-2794

Genetic Variation among Drought Tolerant Potato (*Solanum tuberosum* L) Genotypes for Tuber Yield and Related Traits in North Western Ethiopia

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Abstract

Estimation of variability is the first step in the process of variety development. The study was conducted at Simada research site of Adet Agricultural Research Center in 2016 main rainy season to estimate genetic variability among 105 potato genotypes that included five checks. The experiment was laid out in augmented design and data were collected for 20 traits. The analysis of variance revealed the presence of highly significant ($P<0.01$) differences among genotypes for all traits considered except plant height, and small and medium size tubers percentage. Total tuber yield was ranged from 13.92 to 41.79 ton ha^{-1}. The three new entries (20SET4.2, 20SET4.1 and 16SET5.5) had a total tuber yield advantage of 35 to 51% over the best yielding check (Belete). Phenotypic (PCV) and genotypic (GCV) coefficient of variation values ranged from 1.86 to 32.8 and 1.3 to 25.5%, respectively, while heritability and genetic advance as percent of mean estimates ranged from 45.95 to 89.15 and 3.33 to 40.89%, respectively. Moderate to high GCV, PCV, H^2 and GAM were estimated for majority of the traits, suggesting selection breeding is effective to improve these traits. Since the result revealed exploitable variations among the tested drought tolerant potato genotypes, appropriate breeding method is an option to improve potato production in the terminal moisture stress area.

Keywords: Augmented design, Drought tolerant, Genetic Variation,

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Article information: Received 15 March 2018; revised 6 September 2018; Accepted 3 December 2018

Introduction

Potato (*Solanum tuberosum* L.) is one of the staple food crops in most parts of the world. It is the most consumed food crop world-wide next to wheat and rice (Birch *et al*., 2012; Hancock *et al*., 2014) and plays an increasingly essential role in ensuring food security (Vreugdenhil, 2007). Potato production provides food, employment, and income as a cash crop (Scott *et al*., 2000) and helps in increasing food availability while contributing to a better land use ratio by raising the aggregate efficiency of agricultural production systems (Gastelo *et al*., 2014).

The production of potato is expanding at a faster rate than other food crops in Ethiopia and other developing countries. It is possible to produce potato in Ethiopia on about 70% of the arable land (Medhin *et al*., 2000). In 2015/16 cropping season, a sum of over 3.66 million Mt of potato was produced from an area of over 296,578 hectares of land (CSA, 2016). The national average yield is very low (12.66 t ha^{-1}) as compared to the potential yield (40 t ha^{-1}) obtained under research conditions (Getachew and Mela, 2000).

Environmental stresses represent the most limiting factors for agricultural productivity, have detrimental effects on plant growth and yield and are serious threats to agriculture (Wang *et al*., 2003). Among the environmental stresses, drought stress is one of the most adverse factors to plant growth and productivity (Shao *et al*., 2008). The eastern part of South Gondar such as Simada Woreda is characterized by erratic rainfall pattern with short duration (late onset and early offset of rain) and high intensity this implies that besides the amount, distribution of rainfall plays a lot to drought. Global climate change contributes a lot to this unstable onset and off set of rain. The production of potato in Simada woreda was limited and unsatisfactorily contribute to food and nutrition security. This is mainly due to the absence of drought tolerant potato genotypes in the country. In many areas, potato regularly suffers transient water stress due to erratic rainfall or inadequate irrigation techniques (Thiele *et al*., 2010). Currently, the National Potato Project is focusing on the development of drought tolerant potato genotypes since absence of such varieties is becoming the major production constraint in the country.

Different studies have shown that the responses of potato to drought vary among varieties and some drought tolerant potato cultivars produce reasonable yields under conditions where grain crops fail, particularly when drought coincides with flowering and seed set (Iwama and Yamaguchi, 2006). It is also well established fact that the yield potential of crop genotypes vary due to genotypic differences, environmental influences and the interactions of the two (Becker and Leon, 1988). Hence, evaluating of potato genotypes, assessing the genetic variability and estimation of heritability of traits are critical initial steps to develop potato varieties adaptable to semi-arid areas.

The development of drought tolerant potato varieties not only depend on the availability of genotypes but also on the knowledge of genetic variability of the populations. However, such genetic information is lacking, because no attempt has made to introduce drought tolerant potato genotypes in Simada Woreda in particular and in similar moisture stress areas of the country. Thus, this study was conducted with the objective of to estimate the extent of genetic variability in potato genotypes developed for moisture stress areas.

Materials and Methods

Description of the Experimental Site

The experiment was conducted at Adet Agricultural Research Center, Simada experimental site during the main growing season of 2016. Simada is located in Amhara National Regional State South Gondar Administrative Zone, 770 km North of Addis Ababa and 105 km South East of Debrtabor. Simada is positioned at about $11^0$21'N latitude and$38^0$25'E longitude and at an altitude of 2407 m.a.s.l. It has annual mean temperature of 16.8^{o}C. The area has minimum and maximum monthly mean temperature of 10.3- 23.3^{o}C, respectively. The site receives mean annual rainfall of 838.7mm, which is abundant but mal-distributed.

Treatment and Experimental Design

The experiment consisted of 100 potato genotypes tailored for moisture stress (drought prone) areas of the world by International Potato Center (CIP) (table 1). The genotypes were introduced by Adet Agricultural Research Center. Four released potato varieties (Belete, Gera, Shenkolla and Guassa) in the country and one farmer's cultivar commonly used in Simada district was included in the trail as check. The field trial was arranged in Augmented Block design with 5 blocks. Each block contained 20 genotypes and 5 checks randomized to each experimental plot separately in a block. The genotypes appeared once, while the checks were planted at each block. Each genotype was planted in a gross plot size of 2.25m^2 which accommodate 10 plants. The two most external plants at the beginning and end of each row were considered as boarder plant, this allowed eight middle harvestable plants. The distance between plots and blocks were maintained at1 and 1.5 m, respectively.

Table 1: List of potato genotypes used in the experiment

No.	Accession code	No.	Accession code	No.	Accession code	No.	Accession code
1	16SET5.1	26	11SET3.3	51	24SET5.9	76	F30.4
2	16SET5.2	27	11SET3.4	52	19SET7.1	77	F 16.1
3	16SET5.3	28	11SET3.5	53	19SET7.2	78	F16.2
4	16SET5.4	29	11SET3.6	54	19SET7.3	79	F16.3
5	16SET5.5	30	11SET3.7	55	19SET7.4	80	F26.1
6	16SET5.6	31	11SET3.8	56	5SET6.1	81	F26.2
7	16SET5.7	32	25SET6.1	57	5SET6.2	82	F29.1
8	16SET5.8	33	25SET6.2	58	5SET6.3	83	F29.2
9	16SET5.9	34	25SET6.3	59	5SET6.4	84	F29.3
10	16SET5.10	35	25SET6.4	60	5SET6.5	85	F10.1
11	16SET5.11	36	25SET6.5	61	2SET8.1	86	F10.2
12	16SET5.12	37	25SET6.6	62	2SET8.2	87	F14.1
13	20SET4.1	38	22SET7.1	63	2SET8.3	88	F14.2
14	20SET4.2	39	22SET7.2	64	3SET6.1	89	F14.3
15	20SET4.3	40	22SET7.3	65	3SET6.2	90	F22.1
16	20SET4.4	41	22SET7.4	66	23SET3.1	91	F22.2
17	20SET4.5	42	22SET7.5	67	23SET3.2	92	28SET6.1
18	20SET4.6	43	24SET5.1	68	4SET8.1	93	28SET6.2
19	20SET4.7	44	24SET5.2	69	4SET8.2	94	F18
20	20SET4.8	45	24SET5.3	70	4SET8.3	95	F20
21	20SET4.9	46	24SET5.4	71	27SET7.1	96	F28
22	20SET4.10	47	24SET5.5	72	27SET7.2	97	F23
23	20SET4.11	48	24SET5.6	73	F30.1	98	F24
24	11SET3.1	49	24SET5.7	74	F30.2	99	F15
25	11SET3.2	50	24SET5.8	75	F30.3	100	F21.1

Standard check: Belete, Gera, Shenkolla, Guassa and Loca

Experimental Procedures and field Management

Medium size (35-45 mm diameter) and well-sprouted potato tubers were planted at spacing of 75 and 30 cm between rows and plants, respectively, as per the national recommendation. Fertilizer was applied at the rate of 69 kg ha-1 P2O5 in the form of DAP (150kg ha-1 DAP) and 108 kg ha-1 N in the form of Urea (176kg Urea ha-1 + from 150kg ha-1 DAP) as per Adet Agricultural Research Center recommendation of the neighboring zone Debrtabor. The whole rate of phosphorus was applied during planting while nitrogen fertilizerwasapplied in split application of 50% Urea (46% N) including nitrogen from DAP at the time of planting and the remaining 50% of the recommended rate was applied 30 days after planting. Weeding, cultivation and earthing-up were practiced at the appropriate time to facilitate root, stolon and tuber growth as per the national recommendation for the crop. Before two weeks of harvesting as the crop attained maturity (yellowing of stems and senescence of leaves) dehullming was done to thicken the tubers

Data Collection

Data were collected on the basis of plot, net plot and sample plants from central plants in a row. Phenological parameters (days to emergence, flowering and maturity) were collected from the entire plots. Leaf area, plant height and stem number per plant were collected from five plants randomly taken from the central plants and the average value was considered per plant basis. Tuber size distribution (very small< 20gm, small 20 to < 39 gm, medium 39-75gm, andlarge >75 gm according to Lung'aho et al. (2007) and other yield and yield components were measured from the net plot.

Bulking rate (g day-1): was calculated as total weight of tubers harvested from net plot divided by number of days taken from days to flowering to physiological maturity (CIP, 2014).

Tuber dry matter content (%): Clean and unpeeled tubers were chopped into small 1-2 cm cubes and about 200g chopped samples were dried in an oven at a temperature of 80OC for about 72 hours to a constant weight at regular intervals. The percent of dry matter was calculated according to CIP (2007) as:

Dry matter (%) = (Weight of sample after drying (g))/(Initial weight of sample (g))x100%.

Specific gravity of tubers: Five kg of all sized tubers randomly taken from tubers used to estimate total tuber yield. Specific gravity was determined by the weight in air and weight in water method. Tubers first weighted in air and then weighted submerged in water.

Where, Specific Gravity = (weight in air)/(weight in air- weight in water) (Kleinkopf et al., 1987).

Total starch content (g/100g): Starch content in percent was estimated from specific gravity as established by Talburt and Smith (1959) as cited by Yildrim and Tokuşoğlu (2005) as: Starch content (%) = 17.546 + 199.07 × (specific gravity-1.0988), where specific gravity was determined as indicated above by the weight in air and weight in water method.

Data Analysis

Analysis of variance was computed by using the Statistical package for augmented design (SPAD) software (Abhishek et al., 2010). Significantly different means were separated using critical difference in each category viz., among control, among tests and tests vs control. Correlation and genetic distance were computed using STATISTICA-7 basic statistical analysis software (U.S.A.)

Estimation of Variability Components

All traits were considered for further variability analysis for which mean squares of accessions are significant. The genetic advance that can be made was computed along with heritability, genotypic and phenotypic coefficients of variations were estimated. Estimation of genetic parameters was used to identify and determine the genetic variability among the genotypes. In addition, descriptive statistics (range and mean) was used to compare differences among different groups of accessions. Phenotypic and genotypic variations

Phenotypic and genotypic variances and coefficient of variations were calculated by the methods suggested by Burton and de Vane (1953) as:

Genotypic Variance ($\sigma 2g$) = (MSg-MSe)/r

Phenotypic Variance ($\sigma 2p$) = $\sigma 2g + \sigma 2e$

Where: Environmental variance ($\sigma 2e$) =Mean square of error, MSg = Mean square due to genotypes and r = the number of replications.

Phenotypic Coefficient of Variation (PCV) = (√□2p)/x x100 and Genotypic coefficient of variation (GVC) =(√□2g)/x x100. Where X = Mean value of the trait

Heritability and genetic advance

Heritability in broad sense for those traits for which accessions exhibited significant mean squares was computed by using the formula given by Falconer and Mackay (1996).

H2 = σ2g/σ2px100, Where: H2 = heritability in broad sense, $\sigma 2p$= phenotypic variance and $\sigma 2g$ = $Genotypicvariance$.

Genetic advances under selection (GA): Expected genetic Advances for each character at 5% selection intensity was calculated by the formula described by Johanson et al. (1955).

Genetic Advances (GA) = K.σ p.H2, Where: K =constant (selection differential where K= 2.06 at 5% selection intensity, σp = Phenotypic standard deviation, H2= heritability in broad sense.

Genetic advances as percent of mean was calculated to compare the extent of predicted advances of different traits under selection, using the formula.

GAM= GA/X X100 (Falconer and Mackay (1996). Where: GAM = genetic advances as percent of mean, GA= Genetic advances under selection andX = Mean of population in which selection will be employed.

Results

The analysis of variance showed the presence of highly significant ($P<0.01$) differences among genotypes for all traits except plant height, and small and medium size tubers (Table 2). In separate comparison of tests vs controls, the analysis of variance showed significant ($P<0.05$) differences for all the traits but not for unmarketable tuber yield and very small size tuber in percent. It was also revealed significant ($P<0.05$) differences among controls (check varieties) for all traits except for plant height, average tuber weight, small and large size tubers proportion in percent. It was also observed significant differences among tests (new entries) for all traits except for plant height, and small and medium size tubers.

Table 2. Mean squares and their significance for 17 traits of 105 potato genotypes evaluated at Simada during 2016

		Mean squares					
	Block(4)	Treatment (104)	Among control(4)	Among tests(99)	Tests vs Control (1)	Error	CV (%)
Days to emergence	1.36	6.67**	17.96**	5.29**	98.57**	0.76	5.64
Days to flowering	1.76	21.2**	33.56**	19.99**	90.74**	1.51	2.19
Days to maturity	51.24	44.62**	15.94*	41.25**	492.03**	3.49	2.02
Leaf area(cm^2)	0.5	2.21**	2.69**	2.01*	19.11**	0.37	4.48
Stem number per plant	0.16	2.21**	1.86**	2.15**	9.21**	0.25	12.11
Tuber number per plant	1.28	24.86**	10.05**	42.57**	61.99**	0.59	4.92
Tuber yield per plant(kg)	0.002	0.04**	0.015**	0.037**	0.04*	0.003	9.02
Average tuber weight(g)	19.1	149.54**	24.53NS	152.46**	360.15**	12.75	9.18
Marketable tuber yield (ton ha^{-1})	6.97	27.94**	11.47*	28.72**	16.83*	2.57	6.76
Unmarketable tuber yield(ton ha^{-1})	0.04	1.9**	2.87**	1.86**	0.19NS	0.16	16.63
Total tuber yield(ton ha^{-1})	6.66	27.08**	17.07**	27.55**	20.66**	2.12	5.56
Bulking rate per plot (g/day),	1234.61	1264.29**	879.84**	1238.92**	5313.81**	107.91	7.79
Very small tuber percentage	74.51	137.5**	299.77**	132.06**	26.19NS	37.02	18.59
Large tuber percentage	5.65	77.47**	11.71NS	80.87**	3.23NS	8.95	20.6
Tuber dry matter (%)	0.41	8.68**	2.72*	7.96**	103.73**	0.81	3.47
Specific gravity	0.00007	0.00081**	0.0004*	0.00074**	0.01**	0.00008	0.83
Total starch content(g/100gm),	2.77	32.21**	14.04*	29.26**	396.61**	3.17	13.61

*and**=significant at P<0.05 and P<0.01, respectively, NS=Nonsignificant, CV (%) = coefficient of variation in percent.

Mean Performance of Genotypes

Mean and range performance of tuber yield and yield related traits were given in Table 3. Days to emergence, days to flowering and days to physiological maturity ranged from 11.28 to 21.48, 39.68 to 64.08 and 74.04 to 106.64 days for 105 potato genotypes, respectively. The genotypes also varied for leaf area and stem number per plant ranged from 10.06 to 18.56 cm^2, and 1.67-9.23, respectively. Bulking rate of genotypes ranged from 49.58 to 260.63gm day^{-1} while tuber number per plant, tuber yield per plant and average tuber weight ranged from 7.05 to 38.97, 0.19 to 1.02 kg and 16.36 to 69.62g, respectively. Marketable, unmarketable and total tuber yield of genotypes ranged from 10.81 to 38.99, 0.65 to 9.01 and 13.92 to 41.79 ton ha^{-1}, respectively. Very small size tubers proportion in percent ranged from 9.76 to 60.54, while large size tubers were from 0.17 to 40.59%.

Estimates of Variability Components

Phenotypic and Genotypic Coefficient of Variations, Heritability and Genetic Advance

Analysis of genetic variability components like genotypic and phenotypic variance, genotypic and phenotypic coefficient of variability, heritability in broad sense and genetic advance as percentage of mean for 17 traits are presented in Table 3. Genotypic and phenotypic coefficient of variation ranged from 1.3-25.5 and 1.86-32.8%, respectively. Unmarketable tuber yield and large size tubers as percentage were the highest for both GCV and PCV values. In addition, very small size tubers distribution as percentage (23.1%) and starch content in percent (23.8%) were also high in phenotypic coefficient of variation. Specific gravity was the lowest for both genotypic and phenotypic coefficient of variation.

The estimatedheritability in broad sense ranged from 35.17 (very small tuber size percentage) to 89.15 (tuber number per plant) while geneticadvance as percent of mean was ranged from 3.33 (specific gravity) to 40.89% (unmarketable tuber yield). For the other traits heritability was estimated in the range between 60.94 to 74.09% for days to emergence, days to flowering, days to maturity , stem number per plant, tuber yield per plant, average tuber weight, marketable tuber yield, unmarketable tuber yield, total tuber yield, bulking rate per plot, large tuber percentage, dry matter and total starch content in percent.

The lowest heritability was obtained from leaf area (45.95) and very small tubers proportion in percent (35.17). Genetic advance as percent of mean (GAM) was ranged from 3.33 to 40.89%. The maximum genetic advance as percent of the mean was obtained from unmarketable tuber yield (40.89%), while the lowest was from specific gravity (3.33%)

Table 3. Mean and range values and estimates of variability components for 17 traits of 105 potato genotypes at Simada in 2016.

Traits	Range	Mean	$\sigma^2 g$	$\sigma^2 e$	$\sigma^2 p$	GCV (%)	PCV (%)	$H^2 b$	GA	GA%
Days to emergence	11.28-21.48	15.46	1.18	0.76	1.9	7	8.95	62.11	1.76	11.42
Days to flowering	39.68-64.08	55.97	3.94	1.51	5.45	3.54	4.17	72.29	3.46	6.2
Days to maturity	74.04-106.64	92.27	8.23	3.49	11.72	3.1	3.7	70.22	4.94	5.34
Leaf area(cm^2)	10.04-18.56	13.55	0.34	0.37	0.74	4.28	6.35	45.95	0.81	5.99
Stem number per plant	1.67-9.23	4.18	0.39	0.25	0.64	14.8	19.1	60.94	1	23.98
Tuber number per plant	7.05-38.97	15.67	4.85	0.59	5.44	14.00	14.9	89.15	4.27	27.24
Tuber yield per plant(kg)	0.19-1.02	0.6	0.007	0.003	0.01	13.3	16.7	70.00	0.14	23.99
Average tuber weight(g)	16.36-69.62	38.9	27.36	12.75	40.1	13.4	16.3	68.23	8.88	22.83
Marketable tuber yield (ton ha^{-1})	10.81-38.99	23.7	5.07	2.57	7.64	10.6	11.7	66.36	3.77	15.98
Unmarketable tuber yield(ton ha^{-1})	0.65-9.41	2.45	0.35	0.16	0.51	24.1	29	68.63	1	40.89
Total tuber yield(ton ha^{-1})	13.92-41.79	26.16	4.99	2.12	7.11	8.57	10.2	70.18	3.84	14.75
Bulking rate per plot (g/day),	49.58-260.63	133.26	231.27	107.91	339.18	11.41	13.82	68.18	25.75	19.32
Very small tuber percentage	9.76-60.54	32.73	20.09	37.02	57.12	13.7	23.1	35.17	5.47	16.7
Large tuber percentage	0.17-40.59	14.52	13.7	8.95	22.65	25.5	32.8	60.49	5.92	40.77
Tuber dry matter (%)	18.62-31.28	26.05	1.6	0.81	2.38	4.6	5.62	67.23	2.13	7.77
Specific gravity	1.02-1.15	1.07	0.0002	0.00008	0.00023	1.3	1.86	86.96	0.04	3.33
Total starch content(g/100gm),	1.14-27.19	13.09	5.8	3.17	8.98	19.2	23.8	64.59	3.97	31.59

$\sigma^2 g$, $\sigma^2 e$, $\sigma^2 p$= genotypic, error and phenotypic variances and GCV, PCV=genotypic and phenotypic coefficient of variation, $H^2 b$, GA, GA%= Broad sense heritability, genetic advance and genetic advance as percent of mean respectively.

Discussion

The analysis of variance observed significant variation among genotypes, even in separate comparison of tests and control alone and tests vs control tell the presence of adequate variations that allow applying selection breeding to obtain high yielding variety which combine other desirable traits to improve the yield of potato in the study area and similar agro ecologies. Similar finding was reported by Addisu *et al.* (2013), the presence of significant differences among nine regional and national released varieties for days to emergence, days to flowering, and days to maturity, number of stem per plant, tuber number per plant, tuber yield and big tubers proportion as percentage. Abraham *et al.* (2014) found highly significant difference for all pheonological traits, stem per plant, tuber yield, tuber per plant, and big tubers proportion as percentage. Wassu and Simret (2015) evaluated 26 potato genotypes at Dire Dawa tolerant to heat stress and reported significant differences among genotypes for tuber yield, yield related traits and tuber dry matter content. Habtamu *et al.* (2016) reported the existence of significant differences among evaluated 16 improved varieties and two farmers' cultivars for tuber yield and yield related traits as evaluated at three locations of eastern Ethiopia.

A wide range of variation was noticed in all the traits among the genotypes, which indicated that diverse genotypes were included in the study. This may provide sufficient scope for further selection and improvement on these traits. A total of 5, 71 and 77 new entries (genotypes) showed early emergence, flowering and maturity than the recent released variety (Belete), respectively. The three new entries viz. 20SET4.2, 20SET4.1, and 16SET5.5 which were introduced as drought tolerant genotypes had total tuber yield advantage of 51%, 41%, and 35 % respectively, over the best check (Belete). The genotypes also had wide range of variation for very small and large tubers size proportion. Similar findings were reported by, Addisu *et al.* (2013) who observed wide range of variations among potato genotypes for tuber number per plant, big size tubers proportion as percentage, days to flowering, days to 90% maturity, number of stems per plant, and tuber yield per plant. Wassu and Simret (2015) reported wide range of variations among 26 potato genotypes for total tuber yield, marketable and unmarketable tuber yield, tuber dry matter and starch content evaluated at lowland area. Habtamu *et al.* (2016) reported variations among 18 potato cultivars for total tuber yield, marketable tuber yield, unmarketable tuber yield, average tuber weight and large tuber number as percent at three locations of eastern Ethiopia.

According to Deshmukh *et al.*(1986) phenotypic and genotypic coefficient of variation values greater than 20% are regarded as high, whereas values less than 10% are considered to be low and values between 10% and 20% to be moderate. Based on this demarcation, unmarketable tuber yield and large size tubers as percentage had high genotypic and phenotypic coefficient of variation, while very small size tubers distribution as percentage and starch content in percent exhibited high phenotypic coefficient of variation. Moderate GCV and PCV were found for stem number per plant, tuber number per plant, tuber yield per plant, average tuber weight, marketable tuber yield, and tuber bulking rate. In addition, very small size tubers percentage and total starch content in percent had moderate genotypic coefficient of variation, hence this result may allow implementing selection breeding to improve these traits.In agreement with this study, Addisu *et al. (*2013) reported moderate genotypic and phenotypic coefficients of variation for tuber yield and number of stems per plant.

All phenological traits, leaf area and specific gravity had low GCV and PCV values. This suggested selection based on phenotype expression of genotypes might not possible due to the highest masking of environmental factors on the expression of these traits. Addisu, *et al.,* (2013) also found low phenotypic and genotypic coefficients of variation for days to maturity.

In the present studyphenotypic coefficient variation was generally higher than genotypic coefficient variation values in all traits, implies influence of environmental factors on the expression of traits. This result was similar with the results reported by Sattar *et al.* (2007). Addisu, *et al.* (2013) also stated phenotypic coefficients of variation were found to be higher than genotypic coefficients of variation for all traits. Singh *et al.* (2013) observed sufficient variability in potato genotypes and overall values of PCV were greater than those of GCV. Relatively low difference between GCV and PCV were observed for days to maturity, tuber number per plant and specific gravity, this indicated less environmental influence in the trait. This is in accordance with Tekalign (2009) recorded the lowest GCV and PCV for specific gravity.

Estimates of heritability in broad sense were considered according to Pramoda and Gangaprasad (2007) as heritability estimates low (<40), medium (40-59), moderately high (60-79) and very high (≥ 80%). Based on this category, very high heritability estimates were computed for tuber number per plant (89.15%) and specific gravity (86.96%), suggested the selection of genotypes with high mean values of these traits may lead to the improvement of the mean values in the selected genotypes for traits. The estimated heritability in broad sense could be categorized as moderately high heritable for days to emergence, days to flowering, days to maturity , stem number per plant, tuber yield per plant, average tuber weight, marketable and unmarketable tuber yield, total tuber yield, bulking rate per plot, large tuber percentage, dry matter and total starch content in percent. Getachew *et al.* (2016) reported high heritability (> 60%) for marketable tuber yield, total tuber yield, average tuber weight, and tuber dry matter content. Abraham *et al.* (2014) found high heritability estimates for days to emergence, days to flowering, and days to maturity, tuber number per plant, tuber yield per plant, and stem number per plant. Regassa and Basavaraja (2005) also reported moderate heritability for total weight of tuber per plant, total tuber yield, and tuber dry matter content. According to Singh (2001), if heritability of a trait is very high (≥ 80%), selection for such traits could be fairly easy, since there would be close correspondence between the genotype and the phenotype due to the relative small contribution of the environment to the phenotype.

Medium heritability value was calculated for leaf area while low heritability value obtained for very small tubers proportion in percent. This showed that the environmental effect constitute a major portion of the total phenotypic variation. Singh (2001) also stated for traits with low heritability (≤ 40%) selection may be greatly difficult due to the masking effect of the environment.

In the current study, the extent of heritability for most of the traits was moderate to very high, which might be due to uniform environment where the genotypes grown. In general, the high and moderate heritability estimates for most of the characters suggested the higher chance of improving these traits through Selection.

Genetic advance as percent mean (GAM) was categorized into low (≤ 10%) moderate (10-20%) and high (≥ 20%) as established by Johnson *et al*. (1955). Therefore, stem number per plant, tuber number per plant, tuber yield per plant, average tuber weight, unmarketable tuber yield, large size tubers proportion and total starch content had high GAM. This suggested to the improvement of these traits in genotypic value for the new population compared with the base population under one cycle of selection is rewarding. Genetic advance under selection (GA) refers the improvement of traits in genotypic value for the new population compared with the base population under one cycle of selection at a given selection intensity (Singh, 2001). Similar findings by Tripura *et al*. (2016) reported high GAM for number of tuber per plant, weight of tuber per plant, and single tuber weight during evaluation of 23 potato genotypes.

Days to flowering, days to maturity, leaf area, dry matter and specific gravity showed low GAM. This suggested that the improvement of these traits in genotypic value for the new population compared with the base population under one cycle of selection is not rewarding. Addisu *et al.* (2013)) reported low genetic advance as percent of mean for days to flowering and days to maturity while Sattar*et al*. (2007) found low GAM for tuber dry matter content.

The present study revealed that relatively high heritability coupled with high expected genetic advance as percent of mean for tuber number per plant, tuber yield per plant, stem number per plant, average tuber weight, large tuber percentage, and total starch content. Therefore, these traits could be improved more easily than other traits by the selection of genotypes with high mean values. On the other hand, high heritability associated with medium predicted genetic advance were obtained for days to emergence, marketable tuber yield, bulking rate and total tuber yield. This indicated that these traits were highly heritable and selection of high performing genotypes is possible to the improvement of the traits. Most likely the heritability of these traits is due to additive gene effects and selection may be effective for these traits in early generations. In agreement with this, Regassa and Basavaraja (2005) reported higher heritability estimates were coupled with high genetic advance as percent of the mean for number of main stem per plant, number of large sized tuber, total weight of tuber per plant, marketable and total tuber weight. Getachew *et al.* (2016) also reported high heritability coupled with high genetic advance as percent of mean for total tuber yield, marketable tuber yield and average tuber weight. Singh (2008) found high heritability and genetic advance for marketable tuber yield, total tuber yield, weight of tubers per plant. High heritability estimates along with high genetic advance as percentage of mean are more useful in predicting yield under phenotypic selection than heritability alone (Mondal,2003). Memon *et al*. (2005) stated as high heritability and high genetic advance associated with quantitative traits have great importance in selection of genotype in early generations. Effective selection may be done for the traits having high heritability accompanied by high genetic advance which is due to the additive gene effect Panse (1957).

Moderately to high or low heritability coupled with low expected genetic advance as percent of the mean were found in days to maturity, days to flowering leaf area, and specific gravity. The traits that had low heritability coupled with GAM values suggested the scope of improvement using selection is low due to the high influence of environment that limit the improvement to be made based on phenotypic expression of genotypes. The association of high heritability with low predicted genetic advance was reported to be attributed by predominant effects of non-additive gene (Ahmed *et al*., 2007). Panse (1957) also reported that low heritability accompanied with genetic advance is due to non-additive geneeffects for the particular trait and would provide less scope for selection because of the influence of environment.

Conclusion

The significant differences among genotypes for almost all traits implies the presence of adequate variations among genotypes that allow appropriate breeding methods to develop varieties that combine high yield with desirable traits. Moreover estimates of variability components also exhibited moderate to high for most of the traits. This also suggested that selection breeding is applicable to improve these traits which might provide the higher chance of increasing the mean values of generations. Therefore, the current study results showed that the presence of exploitable variations among the introduced drought tolerant potato genotypes in which selection breeding is possible for the study area and similar areas with similar potato production constraints.

Acknowledgements

The authors acknowledge Amhara Regional Agricultural Research Institute (ARARI) and Adet Agricultural Research Center National

Potato Research Program for financial support.

REFERENCES

Abhishek, R., Parsad, R., and Gupta, V.K. (2010).Statistical package for augmented design (SPAD). New Delhi: IASRI, Library Avenue.

Abraham, L., Yohannes, P. and Mebeaselassie, A. (2014).Correlation and path coefficient analysis between yield and yield components in potato (*Solanum tuberosum* L.). *Plant Science Today,***1**(4):196-200.

Addisu, F., Yohannes, P. and Habtamu Z. (2013).Genetic variability and association between agronomic characters in some potato (*Solanum tuberosum* L.) genotypes in SNNPRS, Ethiopia.*International Journal of Biodiversity and Conservation,***5**(8): 523-528.

Ahmed, N., Chowdhry, M. A., Khaliq, I. and Maekaw M. (2007).The inheritance of yield and yield components of five wheat hybrid populations under drought conditions.*Indonesian Journal of Agricultural Science,* **8**(2): 53-59.

Becker, H. C. and Leon J. (1988).Stability analysis in plant breeding.*Plant Breeding,* 101:1–23.

Birch, P.R.J., Bryan, G., Fenton, B., Gilroy, E., Hein, I., Jones, J.T., Prashar, A., Taylor, M.A., Torrance L. and Toth I.K. (2012).Crops that feed the world.*Food Security,* 4:477-508.

Burton, G.W. and de Vane E.H. (1953). Estimating heritability in Tall Fescue (Festuca Arundinacea) from replicated clonal material. *Agronomy Journal,* **45**: 481-487.

Central Statistical Agency (CSA) (2016).Agricultural Sample Survey 2015/2016. Volume V. Report on area, production and farm management practice of belg season crops for private peasant holdings. *Statistical Bulletin, **578**, Addis Ababa July, 2016.*

Deshmukh, S.N., Basu, M.S. and Reddy P.S. (1986). Genetic variability, character association and path coefficient analysis of quantitative traits in Viginia bunch varieties of ground nut. *Indian Journal of Agricultural Science,* **56:**515-518.

Falconer, D.S. and Mackay, T.F.C. (1996).Introduction to quantitative genetics. Fourth edition. Longman group Ltd, England. Pp.160 -161, 312.

Gastelo, M., Kleinwechter, U. and Bonierbale, M. (2014). Global Potato Research for a changing World. Available on line athttp://cipotato.org/wpcontent/uploads/2014/0 6/006151.pdf.

Getachew, A., Wassu M. and Tesfaye A. (2016). Genetic Variability Studies in Potato (Solanum tuberosum L.) genotypes in Bale Highlands, South Eastern Ethiopia. *Journal of Biology, Agriculture and Health care,* **6** (3): 117-119.

Getachew, T. and Awol M. (2000). The role of SHDI in potato seed production in Ethiopia: Experience from Alemaya integrated rural development project. *Proceedings of the 5th African Potato Association Conference, Volume 5,*May 29-June 2, 2000, Kampala, Uganda, pp: 109-112.

Habtamu, G., Wassu, M. and Beneberu S. (2016).Evaluation of Potato (*Solanum tuberosum* L.)Varieties for Yield and Yield Components in Eastern Ethiopia. *Greener Journal of Plant Breeding and Crop Science*, **4** (2): 014-026.

Hancock, R.D., Morris, W.L., Ducreux, L.J.M., Morris, J.A., Usman, M., Verrall, S.R., Fuller, J., Simpson, C.G., Zhang, R., Hedley, P.E. and Taylor, M.A. (2014).Physiological, biochemical and molecular responses of the potato (*Solanum tuberosum* L.) Plant to moderately elevated temperature. *Plant Cell Environment journal,* **37**:439-450.

International Potato Center (CIP) (2007). Procedures for standard evaluation trials of advanced potato clones.An International Cooperators' Guide.

International Potato Center (CIP) (2013). CIP Strategy and Corporate Plan, Research, Innovation and Impact.2014–2023. Lima, p. 51.

International Potato Center (CIP) (2014). Protocol for Tuber Bulking Maturity Assessment of Elite and Advanced Potato Clones. ISBN: 978-92-9060-441-9

Iwama, K., Yamaguchi J. (2006). Abiotic Stress. In: Handbook of potato production, improvement and post-harvest management, J. Gopal and S.M. Khurana Paul,(Eds.).Food Product Press, New York.

Johnson, H. W., Robinson, H. F. and Comstock, R. E. (1955).Estimates of genetic and environmental variability in Soybean.*Agronomy Journal*, **47**: 314-318.

Kleinkopf, G.E, and Wassermann, D. T. (1987).Specific gravity of Russet Burbank potatoes.*American Potato Journal* ,**64:**579-587.

Lung'aho, C., Berga, L., Nyongesa, M., Gildemacher, P., Kinyale, P., Demo P. and Kabira J. (2007). Commercial seed potato production in eastern and central Africa.Kenya Agricultural Institute, 140 p.

Gebremedhin, W/G., Atsede S, Endale G. and Bekele K. (2000).Multi location testing of clones in Ethiopia.*Progress Report, Ethiopian Agricultural Research Organization (*EARO), Ethiopia.

Memon, S. M., Ansari, B. A. and Balouch, M. Z. (2005).Estimation of genetic variation for agronomic traits in spring wheat.*Indian Journal of Plant Sci*ence, 4: 171-175.

Miller, P.A., Williams, C. Robinson H.F. and Comstock R.E. (1958).Estimates of genotypic and Environmental variances and co-variances in upland cotton and their implications in selection.*Agronomy Journal,***50**:126 –131.

Mondal, M.A.A. (2003). Improvement of potato (*Solanum tuberosum* L.) through hybridization and in vitro culture technique.PhD Thesis.Rajshahi University, Rajshahi, Bangladesh.

Panse, V. G. (1957). Genetics of quantitative characters in relation to plant breeding.*Indian Journal of Genetics and Plant Breeding,* **17** (3).

Pramoda, H.P. and Gangaprasad, S. (2007). Biometrical basis of handling segregation population for improving productivity in onion (Allium cepa L.).*Journal of Asian Horticulture,* **3**(4):278-280.

Regassa, D. and Basavaraja, N. (2005).Correlation and path analysis in potato (Solanum tuberosum L.).*Potato Journal.* **32**(3-4): 233-256.

Sattar, M. A., Sultana, N., Hossain, M. M., Rashid, M. H. and Islam K. M. (2007). Genetic variability, correlation and path analysis in potato (*Solanum tuberosum* L.).Bangladesh *Journal of Plant Breed*ing and *Genetics*, **20**(1): 33-38.

Scott, G.J., Rosegrant, M.W. and Ringler C. (2000).Roots and Tubers for the 21st Century: Trends, Projections, and Policy Options, in Food, Agriculture and the Environment Discussion Paper (*Washington, DC: International Food Policy Research Institute*).

Shao, H.B., Chu, L.Y Jaleel, C.A. and Zhao C.X. (2008).Water-deficit stress-induced anatomical changes in higher plants.*Plant Biology and Pathology*, **331**: 215-225.

Singh, B.D. (2001). Plant Breeding: Principles and methods.Kalyani publishers, New Delhi. 896p.

Singh, G. (2008). Studies on genetic variability, association and divergence in potato (Solanum tuberosum L.). M.Sc. (Ag.) Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, (C.G.).

Singh, S. M., Dubey, R. K., Singh, V. and Kumar M. (2013).Genetic variability, correlation and path analysis for tuber yield and attributing traits in potato (Solanum tuberosum L.). *International Journal of Agriculture and Statistical Science,* **9**(1): 205-214.STATISTICA 7 Software. (2002). StatSoft Revision 06/03/03,U.S.A.

Tekalign, T. (2009).Genetic variability, correlation and heritability in tetraploid potato (Solanum tuberosum L.) germplasm.*Tropical Agriculture,* **86**(2): 52-59.

Thiele, G., Theisen, K., Bonierbale M. and Walker T. (2010).Targeting the poor and hungry with potato science.*Potato Journal,* **37**:75–86.

Tripura, A., Das, A., Das, B., Priya, B. and Sarkar K. K. (2016). Genetic studies of variability, character association and path analysis of yield and its component traits in potato (Solanum tuberosum L.).*Journal of Crop and Weed,* **12**(1):56-63.

Vreugdenhil, D., Bradshaw, J. Gebhardt, C., Govers, F., Mackerron, D.K.L., Taylor, M.A., and Ross, H.A. (2007). Potato biology and biotechnology: advances and perspectives. Amsterdam: Elsevier.

Wang, W., Vinocur, B. and Altman, A. (2003). Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. Planta, **218**: 1-14.

Wassu, M. and Simret, B. (2015).Evaluation of Potato (*Solanum tuberosum* L.) Genotypes for Yield and Tuber Quality Related Traits at Lowland, Dire Dawa, Eastern Ethiopia. *Science, Technology and Arts Research Journal,* **4** (3):01-10

Yildrim, Z. andTokusoglu, Ö. (2005).Some analytical quality characteristics of potato (*Solanum tuberosum* L.) Minitubers (cv.nif) developed via in -vitro cultivation. *Electronic Journal, Environment Agriculture and Food Chemistry*, ISSN: 1579-4377.