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Research Article

EVALUATION OF GENETIC DIVERSITY FOR AGRONOMIC TRAITS IN 127 POTATO HYBRIDS USING MULTIVARIATE STATISTICAL METHODS

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ABSTRACT
The aim was to evaluate the genetic diversity in hybrids produced from crosses of Satina and Luca cultivars. Total 127 hybrids with their parents (totally 129 genotypes) were evaluated. Experimental design used was based on Augmented Design in Ardabil Agriculture and Natural Resources Research Station during 2013. Variance analysis of traits showed that there are significant differences between hybrids for traits like days' number until tuberization, plant height, main stem number per plant, main stem diameter, tuber weight per plant, tuber weight average and tuber yield. The tuber yield in the parents of hybrids was observed between 44.52-53.50 ton ha^{-1} and in hybrids between 15.9-116.6 ton ha^{-1}. The regression analysis showed that day's number until tuberization, plant height, main stem number per plant, main stem diameter, tuber number and weight per plant in hybrids were important in selected plants for high tuber yield. The factor were named in a way like, first factor as "tuber yield", the second factor as "plant structural" and third factor as "tuber uniformity and phonology". Based on the cluster analysis results, hybrids were classified into three groups. In second group, traits such as number of days till tuberization, main stem number per plant, main stem diameter, tuber number and weight per plant and tuber yield were positive for deviation percentage from the total average. After evaluation, based on high tuber yield and some of qualitative traits 24 hybrids were selected. The selected hybrids had yellow tuber skin and yellow to light yellow flesh colour, and shallow eye deep and uniform tuber.

Keywords: *Genetic Diversity, Hybrid, Factor Analysis, Solanum Tuberosum*

INTRODUCTION
Potato (*Solanum tuberosum* L.) is grown and eaten in greater countries more than some other crops (Jackson, 1999). It is a crop that grows mainly in climates with cool temperate and full sunlight, moderate daily temperatures and cool nights. Short days generally induce tubers in potatoes, although many modern cultivars can initiate tuberization in the long days of north temperate regions (Tarn *et al.*, 1992). Among the most important crops in the world (Fernie and Willmitzer, 2001) and Iran (FAO, 2011), potato is ranked in fourth grade in annual production after the cereal species rice, wheat and barley. Iran is the world's 12th potato producer and the third biggest producer in Asia, after China and India's mentioned above (FAO, 2011).

Increase in global numerical population especially in developing nations has gradually led to food shortage and hence increase in poverty. Addressing and tackling the issue and causes of poverty in the developing nations is one major challenge to breeders (Fu and Somers, 2009).

Genetic diversity is a pre-requisite equipment to select the suitable parents which may produce new important recombinant lines (Agahi *et al.*, 2011). Genetic diversity studies therefore, is a step wise process through which existing variations in the nature of individual or group of individual crop genotypes are identified using specific statistical method or combination of methods. It is expected that the identified variations would form a pattern of genetic relationship usable in grouping genotypes (Aremu, 2012). Factor analysis is a statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. For example, it is possible that variations in four observed variables mainly reflect the variations in two unobserved variables. Factor analysis searches for such joint variations in response to unobserved latent variables. The observed variables are modelled as linear combinations of the potential factors, plus "error" terms. The information gained about the interdependencies between observed variables can be used later to reduce the set of variables in a dataset. Computationally this technique is equivalent to low rank approximation of the matrix of observed variables. Factor analysis originated in psychometrics, and is used in behavioural sciences, social sciences, marketing, product management, operations research, and other applied sciences that deal with large quantities of data. Factor analysis is related to principal component analysis (PCA), but the two are not identical. Latent variable models, including factor analysis, use regression modelling techniques to test hypotheses producing error terms, while PCA is a descriptive statistical technique (Bartholomew *et al.,* 2008). A logical attitude for categorizing the traits in the sample which contains the above variation necessitates the use of multivariable methods like factor analysis. The method basically reduces a large number of correlated variables to a small number of uncorrelated variables or factors. This method is a strong method that has been used to estimate the components of yield, to extract a subset of identical variables, to identify the basic concepts of multivariable data, to recognize applied and biological connections among the traits, to reduce a large number of correlative traits to a few number of factors and to explain the correlation among the variables (Zakizadeh *et al.,* 2010). The factor analysis method was used by Bunt and Banks (1947) and Seal (1966) and discussed by Cattell (1965). Walton (1971), Gholamin *et al.,* (2010), Khayatnezhad *et al.,* (2010), Arminian *et al.,* (2011), Mehdi Pour Siahbidi *et al.,* (2012) in wheat genotypes, Agahi *et al.,* (2011) in rice genotypes, Ahmadzadeh *et al.,* (2012) cotton genotypes and Tarighi Taheri *et al.,* (2007), Rabiei *et al.,* (2008), and Hassanpanah (2014) in potato genotypes.

The aims of this research were studying the genetic diversity for agronomic traits in 129 potato hybrids with using cluster and factor analysis methods.

MATERIALS AND METHODS

To evaluate the genetic diversity in hybrids produced from crosses of Satina and Luca cultivars, 127 hybrids with their parents (♂Satina and ♀Luca cultivars), a total 129 genotypes, were taken. Experiment design used based on Augmented Design with four replication in Ardabil Agriculture and Natural Resources Research Station during 2013. Each plot area was 3 square meters. In this investigation length of each row was 2 meters and its width was 1.5 meters. There were 2 rows in each plot and on each row 9 tubers were planted. Row spacing of 75 cm and plant spacing of 25 cm was taken. To control the pests and fungal diseases 250 ml ha^{-1} Confidor and 400 g ha^{-1} Equation-pro were used repectively. During the growing period and after harvest attributes like as days to tubrization, number of main stems per plant, main stem diameter, plant height, tuber number and weight per plant, tuber weight average, tuber yield, skin and flesh colour, eye depth and tuber uniformity were measured. Dates from measured traits in cultivars and hybrids were analyzed by software like "Analysis of Augmented Designs" in web site "Indian Agricultural Statistics Research Institute (IASRI)". Linear correlation coefficients between traits and multiple regression analysis for tuber yield by stepwise method were done using Minitab-16 software. In order to grouping hybrids, cluster analysis was calculated with Ward method and Euclidean distance using Minitab-16 software. In order to understand the inter-relationships of attributes and determine the variables with the highest correlation was used Factor Analysis with Principal Component's method and rotation of factors with Varimax method. To obtain the factor matrices, the number of factors that had Eigen-values greater than one was selected. In each main factor, coefficients of factor greater than 0.5 as a significant factor were considered (Lawley and Maxwell, 1963). To calculate it Minitab-16 software was used.

RESULTS AND DISCUSSION

Variance analysis results of traits showed there are significant differences between hybrids for traits days' number until tuberizatin, plant height, main stem number per plant, main stem diameter, tuber weight per plant, tuber weight average and tuber yield. The tuber yield in their parents of hybrids was observed between 44.52-53.50 ton ha^{-1} and in hybrids between 15.9-116.6 ton ha^{-1}.

The regression analysis showed that day's number until tuberizatin, plant height, main stem number per plant, main stem diameter, tuber number and weight per plant in hybrids was important in selected for high tuber yield (Table 1).

Table 1: Stepwise regression analysis of tuber yield

S.O.V.	D.f.	S.S.	M.S.
Regression	6	327823	54637 **
Residual	122	108572	890
Total	128	436395	
R^2 adjusted: 0.75 **			
Durbin Watson: 2.58			

***: Significant at 1%*

Based on the results of the cluster analysis 129 hybrids and cultivars were divided into three groups. This grouping was done on the basis of all traits (Figure 1). In first group, 72 hybrids, in second group, 7 hybrids and in third group 41 hybrids were kept. In second group, traits such as days' number until tuberization, main stem number per plant, main stem diameter, tuber number and weight per plant and tuber yield were found positive for deviation percentage from the total average (Table 2). This group had the highest mean tuber yield and its components. To increase the tuber yield hybrids of this group in crosses can be used.

Table 2: Mean deviation of hybrids from total mean for all the traits

Cluster	Statistical Parameter	Day's to teubrization	Plant height	Number of main stems per plant	Main stem diameter	Tuber weight per plant	Tuber number per plant	Tuber weight average	Tuber yield
First group 79 hybrids	$\bar{X}$	80.46	57.41	3.01	8.73	1226.40	11.67	139.28	71.03
	$\bar{x}_h - \bar{x}_{..}$	0.38	5.14	0.56	1.13	46.06	0.26	8.46	4.40
Second group 7 hybrids	$\bar{X}$	81.63	58.50	3.13	11.14	2628.98	32.10	113.30	204.92
	$\bar{x}_h - \bar{x}_{..}$	1.55	6.23	0.67	3.54	1448.64	20.69	-17.52	138.30
Third group 43 hybrids	$\bar{X}$	79.29	41.62	1.29	5.24	1084.92	10.87	113.28	57.50
	$\bar{x}_h - \bar{x}_{..}$	-0.79	-10.65	-1.17	-2.35	-95.41	-0.54	-17.53	-9.12
Total mean		80.08	52.27	2.45	7.59	1180.33	11.41	130.81	66.63

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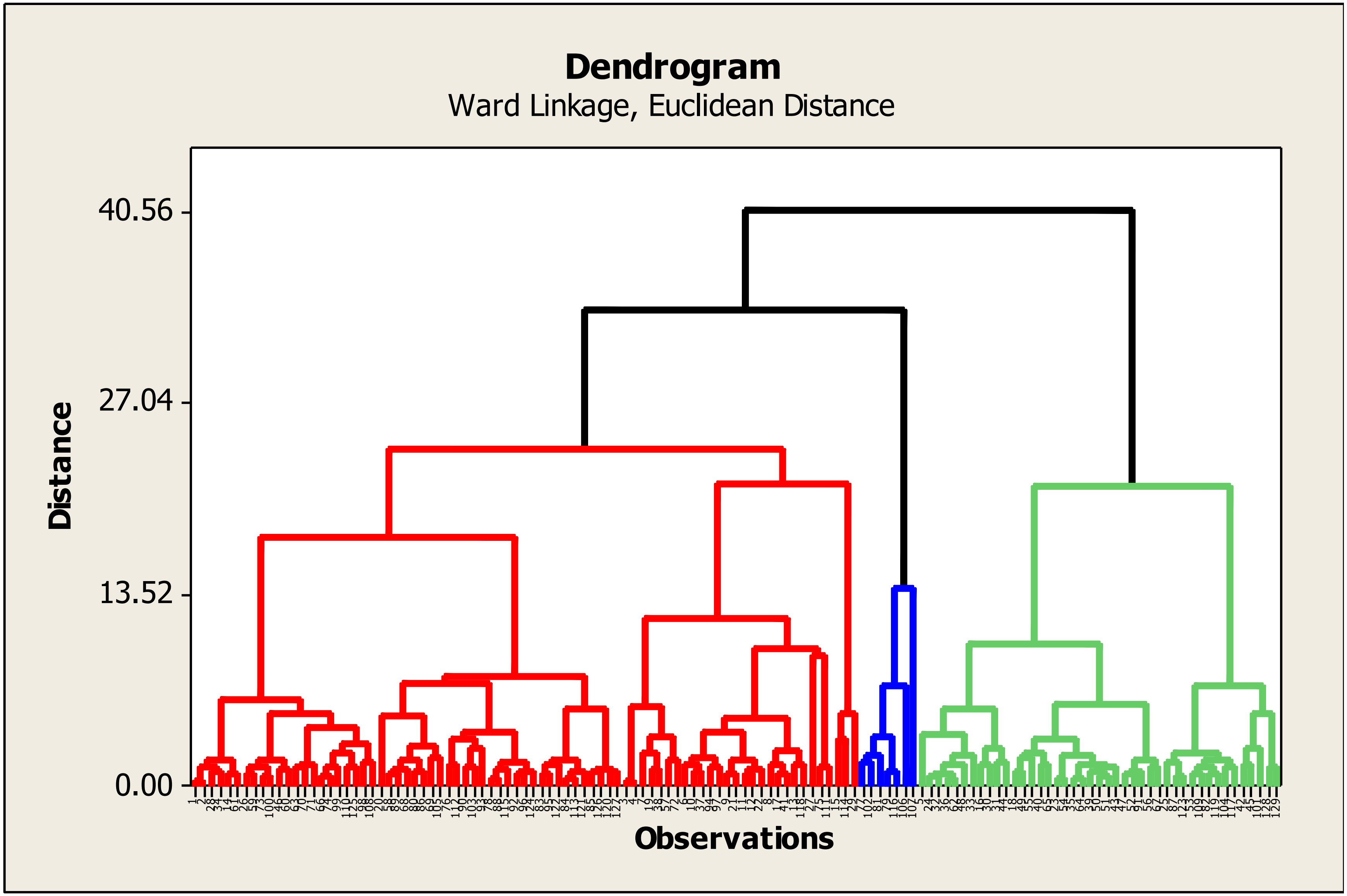

Figure 1: Dendrogram of cluster analysis based on Ward method for hybrids produced from Satina and Luca cultivars crosses base on all traits

According to the number of Eigen-values that was greater than one, three factors were identified. In this analysis three independent factors would explain a total of 76.77 % of the variance. In each main factor, coefficients of factor greater than 0.5 was considered as a significant factor (Lawley and Maxwell, 1963). The total variance explained by factors is indicated in Table 3, only the first 3 factors which account for 76.77% of the total variance are important. A principal factor matrix after orthogonal rotation for these 3 factors is given in Table 3. The values in the table, or loadings, indicate the contribution of each variable to the factors. For the purposes of interpretation only those factor loadings greater than 0.5 were considered important, these values are highlighted in bold in Table 3. Factor 1, which accounted for about 41.28% of the variation, was strongly associated with tuber number per plant, tuber weight per plant and tuber yield. This factor was regarded as productivity per plant factor since it included several traits which are yield components and were named as "tuber yield". All variables had positive loadings in factor 1. The sign of the loading indicates the direction of the relationship between the factor and the variable. This factor was named as "tuber yield". Factor 2 which accounts for about 21.55% of the variation was named a "plant structural" factor since it consisted of main stem number per plant, main stem diameter and plant height. Again all these variables had positive loadings. The third factor was named a "tuber uniformity" factor since it contained days to tubrization and tuber weight average. Factors 2 and 3 each account for about 10% of the variation. The results of this experiment should be chosen of potato genotypes, traits tuber yield and its components, plant structure and tuber uniformity to be considered, respectively. In factor analysis, the effective characteristics in each factor of identified and also, factors based on the effective attributes are named. This method, genetic improvement of factors due to the related traits with them makes possible (Tadesse and Bekele, 2001). Walton (1971), Gholamin *et al.*, (2010), Khayatnezhad *et al.*, (2010), Arminian *et al.*, (2011), Mehdi Pour Siahbidi *et al.*, (2012) in wheat genotypes, Agahi *et al.*, (2011) in rice genotypes, Ahmadzadeh *et al.*, (2012) cotton genotypes and Tarighi Taheri *et al.*, (2007), Rabiei *et al.*, (2008), and Hassanpanah (2014) in potato genotypes.

Table 3: Principal factor matrix after varimax rotation for 8 characters of 127 potato hybrids

Variables	Factor			Extraction
	1	2	3	
Day's to tubrization	0.053	0.095	**-0.494**	0.256
Main stem number per plant	0.048	**0.871**	-0.042	0.763
Main stem diameter	-0.06	**0.790**	-0.026	0.628
Plant height	0.371	**0.552**	-0.010	0.443
Tuber number per plant	**0.816**	0.126	0.089	0.690
Tuber weight per plant	**0.919**	0.001	-0.259	0.912
Tuber weight average	0.011	0.087	**0.890**	0.801
Tuber yield	**0.919**	0.056	0.003	0.848
% of variance	41.28	21.55	13.93	-
Cumulative %	41.28	62.84	76.77	-
Eigen-values	2.503	1.724	1.114	-

Numbers in bold are those with factor loadings greater than 0.50 (Lawley and Maxwell, 1963)
KMO Test =0.520
*Bartlett's Test = 384.44***

Conclusions

After evaluation, based on high tuber yield, some 24 hybrids qualitative traits were selected. The selected hybrids had tuber skin and flesh of yellow till light yellow colour, shallow eye deep and uniform tuber.

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