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ORIGINAL ARTICLE

Investigation of genetic diversity for quantitative traits in 166 potato hybrids of produced from Luca and Caesar cultivars crosses

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ABSTRACT
To genetic diversity evaluation in hybrids produced from crosses of Luca and Caesar cultivars, were evaluated numbers 166 hybrids with their parents (♂Caesar and ♀Luca cultivars) totally 168 genotypes. Experiment design used based on Augmented Design in Ardabil Agriculture and Natural Resources Research Station during 2013. 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 5.5-25.4 ton ha-1 and in hybrids between 53.3-99 ton ha-1. The base on factor analysis results, were named the first factor as "tuber yield and yield component", the second factor as "plant structural", third factor as "phonology" factor and fourth factors as "tuber uniformity" factors. The base on cluster analysis results, hybrids were classified into three groups. In second group, traits of plant height, main stem number per plant, main stem diameter, tuber yield, tuber number and weight per plant and tuber weight were positive for deviation percentage from the total average. After evaluation, base on high tuber yield and some of qualitative traits were selected 82 hybrids. The selected hybrids had tuber skin and flesh of yellow till light yellow colour, shallow eye deep and uniform tuber.
Keywords: *Genetic diversity, Hybrid, Cluster and Factor analysis, Solanum tuberosum*

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is grown and eaten in greater countries more than some other crops [2]. Among the most important crops in the world and Iran [1]. The 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 [1].

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 useable in grouping genotypes [3].

Factor analysis originated in psychometrics, and is used in behavioral 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 modeling techniques to test hypotheses producing error terms, while PCA is a descriptive statistical technique (Bartholomew et al., 2008). The factor analysis method used by Bunt and Banks [4], Seal [5], Cattell [6], Walton [7], Sharma and Choudhary [8], Vetelainen [9], Tarighi Taheri et al [10], Rabiei et al [11], Khayatnezhad et al [12] and Arminian et al [13] in different genotypes of crops.

The aims of this research were studying the genetic diversity for agronomic traits in 168 potato hybrids with using cluster and factor analysis methods.

MATERIALS AND METHODS

To genetic diversity evaluation in hybrids produced from crosses of Luca and Caesar cultivars, were evaluated numbers 166 hybrids with their parents (♂Caesar and ♀Luca cultivars) totally 168 genotypes. Experiment design used based on Augmented Design 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.

Control the pests and fungus diseases were done respectively by use of 250 ml ha^{-1} Confidor and 1 kg ha^{-1} Mancozeb. During the growing period and after harvest were measured attributes like as day's 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.

Dates from measured traits in cultivars and hybrids were analyzed by software of "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 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 were 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 [14]. To calculate it was used Minitab-16 software.

RESULTS AND DISCUSSION

Variance analysis results of traits showed there are significant differences between hybrids for traits day's 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 5.5-25.4 ton ha^{-1} and in hybrids between 53.3-99 ton ha^{-1}.

The base on cluster analysis results, were classified 168 hybrids and cultivars into three groups base on all traits. In first group, 80 hybrids, in second group, 53 hybrids and in third group 35 hybrids were. In second group, traits of plant height, main stem number per plant, main stem diameter, tuber yield, tuber number and weight per plant and tuber weight were positive for deviation percentage from the total average (Table 1). This group had the highest tuber yield mean and its components. To increase the tuber yield can be used from hybrids of this group in crosses.

Table 1. Mean deviation of hybrids from total mean for all the traits

Cluster	Statistical Parameter	Day's to tubrization	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 80 hybrids	$\overline{X}$	77.62	63.69	2.59	12.928	652.6	6.14	118.51	34.73
	$\overline{x}_k - \overline{x}_{..}$	-1.14	4.41	0.26	0.588	-272.33	-1.6	-20.8	-14.46
Second group 53 hybrids	$\overline{X}$	77.547	61.16	3.379	12.697	1558.4	11.79	180.7	82.90
	$\overline{x}_k - \overline{x}_{..}$	-1.45	1.88	1.049	0.357	633.47	4.048	41.39	33.71
Third group 35 hybrids	$\overline{X}$	82.086	46.37	1.657	10.369	588.1	5.243	124.4	31.17
	$\overline{x}_k - \overline{x}_{..}$	3.086	-12.91	-0.673	-1.971	-336.83	-2.497	-15.11	-11.02

According to the number of Eigen-values greater than from one were identified three factors. In this analysis three independent factors would explain a total of 81 % of the variance. In each main factor, coefficients of factor greater than 0.5 was considered as a significant factor [14].

The total variance explained by factors is indicated in Table 2, only the first 4 factors which account for 81% of the total variance are important. A principal factor matrix after orthogonal rotation for these 4 factors given in Table 2. 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 2. Factor 1, which accounted for about 34.52% of the variation, was strongly associated with tuber yield, tuber number per plant and tuber weight per plant. This factor was regarded as productivity per plant factor since it included several traits which are yield components and were named as "yield and tuber yield component". 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 and yield component". Factor 2 which accounts for about 17.82% the variation was named a "plant structural" factor since it consisted of plant height, main stem number per plant and main stem diameter. Again all these variables had positive loadings. The third factor was named a "phonology" factor since it contained day's to tubrization. The fourth factors as "tuber uniformity" factor since it contained tuber weight average. The results of this experiment should be chosen of potato genotypes, traits tuber yield and its components, plant structure, phonology 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. to create genetic diversity and its use in breeding programs, the number of 65 potato genotypes during two years with Agria, Draga and Marfona cultivars as controls resulted that there were significant differences among genotypes in main stem number per plant, plant height, total and marketable tuber number and weight per plant, marketable tuber yield, days number till tuberization and dry matter percent. The main stem number per plant, plant height, total and marketable tuber number and weight per plant and marketable tuber yield had the high diversity and days number till tuberization and dry matter percent relatively high diversity. Cluster analysis divided 65 genotypes into four groups. The third group with five genotypes (Caesar, Luca, Kennebec, Satina cultivars and 397007-9 advanced clone had total and marketable tuber number per plant, marketable tuber yield higher than total average and controls. In factor analysis, four independent factor total 73.49% of the variation explained. The first factor, yield and its components (marketable tuber yield, total and marketable tuber number and weight per plant), the second factor, the structure factor (plant height and number of main stems per plant), the third factor, quality factor (dry matter percent) and the fourth factor, the phenology factor (day's number till tuberization) was named. Many researchers have used this method in potato genotypes [8, 10 and 11].

Table 2. Principal factor matrix after varimax rotation for 8 characters of 168 potato hybrids and cultivars

Variables	Factor				Extraction
	1	2	3	4	
Day's to tubrization	-0.058	-0.164	**-0.657**	0.054	0.464
Main stem number per plant	0.130	**0.698**	0.499	0.032	0.755
Main stem diameter	0.016	**0.805**	-0.166	0.016	0.676
Plant height	0.062	**0.903**	-0.147	-0.01	0.842
Tuber number per plant	**0.956**	0.084	0.098	0.179	0.963
Tuber weight per plant	**0.957**	0.087	0.0939	0.182	0.966
Tuber weight average	**0.855**	0.040	-0.042	-.330	0.846
Tuber yield	0.063	0.015	-0.044	**0.974**	0.955
% of variance	34.52	17.82	14.69	13.88	-
Cumulative %	34.52	52.34	67.03	80.90	-
Eigen-values	2.76	1.42	1.17	1.10	

Numbers in bold are those with factor loadings greater than 0.50 [14].
KMO Test =0.56
Bartlett's Test = 188.88**

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