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Evaluation of Iranian Garlic (*Allium sativum* L.) Genotypes Using Multivariate Analysis Methods Based on Morphological Characteristics

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Abstract: In this study genetic diversity of 39 *Allium sativum* L. genotypes collected from different parts of Iran was investigated by using morphological characteristics. Measuring of characteristics of garlic genotypes were performed based on IPGRI descriptor. Analysis of variance showed that all of the characters in examined genotypes were significant, showing high variability in characters. Also factor analysis was used for determining the number of main factors. Factor analysis showed that most bulb characters were composing the main factors. Effective characters categorized in seven factors that contributed 81.84% of total variance. For each factor eigen value more than 0.6 was used as significant eigen value. Cluster analysis was performed using these seven factors and genotypes in distance of 10 (similarity coefficient) were divided four main clusters. This study showed that multivariate analysis methods could be a useful method for discrimination of garlic genotypes.

Key words: Garlic, morphological characters, multivariate analysis, factor analysis, cluster analysis

INTRODUCTION

The genus *Allium* consists of at least 500 species (Vvedensky, 1944) and garlic (*Allium sativum* L.) is the species in this genus under cultivation for the longest time. Garlic has been cultivated for at least 5000 years (Hahn, 1996) presumably having originated in central Asia (Vavilov, 1951; Hong and Etoh, 1996). Garlic is an asexually propagated crop and it displays great morphological diversity in bulb and leaf size, color and shape, scape presence and height and flower color, fertility and bulbil (topset) development inflorescence (Pooler and Simon, 1993). Characterization of garlic genotypes has based primary on morphological data (Jones and Mann, 1963). Flower-related morphological traits were correlated with isozyme data, while bulb-associated traits and geographical origin were not (Pooler and Simon, 1993). Furthermore *Allium longicuspis* clones were discriminated morphologically purple anthers, higher flowering rate and seed production and smaller bulbils inflorescence (Etoh and Simon, 2002). Baghalian *et al*., (2005) evaluated of allicin content and botanical traits in Iranian garlic (*Allium sativum* L.) ecotypes were performed. For having useful information about morphological and genetical characteristics for breeding and commercialization of promising garlic cultivars, a precise determination and discrimination of the genotypes is require. Factor analysis is one of the powerful multivariate statistical methods for obvious biological relationships between characteristics, reducing many dependent characteristics to limited factors (Walton, 1972; Guertin and Baily, 1982; Johnson and Wichern, 1988). Multivariate statistical methods were used for separation and clustering of sour cherry (Karl *et al*., 1988), date (Jaradat and Zaid, 2004) and other fruit tree genotypes (Koehler-Santos *et al*., 2003; Fatahi *et al*., 2004). With respect to the high importance of garlic in Iran, this study was performed to find more knowledge about relationships among characters of garlic genotypes.

MATERIALS AND METHODS

Plant material: Bulb samples from 39 garlic genotypes (Table 1) were collected from different parts of Iran and were planted three replicated (with distance of 15 cm between plants) in the filed of Horticultural Research Centre of the Agriculture Faculty, University of Tehran.

Morphological characteristics: Twenty seven morphological characteristics measured based on IPGRI descriptor (2001) for *Allium* species (Table 2).

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Table 1: Garlic genotypes used in this study and mean of some characters

No.	Genotypes on sampling region	Shaft length (code)*	Foliage length (cm)	Weight of bulbs (g)
1	Ramsar	5	37	59.75
2	Birjand	5	40	56.50
3	Tarom	5	40	76.60
4	Tarom	5	45	62.72
5	Tarom	7	46	68.18
6	Mashhad	5	42	61.47
7	Arak	7	54	187.00
8	Arak	3	37	81.00
9	Birjand	3	36	48.90
10	Langrod	5	34	45.75
11	Rasht	7	41	33.81
12	Rasht	5	34	41.53
13	Amol	7	41	84.27
14	Sistan	5	41	40.35
15	Khoram Abad	5	42	60.93
16	Ahwaz	7	33	45.80
17	Maragheh	7	43	73.00
18	Dezful	5	33	26.31
19	Tabas	3	32	48.49
20	Behbahan	5	35	38.63
21	Rasht	5	32	48.42
22	Tafresh	3	40	53.00
23	Tafresh	5	32	55.20
24	Azarshahr	7	43	64.90
25	Hamedan	5	42	69.60
26	Jiroft	3	24	22.43
27	Azarshahr	7	42	65.84
28	Rasht	7	40	36.46
29	Rasht	5	40	68.60
30	Ghazvin	3	42	60.88
31	Ghazvin	7	41	52.90
32	Azarshahr	7	45	75.19
33	Rasht	5	30	57.65
34	Hamedan	3	32	48.40
35	Hamedan	3	34	72.38
36	Hamadan	3	32	31.56
37	Mashhad	5	40	34.84
38	Langrod	3	45	52.30
39	Ramsar	3	43	52.70

*: 3 Short (<18 cm), 5 Intermediate (18-27 cm), 7 Long (>27) (IPGRI descriptor, 2001)

Table 2: Garlic characters that measured in this study

No.	Characters*	Unit*
1	Foliage color	code
2	Foliage attitude	code
3	Stem length	code
4	Foliage length	cm
5	Shaft diameter	mm
6	Foliage wide	mm
7	Foliage number	code
8	Weight of bulbs	g
9	Shape bulb	code
10	Bulb skin color	code
11	Bulb diameter	mm
12	Bulb shape horizontal	code
13	Bulb skin no.	code
14	Stem bulbil no.	code
15	Bulbil stem weight	g
16	Bulb structure type	code
17	Weight cloves	g
18	No. cloves	number
19	Clove Skin color	code
20	Scape ability	code
21	Scape structure	code
22	Scape length	cm
23	Flowering ability	code
24	No. Flower in umbel	number
25	No. Bulbil	number
26	100-Bulbil weight	g
27	General fertility	code

*Base on IPGRI descriptor (2001)

Statistical analysis: For each genotypes 30 plants were measured then mean values of each characters were used to perform factor analysis and clustering the genotypes. SPSS Ver. 10 software was used for factor analysis (factor rotation technique and Varimax method) and clustering of genotypes (Ward's method).

RESULTS AND DISCUSSION

Mean values of the studied morphometric characteristics showed large variations between genotypes for all traits also those were used multivariate analysis methods (data not shown). Results from simple correlation analysis showed the existence of significant positive and negative correlations among characteristics (data not shown). Factor Analysis (FA) was used to determine the number of main factors (Table 3). Based on factor analysis 27 characters were divided in seven factors that had eagin value more than one and explained 81.84 of % variance. Percent of variance of each factor is showing importance of that factor. Factor loading more than 0.60 was considered as significant factor loading for each factor. In the first factor weight of bulbs, foliage wide, bulb diameter, weight cloves, flowering ability, No. flower in umbel and general fertility characters were located that explained 28.08% variance and some characters were located in other six factors that had factor lading significant more than 0.60% that listed in Table 3. Grouping of garlic genotypes based on these seven factors showed that genotypes in distance of 10 (similarity coefficient) were divided into 4 sub-clusters (Fig. 1). Cluster divided genotypes more based on flowering ability, scape ability, weight of cloves, bulb diameter and foliage wide characters. Arak genotype (No. 7) with having flowering ability character that did not exist other genotypes was located in one group alone. This study showed that multivariate analysis methods could be a useful method for discrimination of garlic genotypes.

Table 3: Eigen values and cumulative variance for seven factors resulted from factor analysis

	Factors						
Characters	1	2	3	4	5	6	7
Foliage color	0.51	-0.17	-0.27	-0.16	-0.06	0.12	-0.47
Foliage attitude	0.12	0.137	-0.18	0.12	-0.12	-0.04	0.83**
Length stem (code)	0.19	0.77**	0.01	0.16	-0.15	0.19	0.12
Foliage length (cm)	0.56	0.31	0.19	-0.20	0.10	0.44	0.19
Shaft diameter (mm)	0.57	-0.28	0.59	-0.31	0.27	0.14	-0.04
Foliage wide (mm)	0.77**	0.12	0.20	-0.27	0.23	0.30	-0.01
Foliage number	0.05	-0.22	0.85**	-0.16	-0.02	-0.14	-0.02
Weight of bulbs	0.89**	0.17	0.08	-0.08	0.29	0.07	0.06
Shape bulb	-0.23	-0.38	-0.15	-0.02	-0.56	0.08	-0.03
Bulb skin color	-0.05	-0.74**	-0.36	-0.25	0.13	0.02	0.11
Bulb diameter	0.80**	-0.08	0.14	-0.12	0.43	0.13	0.03
Shape horizontal	0.04	0.86**	-0.32	-0.07	-0.19	-0.18	-0.11
No. Skin bulb	0.15	-0.12	-0.22	-0.03	0.38	0.38	-0.50
No. Stem bulbil	-0.08	-0.01	-0.01	0.96**	0.03	0.02	0.08
Weight stem bulbil	-0.08	-0.04	-0.02	0.96**	0.03	-0.01	0.08
Bulb structure type	0.02	0.05	0.10	-0.02	0.12	-0.90**	0.14
Weight cloves	0.92**	0.04	-0.02	-0.07	0.14	-0.09	0.05
No. cloves	-0.04	-0.25	0.89**	0.15	-0.06	-0.08	-0.02
Skin color cloves	-0.10	0.30	0.17	-0.14	-0.70**	0.09	0.27
Scape ability	0.07	0.88**	-0.30	-0.08	-0.18	-0.18	0.04
Scape structure	0.15	0.87**	-0.16	0.06	0.20	-0.02	0.20
Scape length	0.44	0.81	-0.15	-0.03	0.03	0.12	0.04
Flowering ability	0.75**	0.13	-0.04	0.03	-0.21	-0.03	0.04
No. Flower in umbel	0.96**	0.04	-0.06	0.08	-0.04	-0.07	-0.10
No. Bulbil	-0.12	0.78**	-0.11	-0.13	0.10	-0.12	0.18
100-Bulbil weight	-0.11	0.64**	-0.13	-0.11	0.24	0.25	0.11
General fertility	0.96**	0.04	-0.06	0.08	-0.04	-0.07	-0.10
% of variance	28.08	21.61	8.69	8.42	5.96	4.99	4.08
% of cumulative variance	28.08	49.69	58.39	66.81	72.77	77.7	81.84
Egien value	7.58	5.84	2.35	2.27	1.61	1.35	1.10

**Significant factor loading (Values above 0.60)

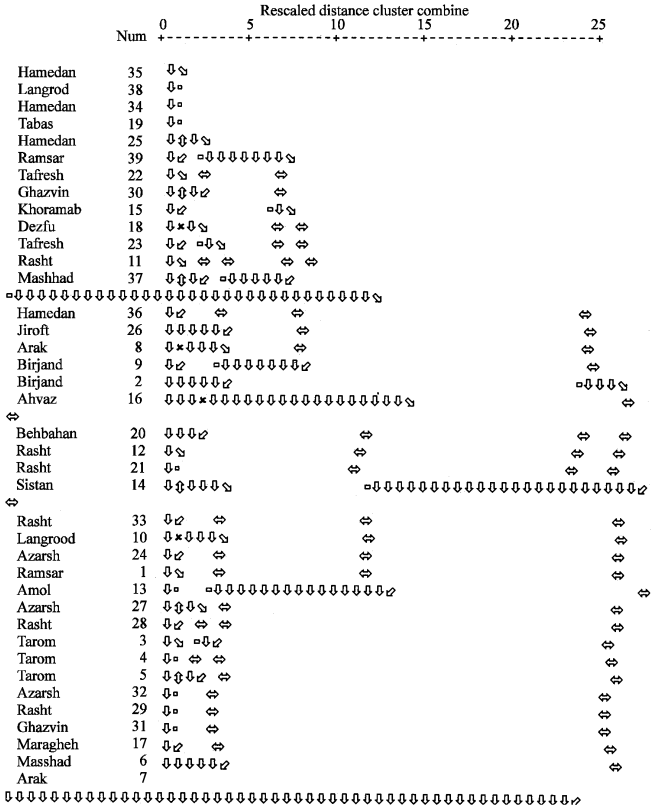

Fig. 1: Dendrogram of grouping 39 Garlic genotypes based on seven main factors (Table 3) and Ward's method

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