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Relationship between biological yield and some agronomic traits of common ecotypes of *Lallemantia* (*Lallemantia iberica* Fisch. et C.A. Mey) from Iran

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Abstract

The present study was conducted in 2015 to investigate the relationship between biological yield and some agronomic traits of common ecotypes of Lallemantia (*Lallemantia iberica* Fisch. et C. A. Mey) from Iran. For this purpose, seeds of common ecotypes of this plant were cultured as a square lattice design (7×7) with three replications at the Research Farm of the Faculty of Agriculture, University of Tabriz. Results showed that there were significant differences among *Lallemantia* ecotypes in all of study traits. The strongest relationship between the studies parameter and biological yield per plant in the means of data was that recorded between biological yield and seeds per plant (r=0.944**). 49 *Lallemantia* ecotypes were grouped in two clusters. Deviation from the mean for different traits showed that the group two ecotypes (1, 5, 43, 15, 38, 27, 16, 30, 45, 49, 7, 25, 20, 8, 40, 19, 18, 23, 31, 13, 44, 14, 32, 21, 36, 22, 34, 47, 37, 6, 24, 29, 46, 39 and 41) had the highest means for studies traits except chlorophyll content index.

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Introduction

Genus *Lallemantia* belongs to the family Lamiaceae which has 46 genera and 410 species and subspecies in Iran (Naghibi *et al.*, 2005). It is distributed in different parts of Iran, especially in north and north-west.

This genus has five different species including *Peltata*, *Royleana*, *Iberica*, *Baldshuanica* and *Canescen* (Zargari, 1990). The seeds are normally used as stimulant, diuretic and expectorant (Naghibi *et al.*, 2005). The mucilage of the seeds is used for treatment of some nervous, hepatic and renal diseases and it was used as general tonic in the Iranian traditional medicine (Amin, 1991; Amanzadeh *et al.*, 2011).

Lallemantia iberica Fisch.et C.A. Mey. (Also named “Dragon's head”) is a crop cultivated from the prehistoric times in South-western Asia and South-eastern Europe. It is an annual plant and has been cultivated for its seeds that contain about 30%-38% drying oil (Siccative oil). Theiodic index of its seeds oil is between 163 and 203.

The oil is used in foods, but especially in dye and varnish industry (Shafiee *et al.*, 2009; Ion *et al.*, 2011). This plant is considered as a linseed substitute in a number of applications including: wood preservative, ingredient of oil-based paints, furniture polishes, printing inks, soapmaking and manufacture of linoleum (Samadi *et al.*, 2007; Shafiee *et al.*, 2009) and also has high ornamental value and it is used in arid landscaping and urban horticulture at various places in many countries (Ozdemir *et al.*, 2014). This plant is an important medicinal and grows in various regions with different environmental conditions (Ozdemir *et al.*, 2014).

Physiological, morphological and genetically variations were seen in populations of species that occurred in different habitat, these variations were created in response to contrasting environmental conditions (Talebi *et al.*, 2014). Koohdar *et al.* (2015) investigated the population genetic structure in *Lallemantia iberica*. They reported that Mantel test revealed significant correlation between genetic distance and geographical distance of the populations. Structure analysis and K-Means clustering revealed population genetic fragmentation and the presence of three gene pools for this species. The assignment test revealed the occurrence of limited gene flow among the populations. The results suggested that genetic divergence, limited gene flow, genetic drift and local adaptation have played role in diversification of *Lallemantia iberica*.

Achieve to high yield is one of the most important purposes for plants. As known, seed yield is a complex character that can be determined by several components which reflect positive or negative effects upon these traits meanwhile, it is important to examine the contribution of each of the various components in order to attract the attention to which one has the greatest influence on seed yield.

Therefore, information on the relation of agronomical traits with biological yield is of great importance to a breeder in selecting a desirable ecotype (Özer *et al.*, 1999). In this work we compared some of the agronomic traits and biological yield of 49 common ecotype of *Lallemantia iberica* to select the best ecotypes based on investigated traits.

Materials and methods

Site description and experimental design

To study of relationship between biological yield and some agronomic traits of common ecotypes of *Lallemantia iberica* (Table 1) a square lattice design (7×7) with three replications was conducted in 2015 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Tabriz, Iran (Latitude 38° 05N, Longitude 46° 17E, Altitude 1360m above sea level). The climate is characterized by mean annual precipitation of 245.75mm per year and mean annual temperature of 10°C. In this research each plot had 5 rows of 1.5m length, spaced 20cm apart. The seeds were sown by hand on 28 May 2015 in 1cm depth of a sandy loam soil. All plots were irrigated immediately after sowing. The next irrigations were applied when needed. Weeds were controlled by hand during crop growth and development as required.

Table 1. The origin of 49 common ecotypes of *Lallemantia iberica*.

Ecotype number	Origin	Ecotype number	Origin	Ecotype number	Origin
1	Kolvanaq 1	18	Tabriz 8	35	Param village 2 (Heris)
2	Kolvanaq 2	19	Kolvanaq 10	36	Peyghamm village (Kaleybar)
3	Kolvanaq 3	20	Kolvanaq 11	37	Alvar village (Bostanabad)
4	Kolvanaq 4	21	Kolvanaq 12	38	Dehlan village (Hashtrud)
5	Ahar 1	22	Kolvanaq 13	39	village (Jolfa)Komar-e Sofla
6	Kolvanaq 5	23	Tabriz 4	40	Gondak village (Bijar)
7	Kolvanaq 6	24	Kolvanaq 14	41	Sero (Urmia)
8	Kolvanaq 7	25	TazehKand	42	Aralan village (Marand)
9	Sarab	26	Kolvanaq 15	43	Majareh village (Khalkhal)
10	Kolvanaq 8	27	Param village 1 (Heris)	44	Lilab village (Varzaqan)
11	Kolvanaq 9	28	Zarnaq	45	Kharvana
12	Tabriz 2	29	Varzaqan 1	46	Kurdistan 2
13	Tabriz 5	30	Ahar 2	47	Takab
14	Tabriz 3	31	Tazehkand	48	Zanjan
15	Tabriz 1	32	Malekan	49	Nazarlu and DarvishBaqqal villages
16	Tabriz 7	33	Mashhad		
17	Tabriz 6	34	Varzaqan 2		

Measurement of traits

Chlorophyll content index (CCI) was recorded by a chlorophyll meter (CCM-200, Optic- Science, USA) in upper, middle and lower leaves of a plant from each plot at grain filling stage. Then mean CCI was calculated for each plot. Also, at maturity stage, other traits such as stem diameter, biological yield per plant, seeds number per main cycle, seeds per plant and 1000 seeds weight were determined.

Statistical analysis

MSTAT-C and SPSS-18 software's used to the data analysed and the means of traits were compared using Duncan multiple range tests at $P \leq 0.05$. Excel software was used to draw the Fig.s.

Linear correlation analyses were applied pairwise to all the studied traits. Path analysis was performed for grain yield based on characters entered into the model in step wise multivariate regression analysis.

Results and discussion

Analysis of variance (Table 2) showed that there were significant differences among *Lallemantia* ecotypes from the aspect of studied traits.

Maximum chlorophyll content index (35.67) was observed in Zanjan ecotype. Maximum and minimum stem diameter was recorded in Varzaqan 1 (ecotype number of 29) and Ahar 2 (ecotype number of 30) ecotypes, respectively. In seeds number per main cycle and seeds per plant.

Kolvanaq 14 was superior ecotype. Maximum 1000 seeds weight (5.23g) was obtained in Varzaqan 2 (ecotype number of 34) and minimum of this trait (3.83 g) was recorded in the Aralan village (Marand) (ecotype number of 42). Maximum biological yield per plant was recorded for Kolvanaq 14 (ecotype number of 24) ecotype (Table 3).

Table 2. Analysis of variance (MS) for different traits of common ecotypes of *Lallemantia iberica*

Source		Df	Mean Square					
			Chlorophyll content index	Stem diameter	Biological yield per plant	Seeds number per main cycle	Seeds per plant	1000 seeds weight
Replications		2	19.062^{ns}	0.116^{ns}	0.967^{*}	22.201^{ns}	2430.43^{ns}	0.177^{ns}
Treatments	Unadjusted	48	75.657^{**}	0.111^{ns}	0.395^{ns}	14.597^{*}	1873.13^{ns}	0.169^{**}
	Adjusted	48	-	-	0.403^{*}	14.652^{*}	1933.99^{*}	-
Blocks within Reps (adj.)		18	6.868	0.089	0.332	11.417	2070.19	0.058
Error	Effective	96	-	-	0.272	8.420	1238.42	-

Source		Df	Mean Square					
			Chlorophyll content index	Stem diameter	Biological yield per plant	Seeds number per main cycle	Seeds per plant	1000 seeds weight
	RCB Design	96	11.061	0.093	0.275	8.615	1316.38	0.067
	Intrablock	78	12.029	0.094	0.262	7.968	1142.42	0.070
CV (%)			16.82	16.16	30.28	21.25	29.52	5.36

ns,* and **: Non significant, significant at P≤0.05 and P≤0.01, respectively.

Table 3. Comparisons of mean for studied traits of 49 common ecotypes of *Lallemantia iberica*.

Ecotype number	Chlorophyll content index	Stem diameter (mm)	Biological yield per plant (g)	Seeds number per main cycle	Seeds per plant	1000 seeds weight (g)
1	17.45g-k	1.87a-e	1.463b-f	14.80a-f	112.4b-g	4.53ef
2	25.63b-e	1.78a-e	1.358b-f	13.21d-g	97.32c-g	4.90a-f
3	20.13e-j	1.67a-e	1.387b-f	12.51d-g	98.27c-g	4.76a-f
4	14.43j-l	1.84a-e	1.334c-f	11.75d-g	97.91c-g	4.73a-f
5	17.67g-k	1.86a-e	1.688a-f	12.88d-g	108.5b-g	4.50ef
6	25.92b-e	2.09a-e	2.427ab	19.18ab	175.3ab	4.86a-f
7	16.83g-l	1.73a-e	1.803a-f	12.43d-g	119.2a-f	4.93a-f
8	19.33e-j	1.83a-e	1.803a-f	13.81b-g	130.1a-f	4.93a-f
9	28.43bc	1.72a-e	1.729a-f	12.73d-g	106.8b-g	4.83a-f
10	19.50e-j	1.66b-e	1.137d-f	10.34fg	76.88fg	4.73a-f
11	29.80b	1.70a-e	1.437b-f	12.03d-g	94.36c-g	4.76a-f
12	14.83j-l	1.69a-e	1.109ef	10.60e-g	79.50e-g	4.83a-f
13	14.35j-l	1.96a-e	1.817a-f	12.46d-g	121.5a-f	4.97a-e
14	15.75i-l	1.95a-e	1.710a-f	12.62d-g	119.3a-f	4.9a-f
15	17.31g-l	1.96a-e	1.718a-f	15.17a-f	131.9a-f	4.6d-f
16	15.53i-l	2.07a-e	1.958a-e	15.00a-f	130.4a-f	4.73a-f
17	15.05j-l	1.59c-e	1.179d-f	10.20fg	86.26c-g	4.96a-e
18	23.18b-g	1.72a-e	1.707a-f	13.58b-g	126.1a-f	4.80a-f
19	17.30g-l	1.86a-e	1.636a-f	13.56b-g	108.8b-g	4.83a-f
20	20.85d-j	1.82a-e	1.621a-f	12.67d-g	104.5b-g	5.00a-e
21	17.45g-k	1.97a-e	1.728a-f	11.97d-g	108.5b-g	5.10a-d
22	16.70g-l	2.14a-e	2.017a-e	12.22d-g	135.8a-f	4.96a-e
23	23.43b-g	1.92a-e	1.867a-f	13.58b-g	128.4a-f	5.00a-e
24	28.20bc	2.21a-c	2.555a	19.78a	186.4a	4.70a-f
25	16.50g-l	1.82a-e	1.756a-f	12.39d-g	106.1b-g	5.00a-e
26	16.00h-l	1.62c-e	1.319c-f	13.26c-g	109.4b-g	4.76a-f
27	14.73j-l	1.84a-e	1.691a-f	12.85d-g	123.7a-f	4.66b-f
28	19.57e-j	1.56de	1.150d-f	11.28d-g	83.34d-g	4.86a-f
29	22.37c-i	2.29a	2.297a-c	16.80a-d	150.8a-e	4.93a-f
30	10.50l	1.51e	1.840a-f	14.30a-f	137.7a-f	4.56d-f
31	22.27c-i	1.93a-e	1.691a-f	15.37a-f	126.9a-f	5.03a-e
32	12.20kl	1.92a-e	1.647a-f	12.78d-g	112.1b-g	5.00a-e
33	25.37b-f	1.60c-e	1.411b-f	12.75d-g	98.81c-g	5.03a-e
34	18.50f-k	2.00a-e	2.198a-d	13.73b-g	143.9a-f	5.23a
35	25.80b-e	1.58c-e	1.314c-f	12.60d-g	96.31c-g	4.86a-f
36	17.47g-k	2.02a-e	1.481b-f	13.19d-g	103.3c-g	5.03a-e
37	18.70f-k	2.08a-e	2.127a-e	16.44a-e	136.7a-f	5.16a-c
38	17.50g-k	1.94a-e	1.741a-f	13.68b-g	120.5a-f	4.70a-f
39	19.78e-j	2.06a-e	1.944a-e	15.46a-f	145.8a-f	4.83a-f
40	19.10e-k	1.87a-e	1.853a-f	14.50a-f	125.6a-f	5.00a-e
41	23.25b-g	2.16a-d	2.317a-c	14.45a-f	147.2a-f	4.63c-f
42	21.12d-j	1.97a-e	0.860f	8.02g	45.13g	3.83g
43	22.90c-h	1.86a-e	1.535a-f	14.36a-f	116.6a-f	4.40f
44	16.53g-l	1.95a-e	1.898a-f	13.11d-g	125.8a-f	5.03a-e
45	20.17e-j	1.73a-e	2.205a-d	16.35a-e	158.2a-c	4.80a-f
46	27.50b-d	2.25ab	2.338a-c	15.49a-f	152.6a-d	5.10a-d
47	14.58j-l	2.17a-d	1.988a-e	14.12a-f	128.5a-f	5.20ab
48	35.67a	1.75a-e	1.869a-f	13.70b-g	124.9a-f	4.96a-e
49	15.37i-l	2.06a-e	1.783a-f	19.09a-c	137a-f	4.53ef
LSD 5%	5.63	0.49	0.85	4.72	57.20	0.43

Different letters in each column indicate significant differences among means at probability level of %5.

The results of the correlation coefficient among the studied traits are shown in Table 4. All the agronomic characters measured correlated positively with together. The strongest relationship between the studies parameters was recorded between biological yield and seeds per plant (r=0.944**). Based on simple correlation coefficient analysis, screening for high biological yield per plant, seeds number per main cycle and stem diameter may be useful to achieving high seeds per plant (Table 4). Sinclair and Jamieson (2006) reported that seed per plant is the main seed yield component in most plants. Muhamman *et al.* (2010), Tamina and Tapash (2011), and Haruna *et al.* (2012) who each reported significant and positive correlations between growth characters and final seeds per plant and seed yield.

Table 4. Correlation coefficients of studied traits for *Lallemantia iberica* ecotypes.

	Chlorophyll content index	Stem diameter	Biological yield per plant	Seeds number per main cycle	Seeds per plant	1000 seeds weight
Chlorophyll content index	1					
Stem diameter	0.020	1				
Biological yield per plant	0.181	0.686**	1			
Seeds number per main cycle	0.209	0.537**	0.762**	1		
Seeds per plant	0.147	0.610**	0.944**	0.878**	1	
1000 seeds weight	0.029	0.106	0.329*	0.093	0.237	1

*,** Significant at p≤0.05 and p≤0.01, respectively.

The residual effect of path coefficient for biological yield per plant trait was 0.25. The direct effect of the seeds per plant on biological yield had the highest value (1.042). Direct effect of stem diameter, 1000 seeds weight and chlorophyll content index on biological yield were positive. Only the seeds number per main cycle had a negative direct effect on biological yield. Seeds number per main cycle had the highest indirect effect on biological yield and in particular, via the seeds per plant (0.915) (Table 5, Fig. 1). Johnson *et al.* (1994) pointed out that understanding the relationships between agronomic traits may assist breeding programs. Assessment of relationship using correlation coefficient analyses help breeders to distinguish significant relation between traits. Step-wise regression can reduce effect of non-important traits in regression model, in this way traits accounted for considerable variations of dependent variable are determined (Agrama, 1996).

Bidgoli *et al.* (2006) who indicated strong direct effects of biomass, seed weight per head and 1000 seed weight and negative direct effect of the head diameter on the seed yield. Ahmadzadeh *et al.* (2012) found positive direct effects of 1000 seed weight on the seed yield. Golparvar (2011) and Behnam *et al.* (2011) reported also positive direct effects of 1000 seed weight on the seed yield. Many of researchers indicated positive direct effects of seeds per head on the seed yield. These differences may be because of the various ecological conditions and genotypes (Behnam *et al.*, 2011; Ahmadzadeh *et al.*, 2012).

Table 5. Direct and indirect effects on biological yield via studied traits in *Lallemantia* ecotypes.

Characters	Direct[a] Effect	Indirect effect via					Total correlation with biological yield
		Seeds per plant	Seeds number per main cycle	Stem diameter	1000 seeds weight	Chlorophyll content index	
Seeds per plant	1.042	-	-0.246	0.116	0.020	0.012	0.944
Seeds number per main cycle	-0.280	0.915	-	0.102	0.0079	0.017	0.762
Stem diameter	0.190	0.635	-0.150	-	0.0091	0.0016	0.686
1000 seeds weight	0.086	0.247	-0.026	0.020	-	0.0023	0.329
Chlorophyll content index	0.080	0.154	-0.058	0.0038	0.0024	-	0.181

[a]: residual effect = 0.25.

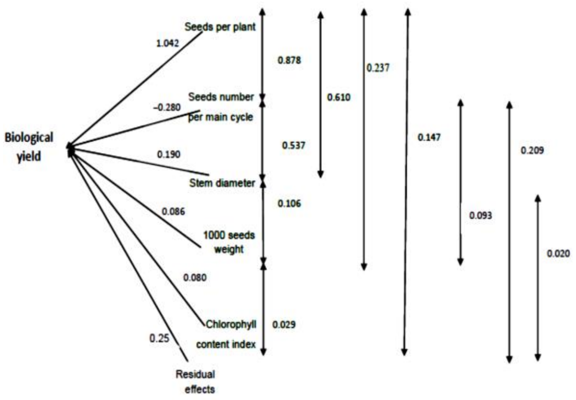

Fig. 1. Path analysis diagram of biological yield per plant and related traits in *Lallemantia* ecotypes.

The path coefficient analysis provides information on internal relation among the investigated characteristics, as well as their effect on certain trait.

The path coefficient is a standardized partial regression coefficient that measures the direct influence of one trait upon another and permits the separation of a correlation coefficient into components of direct and indirect effects (Board *et al.*, 1997). The traits influencing biological yield may directly or indirectly affect each other and for the purpose of breeding programs, they should be subject to separate analysis.

Grouping and classifying different *Lallemantia iberica* ecotypes was performed using study traits based on Ward's method by cluster analysis.

The results of analysis (Fig. 2) showed that 49 *Lallemantia* ecotypes were grouped in two clusters. To determination of cutting point of dendrogram, discriminant analysis was performed (Table 6).

Deviation from the total mean for different traits showed that the group two ecotypes (1, 5, 43, 15, 38, 27, 16, 30, 45, 49, 7, 25, 20, 8, 40, 19, 18, 23, 31, 13, 44, 14, 32, 21, 36, 22, 34, 47, 37, 6, 24, 29, 46, 39, 41) had the highest mean values for stem.

diameter, biological yield per plant, seeds number per main cycle, seeds per plant and 1000 seeds weight (Fig. 2, Table 7). These ecotypes can be used in breeding programs to increase yield and yield components. But, in chlorophyll content index, the group one ecotypes (2, 33, 35, 11, 9, 48, 3, 26, 4, 10, 28, 12, 17, 42) had the highest mean values for this trait (Fig. 2, Table 7).

The observed differences are partly due to environmental variation which exists even in a single region (Weiss, 1983).

Table 6. Discriminant analysis for determination of cutting point of dendrogram.

NO. Groups	Wilks, lambda	Chi-square	Significance
2	0.286	55.037	4.55×10^{-10}
3	0.672	17.282	0.0039
4	0.695	15.653	0.0035
5	0.702	15.017	0.0018

Table 7. Deviation (%) from the total mean for different traits.

Group		Chlorophyll content index	Stem diameter	Biological yield per plant	Seeds number per main cycle	Seeds per plant	1000 seeds weight
I: "2, 33, 35, 11, 9, 48, 3, 26, 4, 10, 28, 12, 17, 42" ecotypes	Mean	22.24	1.69	1.33	11.81	92.28	4.77
	Deviation from the total mean (%)	12.51	-9.90	-23.00	-13.50	-22.58	-1/29
II: "1, 5, 43, 15, 38, 27, 16, 30, 45, 49, 7, 25, 20, 8, 40, 19, 18, 23, 31, 13, 44, 14, 32, 21, 36, 22, 34, 47, 37, 6, 24, 29, 46, 39, 41" ecotypes	Mean	18.77	1.95	1.88	14.39	129.98	4.86
	Deviation from the total mean (%)	-5.00	3.96	9.20	5.40	9.03	0.51
	Total mean	19.76	1.88	1.723	13.65	119.20	4.83

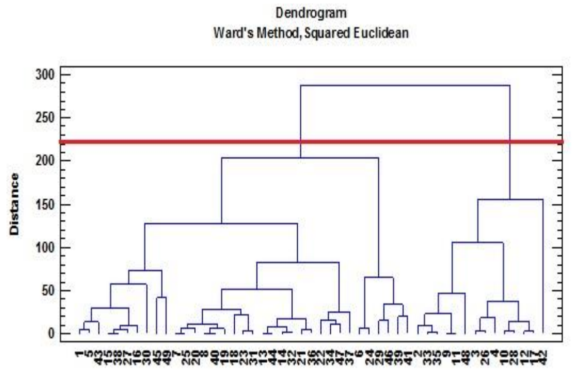

Fig. 2. Dendrogram among 49 common ecotypes of *Lallemantia* using Ward's method and squared Euclidean distance.

Conclusions

In the present study, the *Lallemantia iberica* ecotypes differed significantly in their study traits. Therefore, we may consider them as different ecotypes of *Lallemantia iberica*. This holds particularly true for the ecotypes 1, 5, 43, 15, 38, 27, 16, 30, 45, 49, 7, 25, 20, 8, 40, 19, 18, 23, 31, 13, 44, 14, 32, 21, 36, 22, 34, 47, 37, 6, 24, 29, 46, 39 and 41 which had significantly highest means for stem diameter, biological yield per plant, seeds number per main cycle, seeds per plant and 1000 seeds weight, as compared to the other studied ecotypes.

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