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Phenetic Study of Flower Diversity in *Tulipa montana* Lindl. *(Liliaceae)* Populations in Iran

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Abstract

Phenetic analyses were performed on morphological characteristics of 53 populations belonging to two varieties of *Tulipa montana* Lindl. var. *montana* with red flowers and *T.montana* var. *chrysantha* (Boiss.) Wendelbo with yellow flowers. The populations with orange flowers were encountered distributed among the two varieties with red and yellow flowers respectively. Multivariate statistical analysis revealed the possibility of a hybrid origin for the orange populations.

Keywords: Flower diversity, cluster analysis, hybrid, *Tulipa*.

بررسی فنتیکی تنوع گل در جمعیت‌های *Tulipa montana* Lindl. در ایران

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چکیده

بررسی فنتیکی تعداد ۵۳ جمعیت متعلق به دو واریته *Tulipa montana* با نام‌های *T. montana var. montana* و *T. montana var. chrysantha* با استفاده از خصوصیات ریختی انجام گرفت. این دو واریته به‌ترتیب دارای گل‌های قرمز و زرد می‌باشند که در کنار جمعیت‌هایی با گل نارنجی پراکندگی دارند. رسته‌بندی بر اساس تجزیه به مولفه‌های اصلی و تجزیه خوشه‌ای جمعیت‌های متعلق به دو واریته را کاملاً از هم جدا نمود که بیانگر متمایز بودن آن دو است. به‌علاوه جمعیت‌هایی که دارای گل نارنجی بودند در گروهی جدا از دو واریته اما کمی نزدیک‌تر به واریته *T. montana var. montana* قرار دارد که نشان‌دهنده طبیعت هیبرید این جمعیت‌ها است.

کلیدواژه‌ها: تنوع گل‌ها، تجزیه خوشه‌ای، دورگه، لاله.

Introduction

Tulips (*Tulipa* L.) are among the main plants widely used as ornamentals. They originated in Eastern countries and were introduced into Europe via Iran and Turkey (Wendelbo, 1977; Matin, 1998). The number of *Tulipa* species occurring in Iran varies from seven to 23 according to different authors' estimations.

Although tulips have been studied extensively throughout the world, no report is available on the biosystematics of *Tulipa* from Iran. The present paper is a part of biosystematic study of *Tulipa* in Iran reporting phenetic analyses of *T.montana* Lindl. populations. The two varieties of this species, *T.montana* var. *montana* and *T.montana* var. *chrysantha* (Boiss.) Wendelbo, differ in flower color along with other morphological characteristics. The first variety possesses red flower while yellow flower occurs on the other. Populations with orange flowers were encountered distributed among the two varieties. The present study considers phenetic analyses of *T.montana* populations in order to reveal any possibility of the hybrid nature of populations with orange flowers as suggested by Rechinger (1990) and Matin (1998).

Materials and Methods

Plant material

53 populations of *T.montana* including the two varieties and populations with orange flowers were studied. Details of the localities and the voucher numbers are presented in Table 1. At least five plants were studied for morphometric analyses. Voucher specimens are deposited at Tari, Iran and the Herbarium of Shahid Beheshti University (HSBU).

Morphometry

In total, 53 quantitative and qualitative morphological characteristics were studied (Table 2). Characteristics were selected based on those reported by Van Raamsdonk and Virise (1995) and our own field characteristics were used while qualitative characteristics were coded as binary/ multistate characteristics. Variables were standardized (mean=0, variance=1) for multivariate statistical analyses (Sheidai *et al*, 2002).

In order to group the populations with morphological similarities, cluster analysis using UPGMA (unweighted paired group with arithmetic mean) and WARD (minimum variance spherical clusters) (Ingrouille, 1986) as well as ordination based on principal component analysis (PCA) were performed (Sheidai *et al*, 2002).The squared Euclidean distance was used as a dissimilarity coefficient in cluster analysis of the morphological data.

In order to determine the most variable morphological characteristics among the populations, factor analysis based on principal components analysis (PCA) was performed. SPSS version 8.5 (1998) was used for conducting multivariate statistical analyses.

Results and Discussion

Geographical distribution of *T.montana* populations studied is presented in Figure 1. The two varieties are grown in North and West of Iran, and in some places one or both varieties are seen together with orange flower populations (Figure 2).

Ordination plot based on PCA analysis of 53 *T.montana* populations are presented in Figure 3. Populations of *T.montana* formed three groups. *T.montana* var. *montana* (red flower) and *T.montana* var. *chrysantha* (yellow flower) formed two distinct groups, which the populations with orange flowers are placed between them. This reveals the possibility of hybrid origin for the orange flowering populations (Figure 3) as also suggested by Rechinger mentioned in his classical taxonomic studies (1990). These populations are arranged more closely to *T.montana* var. *montana* supporting Matin studies (1998).

Cluster analysis of morphological data also supported the result of ordination (Figure 4).

among the populations with red, yellow, and orange flowers; factor analysis based on PCA was performed. The first seven factors comprise 74% of total variance. The characteristics of color of outer/inner tepals on both the abaxial and adaxial sides, length of inner

Table 1: The lacality, Collector Herbarium and Voucher number of T. montana populations studied.

Variety / Flower color	Population code No.	Locality	Voucher, Collector and Herbarium
T.montana var chrysanta / yellow flowers (denoted C)	1	Between Semnan and Firuzkooh	Moosavi & Tehrani 12907-IRAN, Wendelbo & Asadi 29756-TARI
	2	Semnan	Matin, Daneshpajooh, Ghanbary 12906-IRAN
	3	Damghan	Iranshahr 12920-IRAN
	4	Ghazvin, Karaj, Khor	Moosavi & Tehrani 12916-IRAN
	5	Tehran, Fasham	Mostafavi 12925-IRAN, Matin & Termeh 12918-IRAN, Javadi 12909-IRAN
	6	Tehran, Shemshak	Asadi & Shahsavari 69720-TARI, Barkhordari 12917-IRAN
	7	Firuzkooh	Termeh et al 12911-IRAN
	8	Tehran, Karaj	Babackkhanlo & Amin 14369-TARI, Ronmark et al 25445-TARI, Zojajifar 99123-HSBU, Asadi & Mozafarian 32836-TARI, Matin & Termeh 12919-IRAN, Asadi et al. 33364-TARI, Asadi 27538-TARI
	9	Golestan forest	Matin & Termeh 12908-IRAN, Iranshahr 12921-IRAN, Daneshpajooh 12912-IRAN
	10	Tehran, Dizin	Ridel & Gibi 12913-IRAN
	11	Karaj, Ghazvin, Afje	Matin & Termeh 12914-IRAN
	12	Tehran, Kooh'e Narun	Matin & Termeh 12915-IRAN
	13	Shahpasand, Shahrood	Iranshahr 12931-IRAN
	14	Tehran, Tochal	Rahimsalehi 12927-IRAN, Rahimsalehi 12928-IRAN, Zojajifar 99121-HSBU, Zojajifar 99122-HSBU, Zojajifar 99114-HSBU
	15	Tehran, Ab'ali	Iranshahr & Ridel 12922-IRAN
	16	Damavand	Eshghi 12934-IRAN
	17	Pol'e Zangoleh	Gheisari 4447-TARI
	18	Tehran	Matin & Zargani 12924-IRAN, Matin & Zargani 12923-IRAN, Vaezi 12930-IRAN, Asadi & Shahsavari 69704-TARI, Sanei 11244-TARI, Wendelbo et al. 11759-TARI, Khanafshar 99104-HSBU, Zargani 12932-IRAN, Termeh 12926-IRAN
	19	Tehran, Khomein	Wendelbo & Asadi 16376-TARI
	20	Semnan, Aabrkooh	Wendelbo et al. 11186-TARI

Variety / Flower color	Population code No.	Locality	Voucher, Collector and Herbarium
	21	Tehran, Rineh	Khanafshar 99110-HSBU
	22	Kashan	Rafiipoor 99124-HSBU
	23	Tehran, Jajrud	Khanafshar 99109-HSBU
T.montana var montana / red flowers (denoted M)	24	KARAJ	Matin & Abbasi 14246-IRAN
	25	Tehran, Haraz road, Emamzadeh Hashem	Khanafshar 99105-HSBU, Matin & Termeh 12939-IRAN, Khanafshar 99106-HSBU, Daneshpajooh 12943-IRAN
	26	Tehran, Lavasanat'E Bozorg	Javadi 12940-IRAN
	27	Firuzkooh	Moosavi & Tehrani 12938-IRAN
	28	Tehran, Fasham	Moosavi 22951-IRAN, Termeh & Matin 12948-IRAN
	29	Tehran, Narun	Matin & Zargani 12950-IRAN, Matin & Termeh 12944-IRAN, Zojajifar 99118-HSBU
	30	Tehran, Polur-Lar	Matin & Termeh 12946-IRAN
	31	Damavand	Matin & Termeh 12947-IRAN
	32	Tehran, Ab'ali	Khanafshar 99108-HSBU, Iranshahr & Ridel 12949-IRAN
	33	Tehran	Vaeezi 12953-IRAN
	34	Tehran, Atashgah	Iranshahr 12952-IRAN
	35	Tehran, Atashkooh	Iranshahr 12954-IRAN
	36	Hamedan	Babai 12956-IRAN
	37	Alvandkooh	Babai 12957-IRAN
	38	Tehran, Rineh	Khanafshar 99111-HSBU
	39	Tehran, Tochal	Zojajifar 99117-HSBU
	40	Tehran, Koshk	Zojajifar 99110-HSBU
	41	Golestan forest	Khanafshar 99102-HSBU
	42	Golestan forest	Khanafshar 99103-HSBU
T.montana / Orange flowers (denoted O)	43	Tehran, Ab'ali	Khanafshar 99107-HSBU
	44	Damavand	Termeh & Matin 12947-IRAN
	45	Tehran	Termeh & Matin 12945-IRAN, Vaezi 12953-IRAN,Termeh 12926-IRAN
	46	Tehran, Fasham	Javadi 12941-IRAN, Moosavi & Karavar 12942-IRAN
	47	Tehran, Lavasanat'e Bozorg	Javadi 12940-IRAN
	48	Tehran, Haraz road, Emamzadeh Hashem	Khanafshar 99105-HSBU, Daneshpajooh 12943-IRAN
	49	Alvandkooh	Bahar 12957-IRAN
	50	Tehran, Koshk	Zojajifar 99119-HSBU
	51	Tehran, Narun	Matin & Termeh 12944-IRAN
	52	Tehran, Rineh	Khanafshar 99112-HSBU
	53	Between Semnan & Firouzkooh	Moosavi & Tehrani 12938-IRAN, Wendelbo & Asadi 29756-TARI

Table 2: Morphological characters studied in Tulipa montana populations and their coding.

	Character	Status	Code
1	Stem length	Cm	Cm
2	Stem pubescent	(y/n)	0-1
3	Number of leaves		N
4	Length of lowest leaf	Cm	Cm
5	Length of second lowest leaf	Cm	Cm
6	Width of lowest leaf	Cm	Cm
7	Width of second lowest leaf	Cm	Cm
8	leaf with deviating margin color	(y/n)	0-1
9	Leaf margin color	1-like blade 2-red 3-white	1-3
10	Leaf pubescent	(y/n)	0-1
11	Leaf margin ciliate	(y/n)	0-1
12	Lowest leaf form	1-crisp 2-falcate 3-straight	1-3
13	Second Lowest leaf form	1-crisp 2-falcate 3-straight	1-3
14	Uppermost leaf form	1-crisp 2-falcate 3-straight	1-3
15	Lowest leaf undulation	(y/n)	0-1
16	Second Lowest leaf undulation	(y/n)	0-1
17	Color of outer tepal at abaxial side	1-red 2-yellow 3-orange 4-white 5-purple 6-pink 7-silvery 8-coppery/ violet	1-8
18	Color of outer tepal at adaxial side	1-red 2-yellow 3-orange 4-white 5-purple 6-pink 7-silvery 8-coppery/violet	1-8
19	Tepal with deviating margin color	(y/n)	0-1
20	Color of inner tepal at abaxial side	1-red 2-yellow 3-orange 4-white 5-purple 6-pink 7-silvery 8-coppery/violet	1-8
21	Color of inner tepal at adaxial side	1-red 2-yellow 3-orange 4-white 5-purple 6-pink 7-silvery 8-coppery/ violet	1-8
22	Length of outer tepal	Cm	Cm
23	Width of outer tepal	Cm	Cm
24	Length of inner tepal	Cm	Cm
25	Width of inner tepal	Cm	Cm
26	Outer tepal blotch	1-absent 2-black/ dark purple 3-purple 4-brown/violet 5-yellow	1-5

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	Character	Status	Code
27	Inner tepal blotch	1-absent 2-black/ dark purple 3-purple 4-brown/ violet 5-yellow	1-5
28	Tip of outer tepal pubescent	(y/n)	0-1
29	Margin of outer tepal pubescent	(y/n)	0-1
30	Midrib of outer tepal pubescent	(y/n)	0-1
31	Tip of inner tepal pubescent	(y/n)	0-1
32	Margin of inner tepal pubescent	(y/n)	0-1
33	Midrib of inner tepal pubescent	(y/n)	0-1
34	Occurrence of yellow/white margin around blotch	(y/n)	0-1
35	Tip of outer tepal form	1-acuminate	1-3
		2-mucronate	
		3-obtuse	
36	Filament length	Cm	Cm
37	Anther length	Cm	Cm
38	Anther color	1-yellow 2-violet	1-3
		3-green/ purple	
39	Pollen color	1-yellow 2- violet/ purple 3-green	1-3
40	Filament color contrasting with flower color	0-similar 1-deviating	0-1
41	Ovary length	Cm	Cm
42	Stigma color	1-yellow 2- brown	1-2
43	Width of bulb	Cm	Cm
44	Tunic type	1-coriaceous 2-papery 3-sub-coriaceous	1-3
45	Color of bulb tunic	1-brown 2-dark brown	1-2
46	Occurrence of hairs at upper part of bulb tunic	(y/n)	0-1
47	Occurrence of hairs at middle part of bulb tunic	(y/n)	0-1
48	Occurrence of hairs at base of bulb tunic	(y/n)	0-1
49	Bulb tufted at top	(y/n)	0-1
50	Type/form of tunic hairs	1-tometose 2-sericeous at tunic base and strigose at summit 3-short hair 4-long hair	1-4
51	Occurrence of carpophore at the base of capsule	(y/n)	0-1
52	Capsule length	Cm	Cm
53	Capsule width	Cm	Cm

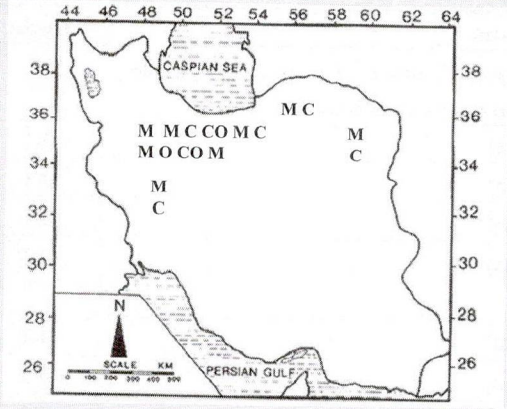

Figure 1. Geographical distribution of *Tulipa montana* varieties and populations.
Abbreviations: M = *T. montana var. montana,* C = *T. montana var. chrysantha,* O = populations having orange flowers.

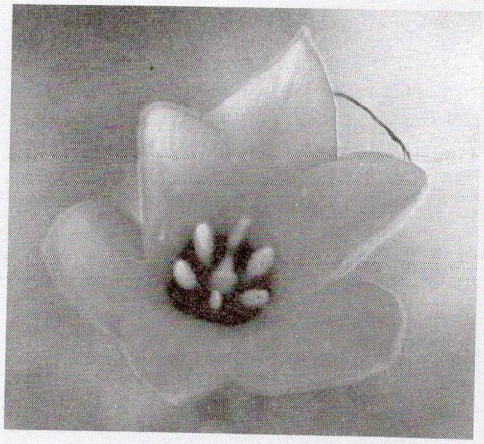

Figure 2. Flower color in diffrent populations of *Tulipa montana.* From top to bottom: *T. montana var. montana, T. montana var. chrysantha,* potential hybrid population with orange flowers.

tepals, color of outer/inner tepals blotch, and contrasting filament color with flower color possessed the highest correlation (>0.7) in the first factor, while stem length, length of outer/inner tepals, width of inner tepals possessed the highest correlation (>0.6) in the second factor. Therefore these morphological characteristics are the most variable characteristics among the different populations studied.

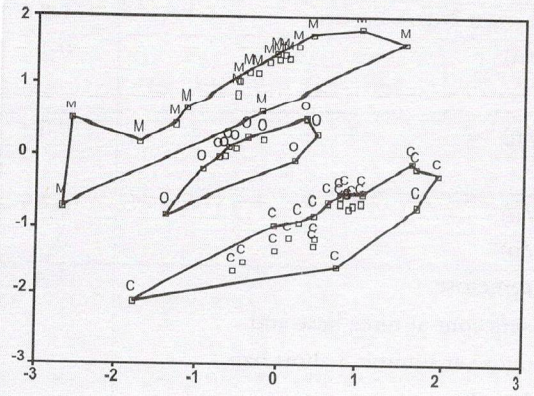

Figure 3. PCA ordination of *Tulipa montana* populations based on morphological characteristics. M = *T. montana var. montana,* C = *T. montana var. chrysantha,* O = Populations with orange flowers.

As the most distinguished characteristics dividing these three groups are related to tepal colors, multivariate analyses were performed on characteristics excluding the flower colors in order to determining the effect of remaining characteristics in similarity/dissimilarity of these three groups. Figure 5 shows an ordination plot based on PCA analysis. Again, populations of *T.montana* formed three groups of plants with red, yellow and orange flowers. Factor analysis of the morphological characteristics except those related to tepal color, shows that the first seven factors comprise about 71% of total variance. The characteristics of length and width of the lowest and second lowest leaves, length and width of tepal, ovary and anther length possessed the highest correlation (>0.6) in the first factor while in the second factor characteristics like the lowest leaf form, outer and inner tepal blotch color, and contrasting of filament color with flower color possess the highest correlation (>0.60).

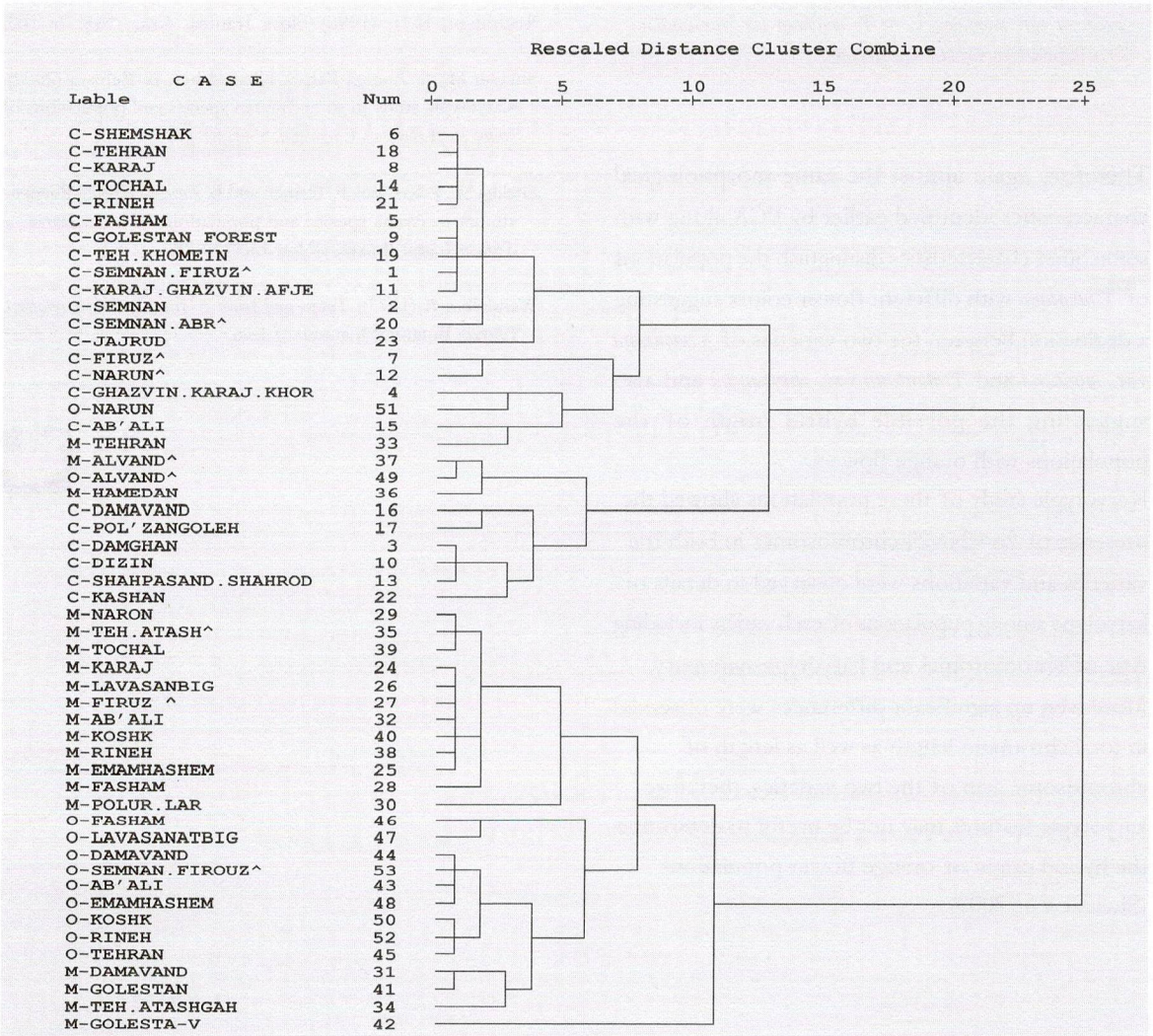

Figure 4. WARD cluster analysis of *Tulipa montanum* populations based on morphological characters. M = *T. montana var. montana,* C = *T. montana var. chrysantha,* O = Populations having orange flowers. (Populations code No. as in Table 1).

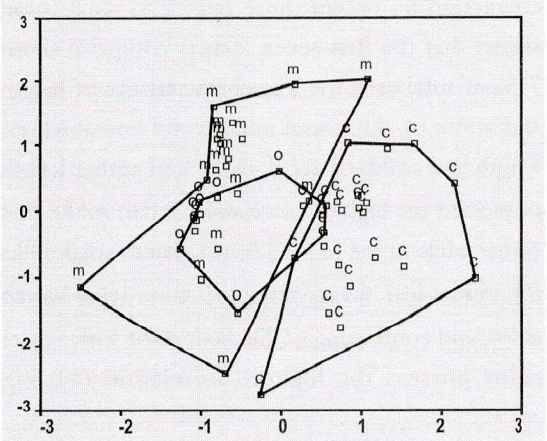

Figure 5. PCA ordination of *Tulipa montana* populations based on morphological characteristics except tepal color. M = *T. montana var. montana,* C = *T. montana var. chrysantha,* O = Populations with orange flowers.

Therefore again almost the same morphological characteristics identified earlier by PCA along with some other characteristics distinguish the populations of *T.montana* with different flower colors suggesting a distinction between the two varieties of *T.montana* var. *montana* and *T.montana* var. *chrysantha* and also suggesting the possible hybrid origin of the populations with orange flowers.

Karyotypic study of these populations showed the presence of 2n=2x=24 chromosomes in both the varieties and variations were observed in details of karyotype among populations of each variety including type of chromosomes and karyotype symmetry. Moreover, no significant differences were observed in total chromatin length as well as length of chromosome arm of the two varieties, therefore karyotypic features may not be useful to determine the hybrid origin of orange flower populations (Sheidai *et al*, 2002).

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