Linzer biol. Beitr.	38/1	165-187	21.7.2006

Crocus biflorus (Liliiflorae, Iridaceae) in Anatolia (Part Three)

H. KERNDORFF & E. PASCHE

A b s t r a c t : Results of field studies of 15 populations belonging to *Crocus biflorus* sensu lato are presented from Caria and Pisidia as well as of additional populations in adjacent parts of Anatolia for comparative purposes. The evaluation considers all south-west Anatolian populations (including the 16 ones of part two from the Lycian and Pisidian Taurus) and the 14 ones for comparative purposes under morphological, statistical, taxonomical, geographical, and phytogeographical aspects. New and unexpected facts were revealed concerning the relationship and distribution of *C. biflorus* taxa in this area of which two new taxa are described for.

K e y w o r d s : *Crocus biflorus*, south-west Anatolia, field studies, morphology, phytogeography, new subspecies *yataganensis* and *caelestis*.

Introduction

In part two of our article on *Crocus biflorus* in Anatolia (KERNDORFF & PASCHE 2003) we have presented results of detailed field studies from individual mountains or ranges in the Lycian and Pisidian Taurus including new results on the occurrence and distribution pattern of *C. biflorus* in these areas. On mountains not known before we discovered many *C. biflorus* populations, belonging to previously known or newly described taxa, or sometimes difficult or even impossible to classify upon the information available (KERNDORFF & PASCHE 2004b). In the course of our investigation, we also visited mountains of Caria and Pisidia (Fig. 1) to complete our research in south-west Anatolia. Especially Pisidia is a large area and it took us three years to visit major mountain stocks and ranges to get an overview on the distribution of *C. biflorus* in both areas, results of which are reported in this article. It seems that south-west Anatolia is the current centre of *C. biflorus* sensu lato. This is supported by all the latest findings and by the discovery of two more *C. biflorus* taxa by us in spring 2004. A description of these is given in this article.

In the meantime, a new crocus was described for south-west Anatolia as *Crocus nerimaniae* (YÜZBAŞIOĞLU & VAROL 2004). In 2003 we also found this taxon at several localities. It certainly belongs to the *C. biflorus* aggregate and will be considered here. As long as additional information e.g. on genetics is not available we agree with MATHEW (1982) and will treat *Crocus nerimaniae* as well as *Crocus wattiorum* as subspecies of *C. biflorus* (GÜNER et al. 2000). In the final part of our work (synopsis of *C.*

biflorus in Anatolia) we will look more precisely at the intraserial position of these latter taxa, not only on the basis of morphological, geographical, and phytogeographical, but also taking genetic parameters into account (especially DNA-fingerprints).

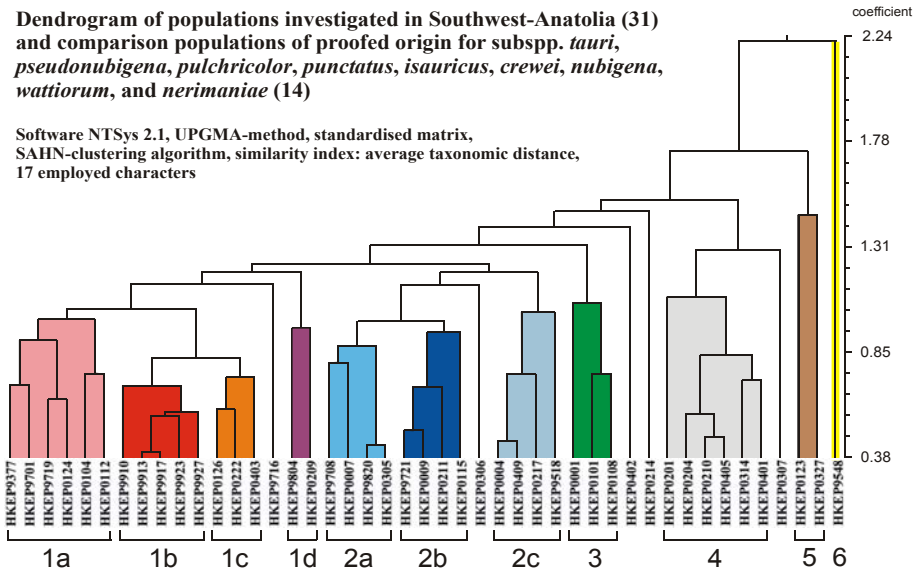
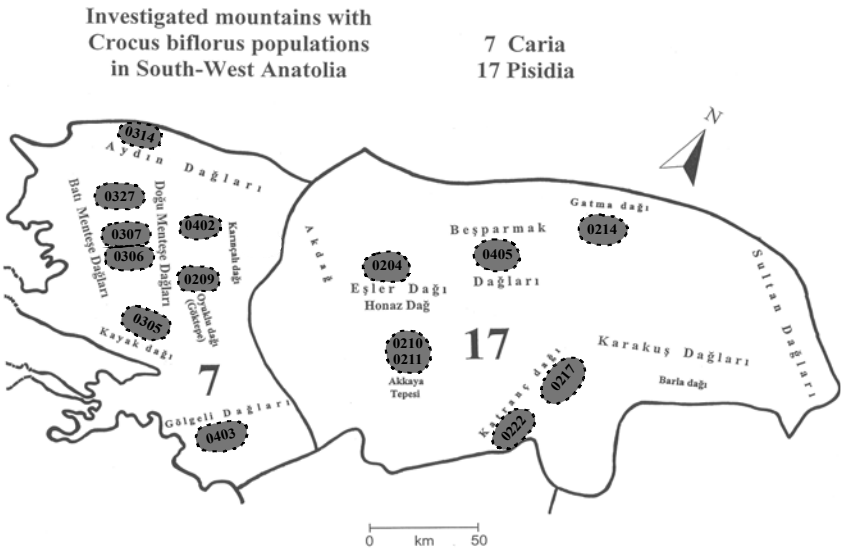


Fig. 1: Cluster analysis.

Climate and phytogeographical areas

From a climatic perspective Caria and Pisidia are quite different areas. Whereas Caria has mainly a typical Mediterranean climate especially near the coast and in the larger river basins, with much rain in winter but almost none in summer, most of Pisidia is characterized by the harsh climate of central Anatolia. The winters are much longer with more snow, increased cold, and drier air throughout the year. From a phytogeographical point of view, this area is more or less inhabited by Irano-Turanian (steppic) plant formations whereas Caria is predominated by East-Mediterranean elements (see Map 1 in KERNDORF & PASCHE 2004b). In the Lycian Taurus members of the Irano-Turanian area often penetrate into the coastal mountain stocks, creating numerous complex transition areas of both phytogeographical regions. By contrast, in both Caria and Pisidia the borders of the phytogeographical zones are relatively sharp as we could observe by a more or less distinct change of floristic elements on several mountains. Furthermore, the Mediterranean area in Caria seems to be smaller compared to the one suggested by DAVIS (1971).



Map 1: Investigated area.

Investigated *Crocus biflorus* populations on individual mountain stocks

The mountains of Caria and Pisidia belong to very different geological formations and have specific histories. In general, rather complex structures exist, predominantly consisting of magmatites and metamorphic rocks with silica based soils but less frequently of calcareous formations like those of the Taurus range. Botanically, silica based soils often imply a somewhat "reduced" flora. This, however, is generally not observed in the Carian and Pisidian mountains. Particularly Caria has a rich mountain flora, which obviously was rather neglected by former botanists. From our point of view this certainly applies to *C. biflorus*. In Map 1 the visited mountains of Caria and Pisidia are presented. On all mountains *C. biflorus* populations could be found to the exception of the Akdağ range west of Denizli and of several high mountain ranges bordering the central Anatolian highland, e.g., Barla dağ, Sultan dağları, Karakuş dağları, and Kumalar dağı.

In general, *C. biflorus* populations of the Mediterranean belt were found between 800 and 1200 m, and those of the Irano-Turanian region mostly between 1400 and 2000 m. Several of the investigated populations belong to new taxa that have been described by us meanwhile (KERNDORFF & PASCHE 2003 and 2004a) or that are described in this paper, while others seem to be transitional forms between known taxa or known and newly described taxa but which are impossible to classify at the moment. Three populations were suggested to be connected with subsp. *pulchricolor* (HERBERT) B. MATHEW so it was necessary to include at least one population of this taxon of proofed origin in our field studies. In 2004 we investigated a large population of subsp. *pulchricolor* in the Bolu region found by us in 1995 (HKEP 9518 in Table 1 and Colour Plates) which is

quite suitable for this purpose. Some other populations were found (slightly) outside the borders of areas 7 and 17 but it is useful to include them into our investigation for comparative purposes (Table 1). All populations can be compared with at least one defined population of proven origin from our investigations of the Lycian and Pisidian Taurus as well as the Antitaurus and Mesopotamia. In addition, populations of two known autumn-flowering members of the *C. biflorus* aggregate in south-west Anatolia are taken into consideration (HKEP 9548 & HKEP 0327 in Table 1 and Colour Plates). In total, 45 populations were investigated, 31 of which are from south-west Anatolia, and 15 from Caria and Pisidia (Map 1). The major aim of the present paper is to provide a synoptic evaluation of their morphological similarity and geographical distribution.

Table 1: Investigated Crocus biflorus populations of Caria, Pisidia, and other regions for comparative purposes.

population identity (HKEP)[1]	area[2]	mountain(s) or area	altitude (m) (range)	date of field studies	specimens investigated (n)	presumed taxon at field-studies
9518	02 BITHYNIA	Bolu (surroundings)	1400-1800	12.03.2004	33	ssp. *pulchricolor*
9548	08 LYCIAN T.	Tahtalı dağları	500-600	24.10.2003	39	ssp. *wattiorum*
201	06 LYDIA	Bozdağlar	800-900	12.03.2002	28	aff. ssp. *crewei*
204	17 PISIDIA	Honaz dağ	1200-2000	15.03.2002	35	ssp. *crewei*
209	07 CARIA	Oyuklu dağı (Göktepe)	1500-1800	17.03.2002	34	aff. ssp. *nubigena*
210	17 PISIDIA	Akkaya Tepesi	1600-1700	19.03.2002	10	ssp. *crewei*
211	17 PISIDIA	Akkaya Tepesi	1600-1700	19.03.2002	31	aff. ssp. *isauricus*
214	17 PISIDIA	Gatma dağı	1700-1900	11.03.2002	34	ssp. (new) *leucostylosus*
217	17 PISIDIA	Katranç dağı	1200-1600	13.03.2002	40	ssp. *punctatus*
222	17 PISIDIA	Katranç dağı	1600-1700	16.03.2002	33	aff. ssp. *isauricus*
305	07 CARIA	Kayak dağları	1000-1100	20.03.2003	23	aff. ssp. *nubigena*
306	07 CARIA	Batı Menteşe dağları	900-1000	15.03.2003	32	ssp. (new) *ionopharynx*
307	07 CARIA	Batı Menteşe dağları	800-900	15.03.2003	28	ssp. (new) *caricus*
314	07 CARIA	Aydın dağları	900-1000	14.03.2003	38	aff. ssp. *crewei*
327	07 CARIA	Batı Menteşe dağları	900-1000	25.10.2003	18	undefined (new)[3]
401	06 LYDIA	Bozdağlar	800-1000	20.03.2004	29	aff. ssp. *crewei*
402	07 CARIA	Doğu Menteşe dağları	1000-1200	18.03.2004	32	undefined (new)[4]
403	07 CARIA	Gölgeli dağları	1300-1600	16.03.2004	33	aff. ssp. *atrospermus*
405	17 PISIDIA	Beşparmak dağı	1400-1600	14.03.2004	32	aff. ssp. *crewei*
409	16 PHRYGIA	Uşak (surroundings)	1200-1400	13.03.2004	33	undefined (new)[4]

[1] investigator H. KERNDORFF & E. PASCHE
[2] according to DAVIS (1965)
[3] described in the meantime as *C. nerimaniae* by YÜZBASIOGLU & VAROL 2004
[4] described in this paper

Field studies

For our field studies of the Carian and Pisidian populations of *C. biflorus* as well as those from adjacent areas for comparative purposes the same characters / parameters were considered as described previously (KERNDORFF & PASCHE 2003). Due to the hysteranthous leaves of the two autumn-flowering taxa we had to visit their localities once more in spring to measure the leaf parameters. Again, we photographed a large number of flowering specimens to document the variability of colouring and feathering of the inner / outer segments of each population. A selection is presented in photo-series including all investigated populations of Caria and Pisidia.

General observations on the regional distribution

Travelling widely in Caria and Pisidia between 2002 and 2004 we observed that some taxa of *C. biflorus* (e.g. subsp. *nubigena*) predominantly occur in the (oro-) Mediterranean region whereas subspp. *crewei* and *isauricus* and also *Crocus chrysanthus* are found frequently in the transitional areas and bordering mountains of central Anatolia, which belong to the Irano-Turanian region. For example, in the western Aydın dağları mainly *C. biflorus* can be found, but in the eastern part only *C. chrysanthus*. We mainly observed pure populations of *C. biflorus* or *C. chrysanthus* and only one mixed population of those taxa was observed among the eight localities visited across this mountain range. A very remarkable observation was made in the Doğu Menteşe Dağları where *C. biflorus* (HKEP 0402) occurs together with *C. chrysanthus*, though in strictly separated areas (allopatric populations). The separation of these two large populations was observed over hundreds of meters without a transition area which could easily be recognised because both populations were at anthesis. Apparently, no hybrids were present as deduced from checking several thousands of individuals (they were supposed to be similar to those of *C. chrysanthus* and *C. biflorus* ssp. *pulchricolor*). In the Doğu Menteşe dağları *C. biflorus* is growing on top of the saddle and in SW and W exposed localities whereas *C. chrysanthus* prefers N and E exposed slopes. Another interesting observation was made on Akkaya Tepesi where completely mixed populations of *C. biflorus* subsp. *crewei* and subsp. *isauricus* exist. Both were at their peak of flowering, without any hybrids visible (see Colour Plate, HKEP 0210 (3)). We wonder what mechanisms (reproductive isolation barriers) might be responsible for keeping both taxa separate.

Table 2a: Results of field studies for cataphylls / bract / bracteole and true leaves.

population	cataphylls/ bract/bracteole	true leaves					
(HKEP)	colour	range	mean	median	diameter (mm)	ribs underneath	white stripe[1]
9518	brownish/brown	3-6	4,09	4	0,7-1,5	0	<1/3
9548	silvery/white	3-5	4,08	4	1,5-2	(0) 1 (2)	1/3
0201	silvery/white	1-3	2,29	2	2,5-3	(2) 3	1/3
0204	silvery/white	2-3	2,23	2	2-(2,5)	38413	1/3
0209	silvery/white	3-8	4,71	5	1,5-2	(1) 2	1/3-(>1/3)
0210	silvery/white	2	2	2	2	3	1/3
0211	silvery/white	4-6	4,55	4	1-1,5	2	<1/3-1/3
0214	silvery/white/br.	3-6	4,91	5	0,5-1	0	1/4
0217	silvery/white	2-6	3,6	4	1-1,5	0 (1)	<1/3-1/3
0222	silvery/white	3-7	4,85	5	1,5-2	2	1/3
0305	silvery/brownish	3-7	4,91	5	1-1,5	(1) 2	1/3
0306	silvery/white	3-6	4,31	4	1-(1,5)	2	1/3 (>1/3)
0307	silvery/yellowish	2-7	4,5	4,5	1-1,5	(0) 1 (2)	1/3
0314	silvery to brownish	2-4	2,87	3	38413	(2) 3 (4)	1/3
0327	silv./yell./brownish	3-5	4,17	4	1-1,5	2	(<1/3) 1/3
0401	silvery/white	2-6	3,21	3	(2) 2,5-3,5	(3) 5-6	1/3
0402	silvery/white	2-5	3,47	3	(1) 1,5	(1) 2	1/3
0403	silvery/white	3-6	4,33	4	1,5	(1) 2	1/3
0405	silvery/white	2-4	2,19	2	(1,5) 2 (2,5)	38413	1/3
0409	silvery/white	3-7	4,06	4	0,5-1	0	<1/3-1/3

[1]in dimension of leaf-diameter (approximately 1/3 is "normal")

Table 2b: Results of field studies for segment sizes.

population	range of segment sizes (mm)			
(HKEP)	outer length[1]	outer width[1]	inner length[1]	inner width[1]
9518	17, 23, 33	7, 10, 21	18, 21, 33	6, 11, 21
9548	22, 31, 44	8, 10, 17	20, 28, 42	7, 9, 15
0201	18, 24, 30	4, 7, 9	16, 21, 27	5, 8, 11
0204	17, 22, 30	5, 8, 10	16, 21, 30	5, 8, 11
0209	21, 26, 35	8, 10, 14	20, 25, 32	7, 10,15
0210	16, 20, 24	5, 6, 8	15, 19, 22	6, 7, 9
0211	15, 22, 30	5, 8, 10	14, 21, 29	4, 8, 10
0214	18, 24, 30	7, 9, 15	17, 23, 29	6, 9, 14
0217	17, 24, 31	5, 7, 12	15, 22, 29	5, 8, 11
0222	20, 27, 33	6, 8, 13	19, 25, 31	5, 8, 11
0305	16, 22, 25	5, 8, 10	15, 20, 25	5, 9, 12
0306	19, 22, 29	6, 8, 11	16, 21, 28	6, 9, 12
0307	17, 22, 28	5, 7, 10	17, 21, 26	5, 8, 11
0314	14, 21, 25	5, 8, 10	14, 20, 24	6, 9, 12
0327	21, 33, 43	9, 12, 17	18, 30, 40	7, 11, 15
0401	18, 21, 32	6, 8, 13	16, 20, 31	6, 9, 16
0402	20, 25, 30	6, 8, 10	15, 22, 29	6, 8, 10
0403	17, 25, 32	6, 9, 12	17, 23, 30	6, 8, 10
0405	14, 21, 26	4, 7, 9	14, 20, 26	5, 8, 11
0409	19, 23, 29	6, 7, 12	18, 23, 27	5, 7, 13

[1] **left side minimum, middle median, right side maximum values**

Results of the morphological studies

The results of the morphological investigation of the *C. biflorus* populations are summarized in Tables 2a, 2b, and 2c. It is noteworthy that (especially in Caria) in several populations, although belonging to different taxa, unusually long filaments can be observed in combination with rather dark colours towards their basis and in the throat. Furthermore, the styles show very extreme features, perhaps due to very different pollinators and/or pollination mechanisms. Considering all populations from south-west Anatolia, style characteristics range from a deep pure red with a mean branch-length of more than 16 mm, and branches mostly hanging out of the flowers (ssp. *wattiorum*), to a clear white with a mean branch-length of only 2,5 mm, and branches stiffly hold upright in the flower (subsp. *leucostylosus*). Also characteristic for most populations in Caria are the predominantly black anthers which are either totally blackish-maroon (e.g., in subspp. *crewei* and *nubigena*, as well as the new taxa *nerimaniae*, *ionopharynx*, and *caricus*) or, in some individuals, at least greyish from the middle of the anther to the apex (colour plate, (HKEP 0306(1)). In subsp. *wattiorum* the deep black anthers are lemon-yellow at their basis (Colour Plate, (HKEP 9548 (1-3)). *Crocus biflorus* subsp. *nerimaniae* first appeared to have sterile shrivelled anthers without pollen. However, in freshly opened flowers we observed many released pollen grains as normal but these were almost immediately eaten by numerous small (1-1.5 mm) black beetles. After a while no pollen was left on the anthers and they began to twist and shrivel, giving the impression of being sterile. An example can be seen on the colour plate (HKEP 0327(2)).

Table 2c: Results of field studies for filaments, anthers and styles. .

population	filaments		anthers		styles		
(HKEP)	length (mm) (mean)	length (mm) (median)	length (mm) (mean)	length (mm) (median)	length[1] (mm) (mean)	length[2] acc. to stamen	papillae on branches[3]
9518	3,24	3	10,79	10	4,9	16, 07, 10	none-sl. sc.
9548	9	9	11,57	11	16,6	04, 01, 30	none-sc.
0201	5,24	5	6,82	7	6,5	04, 10, 03	den. sc.-pap.
0204	7,64	8	7,63	7	6,4	16, 04, 15	den. sc.-pap.
0209	5,3	5	10,5	10	6,5	13, 06, 15	none-sc.
0210	7,09	7	8,25	8,5	6,5	00, 02, 10	den. sc.-pap.
0211	4,09	4	9	9	3,9	13, 07, 09	none-sc.
0214	5,35	5	8,79	9	2,5	19, 10, 05	sl. sc.
0217	4,42	4	9,97	10	5,2	15, 00, 25	none
0222	6,3	6	9,25	9,5	4,7	15, 06, 11	none
0305	5,75	6	9,26	10	4,9	05, 01, 17	sc.–pap.
0306	7,38	7	7,56	7	5	19, 13, 00	sc.–pap.
0307	8,86	9	9,03	9	5	00, 01, 28	sc.–pap.
0314	8,55	8	7,71	8	7,3	16, 04, 18	sc.–(den.)pap.
0327	4,87	5	9,43	10	5,8	04, 00 , 26	none-sl. sc.
0401	7,21	7	9,03	9	6,7	15, 00, 14	(sc.)-den. pap.
0402	3,53	4	8,06	8	7,7	06, 23, 03	(sc.)-den. pap.
0403	4,91	5	9,45	10	5,5	08, 22, 03	none-sc.
0405	7,03	7	7,84	8	5,4	07, 02, 23	sc.–(den.)pap.
0409	3,67	3	9,21	9	5,1	06, 01, 26	none-sc.

[1]length of branches
[2]no. equal, longer, shorter of investigated specimens
[3]sl. = slightly; sc. = scabrid; pap. = papillose; den. = densely

Multivariate statistics

Although it is not possible to consider all characters of *Crocus* in multivariate statistics due to principal problems (e.g., flower colours, striping or feathering) or technical reasons (e.g., shape of segments, cataphylls, bracts, and bracteoles; change of colours of these when drying) we tried to include as many characters from our field studies as possible. This resulted, in general, in a fairly good grouping of existing and newly described taxa and verified our concept.

In part two we have already discussed principles, objectives and problems of multivariate statistical methods as well as our intention to use such an approach in order to provide a baseline for the taxonomic classification of *C. biflorus*. Therefore, no further explanation is required here. However, due to the increased number of populations and taxa some additional parameters can be included due to the increased variance of certain characters. These are the colours of filaments, the length and colours of style branches, and papillae on these. The increased number of parameters, populations and taxa used for clustering refines and improves the information of the resulting dendrogram. On the other hand, the results of cluster analyses lead to changes of similarity/taxonomic distances (see below) and, hence, to changes in the grouping of populations. However, compared to the dendrogram shown in part two the main groups are stable.

Parameter-coding and cluster analysis

Both qualitative and quantitative characters (parameters) have been included in the cluster analysis. The quantitative (metric) parameters used are, in general, the mean-values of

the investigated specimens of a population (normally 30-40). The characters measured are the length and width of the outer and inner segments reflecting the size and proportion of the flowers; the length of filaments, anthers, stamen and style-branches; and the number of leaves. The qualitative parameters are the colours of filaments (white, yellow, orange, or violet-brown), anthers (yellow or black) and styles (white, yellow, orange, or red); the occurrence and form of papillae on the style-branches (none, scabrid, papillose); the style-length according to the stamen (shorter, equal or longer); the white stripe relative to the leaf-diameter (1/3, <1/3, or > 1/3); and the leaf-ribs underneath (0-6). The latter parameter and the leaf-diameter (broadest part of the leaf) are generally not very variable which means, from a statistical perspective, that at least 5 random samples are sufficient to define their ranges. To transform all these qualitative data into interval data for making them comparable to the metric ones the character states were coded with numbers ranging from zero to one. The resulting matrix for cluster analysis comprised 45 populations times 17 characters which culminates in 765 entries. The treeplot which derives from this dataset (Fig. 1) was generated with NTSys 2.1 software (ROHLF 2002); using the UPGMA-method, standardised data, the SAHN-clustering algorithm, and the average taxonomic distance as similarity index.

Table 3: Taxonomical interpretation of the cluster analysis.

	cluster	subcluster		related populations	area	taxon definition
	1 tauri-related populations	1a		9377+9701	8	*atrospermus*
				9719+0124	8	undefined
				0104+0112	9+10	undefined
		1b		9910+9913+9917	21	*tauri*
				9923+9927	22	*tauri*
		1c		0126+0222+0403	7+8+17	undefined
		9716		isolated between 1a/1b/1c and 1d	8	undefined
		1d		9804+0209	7+8	undefined, between 1+ 2
	2 nubigena-, isauricus-, and punctatus related populations	2a		9708+0007+9820+0305	7+8+9	*nubigena*
		2b		9721+0009+0211+0115	8+17	*isauricus*
		0306		isolated within cluster	7	*ionopharynx*
		2c		0004+0409+0217+9518	2+9+16 +17	*punctatus* + *caelestis**+ *pulchricolor*
	3 pseudonubigena-related populations			0001+0101+0108	10+22	*pseudonubigena*
		0402		isolated between clusters	7	*yataganensis**
		0214		isolated between clusters	17	*leucostylosus*
	4 crewei-related populations			0201+0314+0401	7+16	*crewei*
				0204+0210+0405	6+7	*crewei*
		0307		isolated within cluster	7	*caricus*
	5 isolated populations			0123	8	undefined
				0327	7	*nerimaniae*
	6 isolated population			9548	8	*wattiorum*

* description in this paper; areas 2=Bithynia, 6=Lydia, 10=Isaurian Taurus, 16=Phrygia, 21=Upper Euphrates, 22=Mesopotamia

Results

Compared to its overall distribution area, the range of *C. biflorus* sensu lato in south-west-Anatolia is rather small. Nevertheless, in this area this "species" reaches a remarkably high level of phenotypic diversity. Although it is not (and never will be) possible to

consider all populations of *C. biflorus* our results will help to get a better understanding of the phenotypic similarities/dissimilarities of populations of this "taxon" in south-west-Anatolia. At first we will compare the morphological similarities between all 45 investigated populations from a taxonomical point of view. Afterwards, the geographical, and phytogeographical distribution of the classified populations is considered for all south-west Anatolian populations. Finally, the two newly discovered taxa, subspp. *yataganensis* and *caelestis* are described.

Morphological similarities among populations and taxonomical classification

Morphological similarities /dissimilarities between populations are revealed from cluster analysis. The associated dendrogram is presented in Figure 1 and its interpretation in Table 3. Figure 1 shows that all the clusters are separated in a somewhat hierarchical manner and most clusters are close together considering the distances of the coefficients. Only cluster 5 and population HKEP 9548 are more distantly separated. In general, five main clusters are evident which can be interpreted in the following way (table 3). Cluster 1 (red) contains populations which are more or less connected with subsp. *tauri*, cluster 2 (blue) with subsp. *nubigena*, *isauricus*, and *punctatus*, cluster 3 (green) with subsp. *pseudonubigena*, cluster 4 (grey) with subsp. *crewei*, cluster 5 (brown) with a not yet definable population and to subsp. *nerimaniae*. Compared to all others the population of subsp. *wattiorum* (HKEP 9548, yellow) investigated has a clearly separate position.

Cluster 1 can be divided into three subclusters (1a-1c), an isolated population (HKEP 9716), and an associated subcluster (1d). Cluster 1b comprises exclusively populations of subsp. *tauri* from the Anatolian Diagonal (HKEPs 99xx). Subcluster 1a consists of populations which belong to subsp. *atrospermus* (HKEPs 9377+9701) and to yet undefined populations of the Lycian Taurus (HKEPs 9719+0124) and Isaurian Taurus (HKEPs 0104+0112). Subcluster 1c contains populations more similar to those of subsp. *tauri* of more distant localities (Caria, Pisidia, and Lycian Taurus) which also cannot be classified at present. Isolated within cluster 1 are populations HKEPs 9716, 9804 and 0209, the latter two combined in subcluster 1d, all of which are more distantly connected with the "*tauri*-cluster".

Cluster 2 contains three subclusters and one isolated population (HKEP 0306) which is the new subsp. *ionopharynx*. Subcluster 2a comprises populations belonging to subsp. *nubigena* or populations very close to it. Subcluster 2b comprises populations related to subsp. *isauricus*. Subcluster 2c is very remarkable as it contains three easily distinguishable taxa considering all available characters and geographical distances, i.e. subspp. *punctatus*, *pulchricolor,* and the new subsp. *caelestis* (HKEP 0409, described here) but indicates a close relationship between all these three taxa considering the parameters used for the present cluster analysis. On the other hand, subclusters 2a+b are more similar to each other than either is to 2c which suggests a close relationship of subspp. *nubigena* and *isauricus*. In between subclusters 2(a+b) and 2c one can find the interesting and easily distinguishable population of the new subsp. *ionopharynx* (HKEP 0306).

Cluster 3 combines all populations of subsp. *pseudonubigena*.

Cluster 4 is also well defined and clearly separated from cluster 1, 2, and 3 and contains populations more or less allied to subsp. *crewei*. Population HKEP 0307 of the new

subsp. *caricus* is associated with cluster 4. Populations HKEP 0402 (the new subsp. *yataganensis*, described in this paper) and HKEP 0214 which belongs to subsp. *leucostylosus* have a very interesting isolated position between clusters 1/2/3 and 4. Both can be regarded as "morphological links" between these clusters.

Cluster 5 consists of only two populations which are further separated from the other clusters. One of these populations belongs to subsp. *nerimaniae*, the other one to a spring-flowering taxon which is still undefined.

The results show that the investigated 45 *C. biflorus* populations can be classified morphologically into 4 major groups (fig. 1 and tab. 3). This small number is quite remarkable as all known and new taxa of *C. biflorus* in Anatolia are considered except for some additional taxa existing in north-east Anatolia and the Anatolian Diagonal. The populations can be related to a "*tauri*-group", to a "*nubigena/isauricus/(punctatus+pulchricolor)*"-group, to a "*pseudonubigena*-group", to a "*crewei*-group", and to some "in between" or isolated taxa. All clusters are rather well separated but contain populations which are more or less different with respect to the "typical" taxa described in the literature. Especially the *tauri*-group includes several populations which are still undefined. A special case is cluster 2 which is made up of the four well known taxa *nubigena*, *isauricus*, *punctatus*, and *pulchricolor*. Clearly, these four taxa are morphologically more similar to each other than either is to subsp. *tauri*, *pseudonubigena*, and subsp. *crewei*. The two autumn-flowering taxa are rather isolated, one, subsp. *nerimaniae*, is distantly associated with a yet undefined spring-flowering population in a separate cluster (5) and the other, subsp. *wattiorum*, has a completely outstanding position which may justify a classification at species rank level, at least on a morphological basis.

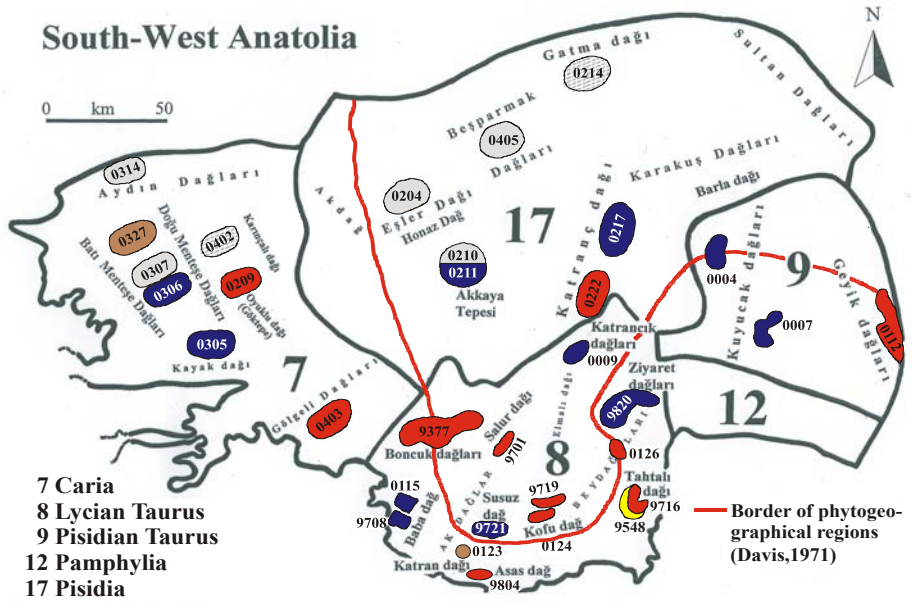
Table 4: Geographical distribution of classified *Crocus biflorus* populations in south-west Anatolia (regionalisation of results of Tab. 3, colours of first column)..

region	*tauri*-related (red)	*nubigena/isauricus/punctatus*-related (blue)	*pseudonubigena*-related (green)	*crewei*-related (grey)	isolated populations
Caria (7)	2	2	0	2	1 brown +1 striped
Pisidia (17)	1	2	0	3	1 striped
Lycian Taurus (8)	7	5	0	0	1 brown +1 yellow
Pisidian Taurus (9)	1	2	0	0	0

Geographical distribution pattern of taxa in south-west Anatolia

The regional distribution of *C. biflorus* sensu lato in south-west Anatolia is rather complex. Nevertheless, trends are recognisable if one looks at the major taxon-groups of Table 4 and whose distributions are presented in Map 2. The *tauri*-related populations (red) can be found predominantly in the Taurus (e.g. Lycian and Pisidian Taurus but also outside of south-west Anatolia in the Isaurian and Cilician Taurus, and the Antitaurus).

Less frequently they can be found in the mountains of Caria and Pisidia. The *nubigena* / *isauricus* / *punctatus*-related populations (blue) are more or less evenly distributed in south-west Anatolia, whereas populations related to subsp. *pseudonubigena* (green) are not present in south-west Anatolia. The *crewei*-related populations (grey) are concentrated in northern Caria and Lydia as well as in the western parts of Pisidia. The two taxa between clusters 1/2/3 and 4 (hatched) are found in northern Caria and northern Pisidia. The three isolated taxa (brown and yellow) are south-west oriented, either occurring in western Caria or at the southern edges of the Lycian Taurus (Table 4). In the next chapter we consider the habitats of the investigated populations and their associated vegetation.



Map 2: Distribution of taxon groups.

Habitats and associated vegetation

To learn more about the regional distribution of *C. biflorus* populations in south-west Anatolia it is useful to connect the taxonomic information revealed from the cluster analysis with major aspects of their habitats. Although our studies are not complete, four different plant formations can be recognised according to the "Vegetation of the middle Taurus" (TAVO 1985), and which are typical habitats of *C. biflorus* in south-west Anatolia. Compared to part two an additional habitat-type has to be considered for Caria (type d). The habitat-types, their major floral elements and the allocated *C. biflorus* populations are listed in Table 5.

Table 5: Characteristic associated vegetation of *Crocus biflorus* habitats.

habitat-type[1]	major floral elements	allocated populations of *Crocus biflorus* (HKEP)
a) moderately cold-tolerant evergreen coniferous forest	*Pinus nigra ssp. pallasiana, Quercus libani, Cedrus libani, Juniperus excelsa, Styrax officinalis, Abies cilicica, Acer monspessulanum, and Populus tremulae*	9708, 9804
b) moderately cold-tolerant evergreen coniferous woodland	*Pinus nigra ssp. pallasiana* and *Juniperus excelsa*	9377, 9701, 9716, 0104, 0112, 0115, 0204, 0209, 0210/0211, 0214, 0403, 0405, 0409, transitional is 0124 + 0108
c) mixed cold-deciduous and evergreen scrub	*Juniperus excelsa, J. oxycedrus, Amygdalus orientalis, Cotoneaster nummularia, Crataegus aronia, Pistacia atlantica, and Quercus pubescens ssp. anatolica*	9719, 0314
d) evergreen needle-leaved forest sensitive to cold with broad-leaved trees or shrubs	*Pinus brutia, Quercus calliprinos, Styrax officinalis, Arbutus andrachne, Ceratonia siliqua, Cercis siliquastrum, Laurus nobilis, Myrtus communis,*	0201, 0306, 0307, 0401, 0402, 0327, 9548

[1]according to TAVO (1983)

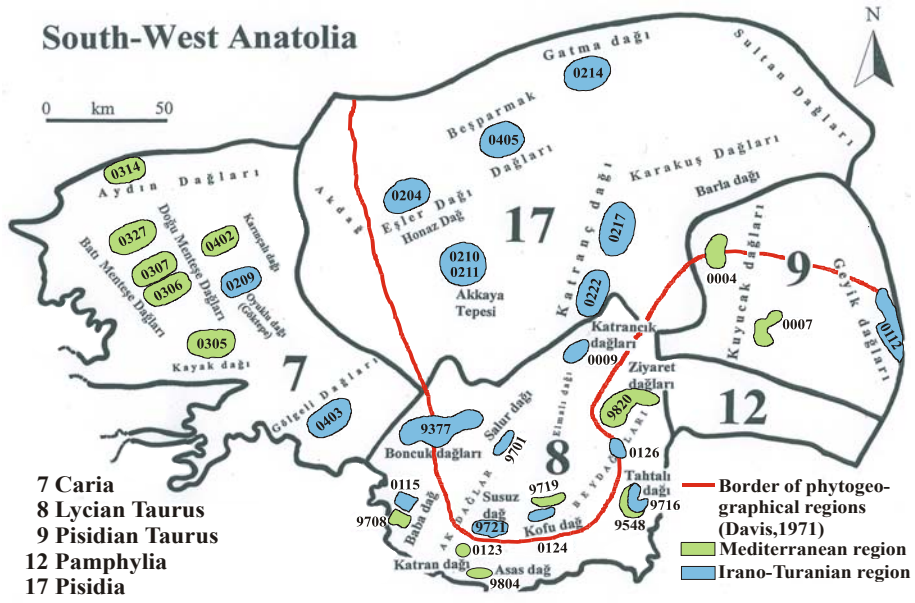
The habitat-types show the following properties:

- Type a): Cold-resistant and moderately cold-resistant xerophytic forests which characterize the montane-subhumid and oreal-humid zone of the oro-Mediterranean region (1200-1300m).
- Type b): With increasing aridity the closed stands of formation a) merge into open stands of trees. These woodlands form a transition zone between the xero-Euxine steppe forests and shrub formations.
- Type c): This scrubland is the remainder of a xero-Euxine steppe forest and indicates that the hills in the central Anatolian highlands could potentially maintain a forest covering.
- Type d): This formation is a typical community of the eastern Mediterranean zone (0-1200m). *Pinus brutia* is an indicator of Mediterranean climatic conditions and only

rarely forms homogeneous forests. Depending on exposure, microclimate and edaphic factors there are numerous variants with evergreen and deciduous broad-leaved trees.

Populations HKEP 9708 and HKEP 9804 occur on isolated mountain stocks near the coast and belong to the oro-Mediterranean region. The vegetation on these mountains is forest-like up to the summit. Contrasting to these are populations HKEPs 9377, 9701, 9716, 0104, 0112, 0115, 0204, 0209, 0210/0211, 0214, 0403, 0405, and 0409, which all grow in open coniferous woodland but in very different areas (populations HKEP 0108 and HKEP 0124 grow in transitional areas of a) and b)). Whereas populations HKEPs 9377, 9701, 9716, 0115, and 0124 occur on mountains in the Lycian Taurus, populations HKEP 0104 and HKEP 0108 inhabit the Isaurian Taurus, HKEP 0112 the Pisidian Taurus, HKEPs 0204, 0209, 0210/0211, 0214, and 0405 Pisidia, HKEPs 0403 and 0209 Caria and HKEP 0409 Phrygia (central Anatolia). Populations HKEP 9719 (Lycian Taurus), and HKEP 0314 (Caria) grow in a mixed cold-deciduous and evergreen scrub habitat. Finally, populations HKEPs 0201, 0401 (Bozdağlar), 0306, 0307, 0327, 0402 (mountains of Caria), and HKEP 9548 (Lycian Taurus) belong to habitat-type d).

Map 3: Phytogeographical classification.



Distribution of populations across the phytogeographical regions

In contrast to geographic aspects, phytogeographical regions convey an additional habitat component and, hence, provide information on the distribution of floral constituents. In south-west Anatolia two major floristic elements exist. These are the Mediterranean province (west Anatolian and Taurus district) and the Irano-Turanian region of central Anatolia (red border-line after DAVIS, 1971, in Map 3). In the newly investigated area 7

(Caria) the populations found predominantly belong to the Mediterranean region whereas in area 17 (Pisidia) they exclusively are part of the Irano-Turanian region. However, there are exclaves of both these areas due to micro-climatic, edaphic, and other factors which were already discussed in part two. Comparing all classified habitats of the investigated localities of *C. biflorus* in South-west Anatolia it can be seen that they fit fairly well into the phytogeographical regions defined by DAVIS (1971) (red line in map 3). Exceptions exist due to harsh micro-climates on high mountains in the Mediterranean region or to sheltered areas at lower altitudes in the Irano-Turanian region. It can be observed that populations related to subspp. *tauri* (including subsp. *atrospermus* plus not yet defined taxa) and *isauricus*, as well as the new subspp. *leucostylosus* and *caelestis* inhabit the Irano-Turanian region. Interestingly subspp. *crewei* and *punctatus* can be found in both phytogeographical regions. Confined to the Mediterranean region are subspp. *nubigena*, *yataganensis*, *nerimaniae*, *caricus*, *wattiorum* and *ionopharynx*.

Description of new taxa

Crocus biflorus subsp. *yataganensis* KERNDORFF & PASCHE, subsp. nova

H o l o t y p u s : Turkey, Caria, Province Muğla, Doğu Menteşe Dağları, 1000-1200 m, 18.3.2004, HKEP 0402 (LI).

Impressio generaliter cum subsp. *pulchricolori* et subsp. *ionopharynx* affinis, sed distinctum ab subsp. *pulchricolori* per folia minores, structura atque ovi putamen, segmentas angustioras, antheras brevioras, 1(2) costas foliis inferioris, stylos qui plerumque sunt longiores vel longas aequalis, et per ramos styli qui sunt distincte longiores, scabrous et papillosos.

Distinctum ab subsp. *ionopharynx* per filamentas brevioras, sine exceptione antherae lutae, antherarum connectivum incoloratum et rami stylorum longiores.

Corm globose, about 10-15 mm in diameter. Tunics coriaceous, splitting longitudinally into numerous stripes, with rings at base. Neck short, approximately 3 mm. Cataphylls 3, silvery-white, drying light brownish. Leaves shorter than flowers at anthesis, 2-5 but normally 3, green, (1)-1.5 mm in diameter, glabrous, (1) 2 ribs underneath. White stripe normal, width approximately 1/3 of leaf diameter. Throat yellow, glabrous, perianth tube whitish. Outer segments between 20 and 30 mm but usually 25 mm long, between 6 and 11 mm mostly 8 mm wide. Inner segments between 15 and 29 mm but usually 22 mm long and between 6 and 10 mm frequently 8 mm wide. Inside all segments are blue-violet without markings, outside also blue-violet rarely with diffuse featherings or specklings but with a distinct dark violet blotch towards the perianth tube. Colouring and marking similar to outer segments but violet blotch much smaller or not existent. Prophyll absent. Bract and bracteole present, silvery-white, conspicuous. Filaments on average 3.5 mm long, deep yellow, glabrous or scabrid; anthers on average 8.1 mm long, yellow, connective colourless. Pollen yellow. The styles are deep red, divided into 3 branches which are trumpet-shaped and fringed towards the end; branches 5-11 mm but usually 8 mm long, scabrid to densely papillose. The styles are mostly longer to equal as the stamens. Capsule and seeds not seen. Chromosome number unknown.

In its overall appearance the new subsp. *yataganensis* is somewhat similar to subspp. *pulchricolor* and *ionopharynx*. The differences to subsp. *pulchricolor* are: coriaceous

corm tunic (membranous in subsp. *pulchricolor*) more narrow segments, shorter anthers, smaller number of leaves with 1 or mostly 2 ribs underneath (subsp. *pulchricolor* usually has none); the styles are usually longer to equal (94%) compared to the stamens. In subsp. *pulchricolor* the styles are mostly equal to or shorter than the stamens (79%). The style-branches are scabrid to densely papillose whereas those of subsp. *pulchricolor* are glabrous or slightly scabrid. Finally, the style branches of subsp. *yataganensis* are relatively long, on average 7,7 mm compared to 4,6 mm of subsp. *pulchricolor*. The differences to subsp. *ionopharynx* are: shorter filaments (3,5 mm compared to 7,4 mm in subsp. *ionopharynx*); always yellow anthers and colourless connectives instead of blackish or dark greyish anthers with blackish connectives towards the apex. The style-branches of subsp. *yataganensis* are 7.7 mm long (mean) compared to 5 mm in subsp. *ionopharynx*.

As can be seen from the dendrogram, subsp. *yataganensis* has a rather isolated morphological position. It is a typical representative of a phenomenon widely observed within the genus. The number and nature of morphological parameters are more or less constant in the genus but often different taxa are only described by their different combinations of characters which is obviously the case for subsp. *yataganensis*. We believe that, in combination with isolated occurrences and/or large geographical distances between allies, a taxonomical recognition seems to be justified in such cases.

D i s t r i b u t i o n a n d h a b i t a t : Turkey, Caria, Muğla Province, very local, in open forests, along mountain slopes, together with *Pinus nigra* subsp. *pallasiana*, *Cistus laurifolius*, *Gagea*, *Draba*, grasses and others. *Crocus biflorus* subsp. *yataganensis* grows on calcareous formations. Known only from the type locality in the Doğu Menteşe Dağları in mountainous areas not far from the City of Yatağan (hence the name *yataganensis*). Specimens of this new subspecies are very colourful as can be seen from the colour-plate and photographs. When looking into an open flower the comparatively long and deep red style-branches are most remarkable. Apart from those of *C. biflorus* subsp. *wattiorum* they are the longest ones (up to 11 mm) found in the "species" considering the populations investigated in south-west Anatolia.

Crocus biflorus subsp. *caelestis* KERNDORFF & PASCHE, subsp. nova

H o l o t y p u s : Turkey, Phrygia, Uşak Province, surrounding areas of the city of Uşak, 1200-1400 m, 13.3.2004, HKEP 0409 (LI).

Subspecies punctato affinis, sed cum colore florum pallidiore, caelestis, sine segmentis peculiaris punctatis vel segmentis triis exterioris extus significante colorata, antherea sine lobis nigris, filamenta incolorata et folia plura.

Corm globose, about 10-15 mm in diameter. Tunics more or less membranous, splitting longitudinally into stripes, with rings at base. Neck short, approximately 3-5 mm. Cataphylls 3, silvery-white, the outer ones drying very light brownish. Leaves shorter than flowers at anthesis, 3-7 but normally 4, green, 0.5-1 mm in diameter, glabrous, no ribs underneath. White stripe normally distinctly smaller than 1/3 of leaf diameter. Throat mostly white or light lemon-yellow to yellow, glabrous. Perianth tube greyish-blue. Outer segments between 19 and 29 mm but usually 23 mm long, between 6 and 12 mm mostly 7 mm wide. Inner segments between 18 and 27 mm but usually 23 mm long and between 5 and 13 mm frequently 7 mm wide. Inside all segments are pale sky-blue without markings, outside also pale sky-blue rarely with very diffuse markings or stripes. Prophyll absent. Bract and bracteole present, silvery-white, conspicuous. Filaments on

average 3.7 mm long, colourless to light yellow, glabrous to scabrid at base; anthers on average 9.2 mm long, yellow, connective colourless. Pollen yellow. The styles are orange to red, divided into 3 branches which are not trumpet-shaped and only slightly fringed towards the apex; branches 3-7 mm but usually 5 mm long, glabrous to scabrid. The styles are mostly shorter to equal compared to the stamens. Capsule and seeds not seen. Chromosome number unknown.

C. biflorus subsp. *caelestis* clearly differs from other *C. biflorus* taxa of south-west Anatolia in colour and overall appearance. It is generally rather pale "heavenly blue" (= caelestis). In most specimens featherings and markings are very diffuse, poorly developed or missing at all. The sky-blue colouring of the segments is most intensive at the apex but decreasing rapidly into a whitish or light yellow colour (rarely deeper yellow) towards the centre of the flower, giving the plant a somewhat "out-washed" appearance. Although morphologically close to subspp. *punctatus* and *pulchricolor* (on the basis of the cluster analysis) it can be distinguished from both considering several additional parameters which are not included in cluster analysis. In case of *C. biflorus* subsp. *punctatus* it is e.g. the lack of both speckling on the outside of the outer segments and the black tips at the lower ends of the anthers. It is also different in having colourless filaments compared to the deep yellow ones of subsp. *punctatus*, and it has on average one more leaf. *C. biflorus* subsp. *pulchricolor* is much more colourful than *C. biflorus* subsp. *caelestis*, mostly rich blue-violet, darker towards the base of the segments, having a deep yellow throat, and distinct brown cataphylls, bracts, and bracteols.

D i s t r i b u t i o n a n d h a b i t a t : Turkey, Phrygia, Uşak Province. As yet only known from the type locality in the vicinity of the city of Uşak in open areas, light forests, scrub, together with *Pinus nigra* subsp. *pallasiana*, *Juniperus*, *Cistus laurifolius*, *Verbascum*, *Crocus chrysanthus*, *Ornithogalum*, *Colchicum* and others. *Crocus biflorus* subsp. *caelestis* seems to prefer calcareous soils. No hybrids between *C. chrysanthus* and *C. biflorus* subsp. *caelestis* could be observed.

Summary and conclusions

In the course of our investigation in south-west Anatolia we studied 31 populations belonging to *C. biflorus* sensu lato and 14 additional populations in different parts of Anatolia for comparative purposes. The results are presented under morphological, taxonomical, geographical, and phytogeographical aspects. Besides the discovery of new taxa many unexpected facts were revealed concerning the relationship and distribution of *C. biflorus* sensu lato in this area. Our results shed some more light on this complex but marvellous "species" in a wonderful country and, hopefully, will open up new areas for further research.

Most importantly from a morphological point of view is the finding that populations of subspp. *nubigena, isauricus, punctatus, pseudonubigena*, and *crewei* form distinct groups whereas subsp. *tauri* is rather complex and subdivided into various groups and outstanding populations which are also geographically separated. Connected to the "*tauri*-complex" is the new subsp. *atrospermus* and several other accessions which are as yet undefined. Only distantly associated to the *tauri*-group are two remarkable and distinct populations from the Asas dağ (HKEP 9804) and Göktepe (HKEP 0209) which may be a "transitional element" to the other taxon-groups. Very surprising is the fact that the

"*punctatus*-group" (cluster 2c) contains two additional distinct taxa, subsp. *pulchricolor* and the newly described subsp. *caelestis* which are different from their overall appearances and from their geographical distribution. The two autumn-flowering taxa (subspp. *nerimaniae* and *wattiorum*) are clearly separated although only subsp. wattiorum seems morphologically distinct enough to be recognized at species level. In our opinion this might be possible also for other "*C. biflorus*-taxa" of south-west Anatolia, but this can be considered only upon sufficient genetic information which is not yet available.

From a geographical point of view it is clear that the *tauri*-group is confined to the higher mountains of the entire Taurus range. Rarely they can be found in the mountains of Caria and Pisidia. This is very remarkable as *tauri*-related populations were known only to occur in the Anatolian Diagonal and eastwards. Populations related to subsp. *pseudonubigena* have been reported only from Mesopotamia and south of the Güneydoğu dağları but we found three exclaves in the middle Taurus, one of which was investigated in detail (HKEP 0108). The *nubigena* / *isauricus* / *punctatus*-related populations are more or less evenly distributed in our study area, whereas *crewei*-related populations are concentrated in northern Caria and Lydia as well as in the western parts of Pisidia. Remarkable are the three isolated taxa; subsp. *nerimaniae* is confined to the Menteşe Dağları, subsp. *wattiorum* to the Tahtalı dağ and a yet undefined population which is spring-flowering and morphologically close to subsp. *nerimaniae* is obviously confined to the Katran dağ.

The distribution of the *C. biflorus* habitats fits fairly well into the phytogeographical regions of south-west Anatolia defined by DAVIS (1971) with exceptions due to harsh micro-climates on high mountains in the Mediterranean region or to sheltered areas at lower altitudes in the Irano-Turanian region. Subspecies *tauri*, *atrospermus*, *isauricus*, *leucostylosus*, *caelestis*, and some yet undefined taxa belonging to the *tauri*-group inhabit the Irano-Turanian region, subspecies *nubigena*, *yataganensis*, *nerimaniae*, *caricus*, *wattiorum* and *ionopharynx* the Mediterranean region and subspecies *punctatus* and *crewei* both areas.

The interrelated complexity of climatic, geological, edaphic, ecological, historical and phytochorological factors in south-west Anatolia is reflected by a culminating variability of *C. biflorus* sensu lato. This complexity might also explain the finding of several new taxa which certainly increases our knowledge on the *C. biflorus* aggregate significantly. However, in our opinion there are most probably many more populations and new taxa to be found in this area.

Although south-west Anatolia undoubtedly can now be regarded as the present distribution centre of *C. biflorus* there is another, even larger area which is inhabited by additional taxa of this multiplex "species" which will be our research area at next: The Anatolian Diagonal. We plan several expeditions, two in the southern parts up to the middle (approximately up to the Munzur mountains) and at least two from the middle to its north-eastern end.

Acknowledgements

We would like to thank our families emphatically for patience and understanding of our work during all the years. Very special thanks go to Alexander Kerndorff for his perseverance while processing the huge data sets with us. Special thanks are also due to Prof. Dr. Peter Comes (University of Salzburg, Austria) for many fruitful discussions on evolutionary, geographically, and

statistical / botanical aspects as well as for his comments on a previous draft of this paper, to Dr. Ruprecht Schleyer for his help in general statistical discussions and to Dr. Bernd Steiner for his great help in perfectly styling the photo-series. Many thanks are also due to Mr. Thomas Minden for assembling maps, figures, and tables in a professional way. We thank all our friends and colleagues for help, hints, and stimulation to this work.

Zusammenfassung

Die Ergebnisse von Freilanduntersuchungen an 15 Populationen von *Crocus biflorus* sensu lato aus Caria und Pisidia sowie zusätzlicher Populationen aus angrenzenden Teilen Anatoliens werden vergleichend dargestellt. Die Untersuchung berücksichtigt alle südwest-anatolischen Populationen (inklusive der 16 von Teil 2 aus Lycien und dem pisidischen Taurus). Morphologische, statistische, taxonomische, geographische und phytogeographische Aspekte werden dargestellt. Neben der Beschreibung zweier neuer Arten aus diesem Gebiet werden neue und unerwartete Daten in Bezug auf Verwandtschaft und Verbreitung der *C. biflorus* Taxa präsentiert.

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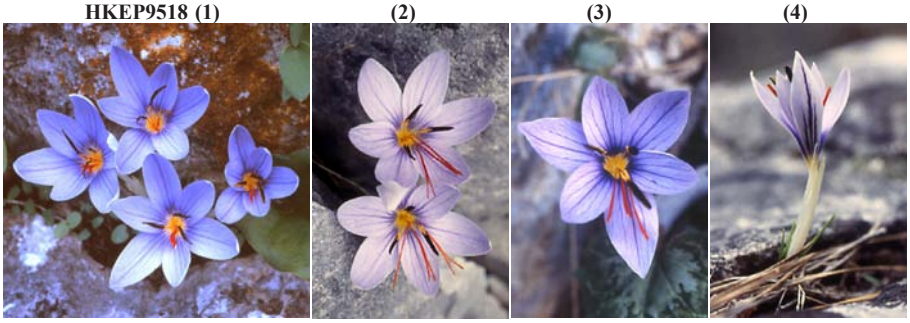
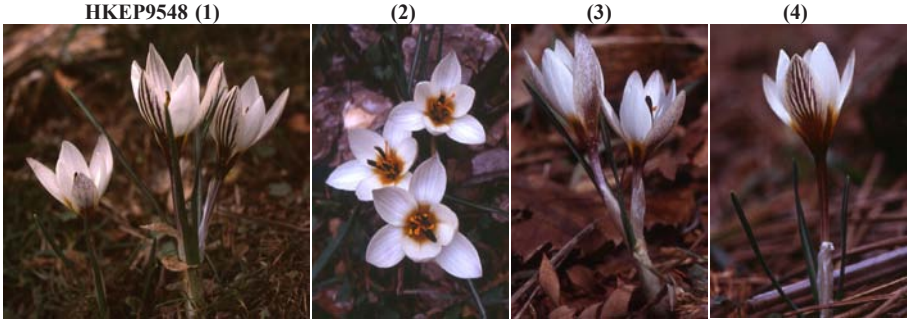
Author's addresses: Dr Helmut KERNDORFF
Sundgauer Str. 144
D-14167, Berlin, Germany
E-Mail: helmut.kerndorff@uba.de

Erich PASCHE
Feldstr. 71
D-42555 Velbert (Langenberg), Germany

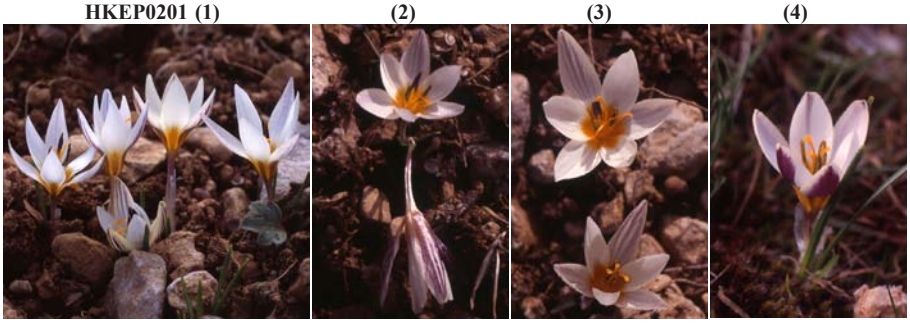
HKEP9518 (1) (2) (3) (4)



HKEP9548 (1) (2) (3) (4)



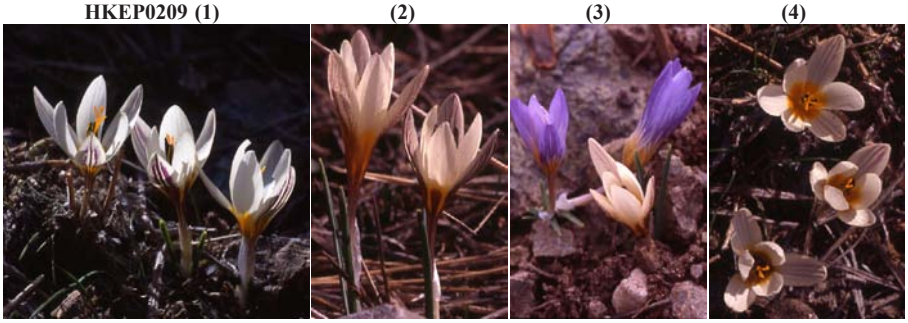
HKEP0201 (1) (2) (3) (4)



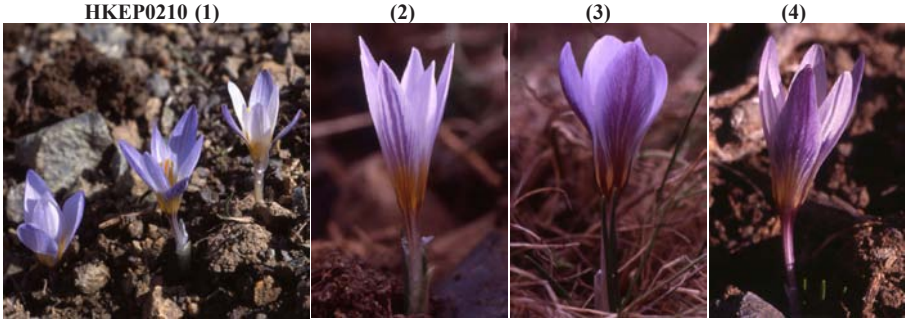
HKEP0204 (1) (2) (3) (4)

Colour plate 1

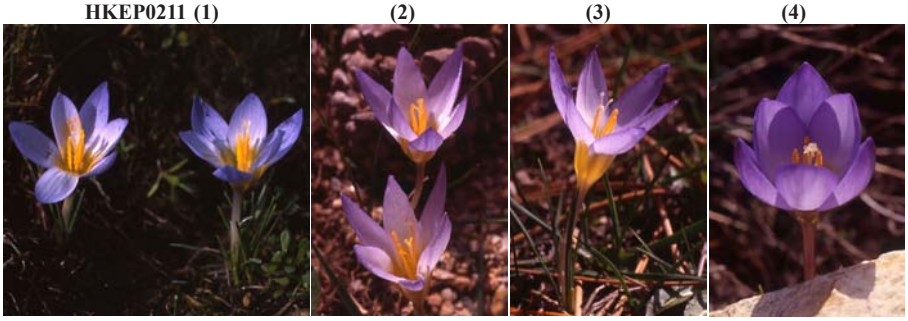
HKEP0209 (1) (2) (3) (4)



HKEP0210 (1) (2) (3) (4)



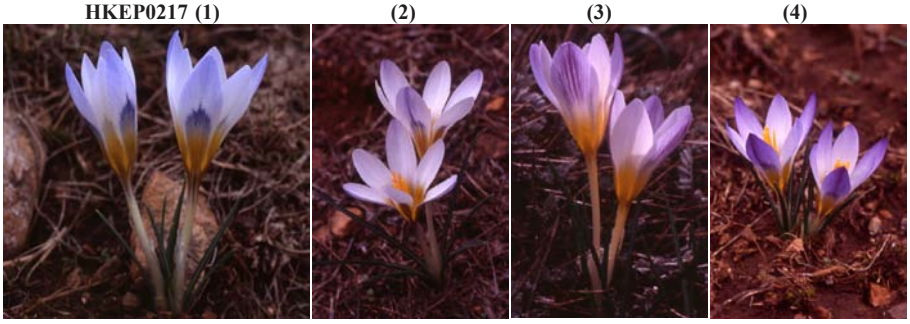
HKEP0211 (1) (2) (3) (4)



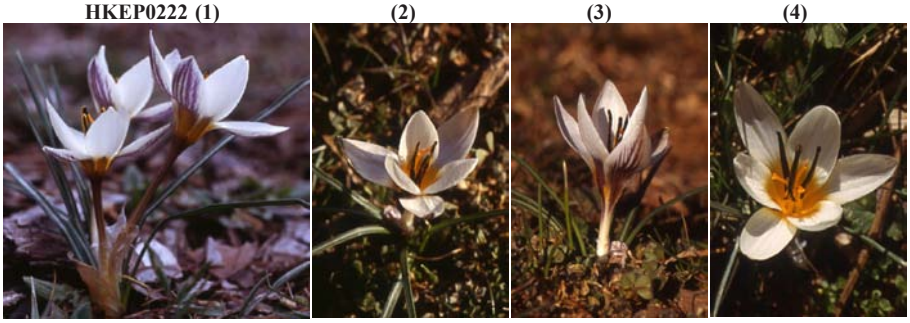
HKEP0214 (1) (2) (3) (4)

Colour plate 2

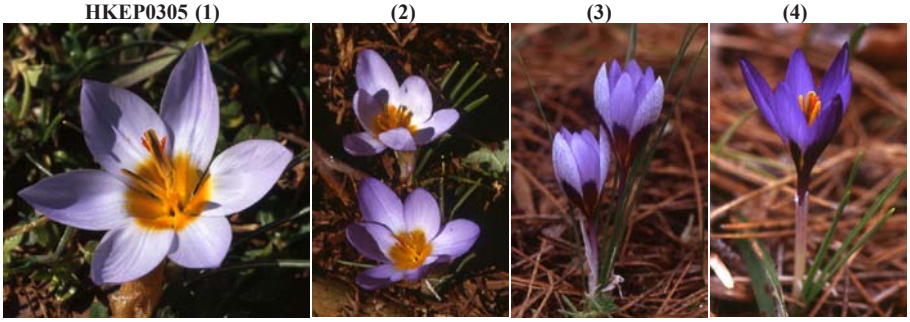
HKEP0217 (1) **(2)** **(3)** **(4)**



HKEP0222 (1) **(2)** **(3)** **(4)**



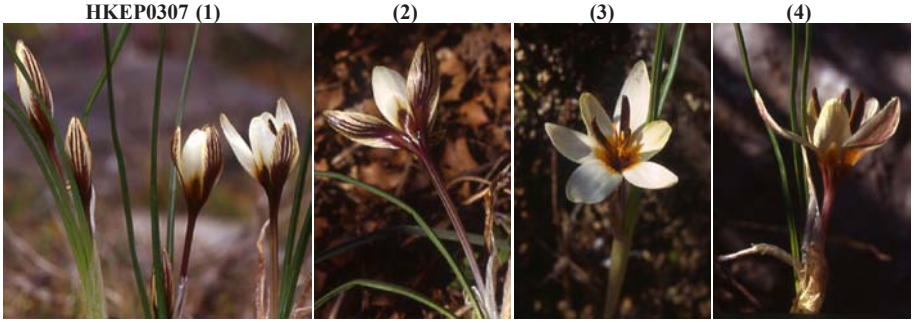
HKEP0305 (1) **(2)** **(3)** **(4)**



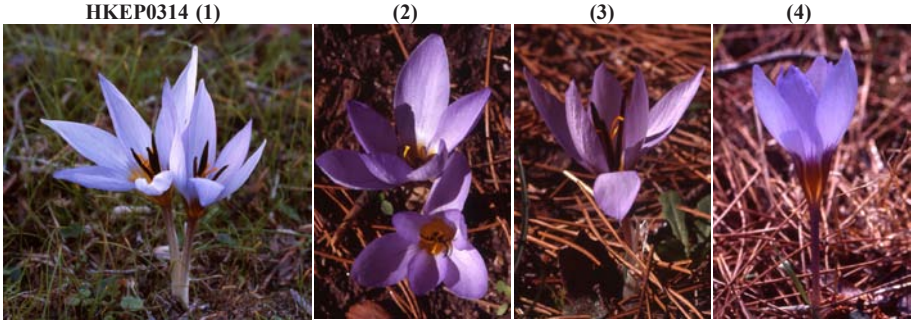
HKEP0306 (1) **(2)** **(3)** **(4)**

Colour plate 3

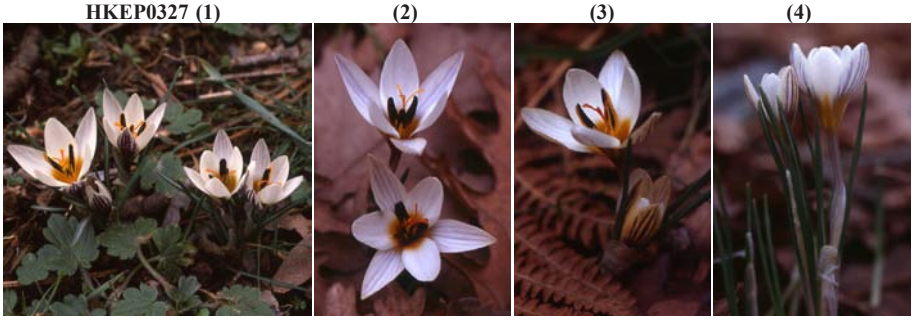
HKEP0307 (1) **(2)** **(3)** **(4)**



HKEP0314 (1) **(2)** **(3)** **(4)**



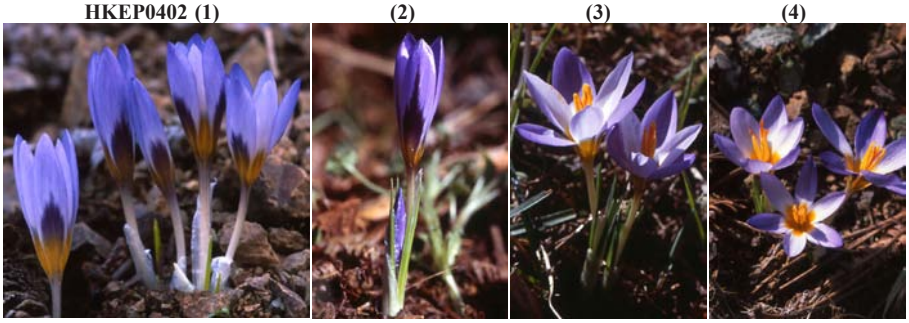
HKEP0327 (1) **(2)** **(3)** **(4)**



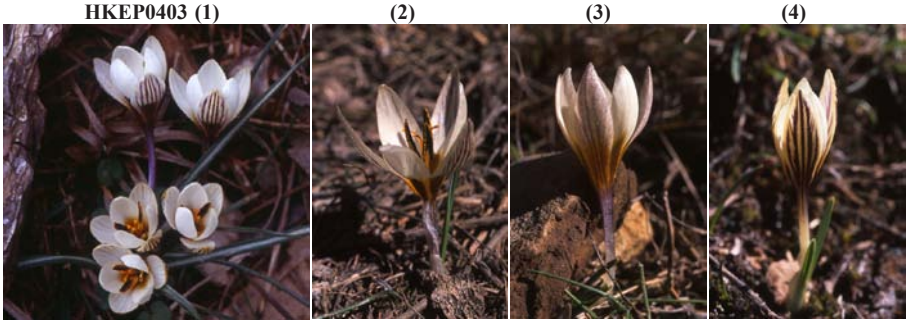
HKEP0401 (1) **(2)** **(3)** **(4)**

Colour plate 4

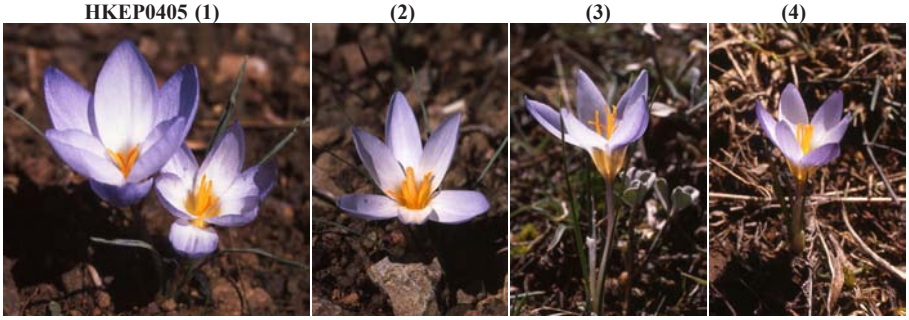
HKEP0402 (1) **(2)** **(3)** **(4)**



HKEP0403 (1) **(2)** **(3)** **(4)**



HKEP0405 (1) **(2)** **(3)** **(4)**



HKEP0409 (1) **(2)** **(3)** **(4)**

Colour plate 5