The Genus *Crocus* (Liliiflorae, Iridaceae): Taxonomical Problems and How to Determine a Species Nowadays?

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Abstract: Due to results of molecular analyses the genus *Crocus* grew from about 140 to more than 200 taxa in the last two decades. Many new taxa have a similar appearance because of their origin history which leads, together with the enormous infra-specific variability, often to extreme difficulties of their determination. Except for species with unique characters which can be recognised immediately without aids there are no actual determination keys for most of the new species. As the complexity and taxonomical problems of the genus grew according to the number of newly described species we present, compare, and discuss differently obtained data sets of different selected species. We also present facts in order to understand the complex situation in the genus better. Along with this we give detailed recommendations how to determine a *Crocus* timely, including a critical look at recently published *Crocus* determinations.

Zusammenfassung: Aufgrund der Ergebnisse molekularer Techniken wuchs die Gattung *Crocus* in den letzten beiden Jahrzehnten von ca. 140 auf über 200 Taxa an. Viele davon sind aufgrund ihrer Entstehungsgeschichte sehr ähnlich, was zusammen mit ihrer enormen infra-spezifischen Variabilität zu extremen Schwierigkeiten bei ihrer Bestimmung führen kann. Ausgenommen von solchen Arten, die einzigartige Merkmale aufweisen und sofort ohne Hilfe bestimmbar sind, gibt es derzeit für die meisten neuen Arten keine Bestimmungsschlüssel. Da die Komplexität und die taxonomischen Probleme der Gattung mit der Anzahl neuer Arten angestiegen sind, präsentieren, vergleichen und diskutieren wir unterschiedlich erhaltene Datensätze ausgewählter neu beschriebener Arten. Wir präsentieren Fakten, die zu einem besseren Verständnis der komplexen Situation in der Gattung führen sollen. Darüber hinaus werden neuere *Crocus* – Beschreibungen anderer Autoren kritisch beleuchtet und es werden detaillierte Empfehlungen gegeben, wie man zeitgemäß einen Krokus bestimmen kann.

Key words: *Crocus*, determination, taxonomy

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INTRODUCTION

Early records of crocuses as garden plants date back to the middle of the 16th century. In the "Generall Historie of Plants gathered by John Gerard", in 1597 only eleven forms of *Crocus* are figured and described. From then on a number of more or less important and differently based monographs appeared, always with an increased number of discovered species. Also, the taxonomical treatment of the taxa in all these works was different.

Going back to the first important early work of Sabine (1830) one is surprised that he only had eyes for the plant, entirely independent on their geographical origin and distribution. In addition Sabine differentiated nearly allied taxa into varieties. The name of the variety he placed directly behind the species name, like *C. sulphureus striatus* or *C. sulphureus concolor* which, of course, cannot be accepted anymore.

In the first real monograph of the genus Herbert (1847) divided a species into numbered and named varieties and sub-varieties, e.g. like *C. vernus* var.1 *Communis* subvar. 1. *Obovatus* justified by morphological and phenotypic characteristics which were, at that time, already rather subtle. New with him was the recognition of origin and geographical distribution of a crocus.

Maw (1886) in his comprehensive monograph taxonomically followed Herbert mainly in this way except for the use of the term "sub-variety", and he gave the geographical distribution of

a taxon an even more important role than Herbert. He introduced each chapter for a species by a copper engraving of the nearest town or landscape where the species occurs.

In the latest revision of the genus by Mathew (1982) the term "subspecies" was brought into the taxonomy of the genus for the first time. In his view many of the species, like e.g. *C. kotschyanus*, *C. pallasii*, *C. cancellatus* or *C. biflorus* were supposed to have vast distributions. Similar but different "forms" known of those species, separated by larger geographical distances, were seen by him as subspecies. So, besides the geographical distance only (a) minor difference(s) between a species and its subspecies was the basis for this kind of treatment. However, subspecies of *C. biflorus* e. g. occur in several series in the recent DNA-based phylogeny (Harpke et al. 2013) which clearly shows that their subspecies status is incorrect and cannot be maintained any longer (Harpke et al. 2016).

Generally, within the field of taxonomy DNA-based data became more and more important in the last decades. Numerous taxonomical classifications were revised as the existing concepts did not reflect the true phylogenetic relationships. Also, our insights gained from molecular phylogenetic investigations resulted in a new understanding of speciation and taxa. It was shown that past species concepts like the biological species concept are not applicable any more (Harrison and Larson 2014).

Molecular analyses also changed the taxonomical situation in the genus *Crocus* dramatically (e.g., Harpke et al. 2013, 2014, 2015; Petersen et al. 2008). The ancient origin of section *Nudiscapus* which was most probably by early hybridization of a (not traceable) species of section *Crocus* with one or more species of section *Nudiscapus* created a great number of new species which were neglected or could not be seen as those in former times, although some of them were recognized as distinct variants or subspecies. Besides the genetic differentiation and improved morphological characterization also the origin of the species plays now a much more important role than ever before, as many species are known now to be confined to rather restricted areas. Actually all these facts have to be considered now when determining a crocus.

In a similar way as the taxonomical treatment changed in time also the requirements for the description of a crocus changed. In the very early history of the genus when only 11 different taxa were known it was easy to differentiate these even with only few significant characters (colour, striping, corm tunic, flowering time, etc.). Later on with an increased number of taxa (Sabine, 1830) Herbert, 1847, Maw, 1886) more parameters were needed for separation and a division of the genus into sections and series containing species of similar characters had to be introduced (Herbert, 1847; Maw, 1886). The number of known taxa in the review of Mathew (1982) was about 140. Presently there are more than 200 known taxa but with the parameters used by Mathew in 1982 hardly all the recently described crocuses can be determined.

Generally speaking one can conclude that parallel to the continuously increasing number of discovered new species the complexity for their differentiation also increased. Molecular investigations showed that several single characters used to define taxonomical units within the genus were not suitable to separate species, e.g. like a reticulate corm tunic which is not confined to series *Reticulati* (Harpke et al. 2014; Kerndorff et al. 2015). The results of molecular methods revealed quite a new understanding of the genus being much more complex than recognized before. For new *Crocus* determinations adequate datasets were defined with many parameters especially suitable for *Crocus* determinations (Kerndorff et al. 2015). Future determinations including all the upcoming new species and definitions of new infra-generic units will be also dependent on how many taxonomically useful characters in the morphology of the genus can still be found.

How to determine a crocus

This question nowadays is often asked by cultivators, enthusiasts, professional gardeners or even botanists. As shown this task is not that easy anymore since Mathew published the latest revision of the genus in 1982. There are several reasons for this. At first there is the increasing number of species which seem to be often rather similar at a first glance. Especially in section *Nudiscapus* the situation is extremely complex as genetic and morphological analyses revealed (Harpke et al. 2013, Kerndorff et al. 2015). Secondly, this causes the extreme variability of crocus individuals concerning their overall appearances within a population of a species. Thirdly matters get even more complicated when looking at individuals of different species which might be very alike. Fourthly the definition of species borders is complicated in cases of hybridization. Clear evidence for ongoing hybridisation is, e.g. when two closely related species grow together in a locality with their intermediates. Such populations can appear as a very variable population of one species. It gets even more complicated in the case of introgression i.a. gene flow between two different species usually due to repeated hybridization and backcrossing. In such cases the determination of species boundaries can be challenging and require thorough investigations (Harrison and Larson 2014). Examples and evidences for such tricky situations in *Crocus* can be found in several series e.g. *Carpetani*, *Verni* (Harpke et al. 2015), and in the newly to be defined series *Sieberi* (Miljković et al. 2016).

The differentiation of species in the genus by molecular methods also revealed by far more detailed taxonomical and systematic results than this was possible for Mathew (1982), when only morphological and phenotypical parameters were seen as important at that time. It is, therefore, necessary to react with morphological and phenotypic descriptions of new species correlated to the genetic results. This means that slight but +/- constant morphological or phenotypical differences between taxa can signalize already different species. To be prepared for this situation in the future we presently work on the availability of more yet hidden or neglected characteristics of taxonomic value which can be found in many parameter-groups of the genus and are useful for identification/differentiation. In other genera nowadays also an increased number of characters are used in species descriptions. In *Gagea* for instance bulbs and bulbils of different developing states have to be considered for determination.

The situation is, admittedly, complex but solutions are available. It is clear that for a determination of a crocus a simple look at the flowers (especially from photographs of few individuals in a pot) in most cases will fail except in those where unique characteristics are present, e.g. like the peaky segment tips of *C. vallicola*. The genus offers few of these peculiar characte-

Tab. 1: Theoretical combinations of three characters each with two different values.

Species 1	throat bearded	filaments white	anthers 7 mm long
Species 2	throat bearded	filaments yellow	anthers 11 mm long
Species 3	throat glabrous	filaments white	anthers 11 mm long
Species 4	throat glabrous	filaments yellow	anthers 7 mm long

ristics which immediately guide to the species in question, the major part of the genus has, unfortunately, none. As a very useful substitute for unique characters different combinations of values or forms of several characters can serve. This is also applied in many other genera of different plant families. An example for *Crocus* (theoretical and simplified) is shown in Tab. 1.

In case four species are very similar in their overall appearance and cannot be distinguished by their flowers but own the following combinations of flower parameters (which have of course to be determined in the right way (explained by KERNDORFF et al. 2015) they are easy to distinguish because the combination of every species is distinct.

These different combinations of morphological and phenotypic similar or identical characters occur very often in the genus *Crocus*. In complicated cases these combinations can consist of many more parameters as shown in the example. This means, many taxa are or can be defined by different combinations of even the same values of taxonomical relevant parameters! Hence, the more parameters and their values are available, respectively considered in combinations, the easier it is to differentiate between the taxa. A welcome "side-effect" lies in the increasing probability of a right determination of a crocus taxon with the number of parameters used.

Unfortunately the things get more complex by the necessity to follow special rules for determining important continuous parameters and to distinguish between two cases of determination necessities. The first and most important case is when a new species has to be described. In the second one an enthusiast or gardener wants to determine a few cultivated crocuses in a pot or in the garden. The reason for separation of different determination necessities can be explained as follows.

Crocuses at their habitats seem to be under a "long-term influence" of the existing natural conditions in these areas and receive of course sufficient feeding for living and propagating. Edaphic factors are normally without significant changes at a locality, which means the amount of water and of available nutrients in the soil is more or less the same for the plants every year. Climatic factors, respectively weather conditions may change from year to year but this has mainly only influence on the flowering time. Contrary to that the growth-parameters (size, shape), and different appearance of many individuals are primarily dependent on the genetic potential of the population. This means that even in a permanent change of generations the population with all its (potential) morphological and phenotypic variants stays more or less constant in time. It is clear why without these facts a definition of a species would be useless. In any case, all factors together lead in most cases to a great but equilibrated variance of individuals of a crocus population at a locality.

In contrast to that cultivated plants have in general luxurious conditions. They are fed regularly, enemies are controlled, the substrate is artificially made of several beneficial ingredients, the water regime is controlled, etc. This treatment results in more or less equally strong plants. Genetically seen the plants which adopt best to the growing conditions with a grower are the survivors. This is especially true if plants are raised from seeds. Unfortunately every grower has different growing conditions concerning nutrients, time and amount of application, watering regime, etc., which has of course different effects on the continuous parameters of the plants. The cultivated crocuses of different growers are, therefore, not comparable in many of their morphological properties and measured values of them would be different with every grower, if measured.

It can be seen that individuals of cultivated plants have only slight differences concerning the continuous flower parameters and in several other parameters increased values (Tab. 2). With these luxurious individuals a clearly reduced spread (variance) of their measured values and a shift of the mean and median values are observable. In contrary to that plants randomly selected and measured at a locality have reduced values and a much wider range of these.

Determination differences between cultivated and wild plants

There are several kinds of *Crocus* determinations in recent literature with different results to the ones investigated by us. To quantify the effects of different kinds of determination we made several comparisons. Most important to us was to document the differences between the statistical procedures and their results we used during our extensive work on *Crocus* populations between 1997 and 2013 (KERNDORFF, H. & PASCHE, E., 1997, 1998, 2003, 2004a, 2004b, 2006, 20011, 2012, 2013) and determinations made by using cultivated plants only. This applies for example to our recent investigation, documented in Tab. 2 where we compared *C. reinhardii* (Iran), recently described by RUKŠĀNS (2015) from pot-cultivated plants ("ex horto") with the results of our randomly selected specimens at the type locality by means of measurements of taxonomically important parameters of a statistically relevant number of individuals. The results show very clearly that all measurements from pot-cultivated specimens are very different to the ones from field studies of wild plants. In the "International Code of Nomenclature for cultivated plants" (2009) it is stated e.g. in chapter 20.2 that…."Plants of a species or lower taxon brought into cultivation may not demonstrate the range of variation associated with that taxon in the wild". The reduced variance of parameters for plants brought into cultivation is documented in Tab. 2. The whole comparison shows that in some genera like *Crocus* a description of new species from

Tab. 2: Comparison of differently obtained data sets for *C. reinhardii*.

	results of measurements of some description parameters of a few specimens "ex horto" from Rukšāns (numbers of investigated specimens are not mentioned!)	results of the same description parameters of ≥ 20 specimens measured at type locality by us
leaves		
number	(5)7(9) n = ?	3-5.5-7 (n = 46)
form	not determined	mainly linear
width	2.5-3 mm n = ?	1.5-1.8-2 mm (n = 22)
white stripe	1/5 to 1/2 of leaf-diameter n = ?	normal (1/3) to > 1/3 (n = 20)
hair	not determined	none
ribs underneath	3 (on both sides of keel)	(1)2(3) (= mainly two, rarely 1 or 3 on both sides of keel)
filaments		
length	4-6 mm, average? n = ?	4-5.5-7 mm n = 25
anthers		
length	8-10 mm, average? n = ?	7-10.4-13 mm n = 25
style		
length of branches	not determined	2.5-5.2-7.5 mm n=33
style-length according to stamen	not determined	100% equal (5) to longer (25), n = 30
segments		
length outer	25-30 mm, average? n = ?	21-27 (22.8) mm n = 30
width outer	6-9 mm, average? n = ?	7-11 (8.4) mm n = 27
length inner	23-29 mm, average? n = ?	18-25 (21.9) mm n = 28
width inner	7-9 mm, average? n = ?	6-12 (7.7) mm n = 28
segment-proportion	not determined	2.7

cultivated specimens and descriptions of wild specimens are quite different and cannot be used together in determination keys. Another example, where the measured parameters in the original description have a reduced variance in comparison to own investigations is *C. rhodensis* (Tab. 3).

Unfortunately, there has been a boom of new crocus descriptions and publications of few cultivated specimens only as well as announcements of forthcoming news recently. But it is regrettable that many of these new descriptions have been based more or less on traditional and long-standing procedures and methods, without further investigations by today's technical possibilities and opportunities e. g., molecular and karylogical analyses. Many of the newly described species were defined lacking several important parameters as can be seen in Tabs. 2, 3 and 4. If they are real new species like in case of *C. duncanii* (Tab. 4) will show forthcoming time.

Due to a missing molecular analysis the majority of the mentioned new species have no place in the phylogeny of the genus for the time being as their taxonomical status is uncertain and their relationship to other crocuses not determined. Nearest relatives of them are therefore unknown.

Importance of the number of investigated individuals at type locality

As an example for this case the comparison of the newly described *C. duncanii* Rukšāns from Portugal and the two different measurement sets made. The data in the first column of Tab. 4 originated from RUKŠĀNS (2016) who investigated 17 individuals of the type population (seven for the neck). The data of column two resulted from us measuring 28 individuals of the same population (19 for no. of leaves).

Tab. 3: Comparison of obtained data sets of continuous flower parameters of *C. rhodensis*.

	results of individuals measured by Rukšāns at type locality	results of 20-22 individuals measured by us at type locality
filaments		
length	4-5 mm n = ?	4-6.2-9 mm n = 21
anthers		
length	9-10 (12) mm n = ?	8-9.8-13 mm n = 22
style		
length of branches	not measured	3-6-11.5 mm n = 22
style-length according to stamen	not measured	91% shorter (14) to equal (6) and 9 % longer (2) n = 22
segments		
length outer	13-19-29 mm n = ?	19-23.9-28 mm n = 20
width outer	(4) 5-6 (8) mm n = ?	6-7.9-9 mm n = 20
length inner	not measured	18-22.9-24 mm n = 20
width inner	(5) 6-7 (9) mm n = ?	8-9.2-11 mm n = 20
segment-proportion	not determined	3.0

The differences in the data sets are obvious and the results of Rukšāns have a comparably low variation as of the data sets in Tabs. 2 and 3. Only the number of leaves is almost congruent but this is not a surprise as 84% of the plants measured by us had only two leaves. The comparison of the other parameters (if present) show large discrepancies which clearly indicates that 17 (7) individuals even investigated of type material are not sufficient to characterise a population correctly. This fact also has to be recognised by us as for one of our newly described species (KERNDORFF et al. 2013a) only of five specimens the segment sizes could be measured. This has to be corrected for a future determination key otherwise we will not use these data.

Concerning *C. duncanii* there are some more problems which must be mentioned here. A clear sign of being a different species compared to *C. carpetanus* is allegedly its long neck. In the photograph of the article (RUKŠĀNS, 2016) only three plants (of seven) with this long neck are shown but nothing is told about the frequency of its occurrence, meaning all the plants have this neck. According to our experience more than 50% (16 of 28) of the plants we investigated had a "normal" neck, typical for *C. carpetanus*. So it is not surprising that we could also find a specimen without extended neck in the Munich herbarium labelled as *C. carpetanus* from the Serra de São Mamede in Portugal (Fig. 1).

It is easy to see that this feature is far away from being ideal to distinguish between the "allegedly" *C. duncanii* and *C. carpetanus*. Unfortunately no other parameters were compared of "*C. duncanii"* and *C. carpetanus* (from type locality!) to look for further differences. As no molecular investigation was made of *C. duncanii* it is even possible that it might not be a new species but *C. carpetanus*. Taken into account that past descriptions of crocuses were often based only on few individuals (e.g. *C. adanensis*) a representative number of individuals of the newly to be described species should be investigated and also a comparison with the locus classicus plants of the allegedly different species (*C. carpetanus*) should be done.

The above mentioned case of *C. duncanii* might be further complicated by unclear species boundaries due to hybridization and introgression. Latter species is likely a polyploid. This is indicated by its chromosome number, which is the second highest within the whole genus (2n = 64). The presence of several distinct copies of the nuclear ribosomal ITS region (see HARPKE et al. 2013) furthermore indicates that hybridization or even introgression has played a role in the "*C. carpetanus* complex". Our material available of the Iberian Peninsula concerning series *Carpetani* gives rise to these assumptions. The unusual high variance of many parameters we could measure and observe investigating "*C. duncanii"* at its type locality (Tab. 4) is a further strong hint in this direction.

The other parameter which is used by Rukšāns to separate *C. carpetanus* and C. *duncanii* is a different ecology of their growing localities. Whereas *C. duncanii* is assumed to grow only in pine forests, *C. carpetanus* is said to grow in more open, deciduous forests, which is not proofed because a comparison with only one locality in the Serra da Estrela (Portugal) is insufficient. At least a comparison with the ecology of the type locality of *C. carpetanus* in the Sierra de Guadarrama (Spain) should have been made. From our experience *C. carpetanus* is primarily a plant of higher mountain regions above the tree-line. Finally we cannot agree with the opinion of Rukšāns that species of series *Carpetani* belong to the most primitive ones in the genus because of the special leaf-shape (transversal dissected) which is said by him to be similar to the ones of the genus *Romulea*. Neither the age of the genus *Romulea* nor of the genus *Crocus* is known. What is known is that crocus leaves are very different compared to the ones of *Romulea* and, in contrary to Rukšāns`s opinion, Brian Mathew states in a personal communication that for him the most "primitive" crocus is represented by *C. boulosii.*

Tab. 4: Comparison of differently obtained data sets for *C. duncanii.*

	results of some description parameters of 17 (7 for the neck) specimens of the type locality made by Rukšāns	results of the same description parameters of 28 specimens measured at type locality by us
leaves		
number	2-3	2-2.2-3 n = 19
form	not determined	inear, erect, channelled
width	not determined	3-4 mm
white stripe	not determined	1/2-1/3 of leaf-diameter
hair	ciliated on margin	strongly ciliated at margins
ribs underneath	none	none
filaments		
length	5-7 mm	2.5-5.3-9 mm
anthers		
length	8-12	7.5-11-14 mm
style		
length of branches	up to 5 mm	2-4.2-9 mm
style-length according to stamen	not determined	29% longer (8); 29% equal (8), 42% shorter (12)
segments		
length outer	not measured	24-34-42 mm
width outer	not measured	7-9-13 mm
length inner	not measured	25.5-28-38 mm
width inner	not measured	8-11.2-14.5 mm
segment-proportion		
outer segments	2.7-3.2 (range not specified)	3.7
inner segments	not measured	2.5

To summarize the whole situation and as a concrete example the following can be concluded. In case of *C. duncanii* it is clearly visible that determinations and characterizations of new *Crocus* species with insufficient material sets, even from the type locality, can be critical. Being aware of the potential problems, like unclear species boundaries and overseen variability, thorough morphological investigations as well as molecular analyses should be applied together in modern taxonomy to define new species.

The species concept within *Crocus*

Molecular investigations showed that subspecies represent independent lineages in *Crocus,* often even having different chromosome numbers. As a consequence, most new taxa were described at species rank (e.g. Miljkovic et al., 2016, Erol et al., 2012, Peruzzi & Carta, 2011, Rukšāns 2016, Kerndorff et al. 2014) or subspecies were raised to species rank (e.g. Harpke et al. 2014, 2015, 2016). However, in some cases the original subspecies description was based on only one or two most significant differences to the species. For all other characteristics of the subspecies it is referred to the species description. In case such an incomplete determination is left for the species-transformed taxon there might be problems when they have more differences not recognised, evaluated, or mentioned before.

Not only subspecies represent different independent evolutionary lineages. We also could show, that there are different new species hidden under one name (e.g., Harpke et al. 2014). The most extreme case probably is "*C. chrysanthus*". It was clearly shown that genetically well differentiated "species" are hidden under this name and often closer related to non-yellow flowering crocuses than to each other (e.g., Petersen et al. 2008; Harpke et al. 2013, Kerndorff et al., 2014). Moreover, crocuses determined as "*C. chrysanthus*" possess different chromosome numbers suggesting that there are strong crossing barriers between

Fig. 1: Herbarium sheet of „*C. duncanii*" archived as *C. carpetanus* in the Munich herbarium.

them. In this context descriptions of "*C. chrysanthus*" subspecies are not timely. In CANDAN & ÖZHATAY (2013), even worse, the alleged subspecies are split up into variants of its own which never happened before in the history of the genus and is contradictory to current developments in plant taxonomy and to what molecular results just helped us to understand (PETERSEN et al. 2008; HARPKE et al., 2013, 2016).

Crocus determinations which allocate new species into a colour-based classification of groups or "complexes" without clarifying their relationships are critical. Species e. g. like *C. henrikii*, *C. muglaensis, C. uschakensis*, and *C. gembosii* were newly described by RUKŠĀNS and determined to belong to a "*C. chrysanthus* – complex" (RUKŠĀNS 2014), without any proof being related to *C. chrysanthus*, except by their yellow colour and an annulate corm tunic! However, the "*C. chrysanthus* complex" sensu RUKŠĀNS is not a monophyletic unit.

A similar situation exists for *C. biflorus* and its former subspecies. Our research of the last 20 years clarified that *C. biflorus* is confined to Italy with only few near relatives outside of Italy (HARPKE et al. 2016). Similarly alleged *C. chrysanthus* "relatives" can be genetically far away from this one and found in different series together with former subspecies of *C. biflorus*, even in newly described ones (series *Isauri,* KERNDORFF et al. 2014), or in upcoming ones (series *Adami,* in preparation), which will include the yellow *C. almehensis*, formerly thought to be a relative of *C. chrysanthus* (MATHEW, 1982). All the yellow species, nowadays thought to belong to "*C. chrysanthus*" will be most probably distributed all over series in section *Nudiscapus*.

To get a basis for the definition of what is "*C. chrysanthus*" the type is needed for molecular comparisons. Unfortunately the type of *C. chrysanthus* is not specified in detail and needs a neotypification. In the initial publication in Edward's Bot. Reg., vol. 29 (1843) is mentioned on page 83: "*C. chrysanthus*; pro Prope Byzantium lege In Roumelia". The specimen at Kew of Frivaldsky is also labelled to be found "In Roumelia". "Rumelia" was, at that time, an autonomous territory in the Ottoman Empire. It included the provinces of Thrace, Macedonia and Moesia, today's Bulgaria and Turkish Thrace, bounded to the north by the rivers Sava and Danube, west by the Adriatic coast, and south by the Morea. Much later the name Rumelia was ultimately applied to a province composed of central Albania and north-western Macedonia, with Bitola for its chief town. The area at the time of the first publication of *C. chrysanthus* was much too large to pick out a special place as in all of the provinces of Rumelia "*C. chrysanthus*" can be found in profusion. The "type-declared" material of *C. chrysanthus* from Mt. Falakro in Greece recently

used by Rukšāns for a discrimination of newly described species is, therefore, defined rather accidently (Rukšāns, 2014).

Finally, some words in case enthusiasts want to determine their cultivated crocuses in a pot. As demonstrated this it is in many cases not possible because 1) the results of measurements would be for every cultivator different and 2) would not reveal the average properties of a species necessary for determination as shown in all our comparisons. Measures of few cultivated crocuses are not suitable to determine a crocus with a key made from representative type material.

CONCLUSIONS

Regarding the presented facts it should be clear, why a representative statistical assessment of the continuous flower parameters of a crocus population is necessary for a determination of a new species. The following points should be recognised:

- Most important is a random selection of individuals at the type locality for measurements and counting without any preferences, like special colour forms, strong plants, etc.
- Continuously varying parameters with high variance should be measured at least of 20 individuals, better are 30-35 individuals of these selections. High variance have, in general, the number of leaves (only to be counted of flowering specimens!), segment sizes, length of anthers, length of filaments, and length of style-branches. If multivariate statistical procedures are necessary mean or median values should be determined of these. Integrated two span lengths e.g. like (4)5-6(8) without a mean value are not suitable for this purpose. Very variable are also style-lengths according to stamen which should be counted for equal, longer and shorter.
- The measured values of these parameters are only suitable for determination keys and statistical procedures when they originate in the mentioned way solely of a representative number of specimens of the type locality.
- Parameters with low variance, like the form and the diameter of the leaves, dimension of the white stripe, and the ribs underneath the leaves can be measured of a lower number (5-10) but also of randomly selected specimens from type locality.
- A newly described species should be characterised as far as possible using as many parameters as possible (combinations of the same parameters or parameter values might be dissimilar and useful in species separation!).
- Photographs of new species should only show typical representatives of it and not special colour variations which might occur only once among thousand individuals in a population.
- As species of different series are preferably characterised with an individually compiled set of parameters a selection of adequate parameters for individual series can be composed out of the parameter list provided by Kerndorff et al. (2015) because several parameters in a certain species group or series might be invariable which makes them useless for separation!
- A morphological and phenotypic comparison of a newly defined species with the nearest relative(s) is necessary to compare and recognise their differences. Species determinations without these connections to (a) near relative(s) are useless as species are without a place in the genus. In cases where the closest relative is not sufficiently described, the type location is unknown and/or no type specimen exists, epi- and neotypes, respectively, have to be defined.
- Molecular analysis should be conducted to confirm the taxonomical status, but also to identify the affiliation of a new species.
- Values originated from measurements of cultivated plants cannot be joined in one key with wild material as their datasets are quite different and do not represent the characters of the species. They also cannot be used in statistical treatments.
- More important than in former times are the geographical information and provenance of a species, as several species are rare and have confined distribution areas.
- But, it was never more important to respect and protect nature and environment. This means that exactly defined localities or even coordinates should be strictly avoided and never be published because this leads in 3-5 years to a complete extinction of the crocuses at the given locality. The authors have several proofs of this fact as can be seen, e.g. with the type localities of *C. mathewii, C, wattiorum* and *C. roseoviolaceus*. In case of *C. istanbulensis* it is even worse because watch personal and a fence around its single known locality are needed to prevent this crocus from extinction. We think that this method should remain an exception. It could be greatly avoided in future by renouncing to publish exact localities.
- In series where hybridisation and introgression are common, species boundaries have to be defined. This is only possible by thorough morphological and molecular analysis prior to a description of a new taxon. Otherwise it can easily end in wrong new species descriptions

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