BIOSYSTEMATICS OF INDIAN PLANTS

II. The Problem of *Centaurium pulchellum* Complex

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ABSTRACT

The genus *Centaurium* is represented in Amritsar District by three types of plants, distinguishable chiefly on the basis of flower-colour. The three races possess different chromosome numbers: white, $n = 18$; purple, $n = 27$; and cosmos, $n = 28$.

A new basic number, 9, has been found to exist in the genus.

The white-flowered ($4x$) and purple-flowered ($6x$) races are, in all probability, alloploid in character. The exact nature of the cosmos-flowered race ($n = 28$), however, is not known at present. It may either be an octoploid on the basic number 7, or a secondary polyploid from the hexaploid of $x = 9$ ($2n = 56 = 6x + 2 = 54 = 2$). All the three colour-forms have been referred to *E. ramosissima* Pers. now called *C. pulchellum* (Sw.) Druce by most taxonomists. However, the present investigation reveals that none of the races conforms strictly to this or to any other Indian species described by Hooker (1883). It appears that all or most of these species have arisen after extensive interspecific hybridization, which has resulted in a complete reticulation of characters. Furthermore, *C. pulchellum* in itself is a complex with $n = 10, 18, 20, 27, 28$. In order to have a clear picture of the relationships of the Indian forms *vis-a-vis* their European counterparts, it is essential to conduct a well-planned biosystematic investigation based on samples from the entire range.

The taxonomic tangle and synonymy needs to be clarified by reference to the type material.

THE genus *Centaurium* Hill (Syn. *Erythraea* Borck.) is represented in India by *Erythraea ramosissima* Pers., *E. roxburghii*. G. Don, *E. babylonica* Griseb. and *E. meyeri* Bunge. (Hooker, 1883). All the four species, as is evident from the description given in the *Flora of British India* (Hooker, 1883), are very closely related. As a result, their taxonomic boundaries have been a

matter of controversy among taxonomists. Some authors as Hooker (*loc. cit.*, p. 101) significantly stated, refer all these species as varieties of *E. ramosissima*, while others, including Hooker, consider them as distinct species.

Out of the above four species *E. ramosissima* Pers. now generally known as *C. pulchellum* (Sw.) Druce* occurs in the plains of Punjab (India). The description of the species given by Kashyap and Joshi (1936) embraces all the three forms discovered by the present writers in the Amritsar District. These forms are distinguishable on the basis of flower colour. Following the standards given by Maerz and Paul (1930), the three forms may be referred to as white, purple and cosmos (a shade of pink). The plants are not only true breeding for the flower colour, but associated with these colours are some distinct morphological characteristics.

In view of the cytological heterogeneity already reported in *C. pulchellum* (Table II), and the fact that the three colour races (white, purple and cosmos) discussed here are distinct cytologically ($n = 18$, 27 and 28 respectively; Khoshoo, Khushu and Singh, 1961), this collective species is a worthwhile subject for a cytotaxonomic study.

Observations

As indicated earlier, the three races met with in Amritsar are recognizable chiefly on the basis of the colour of their flowers. A comparative morphological analysis is given in Table I. Some important features have, however, been mentioned below.

All the three races occur in exactly the same kind of habitat, *i.e.*, in cultivated fields and on the banks of a drain around Amritsar. Often the three occur together. However, the purple-flowered race is more commonly found than the other two. The voucher material is deposited in the Herbarium, Panjab University, Chandigarh.

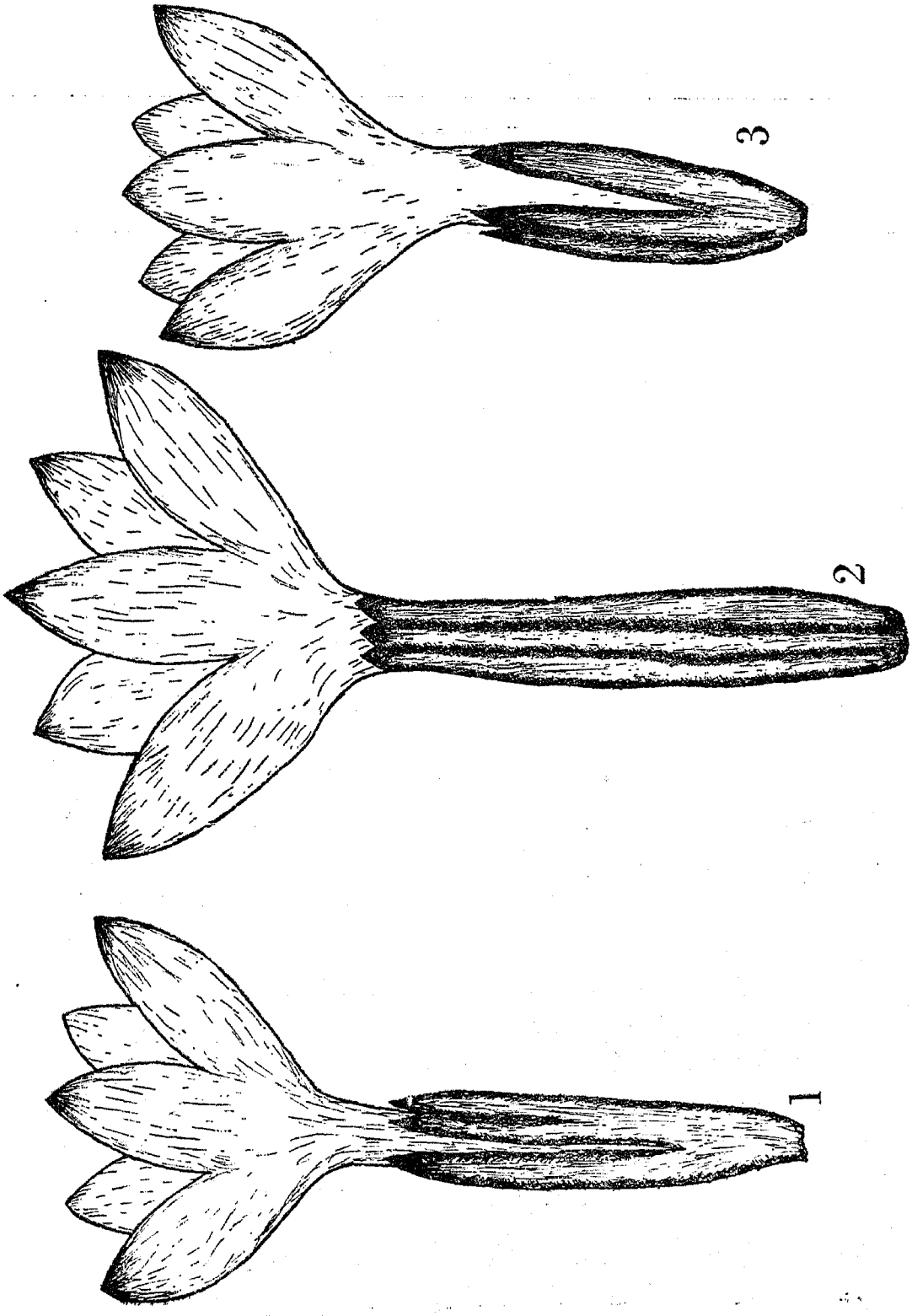
White-Flowered Race ($n = 18$)

Height 3·5–19·2 cm., stem quadrangular, sparsely or very leafy; cymes repeatedly biparous, fastigiate or wide; flowers in clusters, sub-sessile or pedicellate, bracts more or less prominent, corolla-tube slightly longer than the calyx, lobes white (Plate III, Fig. 1; Text-Fig. 1).

* Some treat it as *C. ramosissimum* Druce (*see* Maheshwari, 1963), while others treat it equivalent to *E. pulchellum* (Sw.) Druce (*see* Zeltner, 1961, Druce, 1932, etc.). The latter view is followed here. At any rate, it indicates the existing taxonomic confusion and the need for critical work.

TABLE I. *Chief morphological features of the races*

Character	White (n=18) (Plate III, Text-Fig. 1; Figs. 1, 4)	Purple (n=27) (Plate III, Text-Fig. 2; Figs. 2, 5)	Cosmos (n=28) (Plate III, Fig. 3; Text-Figs. 3, 6, 7)
Stem ..	3·5–19·2 cm., quadrangular, ridges not prominent	5·1–34·2 cm., quardrangular, ridges prominent	4·5–23·8 cm., quadrangular; ridges not prominent, undivided below
Branching pattern ..	1–2 at each node, arising from all over, or from only upper half of main stem. Some forms are dwarf and bushy, with a short main stem	Same as white	1–2 at each node, arising laxly from upper half of main stem
Colour of stem ..	Pale-green or green	do.	Ash-green
Lamina—Length × breadth (cm.)	0·55–2·5 × 0·35–1·2	0·9–3·5 × 0·5–1·8	1·1–2·3 × 0·35–0·75
Inflorescence ..	Cymes repeatedly biparous, fastigiate or wide, flowers in clusters	Cymes repeatedly biparous, fastigiate, flowers in clusters	Cymes repeatedly but always widely biparous, flowers not in clusters
Flower ..	Sub-sessile or pedicellate, pedicel 1–6 mm. long; bracts more or less prominent	Sub-sessile or pedicellate, pedicel 1–9 mm. long; bracts prominent	Pedicellate, pedicel 0·45–1·2 cm. long; bracts not prominent
Calyx ..	Slightly shorter than the corolla-tube	About as long as the corolla-tube	Shorter than the corolla-tube
Corolla ..	White, sometimes with a shade of pink	Purple with white throat	Cosmos (pink)
Ovary—length × thickness (mm.)	4·5–6·25 × 0·6–0·9	5·5–7·5 × 0·8–0·9	5–6 × 1
Style—length × thickness (mm.)	2 × 0·15–0·2	2·75–3·5 × 0·2–0·24	1·25–1·75 × 0·15–0·23
Pedicel in fruit length (mm.)	1–3–6	1–3·5–4·5–10	5–15
Surface of fruit ..	Ridged, ridges prominent	Ridged, ridges most prominent	Ridged, ridges not prominent
Diameter of pollen μ	17–30	20–28	24–32
Diameter of seeds μ ..	167–192–218	192–218–244	141–179–192



TEXT-FIGS. 1–3. Flowers of White (Fig. 1), Purple (Fig. 2) and Cosmos (Fig. 3) flowered races, ×1.

TABLE II

Chromosome Number in Centaurium *species*

Species	Chromosome Number		Author
	n	*2n*	
Centaurium ($x = 9, 10, 11$) *chloodes* Brot.	20	..	Zeltner, 1961, 1962.
grandiflorum (Pers.) Ronn.	10	20	Zeltner, 1962.
majus (Hoff. and Link) Ronn.	..	20	Zeltner, 1963.
maritimum (L.) Fritsch.	10	20	Zeltner, 1961, 1963.
minus Moench.	20	40	Zeltner, 1962.
	..	20	Zeltner, 1963.
pulchellum (Sw.) Druce	18	..	Khoshoo *et al.*, 1961.
	27	...	Khoshoo *et al.*, 1961.
	28	...	Khoshoo *et al.*, 1961.
	10	20	Zeltner, 1961, 1962.
	20	40	
(sensu stricto)	18	36	Zeltner, 1962, 1963.
spicatum (L.) Fritsch	11	22	Zeltner, 1961, 1962.
tenuiflorum (Hoff. and Link.) Fritsch	10	20	Zeltner, 1963.
vulgare Rafn.	20	...	Zeltner, 1962.

Eighteen bivalents were counted at metaphase-I (Text-Fig. 4). No multivalent formation was observed. The bivalents disjunct normally at anaphase-I and no laggards are left behind. Further course of meiosis is regular, resulting in normal tetrads. Pollen is well-filled and stainable.

PURPLE-FLOWERED RACE ($n = 27$)

Height 5·1–34·2 cm., stem quadrangular, ridges prominent; sparsely or very leafy; cymes repeatedly biparous, fastigiate; flowers in clusters, sub-sessile or pedicellate, bracts prominent; corolla-tube about as long as the calyx, lobes purple with a white spot at the base (Plate III, Fig. 2; Text-Fig. 2)

Meiosis in the pollen mother-cells is perfectly normal and twenty-seven bivalents have been persistently counted at metaphase-I (Text-Fig. 4). About 85% pollen is stainable.

COSMOS-FLOWERED RACE ($n = 28$)

Height 4·5–23·8 cm., stem feebly quadranuglar, ridges almost imperceptible, undivided below; cymes repeatedly but widely biparour; flowers not in clusters, pedicellate, bracts not prominent; corolla-tube longer than calyx, lobes cosmos (pink) (Plate III, Text-Fig. 3; Fig. 3).

Twenty-eight bivalents were clearly counted at diakinesis (Text-Fig. 6) and metaphase-I (Text-Fig. 7). These disjunct normally at anaphase-I. Futher course of meiosis is regular and normal tetrads are formed. Pollen is stainable and seeds are well-filled.

TEXT-FIGS. 4–7. Chromosomes from pmc of White ($n = 18$, Fig. 4), Purple ($n = 27$, Fig. 5) and Cosmos ($n = 28$, Figs. 6–7), ×2,600.

DISCUSSION

Nature of polyploidy.—As may be seen from the foregoing account (Table I) the races within this complex possess some distinctive morphological features, both quantitative and qualitative in character. These differences are correlated with the different chromosome numbers met with in the complex.

The white ($n = 18$) and the purple ($n = 27$) forms appear to be based on the basic number 9, and are, therefore, tetraploid and hexaploid respectively. Furthermore, no multivalent formation was observed either in the tetraploid or hexaploid. Meiosis is perfectly normal in both these races and results in well-filled and stainable pollen. Seeds are 100% viable. All these features suggest that both the tetraploid and hexaploid are perfectly diploidized and are, in all probability, alloploid in character.

It is, however, rather difficult to determine the exact nature of the cosmos-flowered race with $n = 28$. Two possibilities about its probable origin exist. One is that it might be an octoploid, originated from the basic number 7. If all the three forms belong to one taxonomic species, then it is dibasic in India ($x = 7$ and 9). It is also dibasic in Europe ($x = 9$ and 10). The other, but perhaps less convincing, possibility would be that the cosmos race has also arisen from the basic number 9, through addition of two chromosomes to the hexaploid complement ($2n = 56 = 6x + 2$). In this sense, it would be called a secondary polyploid (Darlington, 1956).

When the above results are considered together with the work of Zeltner (1961–63), it becomes apparent that the species is a complex of 5 races with $n = 10$, 18, 20, 27, 28 (*cf.* Table II). The chromosome numbers ($n = 17$, 19, 21) reported doubtfully by earlier workers (Zeltner, 1961) have been left out of consideration. However, according to Zeltner (1963) *C. pulchellum* (sensu stricto) possesses $n = 18$, a number reported by us in 1961 (Khoshoo *et al.*). In the absence of a biosystematic investigation, it is unwise to discuss this dysploid-euploid series. The genus as a whole is *at least* tribasic ($x = 9$, 10, 11).

Taxonomic Considerations.—Following *Flora of British India* (Hooker, 1883) and *Lahore District Flora* (Kashyap and Joshi, 1936), the three races from Amritsar (hardly 55 km. from Lahore) fall within the description of *E. ramosissima* Pers. After the merger of the genus *Erythraea* in *Centaurium*, the species *E. ramosissima* Pers. seems to have been treated in two ways. While some treat it as *C. ramosissimum* Druce (Maheshwari, 1963), others include it in *C. pulchellum* (Sw.) Druce (Druce, 1932; Zeltner, 1961). If we go by the latter view, then *C. pulchellum* is a complex of about five cytological races (Table II). In order to have a clear-cut picture of the situation, it is essential to conduct a critical biosystematic study on the various races. After establishing the relationships among the races, the taxonomic tangle and synonymy can be clarified only by reference to the type material. Furthermore, the remark of Hooker that this Punjab plant is not exactly the type of *E. ramosissima* offers an important pointer in this direction.

Some authors are of the opinion that other Indian species of the genus are "varieties to *E. ramosissima*" (Hooker, 1883, p. 101). Therefore an attempt was made to compare the morphological features of the three races with one another as well as with the four species described by Hooker (1883). Two significant points were brought out by this study.

Firstly, no race conforms strictly to any of the four Indian species, as described by Hooker. In fact, the races overshoot the specific boundaries and share the characters, and even the distinguishing features of one or more species, thus reducing the importance of the characters, as of taxonomic value, on which Hooker based the four species. The tetraploid resembles *E. meyeri* in possessing white flowers but differs from it in most of the other distinguishing features, such as the branching of the stem, the type of inflorescence and the length of the pedicel and, above all, in distributional range. In these characters it nearly resembles the description of *E. ramosissima*. The hexaploid resembles *E. ramosissima* in being very leafy and possessing flowers in clusters, but differs from it in having sub-sessile or even pedicellate flowers (in *ramosissima* the flowers are described as sessile) and quadrangular stem. In this character, it resembles *E. babylonica*. Lastly, the cosmos-flowered race resembles *E. roxburghii* in a few important characters, like the type of inflorescence, the length of the corolla-tube in relation to the calyx, etc.; however, the resemblance is not complete.

Secondly, a comparison of the races with one another reveals a number of morphological differences, some of which are qualitative, while others are only quantitative (Table I) in nature. The most significant difference is in the colour of the flower (white in the tetraploid, purple in hexaploid and cosmos in the third race with $n = 28$). With the help of this character, supplemented by other relatively minor ones, it is, in fact, quite easy to distinguish the three forms in nature.

All the three forms co-exist in exactly the same kind of habitat. In spite of this, no natural hybrids are found. This shows that the races are distinct, well-established entities, separated by some effective isolating barriers.

In conclusion, it must again be emphasized that, in spite of the present study, the taxonomic position of this peculiar dibasic species-complex is in no way in a vivid state. Specific boundaries, as defined by Hooker, have been completely lost, at least in the ployploids, and reticulation of character has taken place. One cannot, however, help confessing to a feeling that the specific distinctions, given by Hooker, might be existing in the species at the diploid level. If this be the case, then it would be logical to say that extensive

interspecific hybridizations, followed by polyploidy have taken place, involving all the four species, described by Hooker. This assumption can, however, only be accepted or rejected if and when the diploids of these species are discovered and identified as definite species.

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