

## The distinction between *Cerastium tomentosum* L. and *C. biebersteinii* DC. (Caryophyllaceae), and their occurrence in the wild in Britain

M. K. KHALAF and C. A. STACE

*Department of Biology, University of Leicester, Leicester LE1 7RH*

### ABSTRACT

Differences between *Cerastium tomentosum* and *C. biebersteinii* are summarised. Due to the enormous variation of the former in most readily observable characters, certain identification can be effected only by using features of the morphology of the capsule teeth (not present in most material) and the anatomy of the non-glandular hairs (a microscopic character). No material of *C. biebersteinii* has been seen from the British Isles other than in a few botanic gardens, and there is no good evidence of its existence here either as a garden ornamental or in the wild, nor of its hybridization with *C. tomentosum*. Hybrids between *C. tomentosum* and *C. arvense* are frequent both in cultivation and in the wild.

KEYWORDS: *Cerastium*, morphology, chromosome numbers, hair anatomy, hybridization.

### INTRODUCTION

*Cerastium tomentosum* L. and *C. biebersteinii* DC. belong to a group of up to twenty species that can conveniently be termed the *C. tomentosum* group. This was recognised by Schischkin (1936) as series *Grandiflora* (Borza) Schischk. in the following classification:

Subgenus *Dichodon* (Bartl.) Fenzl

Subgenus *Eucerastium* (Boiss.) Pax (= *Cerastium*)

Section *Strephodon* Ser.

Section *Schizodon* (Fenzl) Schischk.

Section *Orthodon* Ser. (= *Cerastium*)

Subsection *Fugacia* (Fenzl) Pax & K. Hoffm.

Subsection *Perennia* (Fenzl) Pax & K. Hoffm. (= *Cerastium*)

Series *LasioSTEMONA* (Fenzl) Schischk.

Series *LeioSTEMONA* (Fenzl) Schischk.

Series *Alpina* (Borza) Schischk.

Series *Arvensia* (Hayek) Schischk. (= *Cerastium*)

Series *Grandiflora* (Borza) Schischk.

The names of four of the above taxa have to be corrected to *Cerastium*, as shown, since *C. arvense* L. is the type of the genus.

None of these five series is well defined, however, and certain hybrids between species in the last three can be synthesised with ease (Khalaf & Stace 2000). The *C. tomentosum* group was defined by Buschmann (1938) by its perennial habit, presence of many non-flowering axillary shoots, relatively large flowers and presence of (usually very dense) long white hairs. Although these characters are not strictly diagnostic of the group, either individually or in combination, all apply to *C. tomentosum* and *C. biebersteinii*, which can be considered among the core species of this informal grouping. Subsection *Perennia* (= *Cerastium*), as redefined by Söllner (1954) when he removed series *LeioSTEMONA* (which includes *C. fontanum* Baumg.), seems to be a well defined taxon which is best not subdivided above the species level (Khalaf & Stace 2000).

*Cerastium tomentosum* itself is an extremely variable taxon, and there have been considerable divergences of opinion about its delimitation. Moggi (1963) pointed out that at least six species

had been segregated from it in Italy and Sicily alone. On the other hand the name has been used for plants from Spain (e.g. Linnaeus 1753), the Alps (e.g. Nyman 1855), the Balkans (e.g. Stojanoff & Stefanoff 1924), the Crimea (fide Schischkin 1936) and the Caucasus (e.g. Fenzl 1842). Today it is recognised as endemic to Italy and Sicily, where no other taxa from the *C. tomentosum* group occur. Of all its variations, specimens from higher altitudes on Mt Etna, Sicily, are the most distinct in having only sparse hairs, narrower leaves, shorter petals and capsules and smaller seeds; these can be recognised as var. *minus* C. Presl (var. *aetnaeum* Janka).

The only other Linnaean species possibly in the *C. tomentosum* group, *Cerastium repens* L. from France and Italy, is a name of uncertain application. No type specimen has been traced; the specimen in LINN is not a type and is in our opinion referable to *C. arvense*, a conclusion apparently behind De Candolle's (1822) inclusion (with some doubt) of the name under the latter species. It has also been used for the Italian species (*C. tomentosum*) by Buschmann (1938) and for the Crimean species (*C. biebersteinii*, see below) by Marschall von Bieberstein (1808).

The first species recognised in the group from outside the Mediterranean area were *C. repens* M. Bieb. (from Crimea) and *C. argenteum* M. Bieb. (from Tiflis, now Tbilisi in Georgia), described by Marschall von Bieberstein (1808). The Crimean species was realised by De Candolle (1822) to be different from *C. repens* L., so he renamed it *C. biebersteinii*. De Candolle's material consisted of cultivated plants originating from material collected by Steven in Crimea. Buschmann (1938) noted "I have seen the plants which were collected by Steven in Tauria [Crimea] in 1821. He called it *C. repens* and certainly it belongs to *C. biebersteinii*". Schischkin (1936) stated that "*C. biebersteinii* is an endemic Crimean plant, very widespread in the mountainous part of the Crimea. It displays the closest relationship to *C. szowitsii* Boiss. (Eastern Transcaucasia) and *C. argenteum* M. Bieb. (Central Transcaucasia) which are similarly white-tomentose but differ in some other characters. Early investigators identified the Crimean plant with *C. tomentosum*, although this species is confined to the central and southern parts of Italy. *Cerastium biebersteinii* does not occur in a wild state outside the Crimea. The report by Taliev and Voinovskii (1902) referring to the occurrence of this species in inundated meadows of Buguruslan County of Samara Province [north of the Caspian Sea in Ukraine] is certainly wrong". However, Buschmann (1938) considered that *C. biebersteinii* does occur in Transcaucasia, since he favoured a wider taxonomic concept of it, including two of Schischkin's Caucasian species in his *C. biebersteinii* subsp. *transcaucasicum* Buschm. According to Schischkin (1936) the only other member of the *C. tomentosum* group to occur in Crimea is *C. stevenii* Schischk., which is a very different-looking species and perhaps does not belong to this group at all. It is therefore likely that *C. tomentosum* and *C. biebersteinii* each occur in widely separated areas neither of which supports any other closely similar taxa.

*C. tomentosum* var. *tomentosum* has long been introduced in central and northern Europe as a garden ornamental. From here it has escaped into the wild and in places has become extremely well naturalised not only in marginal and disturbed ground but sometimes in natural habitats, such as sandy grassland and maritime sand-dunes. Already by 1960 it was found scattered in the wild all over the British Isles (Perring & Walters 1962). It has caused taxonomic problems in two ways. Firstly, it has quite frequently hybridised (in eastern and south-eastern England and one part of central Scotland) with the native *C. arvense* (belonging to a different series from *C. tomentosum*, see classification above) to produce plants that superficially resemble another member of the *C. tomentosum* group, the Balkan *C. decalvans* Schlosser & Vuk., and which have been wrongly so called. Hybrids between *C. tomentosum* and *C. arvense* have also been reported from Canada (Morton 1975), Sweden (Karlsson 1997) and Luxemburg and Finland (Kaleva 1966), as well as in several botanic gardens throughout Europe. Secondly, there are several reports of the introduction to gardens of the Crimean *C. biebersteinii* DC., and the variability of *C. tomentosum* has often been partly explained by determination of some naturalised plants as this or as various Balkan species of the group. Clapham (1987) stated that *C. biebersteinii* "is also much grown in gardens" and that "some cultivated material may well be of hybrid origin". Walters (1989) claimed that both *C. biebersteinii* and Caucasian taxa were introduced in the 19th century and that "complex hybridization seems to have taken place in cultivated plants".

As part of a study of the breeding relationships of subsection *Perennia* sensu Schischkin, we attempted to describe precisely the differences between *C. tomentosum* and *C. biebersteinii* and to investigate the occurrence in the wild of these two taxa in Britain.

Due to their wide geographical separation the two species are not often treated in the same Flora. Fenzl (1842) covered both species, but his *C. tomentosum* from "provinciis caucasicis. Iberia" must have been misapplied. Boissier (1867) stated that *C. biebersteinii* has a denser tomentum, longer narrower sepals and capsule teeth with flat (not revolute) margins. Buschmann (1938) separated *C. biebersteinii* from a group of species including *C. tomentosum* in his key (couplet 8): capsule straight, strong-walled, with patent teeth flat on the margins in the former; capsule straight or curved, soft-walled, with erect teeth revolute at margins in the latter. Jalas *et al.* (1964) agreed about the narrower sepals and flat capsule-teeth in *C. biebersteinii*, and added shorter stems, shorter and narrower leaves and erect (not patent, contrary to Buschmann) capsule teeth. Walters (1989) included both species in the "*C. tomentosum* group" and did not attempt to distinguish them. Kaleva (1966) is apparently the only person to have studied these species in a scientific and comparative way. He listed eight differences: growth habit; leaf size and shape; petal shape; capsule size; capsule wall anatomy; seed size; pollen grain size; and chromosome number. However, he concluded that the revolution of the margins of the capsule teeth is not a good discriminator ("± flat" in both), and he did not mention capsule-teeth posture. Nevertheless his photographs showed clearly more patent capsule teeth in *C. tomentosum*, in agreement with Jalas *et al.* (1964) but not with Buschmann (1938).

#### MATERIALS AND METHODS

Living accessions were obtained as plants or seeds by collecting in the wild, from correspondents in Continental Europe, and by the seed-exchange schemes. Frequently material from the last of these sources was misidentified. Much herbarium material was also examined. Up to 25 measurements were made of each character for each accession. Unfortunately, our observations on *C. biebersteinii* were restricted to two living accessions and about a dozen herbarium specimens, few of which carried ripe capsules.

Seed accessions were germinated at 15–19°C in a 3:7:2 loam:peat:grit mixture under a light regime of 16 hr light/8 hr dark. Germination occurred between 4 and 7 days; seedlings were potted on and after 1–2 months were transferred to an unheated glasshouse where they were kept permanently. Plants flowered much more profusely after vernalization over winter in a cold glasshouse. Vouchers of all accessions at flowering are deposited in **LTR**.

Chromosome counts were made on root-tips obtained from fresh stem-cuttings after 10–15 days; these possessed larger meristems and a higher mitotic index than root-tips gathered from mature plants or from seedlings. They were pretreated in 50% saturated aqueous paradichlorobenzene, washed in tap-water, fixed for 3 hr in ethanoic acid:ethanol (1:3), washed again and stored in 70% IMS. After storage they were rewashed, hydrolysed in 5N HCl at room temperature for 3–6 min, washed in 70% ethanol, and transferred to a drop of 45% ethanoic acid on a slide. The meristematic region was dissected from the rest of the tissue and transferred into a drop of 2% aqueous aceto-orcein on another slide. The meristem was dissected apart and squashed in the usual way and then gently heated over a spirit lamp to flatten the cells, and the coverslip was sealed with rubber solution. Suitable spreads were photographed.

Thirty characters (Table 2) were measured by us for all the material at our disposal to see whether any discrimination could be achieved. Means per plant, overall ranges or ranges of means were used according to which we considered the most diagnostically useful.

#### RESULTS

##### CHROMOSOME NUMBERS

Table 1 shows that all our accessions from the wild in Britain of *C. tomentosum* var. *tomentosum*, *C. arvense* and their hybrids had  $2n = 72$ , representing the octoploid level, except that six of the seventeen accessions of *C. tomentosum* had up to nine B-chromosomes. Octoploid counts are also the commonest ones reported in the literature for *C. tomentosum* and *C. arvense*, but in addition there are tetraploid and dodecaploid counts ( $2n = 36$  and 108) for *C. tomentosum*, and tetraploid and decaploid ( $2n = 36$  and 90) for *C. arvense* (Khalaf & Stace 2000). However, the three previous counts of *C. arvense* and one of *C. tomentosum* from Britain (Brett 1955, Blackburn & Morton

TABLE 1. CHROMOSOME COUNTS OF WILD MATERIAL FROM THE BRITISH ISLES OF *CERASTIUM TOMENTOSUM* VAR. *TOMENTOSUM*, *C. ARVENSE* AND THEIR HYBRID

	Site	Vice-county	Grid Ref.	Count
<i>C. tomentosum</i> var. <i>tomentosum</i>				
CER 4	Gorebridge	Midlothian	NT353605	2n = 72 + 1–3B
CER 5	Blackford Quarry	Midlothian,	NT261702	2n = 72 + 5B
CER 20 & 21	Shingle, Snettisham	W. Norfolk	TF648328	2n = 72
CER 25	Shingle, Snettisham	W. Norfolk	TF648333	2n = 72
CER 26	Shingle, Snettisham	W. Norfolk	TF648333	2n = 72 + 2B
CER 31	Sand-dunes, Holme	W. Norfolk	TF702442	2n = 72
CER 103	Near Dumbarton Rock	Dunbarton	NS37	2n = 72
CER 104	Sea front, Crosby	S. Lancashire	SJ39	2n = 72
CER 105	Behind beach, Southwold	E. Suffolk	TM507753	2n = 72
CER 106	Wall, Old Town, St Mary's	Scilly	SV912013	2n = 72 + 7B
CER 118	Wall-top, Llaniestyn	Caernarvonshire	SH282337	2n = 72 + 9B
CER 126	Near railway, Great Heck, York	M.W. Yorkshire	SE5920	2n = 72
CER 139, 140 & 141	Heathland, near Ipswich	E. Suffolk	TM14	2n = 72
CER 143	Hedgerow, Orrisdale	Isle of Man	SC325930	2n = 72 + 9B
<i>C. arvense</i>				
CER 27	Grassy roadside, near Snettisham	W. Norfolk	TF669336	2n = 72
CER 29	Sand-dunes, Holme	W. Norfolk	TF700442	2n = 72
<i>C. arvense</i> × <i>C. tomentosum</i>				
CER 6	Borthwick Bank	Midlothian	NT369603	2n = 72
CER 19	Shingle, Snettisham	W. Norfolk	TF648328	2n = 72
CER 23	Shingle, Snettisham	W. Norfolk	TF648330	2n = 72
CER 24	Shingle, Snettisham	W. Norfolk	TF648333	2n = 72
CER 28	Sand-dunes, Holme	W. Norfolk	TF700442	2n = 72
CER 30	Sand-dunes, Holme	W. Norfolk	TF701442	2n = 72

1957) have all been octoploids, as have the numerous counts we have made of British garden material of *C. tomentosum*.

The other members of the *C. tomentosum* group vary from tetraploid (2n = 36) to 16-ploid (2n = 144), and several species are represented by more than one ploidy level (Khalaf & Stace 2000). *C. biebersteinii* has been reported as tetraploid (one count of wild Crimean material, Kaleva 1966) and as octoploid (three counts of botanic garden material); this species has been widely misidentified and the true identity of the three cultivated octoploids requires confirmation. We used two accessions of *C. biebersteinii*, one of wild South Crimean ("Tauria meridionalis") and the other of München botanic garden origin; both were tetraploids (2n = 36).

#### MORPHOLOGICAL AND ANATOMICAL CHARACTERS

The vast range of morphological features of wild Italian material of *C. tomentosum* var. *tomentosum* strongly suggested to us that many of the characters of *C. biebersteinii* would be covered by those of the former taxon, and that few of them would be likely to distinguish the two species. The results shown in Table 2 can be classified as follows:

- i - characters showing differences in the means, or in a good part of the ranges, between the two species, but with overlap, viz. sepal length and breadth, pollen grain diameter, capsule length, capsule shape, capsule wall rigidity, capsule tooth length and breadth, capsule tooth margins, and seed length (also seed breadth, not listed in Table 2).
- ii - characters apparently clearly discriminating the two species, viz. presence of rhizomes and stolons, leaf thickness, filament length, anther length, ovary length, and seed weight.
- iii - characters not discriminating between the two species, viz. 13 of the other 16 characters (the three hair characters are covered below).

TABLE 2. DIAGNOSTIC CHARACTERS OF *CERASTIUM TOMENTOSUM* VAR. *TOMENTOSUM* AND *C. BIEBERSTEINII*

Character	<i>C. tomentosum</i> var. <i>tomentosum</i>	<i>C. biebersteinii</i>
Height of flowering stems to tip of highest flower*	200–450 mm	100–300 mm
Presence of rhizomes and stolons	Both	Neither
Length of uppermost internode of flowering stem, i.e. internode between uppermost leaf-pair and lowermost bract-pair	13.3–120 mm	63.7–125 mm
Mean length of next 3 lower internodes	7.2–57 mm	8.4–69.5 mm
Length and breadth of uppermost pair of leaves on flowering shoot	7–49.7 × 1.5–8.5 mm	17.8–42 × 1.9–7 mm
Thickness of same leaves	0.1–0.2 mm	0.2–0.3 mm
Length and breadth of lowest bracts	4–9.7 × 2–4 mm	5–9.5 × 2.5–4 mm
Length of scarious tip of lowest bracts	0.2–1.8 mm	0.5–0.9 mm
No. flowers per inflorescence	2.6–12.2	4.3–10.5
Pediceal length of terminal flower	12.7–42.8 mm	13.7–47 mm
Sepal length and breadth	4–9 × 2–3.4 mm	6.5–9.7 × 2–2.7 mm
Length of scarious tip of sepals	0.2–1.3 mm	0.5–1.1 mm
Petal length and breadth	11–18 × 5–10 mm	17–17.3 × 6.8–7 mm
Ratio petal cleft length/petal length*	0.2–0.3	0.2–0.3
Filament length*	4–5 mm	5.4–5.8 mm
Anther length*	1–1.1 mm	0.7–0.9 mm
Pollen grain diameter (tetraploid)	34.3–36.5 µm	35.8–37 µm
Pollen grain diameter (octoploid)	35.3–40.1 µm	-
Pollen grain diameter (dodecaploid)	43–45.5 µm	-
Ovary length*	2–2.5 mm	1.7–1.9 mm
Style length*	3–6 mm	3–4.4 mm
Capsule length*	8–12 mm	10–15 mm
Capsule shape	Straight or bent	Straight
Capsule wall rigidity	Pliable	Pliable or rigid
Capsule tooth length, and breadth (0.2 mm behind apex)*	0.7–1.3 × 0.1–0.3 mm	1–1.5 × 0.3–0.5 mm
Capsule tooth posture	Erect to patent	Erect to patent
Capsule tooth margins	mostly revolute	mostly ± flat
Seed length (from hilum to furthest point)*	1–1.9 mm	1.5–2.2 mm
Seed weight per 100 seeds	33.75–42 mg	67–70.5 mg
Upper leaf-surface hair density (1)	5–62.8	4.4–26
Lower leaf-surface hair density (1)	6.6–51	12.8–30.2
Length-ratio terminal/subterminal hair-cells	(3.7)4–19(19.8)**	(1)1.1–1.7(1.8)**

Ranges of means per plant, or (\*) overall ranges, or (\*\*) range of means with overall ranges in parentheses (1) Number of hair-bases in circle of diameter of 250 µm (0.05 mm<sup>2</sup>) at midpoint of uppermost pair of leaves on flowering shoot

## HAIR CHARACTERS

Both *C. tomentosum* var. *tomentosum* and *C. biebersteinii* possess only unbranched non-glandular uniseriate-celled hairs. The great range in visible hair density in the former suggested that this character would be of no value in distinguishing between the two taxa, and precise counts bear this out (Table 2).

However, a good difference in hair anatomy was discovered between these two taxa (Table 2). The uniseriate hairs consist of three to six (usually four or five) cells, of which the terminal one is very long and the basal one or two (rarely three) are very short. The subterminal cell is much shorter than the terminal cell in *C. tomentosum* var. *tomentosum* (and also in *C. tomentosum* var. *minus*) but only slightly so in *C. biebersteinii*; the ratio between the two cells clearly separates the

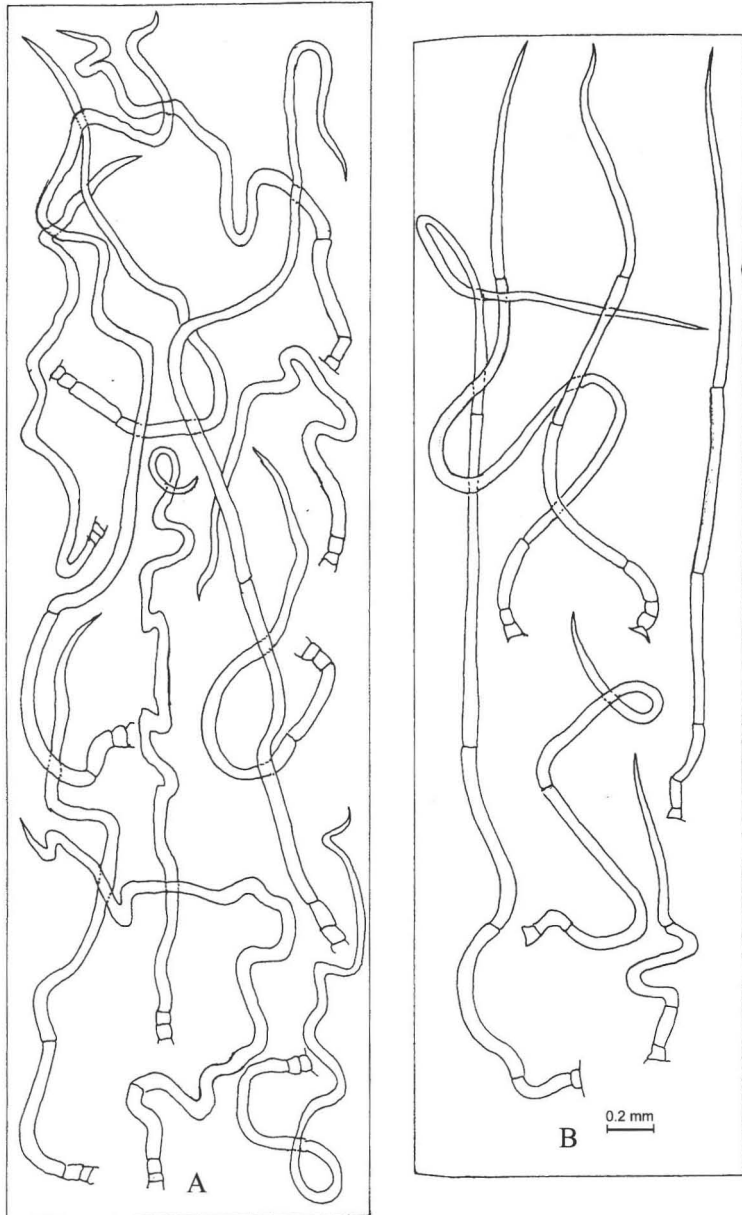


FIGURE 1. Representative leaf-hairs of *Cerastium*. A: *C. tomentosum*. B: *C. biebersteinii*.

two species in all cases (Table 2; Fig. 1). Of the other seven species of the *C. tomentosum* group examined in this study, none agrees with *C. tomentosum* in this character, five (*C. argenteum* M. Bieb., *C. decalvans* Schloss. & Vuk., *C. gibraltarium* Boiss., *C. lineare* All., *C. moesiacum* Friv.) agree with *C. biebersteinii*, and two (*C. candidissimum* Correns, *C. grandiflorum* Waldst. & Kit.) differ from all the others in having branched hairs (of quite different form in the two species - dendroid in *C. candidissimum*, T-shaped in *C. grandiflorum*). In addition some or all plants of *C. gibraltarium*, *C. moesiacum* and *C. decalvans* possess unbranched, uniseriate-celled glandular hairs, which are also present in *C. tomentosum* var. *minus*.

## DISCUSSION

Our chromosome counts lead us to believe that British wild and cultivated material of the above three species mainly or entirely consists of tetraploid *C. biebersteinii* and octoploid *C. tomentosum* and *C. arvense*, although of course some clones at other ploidy levels might exist as yet undetected.

In general appearance *C. biebersteinii* is a shorter, less mat-forming, more sturdy plant than *C. tomentosum*, with larger leaves, a denser, more matted tomentum and longer sepals. However, the ranges of many characters of *C. tomentosum* are wider than those of *C. biebersteinii* and in several cases completely overlap them. This is due not only to the much greater variation shown by *C. tomentosum* but also to the relatively small number of specimens of *C. biebersteinii* that were examined. In general our measurements, even the means, show wider ranges than those of Kaleva (1966), presumably due to our greater sample size and possibly to the fact that our samples of *C. tomentosum* included tetraploids and dodecaploids as well as octoploids. Because of this, some characters previously claimed to separate the two species were found by us to be of virtually no value, viz. leaf length and breadth, leaf-hair density, petal length and breadth, depth of petal cleft and capsule tooth posture.

Clapham (1987) and Walters (1989) suggested that there has been hybridization between *C. tomentosum* and *C. biebersteinii* in cultivation; their views are plausible, but we are unable to substantiate them. We have found no evidence that any spontaneous hybrids between these two species exist. In our experiments (Khalaf & Stace 2000) no capsules were produced from crosses between tetraploid *C. tomentosum* and *C. biebersteinii*. In crosses using octoploid *C. tomentosum* as the male parent some hybrid seeds were produced, of which 7.7% was viable, but no mature hybrid plants could be obtained. But when octoploid *C. tomentosum* was used as the female parent 74% of the hybrid seed was viable and mature flowering hybrid plants were obtained. Moreover, these were fertile to some degree, despite being hexaploids ( $2n = 54$ ). Specimens have been deposited in LTR. All the hybrids obtained in the *C. tomentosum* group resembled their female parent more closely than their male parent. In the case of the *C. tomentosum* × *C. biebersteinii* hybrids, the length ratio of the terminal/subterminal cells of the non-glandular hairs was well within the range of that of *C. tomentosum*.

Hybrids between *C. arvense* and *C. tomentosum* occur in the wild in Britain as well as in botanic and other gardens. They have no valid binomial. They are fertile octoploids and have the potential of extensive and repeated back-crossing. Similar fertile hybrids were synthesised reciprocally by us with ease. They can be distinguished from *C. tomentosum* by their greener appearance, with much less dense non-glandular hairs, frequent possession of glandular hairs, and less sturdy growth habit. These characters are shared by *C. tomentosum* var. *minus*, which might have such a hybrid origin.

The 16 characters that show some promise as distinctions between *C. biebersteinii* and *C. tomentosum* var. *tomentosum* are briefly discussed below.

*Presence of rhizomes and stolons*

Rhizomes and stolons are certainly more evident and far-reaching in *C. tomentosum*, but we cannot be certain of their absence in *C. biebersteinii*. Field studies in Crimea are required to elucidate this.

*Thickness of uppermost pair of leaves on flowering shoot*

According to our measurements this character separates the two species, but further sampling is required to see whether there is some overlap. In any case this is not a character that is easy to measure for identification purposes.

*Sepal length and breadth*

The sepals are usually longer and narrower in *C. biebersteinii*, but the ranges of both measurements overlap. The length/breadth ratio provides a better discriminator, but there is still overlap. Kaleva's (1966) sepal length measurements were contained within ours and gave a clear separation of the two species, but with a sample size of only 10.

*Filament, anther and ovary lengths*

These all gave good separation in our material, but further sampling is desirable to ensure that there is no overlap. The ovary must be measured at anthesis, before there is any chance of its swelling after pollination.

*Pollen grain diameter*

The pollen of the tetraploid *C. biebersteinii* is similar in size to that of tetraploid and octoploid *C. tomentosum*, but that of dodecaploid *C. tomentosum* is slightly larger. Kaleva's (1966) measurements were very close to ours.

*Capsule length*

Again, there is a difference, but with overlap. Kaleva's (1966) measurements were very close to ours.

*Capsule shape*

Whereas *C. biebersteinii* always has straight capsules, those of *C. tomentosum* can be straight or bent/curved.

*Capsule wall rigidity*

The walls of the ripe empty capsules of *C. tomentosum* are rather soft and pliable, whereas those of *C. biebersteinii* are harder and more rigid, often fracturing when pressed with a needle. Kaleva (1966) showed that this difference is based on the capsule wall anatomy; in *C. biebersteinii* the lignified outer wall of the outer epidermal layer is at least twice as thick as in *C. tomentosum*. However, we found that some capsules of *C. biebersteinii* had pliable walls, although this might be due to the conditions under which the plants grew. Field studies in Crimea are required to check this.

*Capsule tooth length and breadth*

The capsule teeth are generally longer and (especially) wider in *C. biebersteinii*, but there is some overlap in length and ranges of breadths are contiguous. Breadth measurements are difficult to compare as the point at which the measurement is taken is critical.

*Capsule tooth margins*

This is the most frequently cited diagnostic character, and we found it reliable (Fig. 2). The greater revolution in *C. tomentosum* renders the apparent capsule tooth breadth more distinct from that of *C. biebersteinii* than it would otherwise be. Kaleva (1966), however, found this character to be unreliable, stating that both species possessed "± flat" tooth margins. But his "*C. tomentosum* strain B", which he very plausibly concluded was *C. tomentosum* × *C. arvensis*, had "revolute" tooth margins. The capsule teeth in *C. arvensis* are even more revolute at the margins than in *C. tomentosum*, and it is therefore possible that Kaleva differed from us simply in his verbal interpretation of the same structures.

*Seed length*

The ranges of the two species differ, but overlap. Kaleva's (1966) measurements agree closely with ours.

*Seed weight*

Seed weight gave a good separation between the two species; this is a combination of seed length, breadth and thickness plus any possible anatomical differences.

*Length ratio of terminal and subterminal hair-cells*

A very clear separation was obtained between *C. tomentosum* and *C. biebersteinii* (along with all other species in the group) (Fig. 1). The difference is so clear that after some experience it is not necessary to make detailed measurements.

*Chromosome number*

Octoploid counts of *C. biebersteinii* need to be confirmed among wild collections; until then it is safer to consider this species a tetraploid. *C. tomentosum* var. *tomentosum* is usually octoploid and var. *minus* always so. Rarely tetraploid and dodecaploid populations of var. *tomentosum* are reported; all our material of these two cytotypes was of botanic garden material, but according to Favarger (1972) all three ploidy levels occur in the wild in the Italian Apennines.



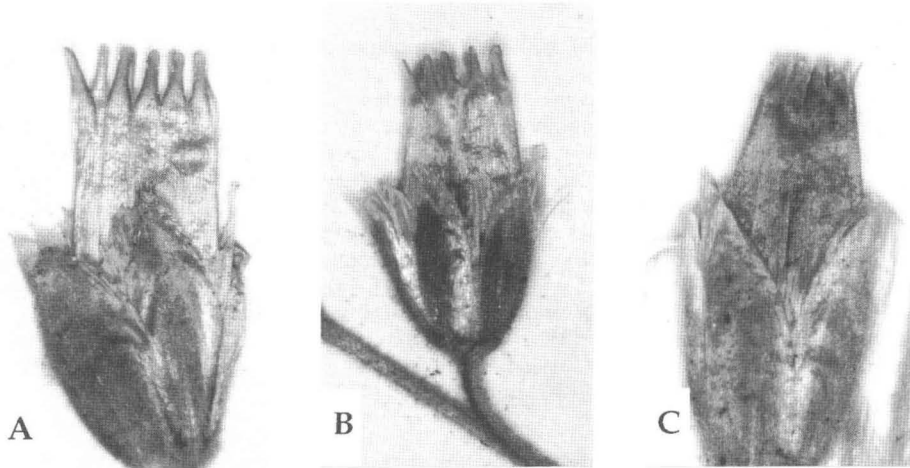


FIGURE 2. Dehiscent capsules of *Cerastium*. A: *C. tomentosum*. B: *C. arvense*. C: *C. biebersteinii*.

#### CONCLUSIONS

All the material of the *C. tomentosum* group that we have seen either from the wild or cultivated as ornamentals in Britain has been referable to *C. tomentosum* var. *tomentosum* or to hybrids between that and *C. arvense*. Despite the apparent absence of *C. tomentosum* var. *minus* and *C. biebersteinii*, all three taxa are described here in order to allow future identification:

#### *CERASTIUM TOMENTOSUM* L. VAR. *TOMENTOSUM*

Plant mat-forming, with stolons and/or rhizomes, almost completely covered with simple non-glandular hairs; length ratio of terminal to subterminal cell (3.7)4–19(19.8); glandular hairs absent; flowering stems 20–45 cm, their uppermost internode 13.3–120 (135) mm. Uppermost leaves on flowering shoots linear to oblong- or elliptic-lanceolate, 7–49.7(54) × 1.5–8.5(19) mm, 0.1–0.2 mm thick, acuminate or acute to subobtusate at apex, greyish-green to greyish white, with hair density on upper and lower surfaces (4)5–62.8(68) and (5)6.6–51(55) per 0.05 mm<sup>2</sup> respectively. Inflorescence contracted to spreading, with (1)2.6–12.2(16) flowers; pedicel of terminal flower (10)12.7–42.8(60) mm; lowest bracts 4–9.7(10) × 2–4 mm, with scarios tip (0.1)0.2–1.8(2) mm. Sepals 4–9(9.2) × 2–3.4(4) mm, lanceolate to oblong- or ovate-lanceolate, with scarios tip 0.2–1.3(1.5) mm, subacute to obtuse at apex. Petals (10.3)11–18(18.5) × (4.5)5–10(11) mm, with cleft 3–6 mm. Filaments (4)4.2–4.6(5) mm; anthers 1–1.1 mm; pollen grains (32.5)34.3–36.5(38) μm in tetraploid, (35)35.3–40.1(42) μm in octoploid, and (42)43–45.5(50) μm in dodecaploid. Ovary (2) 2.2–2.4(2.5) mm; styles (3)3.2–5.7(6) mm. Capsules 8–11(12) mm, straight to bent, with pliable walls, with teeth (0.7)0.8–1.2(1.3) mm and (0.1)0.2–0.3 mm wide and with revolute lateral margins. Seeds (1)1.19–1.6(1.9) mm. 2n = 36, 72, 108.

#### *CERASTIUM TOMENTOSUM* VAR. *MINUS* C. PRESL

Plant mat-forming, with stolons and/or rhizomes; flowering stems 5–20 cm, their uppermost internode (20)33–42.5(46) mm and with simple non-glandular hairs, simple glandular hairs, or both. Uppermost leaves on flowering shoots linear to lanceolate, (8.3)9–30 × 1–3 mm, 0.2–0.3 mm thick, acute to acuminate at apex, greyish-green to green, with simple non-glandular hairs only, with hair density on upper and lower surfaces (4)4.8–13.4(16) and (5)5.3–6.8(18) per 0.05 mm<sup>2</sup> respectively; length ratio of terminal to subterminal cell (6)6.5–15.8(16). Inflorescence contracted, with (2)3.3–4.1(7) flowers; pedicel of terminal flower 10–19.3(23) mm; lowest bracts (4)4.5–7.3(7.5) × 2–3 mm, with scarios tip (0.1)0.2–0.4(0.7) mm. Sepals (4.5)5–8 × 2–2.2(2.5) mm, lanceolate to oblong-lanceolate, with scarios tip (0.2)0.3–1 mm, subacute to acute at apex. Petals (8.9)9–11.7(12) × (5.3)6(7) mm, with cleft 3–4.1(4.5) mm. Filaments (3.8)4–4.1 mm; anthers 1–1.1 mm; pollen grains (35)35.5–39.2(42) μm. Ovary (1.8)1.9–2 mm; styles (3)3.1–3.5(4) mm. Capsules 8–8.1(8.2) mm, straight to bent, with pliable walls, with teeth 1–1.1 mm long and 0.1–0.2 mm wide and with revolute lateral margins. Seeds (0.9)1.18–1.4(1.5) mm. 2n = 72.

*CERASTIUM BIEBERSTEINII* DC.

Plant forming tussocks or small mats, without(?) stolons or rhizomes, almost completely covered with simple non-glandular hairs; length ratio of terminal to subterminal cell (1)1.1–1.7(1.8); glandular hairs absent; flowering stems 10–30 cm, their uppermost internode (53)63.7–125(160) mm. Uppermost leaves on flowering shoots lanceolate to oblong-lanceolate, (14)17.8–42(50) × (1.5)1.9–7 mm, 0.2–0.3 mm thick, acute to obtuse at apex, white to greyish white, with hair density on upper and lower surfaces (4)4.4–26.8(29) and (10)12.8–30.2(32) per 0.05 mm<sup>2</sup> respectively. Inflorescence contracted, with (3)4.3–10.5(12) flowers; pedicel of terminal flower (13)13.7–47 mm; lowest bracts 5–9.5 × 2.5–4 mm, with scarious tip 0.5–0.9 mm. Sepals 6.5–9.7 (10) × 2–2.7(3) mm, lanceolate to oblong- or ovate-lanceolate, with scarious tip 0.5–1.1(1.2) mm, acute to obtuse at apex. Petals (16.5)17–17.3(17.5) × (6.5)6.8–7(7.1) mm, with cleft (3.5)4(4.2) mm. Filaments (5.4)5.5–5.7(5.8) mm; anthers (0.7)0.8–0.9 mm; pollen grains (32.5)35.8–37(37.8) µm. Ovary (1.7)1.8–1.9 mm; styles (3)3.1–4.1(4.4) mm. Capsules 10(10.1)–14(15) mm, straight, with usually rigid walls, with teeth (1)1.2–1.4(1.5) mm and (0.3)0.4–0.5 mm wide and with ± flat lateral margins. Seeds (1.5)1.83–1.87(2.2) mm. 2n = 36, (?72).

## IDENTIFICATION

Despite the enormous range of variation of *C. tomentosum* in many morphological characters, after some familiarization with these two species it is possible to distinguish between them in the great majority of cases using the following characters as clues: growth habit; leaf size, thickness and indumentum; sepal size; filament, anther and ovary length; capsule, capsule-tooth and seed size, and capsule wall rigidity. It is very difficult, however, to express these as opposing character-states in a key, and a fully confident identification cannot be guaranteed using them alone. Study of a much wider range of wild material of *C. biebersteinii* is required before we can be sure of the diagnostic value of the above characters.

Notwithstanding the conclusions of Kaleva (1966), we have found the revolution of the lateral margins of the capsule teeth to be absolutely reliable (Fig. 2). Unfortunately most herbarium specimens do not carry ripe capsules, and it seems that these are not always produced. This is not due, however, to self-incompatibility, as was surmised by Walters (1989), but to lack of self-pollination in these highly protandrous but self-compatible plants (Khalaf & Stace 2000). The lack of capsules does, of course, present a problem in certain identification. In such cases the hair anatomy (Fig. 1) will provide an unequivocal answer, since this character always clearly differentiates between the two species.

## REFERENCES

- BLACKBURN, K. B. & MORTON, J. K. (1957). The incidence of polyploidy in Caryophyllaceae of Britain and Portugal. *New Phytologist* **56**: 344–351.
- BOISSIER, E. (1867). *Cerastium*, in *Flora Orientalis* **1**: 712–730. Herbar Boissier, Geneva.
- BRETT, O. E. (1955). Cytotaxonomy of the genus *Cerastium*, 1. Cytology. *New Phytologist* **54**: 138–148.
- BUSCHMANN, A. (1938). Über einige ausdauernde *Cerastium*-Arten aus der Vermandtschaft des *C. tomentosum* L. *Feddes Repertorium* **43**: 118–143.
- CLAPHAM, A. R. (1987). *Cerastium*, in CLAPHAM, A. R., TUTIN, T. G. & WARBURG, E. F. *Flora of the British Isles*, 3rd ed., pp. 131–136. Cambridge University Press, Cambridge.
- DE CANDOLLE, A. P. (1822). *Sur les plantes rares ou nouvelles du jardin de botanique. Mémoires de la société physique et d'histoire naturelle de Genève* **1**.
- FAVARGER, C. (1972). Contribution à l'étude cytologique de la flore des Apennins, 2. Le groupe de *Cerastium tomentosum* L. *Saussurea* **3**: 65–71.
- FENZL, E. (1842). *Cerastium* L., in LEDEBOUR, C., ed., *Flora Rossica* **1**: 396–416. E. Schweizerbart, Stuttgart.
- JALAS, J., SELL, P. D. & WHITEHEAD, F. H. (1964). *Cerastium* L., in TUTIN, T. G., HEYWOOD, V. H. et al., eds., *Flora Europaea* **1**: 136–145. Cambridge University Press, Cambridge.
- KALEVA, K. (1966). Biosystematic notes on *Cerastium Biebersteinii* DC. and some ornamental strains of *C. tomentosum* L. (Caryophyllaceae). *Annales Botanici Fennici* **3**: 100–109.
- KARLSSON, T. (1997). Förteckning över svenska kärlväxter. *Svensk Botanisk Tidskrift* **91**: 241–560.
- KHALAF, M. K. & STACE, C. A. (2000). Breeding systems and relationships of the *Cerastium tomentosum* group. *Preslia, Praha* **72**: 323–344.
- LINNAEUS, C. (1753). *Species Plantarum*. Laurentius Salvius, Stockholm.
- MARSCHALL VON BIEBERSTEIN, M. (1808). *Flora Taurico-caucasica* **1**. Charkow.

- MOGGI, G. (1963). Considérations géographiques et systématiques sur la flore d'Italie du sud. *Webbia* **118**: 65–72.
- MORTON, J. K. (1975). *Cerastium* L., in STACE, C. A., ed., *Hybridization and the Flora of the British Isles*, pp. 171–174. Academic Press, London.
- NYMAN, C. F. (1855). *Sylloge Florae Europaeae*. N. M. Lindh, Örebro.
- PERRING, F. H. & WALTERS, S. M. (1962). *Atlas of the British Flora*. Thomas Nelson, London.
- SCHISCHKIN, B. K. (1936). *Cerastium* L., in KOMAROV, V. L. & SCHISCHKIN, B. K., eds., *Flora URSS* **6**: 430–466. Izdatel'stvo Akademii Nauk SSSR, Moscow & Leningrad.
- SÖLLNER, R. (1954). Recherches cytotaxonomiques sur le genre *Cerastium*. *Bulletin de la Société Botanique Suisse* **64**: 221–354.
- STOJANOFF, N. A. & STEFANOFF, B. (1924). *Flore de la Bulgarie*. Minist. Agric. Bulg., Sofia.
- WALTERS, S. M. (1989). *Cerastium*, in WALTERS, S. M. et al., eds., *The European Garden Flora* **3**, pp. 191–192. Cambridge University Press, Cambridge.

(Accepted March 2001)