

The identification of *Rorippa* species and hybrids (Cruciferae) based on external morphological features of their seeds

Ferenc RADICS

Botanical Department of the Hungarian Natural History Museum, Budapest

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ABSTRACT: Author's extensive comparative examinations made it possible to separate the basic forms of *Rorippa* species and hybrids on the basis of the shape and size of the seed and hilum, and colour and pattern of testal surface.

A reliable identification of most *Rorippa* hybrids is not yet cleared up to now, moreover too much number of sub-taxa of their species has also been recently discriminated morphologically. The first scientist engaged in the study of *Rorippas* of the Carpathian Basin giving a detailed and comprehensive summary of each, was BORBÁS (1878, 1879a). He described some 60 species, varieties, forms or hybrids together with a precise morphological description and analysis of many specimen. The majority of these specimens were collected by himself. In several cases he compared them with specimens received from abroad. Occasionally, he did not hesitate to express his doubts regarding the correctness of his statements. The principles of his identification key were the following: occurrence on dry ground (*Xerobiae* Boiss. Fl. Orient.); in water or at water side (*Helobiae*); this later is divided into two subgroup presence of big flowers (*Macranthae*: floribus calice evidenter maioribus), or of small flowers (*Micranthae*); finally, in the former group: shape of pods (*Siliculosae* ellipsoideae, *sphaerocarphae*, *subsiliquosae*, *Eusiliquosae*). On the other hand, when going into details, he also emphasized that the various *Rorippa* specimens, originating from the same parents, frequently differ from each other substantially, when they occur either on different or at the same places (BORBÁS 1879a:13). This phenomenon can be attributed, according to him, to the fact, that "the number of *Rorippa* species is rather small, their reproductive and vegetative organs do not show great differences from each other. Perhaps this is the very reason why the *Rorippas* within the group of *Cruciferae* otherwise so obstinate against hybridization, show a striking disposition to interbreeding." BORBÁS found also many *Rorippa* hybrids whose probable parents did not occur at all on that place, but were characteristic for the region concerned: e.g. *Rorippa kernerii* MENYH. (near Budapest, Rákosmező) *Rorippa armoracioides* TAUSCH (near Nagyvárad, Transylvania), *Rorippa terrestris* var. *pinnatifida* TAUSCH (Ipolylitke) and *Rorippa barbaraeoides* var. *subsiliquosa*

BORB. (near Nagyenyed, Transylvania) (BORBÁS 1879b: 247). Simultaneously with BORBÁS, SIMKOVICS (SIMONKAI) also tried to establish a system for "Nasturtia" belonging to the series Helobiae known to him in the Carpathian Basin. In his opinion the length of pods, its proportion to the peduncle, the length and thickness of pistil alone are not sufficient for the discrimination of the various forms, because these data vary and "should be employed with great restriction only". On the other hand, in his opinion, in addition to the proportional length of petals, the thickness and cannellure of stem, its softness and cylindrical shape, the thickness of pods and their colour, even the sharpness of its edges (l. c. 87-88) are of constant characters. SIMKOVICS discriminated within the group of Helobiae 75 taxa, among them 7 hybrid forms. Four of them were mentioned by BORBÁS, too. The new hybrids were: Nasturtium pestinense SIMK. (N. palustri x silvestre SIMK.); and Nasturtium pseudoriparium SIMK. (N. austriaco-riparium SIMK.); and Nasturtium turczaninowii (CZERN.)SIMK. (N. austriaco-reichenbachii SIMK. Nasturtium riparium SIMK. = N. reichenbachii riparium KNAF = N. austriaco x supersilvestre SIMK.). SIMKOVICS held the view that Nasturtium armoracioides TAUSCH was an independent species. Later however (in KERNER 1893) he decidedly asserted that the Rorippa armoracioides is a hybrid of R. austriaca x silvestris and mentioned also that, at the place of its occurrence, Rorippa palustris is also to be found, in addition to both parents, though it flowers somewhat later (l. c. 18). Before him, POLÁK (1880) was inclined to consider Rorippa armoracioides to be a frequent and constant plant in Bohemia, on the banks of the river Vltava, as a hybrid of Rorippa austriaca x palustris.

FRÖHLICH (1914) was able to morphologically separate in Moravia some mixed forms between R. silvestris and R. austriaca, or rather similar to one or the other parent. Upon the strength of original specimens, he decidedly asserted that Nasturtium terrestre var. pinnatifidum is the same which was considered by BORBÁS already as a hybrid. According to FRÖHLICH, however, it is "very probable" that R. armoracioides belongs here (l. c. 131). As an argument, he cites a statement of SIMKOVICS and he says that BORBÁS gave no particulars concerning this. Apparently, FRÖHLICH did not know the study of BORBÁS (1878) where BORBÁS said: "Num sit R. armoracioides (TAUSCH) species genuina aut hybrida, mihi incertum, sed nunc in Transsylvania semina maturat" (l. c. 154) since he was unable to recognize the forms of R. armoracioides, he identified them to be the forms of R. terrestris with certainty. Nevertheless, subsequent systematists, so FRÖHLICH determined R. armoracioides as a hybrid of R. austriaca x silvestris.

On the other hand, it is true that BORBÁS (1879a) mentioned also that "R. armoracioides, R. terrestris var. integrifolia and R. capillipes, since they agree with each other as to the shape of their leaves, represent three degrees between R. silvestris and R. austriaca" (l. c. 16). JÁVORKA in his floristic work (1924-25) enumerated all 16 Rorippa taxa, among them four partly dubious hybrids: R. barbaraeoides (TAUSCH) ČELAK. (R. islandica x silvestris?); R. hungarica BORB. (R. amphibia x austriaca), R.

repens BORB. (R. amphibia x silvestris), R. prostrata (BERG.) SCHINZ and THELL (R. amphibia x islandica ?).

In the same book, he mentioned also 10 further hybrids, occurring sporadically or to be recognized with difficulty, e. g. R. neogradensis BORB. (R. islandica x austriaca), R. menyhártiana BORB. (R. islandica x silvestris), R. küllödensis PROD. (R. kernerii x amphibia).

Recently SOÓ (1968) discriminated in his synopsis altogether 112 taxa due regard to the territory of present-day Hungary, taking into account the above systematisations and with the results of researches from abroad. He begins the description of the Rorippa genus with the following words: "This genus is the most difficult one among the Cruciferae: it is a complex of species, hybridogen stabilized species, transition forms and hybrids of species. Origin and value of various taxa can be cleared up later only, by genetic examinations and analyses of population." (l. c. 359).

SOÓ described four basic species in detail: R. islandica (palustris resp. JONSELL 1968), R. austriaca, R. amphibia and R. silvestris; and one subspecies: R. silvestris ssp. kernerii and three hybrids: Rorippa x prostrata (BERG. 1786 sub Myagro) SCH. et TH. 1913; Rorippa x astylis (RCHB. 1932 sub Nasturtio) RCHB. 1838 = syn. R. barbaraeoides (TAUSCH 1840 sub Nasturtio) ČELAK, 1874 and R. armoracioides (TAUSCH 1840 sub Nasturtio) FUSS 1866. The second hybrid has 3 subspecies: R. x astylis ssp. astylis (barbaraeoides var. astyla typica NYÁR. 1955), R. x astylis ssp. reichenbachii (KNAF in OPIZ 1852 sub Nasturtio) SOÓ 1966 and R. x astylis ssp. capillipes (BORB. 1379 p. sp.) SOÓ 1966. As to this latter, he says that it is the hybrid R. austriaca x silvestris (l. c. 365). Two subspecies belong to the third hybrid: R. x armoracioides (var. pinnatifidum TAUSCH) and R. x armoracioides ssp. terrestris (TAUSCH 1840 sub Nasturtio p. sp.) JÁV. 1924. According to SOÓ, R. x prostrata is probably a stabilized hybrid of R. silvestris and R. amphibia. R. astylis is originated from R. islandica x R. silvestris, and R. x armoracioides from R. austriaca and R. silvestris. As to this latter hybrid, he refers to FRÖHLICH (1914). Further on, he enumerates 9 hybrids saying that the origin of hybrids is "partly dubious".

Moreover, he enumerates 8 hybrids (l. c. 367). Lately, a revision made by TOMŠOVIČ (1969) stated the occurrence of 5 basic species in the territory of present-day Czechoslovakia, thus partly in the Carpathian Basin: R. amphibia, R. palustris, R. austriaca, R. silvestris and R. pyrenaica, further 3 hybrids: R. x hungarica BORB. 1877 (R. amphibia x austriaca), R. x barbaraeoides (TAUSCH) ČELAK. 1874 (= R. amphibia x silvestris) and the R. x armoracioides (TAUSCH) FUSS 1866 (= R. austriaca x silvestris).

He also inserted R. x prostrata (BERG.) SCH. et TH. into the sphere of R. x barbaraeoides (TAUSCH) ČELAK and R. terrestris ČELAK, into that of R. x armoracioides. Formerly, BORBÁS (1878) thought that the taxon

Rorippa barbaraeoides (TAUSCH) ČELAK[✓] is, as a subspecies of Rorippa anceps (WAHL) a hybrid of R. amphibia and R. silvestris. (l. c. 191). However, one year later he modified his statement saying that the R. barbaraeoides was a hybrid of R. austriaca x silvestris, and R. anceps (WAHL) was not a hybrid of R. amphibia x silvestris, but R. amphibia x palustris. For the hybrid R. amphibia x silvestris we may give the name R. repens BORB. (BORBÁS 1879 l. c. 11).

TOMŠOVIC[✓] determined the taxon R. x barbaraeoides as a hybrid of R. amphibia and R. silvestris. What is more, after a revision of the specimens preserved in the Botanical Department of the Hungarian Natural History Museum he accordingly corrected the schedules of all such hybrid specimens. ČELAKOVSKY (1875) believed that the taxon R. barbaraeoides TAUSCH was nothing else but a hybrid R. amphibia x silvestris (l. c. 458) and he thought it better to cast off the name R. anceps (sub Nasturtio) WAHL. with a view to its manifold use.

With the help of his complementary ecological and cenological examinations, TOMŠOVIC managed to concretize several conclusions of BORBÁS, mentioned in the introduction of this paper, he had drawn merely on floristic basis. TOMŠOVIC stated that in view of the fact that some Rorippa species have not been separated from each other, neither by a "sterility barrière" nor by geographical isolation, they may have only been separated ecologically. This ecological isolation, however, has been disturbed by frequent anthropogen modifications of their living place. Just for this reason, a large number of hybridizations took place; the fertile hybrids, owing to their greater capacity of accomodation, were able to subsist (l. c. 37).

MATERIAL AND METHODS

For the present examinations I used the exsiccata from the Herbarium of the hundred years old Botanical Department of the Hungarian Natural History Museum. These dried plants were collected in the Carpathian Basin. Among these specimens and their fertile or sterile seeds, I examined first of all the Rorippa species collected and determined by BORBÁS, SIMONKAI, JÁVORKA and SOÓ. For comparative purpose, I examined also others collected or described by various other writers.

Samples were taken mostly from herbarial specimens which the authors described very well (single specimens, in masses, or in association with other Rorippa species). The method of taking samples was the following: from the sheet of the Rorippa specimen chosen for examination, I analyzed all seeds of three pods, taken from different flower stalks from the point of view of their external morphological features. Seeds have been soaked,

previously, for 2-3 days, in a mixture of one part of glycerine and two parts of water. During this procedure the formation of sline, or its absence was controlled; it served also to protect the seeds from drying out over a long period of time. The seed-analysis from the point of view of external morphological characteristics was carried out according to the traditional method. However, owing to the small size of the seeds, I was compelled to use a microscope with the magnifying scale 2.5 x 6.3, 6.3 x 6.3 and a projective 6.3 MF, a PRONTOR PRESS camera and ORWO NP 15 roll films.

I examined the size and shape of seeds of the basic species, the morphological features of the hilum region, pattern of the surface of seed coat (testa), that of its sclerotic layer, all characteristics originated from the structure of the seed coat perceptible from outside, too, occasionally a special colour or some other hereditary morphological features. My conviction that this method was employable, was strengthened by the detailed comprehensive examinations of VAUGHAN and WHITEHOUSE (1971) as to the structure of the seed coat and further morphological features referring to the Rorippa species (Cruciferae). The results of similar examinations of ČERNOHORSKÝ (1947) gave me further assistance.

RESULTS

VAUGHAN and WHITEHOUSE (1971) described the seeds of three Rorippa species (R. islandica, R. pyrenaica and R. silvestris) from their external morphological features. ČERNOHORSKÝ described four Rorippa species (R. amphibia, R. austriaca, R. islandica and R. silvestris) on the basis of the morphological characters of seeds. Consequently, it became necessary to have a description of external morphology of the seeds of six Rorippa species, especially in order to clear up the hybrid forms, and in addition to those named above, it was wanted to describe the external morphological characteristics of the seeds of Rorippa prolifera HEUFFEL (1854).

A detailed description of the latter Rorippa species is to be found in a publication of HEUFFEL (1858) among the species of the Carpathian Basin. Before enumerating the morphological features of the seeds of basic species, to observe the seeds of hybrids too I compile a table in order to give a survey of the feature categories and to clear up the termini employed (Table 1).

Characteristic morphological features of seeds of the basic
Rorippa species

Rorippa amphibia (L.) BESS. (Plate I, 1-2)

Length: 1 to 1.2 mm.

Shape: ellipsoid or oval, rather pointed on both ends, at the arched, opposite to hilum truncate.

Sclerotic layer of seed coat (testa), when seen from above, reticulated, with dimples. Epidermis cells are less transparent and as their horizontal extension is bigger than that of cells below them, presenting thickened walls in U-shape, they are mostly ruffled and adhere to latter, especially when dry.

Colour: brown.

Radicle (radicula): accumbent to cotyledons.

Rorippa austriaca (CR.) BESS. (Plate I, 3-4)

Length: 0.7 to 0.8 mm.

Shape: rounded or angular, near hilum horizontally cut off (truncate), opposite to hilum, however, it appears to be cuspidate.

Horizontal extension of cells of sclerotic layer is among all Rorippa species the largest. This layer is hardly visible because the epidermis cells are granulated by oil like globules, consequently seed surface entirely granulated. Side walls of sclerotic cells are thinner than other Rorippa species belonging here. Thus, common side wall of every two cells, when looking at edge of seeds forms an acute angle.

Colour: yellowish brown.

Radicle: accumbent.

Rorippa palustris (L.) BESS. (Plate I, 5-6)

According to JONSELL (1968) and TOMSOVIC (1969) this is the correct name of this taxon.

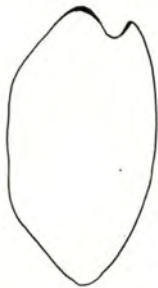











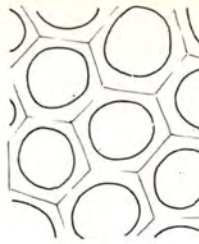
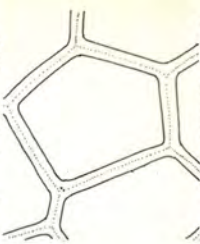
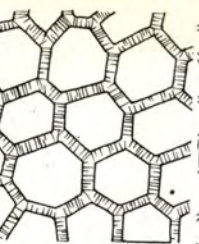
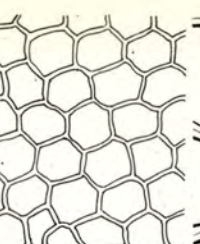
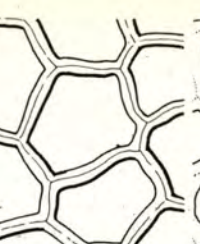
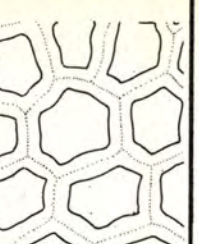

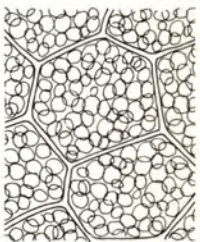
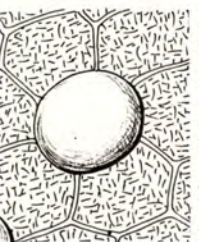
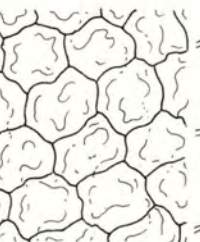
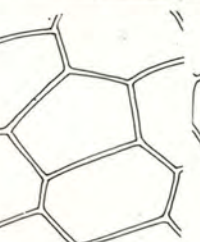
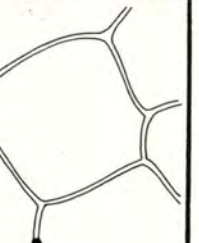
Length: 0.6 to 0.7 mm.

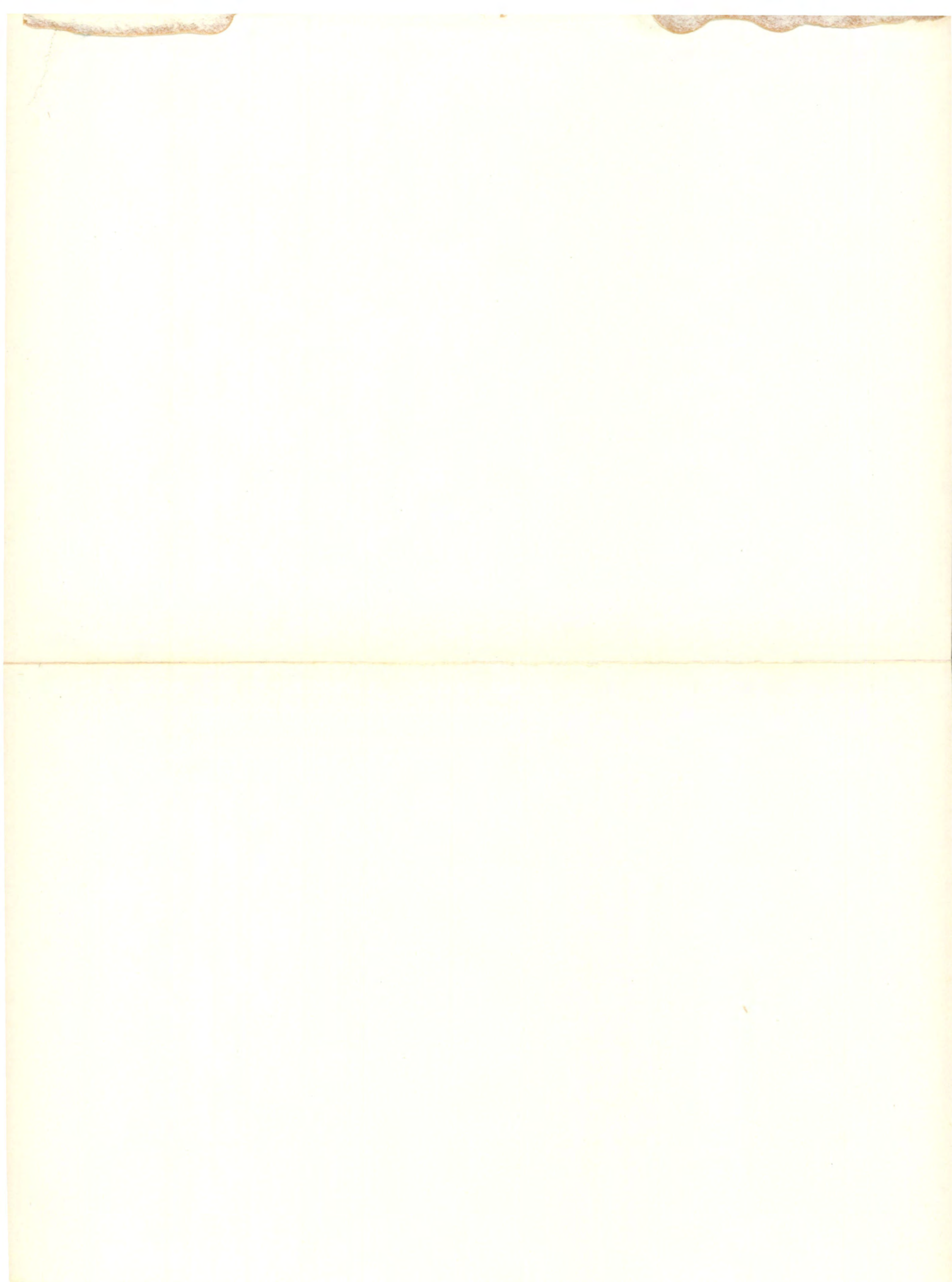
Shape: obovate. Near hilum, obliquely cut off, opposite to hilum pointed, cuspidate.

Pattern of sclerotic layer likewise reticulated, with dimples, but meshes of network - excepting Rorippa prolifera - a less extension than those of other basic species. This network on the seeds of basic species, view from above, is hardly perceptible owing to the slime content of the dotted epidermis cells, seed surface appears to have a velvety surface.

Colour: darker brown.

Radicle (radicula): accumbent.

| | <i>Rorippa amphibia</i> | <i>Rorippa austriaca</i> | <i>Rorippa palustris</i> | <i>Rorippa prolifera</i> | <i>Rorippa pyrenaica</i> | <i>Rorippa sylvestris</i> |
|---|---|---|---|---|---|---|
| size in mm. | > 0.6-07 | ≈ 0.6-07 | = 0.6-07 | < 0.6-07 | = 0.6-07 | = 0.6-07 |
| shape of seeds |  |  |  |  |  |  |
| | ellipsoidial | spherical to angular | oboval | jug-like | oval | oval |
| contours in the vicinity of hylum |  |  |  |  |  |  |
| beside hylum | arched | horizontally cut | aslant cut | roundish | peaked and tight obtuse | obtuse |
| opposite hylum | cut | pointed | pointed | pointed | obtuse | cut |
| pattern of thickened and pigmented layer of testa |  |  |  |  |  |  |
| | pitted-reticulate | broadly reticulate | straitly pitted-reticulate | subtly pitted-reticulate | roughly pitted-reticulate | pitted-reticulate |
| pattern and quality of testa epidermis |  |  |  |  |  |  |
| | crumpled, less transparent | granulous, less transparent | dotted, less transparent | rippling, less transparent | transparent | transparent |
| colour of seeds | brown | yellowish brown | darker brown | brown | reddish brown | brown, the border dark brown |



Rorippa prolifera HEUFF. (Plate II, 1-2)

Length: 0.3 to 0.4 mm.

Shape: juglike, beneath hilum somewhat inclined, provided with neck. Near hilum rounded, opposite to hilum: pointed. Sclerotic layer netlike covered with small dimples, but meshes (colliculate bays of network) here being the smallest: (10 to 15 μ m). Exterior walls of epidermis cells wrinkled even when wet.

Colour: brown.

Radicle: appearing to be spiriobal.

Rorippa pyrenaica (LAM.) RCHB. (Plate II, 5)

Length: 0.6 to 0.7 mm.

Shape: oval. Near hilum, beak-shaped and thin, obtuse, opposite to hilum obtusely pointed. Pattern of sclerotic layer: roughly (more thickly than in other species) reticulated with dimples. Lower wall of cells of this layer dotted. Epidermis layer transparent.

Colour: reddish brown.

Radicle: frequently obliquely accumbent to cotyledons.

Rorippa silvestris (L.) BESS. (Plate II, 3-4)

Length: 0.6 to 0.7 mm.

Shape: oval.

Near to hilum blunt, opposite to hilum slightly cut off. Sclerotic layer: netlike with dimples and it is perceptible well owing to the transparent epidermis cells. Horizontal extension of meshes (bays) agreeing basically with that of *R. amphibia*.

Colour: brown, but margin of seeds is bordered with a darker, reddish brown band.

Radicle: accumbent.

The morphological features of the six *Rorippa* species also appear on their hybrids, thus they are hereditary, namely: purely, combined or seldom mosaic-like. Of course, when trying to state the morphological features of *Rorippa*-seeds, also the immediate influence of some foreign pollenizing father-plant (metaxeny) should be taken into consideration. This phenomenon has been observed by FEDOSSEJEWA (1936) also among other Cruciferae (l. c. 79).

But the plants examined by me differ from the other *Rorippa* specimens in the same way, not only as far as their seeds are concerned but also with a view to their habit. Moreover, the identical morphological features of these seeds appear on *Rorippa* specimens originating from different places and from different years. Especially convincing arguments are some morphological features of hybrid seeds if the parents do not occur at that place at all. Furthermore, the seed pictures of the stabilized hybrids already present sufficiently balanced combinations of species, just as their external appearance. I examined also a polymorph, unbalanced, so-called transitional *Rorippa*-hybrid with unaltered habit. Such a habit has been saved only by vegetative propagation (by shoots) But these plants had

some specimens also which have come up from seeds; these specimens differed from the mother-plant even in their appearance. The seeds of these latter plants did not show the whole spectrum of the mother-plant. Thus, it may be concluded that even the exterior morphological characters of seeds of such plants are inherent, i. e. hereditary. The phenomena mentioned previously show at the same time the fact that in the case of *Rorippa* species, which are able to interbreed easily, it is necessary to examine not only the habit of the hybrid plant, or the seeds of several plants of the same type, but also the way of propagation and population of the respective plants.

Identification of *Rorippa* hybrids, on the basis of the external
morphological characters of their seeds

Rorippa barbaraeoides (TAUSCH 1840 sub. *Nasturtio*) CELAK 1874.

Syn.: *Rorippa x astylis* (RCHB. 1832 sub *Nasturtio*)
RCHB. 1938/SOÓ 1968.

As already mentioned, BORBÁS (1878) has determined this hybrid formerly as *R. amphibia x silvestris* and later (BORBÁS 1879a) as *R. austriaca x silvestris*. Even TOMŠOVIĆ when he revised our collection of *Rorippas* stated that it is a hybrid of *R. amphibia x silvestris*. (TOMŠOVIĆ 1969). According to SOÓ's synopsis the said *Rorippa* specimen is a mixture (hybrid) of *Rorippa islandica x silvestris*, a stabilized hybrid (SOÓ 1968). When comparing the seeds of the morphologically identical dried plants in the Herbarium of the Botanical Department, collected at various places at various dates, it can be stated, that these hybrids show without exception rather balanced combinations of the features of seeds of *Rorippa amphibia*, *Rorippa austriaca* and *Rorippa silvestris*. Thus, the said *Rorippa* specimen evolved by a triple hybridization, and since it has become independent and constant, it may be considered as a hybridogenous species. The seeds of *Rorippa barbaraeoides* have some morphological features of *R. amphibia*, *R. austriaca* and *R. silvestris* respectively: namely: greater size, characteristics of hylum of *R. amphibia*; as well as the shape and the granulate surface of hylum region, the side walls of the sclerotic layer cells of the *R. austriaca* seeds which walls are especially well visible under greater magnification, sticking out like thorn and forming an acute angle meeting each other; the shape and hylum region and their darker marginal stripe of *R. silvestris* seeds. On the seed picture of this species not one of characteristic features of *R. islandica* (resp. *palustris*) is found.

For illustration purposes, I wish to give three seed pictures of *Rorippa barbaraeoides* TAUSCH (Plate II, 6-7) in two enlargements. And for comparative purposes in order to easily discern the features enumerated above I enclose the seed pictures of three other stabilized hybridogenous spe-

cies: Rorippa repens BORB. (R. amphibia x silvestris) (Plate III, 1); Rorippa hungarica BORB. (R. amphibia x austriaca) (Plate III, 4); and Rorippa erythrocaulis BORB. (R. amphibia x palustris) (Plate III, 2). As the seed picture of Rorippa repens shows, in the combination of species the features of R. austriaca-type are not present, it is the character of R. silvestris which prevails: its shape rather widened below, the hilum region is not arched but rather obtuse, and on the margin there is a darker stripe; on the seed picture of R. hungarica the morphological features of seeds of R. silvestris are not present; finally, as to the seeds of R. erythrocaulis, the features of R. palustris are combined, these latter features cannot be observed on the seeds of R. barbaraeoides. (I mentioned only the morphological features visible on the photos.)

Rorippa armoracioides TAUSCH (sub Nasturtio 1840)

Syn.: R. x armoracioides (TAUSCH 1840 sub Nasturtio) FUSS 1866.

This taxon is mostly considered to be a hybrid of R. austriaca and R. silvestris. However, neither BORBÁS (1879a), nor FRÖHLICH (1914) has unequivocally affirmed this, whilst POLÁK (1880) was inclined to take it for a hybrid of R. austriaca and R. palustris. FRÖHLICH said only that it is "probably" a hybrid of R. austriaca and R. silvestris. On the rather similar seeds of Rorippa armoracioides, the characteristic features of R. austriaca and R. silvestris can be observed, namely: the shape of seeds and that of the hilum region, the darker margin of seeds and the thorn-like projection of the thickened cell-walls on the margins (Plate III, 3).

These features are still more explicit on the likewise similar seeds of Rorippa terrestris TAUSCH, also found in the Carpathian Basin (Plate III, 5). According to BORBÁS (1897), these latter Rorippa plants, regarding their morphological features, are the hybrids of Rorippa austriaca and R. silvestris. On the other hand, on the seeds of the specimens of Rorippa armoracioides to be found in our collection also the features of Rorippa palustris (shape and seed surface) can be perceived in various combinations (Plate III, 3). Therefore also Rorippa armoracioides seems to be a stabilized hybridogenous species of triple hybrid origin in such a degree, that there is in our collection a tall Rorippa specimen (No. 70, 106), collected near Nagyenyed, Transylvania, together with R. armoracioides, in an abandoned ditch of the river Maros, but it has been determined as Nasturtium subarmoracioides (Nasturtium barbaraeoides x armoracioides) CSATÓ et SIMK. (Plate IV, 1). The seed picture represents the features of R. austriaca and R. silvestris more distinctly and visible, whilst the features of R. amphibia and R. palustris are shown in an entirely new combination. At the same time, it is characteristic both for the simple primary hybrids and for the mixture of hybridogenic species that their seeds are of various size and shape, and there are many sterile and even distorted seeds among them.

Rorippa kernerii MENYHÁRTH 1877.

This Rorippa species has been found by MENYHÁRTH near Kalocsa "in pratis siccis abunde salsis". He recognized it as an independent species (l. c. 39-40). BORBÁS (1879a), however, expressed his doubt regarding this specimen. He could not tell whether it was a constant alkaline or marshy species of the Hungarian Lowland (l. c. 43a). Later BORBÁS collected the same species near Budapest, on the meadow Rákosmező, on swampy ground, in the society of R. silvestris, R. austriaca and R. amphibia, and even together with anomalis (fastinatio and chloranthia) (l. c. 64).

BORSOS (1951), SOÓ-JÁVORKA (1951) and SOÓ (1954, 1966, 1968) described this species always as a Rorippa silvestris ssp. kernerii (MENYH. et BORB. 1878) SOÓ, although MARKGRAF (1960) did not accept the experimental proofs of BORSOS (1951). JONSELL (1964) wrote the following about this plant: "It seems, however, very doubtful whether this species should be maintained or to be included in R. silvestris BORSOS 1951" (l. c. 205). But in 1968, he was already inclined to consider it probable that it is an ecotype of R. silvestris on alkaline ground (l. c. 96). The type-specimen of MENYHÁRTH (holotype) No. 197, 995, and several isotypes, as well as many specimens collected near Budapest by BORBÁS are found in the Herbarium of the Botanical Department. On the seeds of MENYHÁRTH's type-specimen (Plate IV, 3) it is very well perceptible, that our plant is a new, rather balanced combination of Rorippa austriaca x silvestris x palustris. It may be considered as an independent, hybridogenous species.

On the half of the seeds of the R. kernerii specimens, collected by BORBÁS near Budapest, the features of the R. amphibia seeds come forward, probably as a result of the interbreeding of the two species occurring together at the same place. In the case of the other seeds the features of R. silvestris and R. palustris prevail, so the seeds are of smaller size. Also the plant itself is taller and stronger than the specimens collected by MENYHÁRTH (Plate IV, 2). Furthermore, MENYHÁRTH's dried plant which he named "silvestris formae" agrees entirely with Rorippa hortobágyensis SOÓ (R. kernerii x silvestris) (Plate IV, 4), not only in view of their habit but also in view of their seeds. Both are near to R. silvestris. Studying the Rorippa collection of the Museum, TOMSOVIC determined this species as a hybrid of R. silvestris. The examination of the seeds of PRODÁN's type-specimen (1914) (No. 79, 287), i. e. Rorippa küllödensis PROD. (Plate IV, 5) shows that the plant is a hybrid of R. kernerii x amphibia. PRODÁN's hybrid, with its mighty structure, thick and hollow stem, the shape of the leaves and with its seeds differs basically from the specimens of R. kernerii.

SUMMARY AND CONCLUSIONS

My examinations involved only the basic Rorippa species and some most contestable Rorippa hybrids first of all with a view to the external morphological features of their seeds. The statements and results regarding the seeds and the nature of plants were controlled by the study of the plants habit. Neither the varieties nor the forms were taken into account, although with a view of some supplementary data it may be supposed that, in some way, the hybridization took part in their formation too.

Among the six basic species of the Rorippa genus the seeds of the auto-gamous Rorippa palustris are almost identical whilst those of the other species probably owing to their allogamous reproduction and frequently secondary occurrence, somewhat differ from each other. On the other hand, on basis of the seeds, also the fact can be stated that within this genus, in addition to the so-called hybridogenous, stabilized species, there are further unbalanced hybrids. These are not yet stabilized, thus propagate constantly their race in a vegetative way only. If they occur alone, they may separate and create the so-called "swarm of hybrids" in the generative way, just as the primary hybrids or by introgressive re-crossing. The Rorippa hybrids I examined first of all on basis of their seed pictures, proved to be double or triple hybrids. The single specimen of Nasturtium subarmoracioides (N. barbaraeoides x armoracioides) CSATÓ et SIMK. was examined as control. According to other authors (BORBÁS, JÁVORKA, TOMSÓVIC, FRÖHLICH etc). I think that the following hybrids are double, stabilized hybrids, thus, independent hybridogenous species: Rorippa repens BORB. (R. amphibia x silvestris), Rorippa hungarica BORB. (R. amphibia x austriaca), Rorippa terrestris TAUSCH (R. silvestris x austriaca) and Rorippa erythrocaulis BORB. (R. amphibia x palustris).

The following ones are equally hybridogenous, stabilized species, but with a view to their composition, or more correctly, to their origin, they are not double hybrids but in opposition to earlier statements, triple hybrids: Rorippa barbaraeoides TAUSCH (R. amphibia x silvestris x austriaca), Rorippa armoracioides TAUSCH (R. silvestris x austriaca x palustris), and Rorippa kernerii (R. austriaca x silvestris x palustris). Thus this latter plant is not a subspecies of Rorippa silvestris (L.) BESS. but it is an independent hybridogenous species. This is proved also by the fact that it can be crossed with R. amphibia (Rorippa küllödensis PROD, or with R. silvestris) (R. hortobágyensis SOÓ). The forms of Rorippa kernerii MENYH. collected by BORBÁS seem to be a primary crossing namely with Rorippa amphibia.

It can be concluded that any analysis of the population, any horticultural or crossing experiment, any cytological examination of Rorippa specimens has to be preceded, in addition to the diagnosis of their habit, also by an analysis of the external morphological features of their seeds. JONSELL

(1968) in his Rorippa monograph to emphasized that "statements in following refer, unless otherwise stated, to Nordic and British material only and are not necessarily applicable to e. g. Central European plants" (1. c. 112). Neither can the fact be interrelevant that JONSELL never succeeded in re-crossing the artificial hybrids of R. amphibia while in the case of several spontaneous hybrids he reached results easily (1. c. 40).

RADICS F.: Rorippa (Cruciferae) fajok és hibridek azonosítása magvaik külső alaktani sajátosságai alapján

Vizsgálataink csak a Rorippa-törzsfajokra és néhány leginkább vitatott Rorippa-hibridre terjedtek ki, mindenekelőtt a magvaik külső alaktani sajátosságai alapján. Természetesen a magvakról levont és e növények természetére vonatkozó megállapításokat az illető növény habitusának a diagnózisával is ellenőriztük.

E vizsgálatokba nem vontuk be a Rorippa-fajváltozatokat (varietas) és -formákat, bár néhány kiegészítő adat alapján feltételezhető, hogy a hibridálódás ezek képzésében is valamilyen módon közrejártszik.

A R.-nemzetség hat törzsfaja közül az autogam Rorippa palustris magvai majdnem teljesen egyformák, míg a többi fajú, bizonyára allogam generatív szaporodásmódjuk és gyakran szekundér előfordulásuk miatt kis mértékben különböznek egymástól. Viszont a Rorippa-magvak alapján az is megállapítható, hogy e nemzetségen belül az ún. hibridogén állandósult fajokon kívül általam ún. "átmeneti hibridnek" (unbalanced hybrids) nevezett hibridek is vannak, melyek még nem állandósultak, illetve változatlanul csak vegetatív módon terjeszkedhetnek. Ha egyedül fordulnak elő, generatív módon éppúgy, mint az ún. primér hibridek introgresszív visszakereszteződése, ún. "hibrid-raj"-t különíthetnek el.

A vizsgált Rorippa-hibridek főleg a magképeik alapján kettős, hármas hibridnek bizonyultak. Az ún. Nasturtium subarmoracioides (N. barbareoides x armoracioides) CSATÓ et SIMK. egyetlen példányát csak ellenőrzésképpen vontuk be a vizsgálatba. Más szerzőkkel (BORBÁS, JÁVORKA, TOMSOVIC, FRÖHLICH, stb.) megegyezően kettős, állandósult hibridek, tehát önálló hibridogén fajok a következők: Rorippa repens BORBÁS (R. amphibia x silvestris), Rorippa hungarica BORB. (R. amphibia x austriaca), Rorippa terrestris TAUSCH (R. silvestris x austriaca) és a Rorippa erythrocaulis BORB. (R. amphibia x palustris). Szintén hibridogén állandósult fajok, de az összetételük, helyesebben a keletkezésük szerint - az eddigi megállapításokkal ellentétben - nem kettős, hanem hármas hibridek a Rorippa barbaraoides TAUSCH (R. amphibia x silvestris x austriaca), a Rorippa armoracioides TAUSCH (R. silvestris x austriaca x palustris) és a Rorippa kernerii (R. austriaca x silvestris x palustris). Tehát ez utóbbi növény nem alfaja a Rorippa silvestris (L.) BESS. -nek, hanem önálló hib-

ridogén faj, amit az is bizonyít, hogy kereszteződhet pl. a R. amphibia-val (Rorippa küllódensis PRODÁN) vagy a R. silvestris-szel (R. hortobágyensis SOÓ), stb. Primér kereszteződésnek látszanak BORBÁS-nak pestkörnyéki Rorippa kernerii MENYH. alakjai, mégpedig a R. amphibia-val.

A fentiekből következik, hogy a Rorippa-egyedek populáció-elemzését, kerti és keresztező kísérleteit, citológiai vizsgálatait - habitusuk diagnózisán kívül - magvaik külső alaktani elemzésének is meg kell előznie. JONSELL (1968) Rorippa-monográfiájában okkal hangsúlyozta, hogy "Statements in following refer, unless otherwise stated, to Nordic and British material only and are not necessarily applicable to e. g. Central European plants" (l. c. 112). Továbbá az sem lehet közömbös, hogy JONSELL-nek pl. R. amphibia mesterséges hibridjei esetében a visszakereszteződés sohasem sikerült, míg néhány spontán hibridé könnyen ment (l. c. 40).

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EXPLANATION OF PLATES - ÁBRAMAGYARÁZAT

Plate I.

Fig. 1. - *Rorippa amphibia*, 6.3 x 6.3 (No. 226, 133). - Fig. 2. - *Rorippa amphibia*, 16 x 6.3 - Fig. 3. - *Rorippa austriaca*, 6.3 x 6.3 (No. 355, 647) - Fig. 4. - *Rorippa austriaca*, 16 x 6.3 - Fig. 5. - *Rorippa palustris*, 6.3 x 6.3 (No. 70, 219) - Fig. 6. - *Rorippa palustris*, 16 x 6.3

Plate II.

Fig. 1. - *Rorippa prolifera*, 6.3 x 6.3 (No. 198, 421) - Fig. 2. - *Rorippa prolifera*, 16 x 6.3 - Fig. 3. - *Rorippa silvestris*, 16 x 6.3 (No. 254, 925) - Fig. 4. - *Rorippa silvestris*, 6.3 x 6.3 - Fig. 5. - *Rorippa pyrenaica*, 6.3 x 6.3 (No. 198, 414) - Fig. 6. - *Rorippa barbaraeoides*, 2.5 x 6.3 (No. 225, 266) - Fig. 7. - *Rorippa barbaraeoides*, 6.3 x 6.3 (No. 197)

Plate III.

Fig. 1. - *Rorippa repens*, 2.5 x 6.3 (No. 259, 268) - Fig. 2. - *Rorippa erythrocaulis*, 2.5 x 6.3 (No. 357, 832) - Fig. 3. - *Rorippa armoracioides*, 2.5 x 6.3 (No. 70, 950) - Fig. 4. - *Rorippa hungarica*, 2.5 x 6.3 (No. 329, 957) - Fig. 5. - *Rorippa terrestris*, 6.3 x 6.3 (No. 329, 955) - Fig. 6. - *Rorippa kernerii*, 2.5 x 6.3 (No. 197, 995)

Plate IV.

Fig. 1. - *Rorippa subarmoracioides*, 2.5 x 6.3 (No. 70, 106) - Fig. 2. - *Rorippa kernerii*, 2.5 x 6.3 (Rákosmező near Budapest, Borbás No. 70, 235) - Fig. 3. - *Rorippa kernerii* "silvestris - formae" from Menyhárh, 2.5 x 6.3 (No. 70, 282) - Fig. 4. - *Rorippa hortobágyensis* Soó, 2.5 x 6.3 (No. 198, 232) - Fig. 5. - *Rorippa küllődensis* Prod., 6.3 x 6.3 (No. 70, 286) - Fig. 6. - *Rorippa küllődensis*, 16 x 6.3

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FERENC RADICS
Botanical Department
Hungarian Natural History Museum
1406 Budapest, Pf.: 36.
HUNGARY

Plate I.

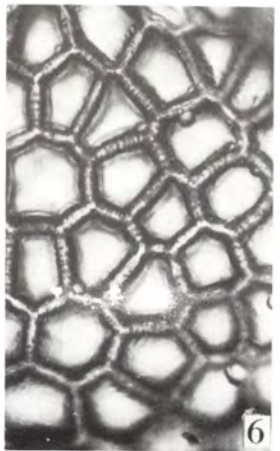
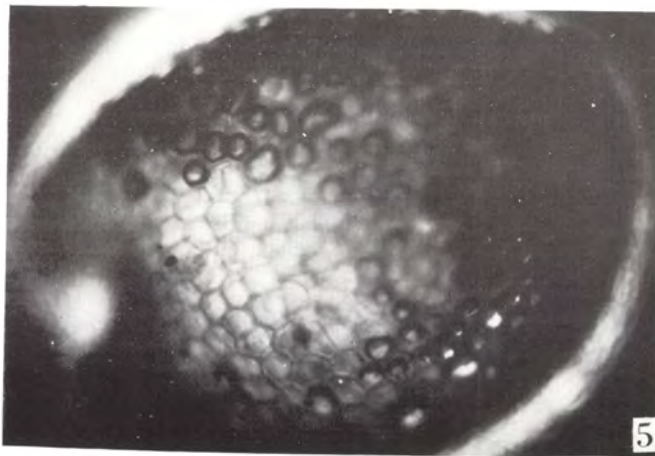
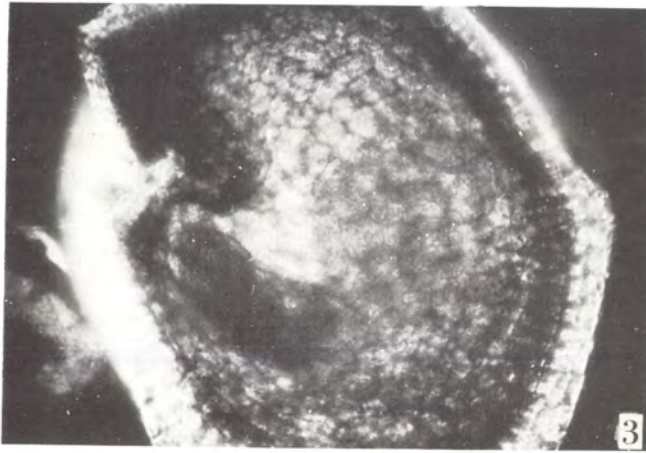
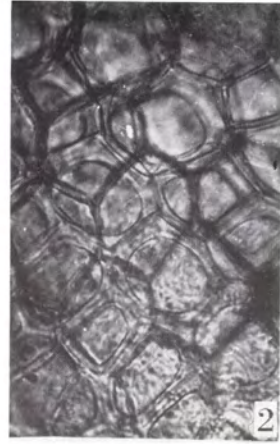


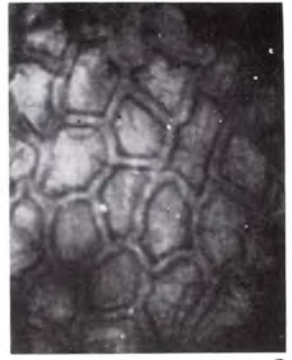
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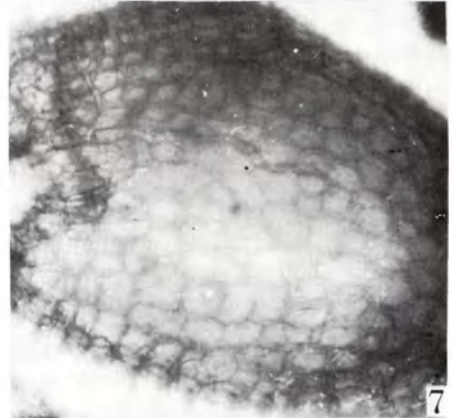
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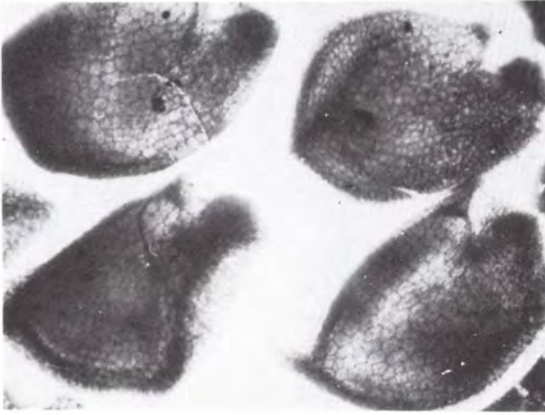


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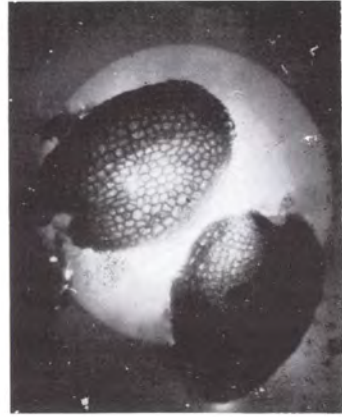


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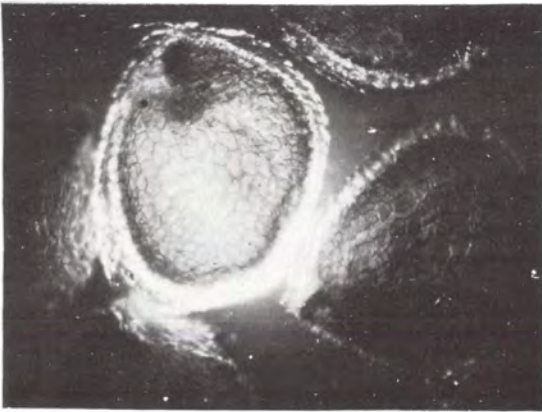
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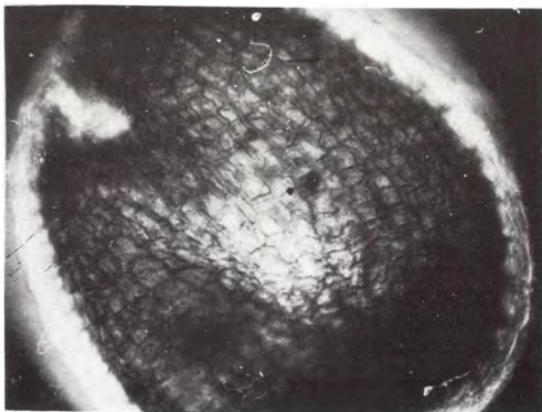
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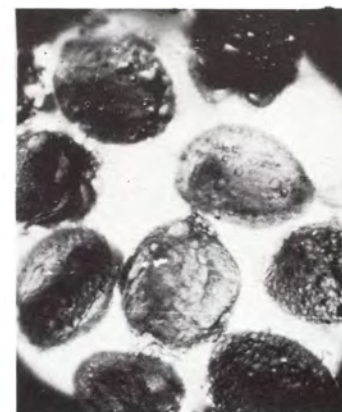
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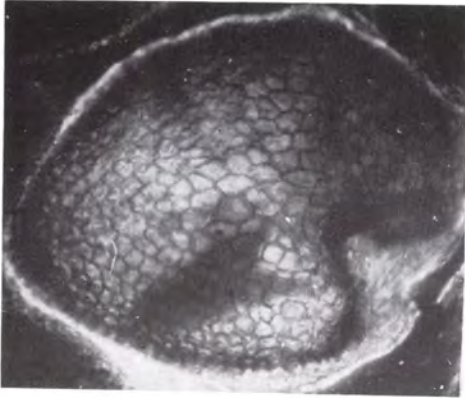
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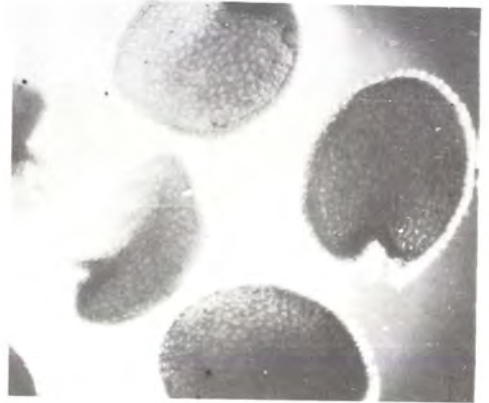
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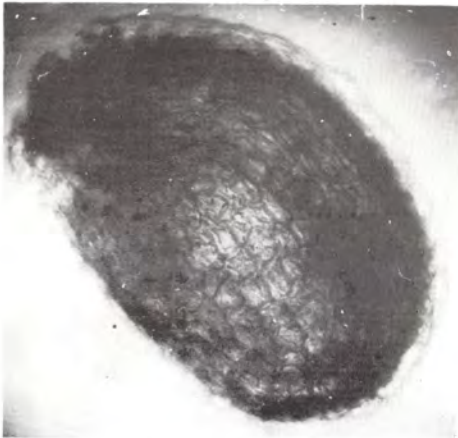
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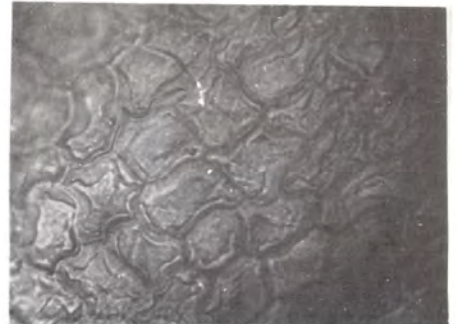
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