The morphology of hairs in species of *Plantago* L. Sections: *Bauphula* Decne and *Arnoglossum* Decne

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Abstract

The hairs of one representative of the monotypic sectio *Bauphula* and of seven taxa of the section *Arnoglossum* were investigated. Unlike *P. amplexicaulis* (sectio *Bauphula*) the representatives of sectio *Arnoglossum*, were found to have headless hairs on the scape with cells overlapping in a characteristic manner. They had no hairs with a unicellular stalk and head divided vertically into two cells, commonly occurring in the representatives of different sections of the genus *Plantago*: *Polyneuron*, *Lamprosantha*, *Coronopus*, *Oreades*, *Leucopsyllium*, *Hymenopsyllium* and *Psyllium*.

Rahn's decision (1978) to transfer the sections *Bauphula* and *Arnoglossum* to the subgenus *Psyllium* seems incorrect. The representatives of the investigated sections, unlike the taxa of the sectio *Psyllium*, have no hairs with multicellular stalks and unicellular heads, club-like hairs and iridoid-plantarenalioside, while they have morel-like hairs, hairs with overlapping cells and an iridoid-catalpol, lacking in the taxa of the subgenus *Psyllium*.

Key words: genus *Plantago* L., sectio *Bauphula* Decne, sectio *Arnoglossum* Decne, hairs, scanning electron microscopy

INTRODUCTION

The representatives of sections *Bauphula* Decne and *Arnoglossum* Decne (syn. *Lancifolia* Barn.) are morphologically similar (Pilger 1937). The

chemotaxonomic studies of Andrzejewska-Golec and Świątek (1984) confirmed this homology (the presence of catalpol). According to Pilger (1937), as well as many other authors (Grigoriev 1958, Clapham et al. 1962, Chater and Cartier 1976), sections *Bauphula* and *Arnoglossum* belong to the subgenus *Plantago* (syn. *Euplantago*) of the genus *Plantago* L., whereas Rahn (1978) transfers both these sections to the subgenus *Psyllium* (Juss.) Harms et Reiche. The hairs of *P. amplexicaulis* Cav. — the only representative of the monotypic sectio *Bauphula* — have not been described yet. From among the taxa of the sectio *Arnoglossum* only the hairs of *Plantago lanceolata*, the best known representative of the section, whose leaves are used as medicinal raw material, have been studied.

Pilger (1898) described hairs in *P. lanceolata* with a large basal cell, thin, square first cell of the stalk ("Fusszelle") and whip-like, thin-walled tip cell. These hairs are, according to Pilger, a characteristic feature not only of the representatives of the sectio *Arnoglossum*, but also of *Oreades* and *Leucopsyllium*.

On the leaves of *P. lanceolata*, Unger (1926) observed headless hairs consisting of a considerably enlarged basal cell, small first cell of the stalk and two stalk cells characteristically joined with each other. In autumn, according to this author, hairs of the above type with considerably elongated, easily breaking tips can be observed. Another type of headless hairs are cylindrical hairs with varied cell numbers. Unger also described hairs with unicellular, strongly cutinized stalks and multicellular conical heads, and hairs with short, strongly cutinized stalk completely hidden among epidermis cells and with a multicellular, crownshaped head ("Krönchenhaare"). The occurrence of these hairs was not confirmed by other authors.

While on the stalk of *P. lanceolata* there are, according to Unger, headed hairs built similarly as those on the leaf, the headless hairs consist of overlapping cells ("Haar ein zopfönliches Aussehen"). Fuchs (1932) also observed hairs similar to those described by Pilger (1898) and Unger (1926).

Also Fischer (1937) was concerned with the hairs of *P. lanceolata*. He described three types of hairs present on the leaves of this taxon; 1) headless hairs with a square first cell of the stalk, described previously by Pilger (1898) and Unger (1926), 2) multicellular, thin-walled web-like hairs, occurring only on the leaf base, 3) headed morel-like hairs with unicellular stalks and multicellular heads of irregular shape ("Form Morcheln ähnliche Drüsenhaare").

MATERIALS AND METHODS

The hairs of leaves, scapes, bracts, calyces and corollas of one representative of sectio *Bauphula* Decne (monotypic section) *Plantago amplexicaulis*

Fig. 1. *Plantago amplexicaulis* Cav. $\times 0.5$

Fig. 2. *Plantago lanceolata* L. subsp. *sphaerostachya*. $\times 0.3$. Plants from our field culture

Cav. were studied as well as the respective parts of seven representatives of sectio *Arnoglossum* Decne: *Plantago lanceolata* L., *P. lanceolata* L. subsp. *sphaerostachya*, *P. leiopetala* Lowe, *P. altissima* L., *P. argentea* Chaix, *P. lagopus* L., *P. lagopus* L. var. *lusitanica* (Willd.) Ball.

The plants were grown in the Garden of Medical Plants of the Department of Pharmacognosy (Figs. 1-6).

The seeds for culture were obtained from European botanical gardens.

The identity of the investigated taxa was checked with Pilger's mono-

Fig. 3. *Plantago altissima* L. $\times 0.5$. Plant from our field culture

graphy (1937), Flora Polska (Taciak 1967) and Flora Europea (Chater and Cartier 1976).

The material was collected in the florescence period (August-September 1984-1987). Both fresh and conserved material was used for investigation.

Light microscopic figures were drawn with the use of Abbe's apparatus. Scanning microscopy observations were also carried out. For this purpose the fragments of the investigated plant were fixed in glutaraldehyde and osmium tetroxide and then carried through a dehydrating acetone-alcohol series and transferred to a critical point drying apparatus. Samples prepared in this way were coated with gold and palladium alloy.

Fig. 4. *Plantago lagopus* L. $\times 0.25$. Plant from our field culture

Fig. 5. *Plantago lagopus* (Willd.) var. *lusitanica* Ball $\times 0.1$

Fig. 6. *Plantago leiopetala* Lowe $\times 0.3$. Plants from our field culture

RESULTS

The results are presented in Table 1 and in Figures 7-35.

SECTIO BAUPHULA (*P. AMPLEXICAULIS*)
(FIGS. 7, 8, 20-29)

Headed hairs. Hairs with a unicellular stalk and heads divided vertically into two cells (e.g. Figs. 7A, B, G, H, 20, 21) occurred in all of the examined parts except for the bract and corolla. These hairs commonly occur in the

Fig. 7. *Plantago amplexicaulis* Cav. hairs: A-F — from a leaf: C — a nontypical hair with two-celled stalk, E — a characteristic joining of the cells of a headless hair, F — "trace" of a headless hair, G-J — hairs from a stem, J — a nontypical hair, K-S — headed hairs from a scape, R — a nontypical hair. Scale bar A-C — 0.1 mm; E, G-S — 0.05 mm; F — 0.2 mm; D — 0.4 mm

Table 1
Hair types occurring in sections *Bauphula* Decne and *Arnoglossum* Decne

The name of the section	The name of the plant*	The investigated part of the plant**	Headed hairs			Headless hairs			
			two-celled head	(3) 4 (5)-celled head	multi-celled head (morel-like)	consisting of several cells with		multi-cellular (web-like)	
						small square cell			without small square cell
						over-lapping cells	characteristically jammed cells		
<i>Bauphula</i> Decne	<i>Plantago amplexicaulis</i> Cav. (Arhus)	L	+	+ round head	—	—	+	—	+
		T	+	+ round head	—	—	+	—	+
		S	+	morel-like + round head	—	—	+	—	+
		B	—	—	—	—	—	—	—
		C	+	—	—	—	+	—	—
		R	—	—	—	—	—	—	—
<i>Arnoglossum</i> Decne	<i>Plantago lanceolata</i> L. (Dębki)	L	—	—	+	—	+	—	+
		S	—	—	+	+	—	—	+
		B	—	—	+	—	+	—	—
		A	—	—	+	—	+	—	—
		C	—	—	+	—	+	—	—
		O	—	—	+	—	+	—	—
		R	—	—	—	—	—	—	—
	<i>Plantago lanceolata</i> L. ssp. <i>sphaerostachya</i> Hayek (Rostock)	L	—	—	+	—	+	—	+
		S	—	—	+	+	+	—	+
		B	+***	—	+	—	+	—	—
		A	—	—	+	—	+	—	—
		C	—	—	+	—	+	—	—
		O	—	—	+	—	+	—	—
		R	—	—	—	—	—	—	—
	<i>Plantago leiopetala</i> Lowe (Nancy)	L	—	—	+	—	—	—	+
		S	—	—	+	+	—	—	—
		B	—	—	+	—	+	—	—
		A	—	—	—	—	—	—	—
		C	—	—	—	—	—	—	—
		O	—	—	—	—	—	—	—
		R	—	—	—	—	—	—	—

<i>Plantago altissima</i> L. (Marburg)	L	—	+ morel-like	—	+ ****	+	—	+
	S	—	+ morel-like	—	+ *****	—	—	+
	B	—	+ morel-like	—	—	+	—	—
	C A	—	+ morel-like	—	—	+	—	—
	O	—	+ morel-like	—	—	+	—	—
	R	—	—	—	—	—	—	—
<i>Plantago argentea</i> Chaix (Szeged)	L	—	—	+	+	—	—	+
	S	—	—	—	+	—	—	—
	B	—	—	—	—	+	—	—
	C A	—	—	—	—	+	—	—
	O	—	—	—	—	+	—	—
	R	—	—	+	—	+	—	—
<i>Plantago lagopus</i> L. (Bochum)	L	—	—	+	—	+	—	+
	T	—	—	+	—	—	—	—
	S	—	—	+	+	—	—	—
	B	—	—	+	—	+	+	—
	C A	—	—	—	—	+	+	—
	O	—	—	+	—	+	+	—
<i>Plantago lagopus</i> L. var. <i>lusitanica</i> (Willd.) Ball (Coimbra)	R	—	—	—	—	—	—	—
	L	—	—	+	—	+	—	+
	T	—	—	+	+	—	—	+
	S	—	—	+	+	—	—	—
	B	—	—	—	—	+	—	+
	C A	—	—	—	—	+	—	—
	O	—	—	—	—	+	—	—
	R	—	—	—	—	—	—	—

* The name of the species according to the catalogue of the botanical garden (the seat of which is given in the brackets) from which the seeds were imported.

** L — leaf, S — scape, T — stem, B — bract, C — calyx, A — anterior sepal, O — posterior sepal, R — corolla.

*** Sporadically occurring hairs.

**** They are sparse and have 2 small square cells (Pilger (1898) mentions *P. altissima* as an exceptional hairless taxon in the genus *Plantago*).

***** Rarely observed whole hairs, more often their traces (basal cell, the first stalk cell).

Plantaginaceae family (Vesque 1885, Unger 1926, Fischer 1937, Andrzejewska-Golec and Świętosławski 1987, 1988).

Hairs with a unicellular stalk and 4-celled round head (e.g. Figs. 7N, O) and 4-5 celled conical head (morel like) (e.g. Figs. 7S, 8A, 26, 27) were presented only on the scape. The nontypical hairs with a unicellular stalk and 3-celled head (e.g. Figs. 7I, P, 22, 23) and with 2 (3)-celled stalk and two celled

Fig. 8. *Plantago amplexicaulis* Cav. hairs: A, B — headed hairs from a scape; C-N — headless hairs (or their fragments) from a scape; E, K — a joining of two cells of the stalk; H — a one-celled hair; I, M, N — a base of the hairs. Scale bar: C-F, H, J, M, N — 0.1 mm; A, B, I, K — 0.05 mm; G, L — 0.2 mm

head (e.g. Figs. 7C, J, R) occurred on the leaf, the stem and the scape sporadically.

Headless hairs. The web-like (woolly) hairs had a similar structure as those found in other representatives of the genus *Plantago* (Andrzejewska-Golec and Świętosławski 1987, 1988).

The hairs with a large basal cell and small, square first cell of the stalk with cutinized walls (intensely stained with Sudan III) had a unicellular or a multicellular tip (in such a case the cells were characteristically jammed) (e.g. Figs. 7D, 8C-N, 29).

SECTIO ARNOGLOSSUM

(FIGS. 9-19, 30-35)

Headed hairs. In the studied taxa of this section (with the exception of *P. altissima*) hairs with a unicellular stalk and multicellular conical head occurred (e.g. Figs. 9D-F, 10A-J, 19A-D, 35), while headed hairs with unicellular stalk and head consisting of two cells were lacking (with the exception of sporadically occurring hairs on the bract of *P. lanceolata* subsp. *sphaerostachya* (Figs. 11F-I)).

Fig. 9. *Plantago lanceolata* L. hairs: A, B, D — from a leaf; C — from a scape; E — from an anterior sepal; F — from a posterior sepal. Scale bar: A — 0.2 mm; B-F — 0.1 mm

Web-like hairs (e.g. Figs. 16E-G) were present in all the investigated species on the leaf base, and in most of the taxa also on the scape base.

Hairs consisting of two or more cells with the small first cell of the stalk were built similarly as those of *P. amplexicaulis* (e.g. Figs. 9A, B, 18B, C, 19F, 32-34).

Fig. 10. *Plantago lanceolata* L. subsp. *sphaerostachya* hairs: A-H — morel-like hairs from a leaf; J-U — hairs (or their fragments) from a scape; L — a typical "trace" of a headless hair; N — the placement of the hair in relation to the surface of the scape; M — a base of the web-like hairs; R, S, U — a typical joining of the web-like hairs; T — the ending of a web-like hair cell. Scale bar:

A-H, K-M, O, R-U — 0.1 mm; I, J — 0.05 mm; P, N — 0.2 mm

Hairs consisting of several cells with overlapping cells (e. g. Figs. 9C, 10N, P, 13C, D, 30, 31) were characteristic of the scape of all *Arnoglossum* representatives. Only in *P. argentea* did they also occur on the leaves (Figs. 15A, B).

Fig. 11. *Plantago lanceolata* L. subsp. *sphaerostachya* hairs: A-J — from a bract; B, D, E — fragments of the headless hairs; K-S — from a calyx. Scale bar 0.1 mm; J, R, S — 0.05 mm; A — 0.2 mm

DISCUSSION

P. amplexicaulis has many features in common with the representatives of the sectio *Arnoglossum*. One of them is the presence of an iridoid-catalpol (Andrzejewska-Golec and Świątek 1984), another — the presence of headless hairs with the small first cell of the stalk and morel-like hairs on the scape.

The taxa of the sectio *Arnoglossum*, unlike sectio *Bauphula* and represen-

Fig. 12. *Plantago leiopetala* Lowe hairs: A-F — from a leaf; A-D — fragments of headless hairs; G-L — from a scape. Scale bar: E-G — 0.1 mm; H-J — 0.05 mm; A-D, K, L — 0.2 mm

tatives of numerous other sections: *Polyneuron*, *Lamprosantha*, *Coronopus*, *Leucopsyllium*, *Hymenopsyllium*, *Psyllium* (Vesque 1885, Unger 1926, Andrzejewska-Golec and Świętosławski 1987, 1988 and unpublished data) have no hairs with unicellular stalks and bicellular heads. On the other hand, headless hairs with overlapping cells are characteristic of the taxa of the sectio *Arnoglossum* and distinguish them from *P. amplexicaulis*.

The inclusion of sections *Bauphula* and *Arnoglossum* in the subgenus *Psyllium*, proposed by Rahn (1978), seems incorrect because of considerable differences between these taxa and the taxa of the sectio *Psyllium*.

Fig. 13. *Plantago altissima* L. hairs: A, B — from a leaf; A — a fragment of a headless hair; C-G — from a scape, G — a joining of two cells of a headless hair. Scale bar: A, E, F — 0.1 mm; B-D, G — 0.05 mm

The subgenus *Psyllium* is characterized, as it was found in previous studies, by the presence of an iridoid-plantarenalloside (Popow et al. 1981, Andrzejewska-Golec and Świętek 1984, Kuzmanov et al. 1984) and of an unidentified iridoid substance (Andrzejewska-Golec and Świętek 1984). These iridoids are absent in the investigated representatives of the sections *Bauphula* and *Arnoglossum*. The hairs with multicellular stalks and unicellular heads, and club-like hairs characteristic of the representatives of sectio

Fig. 14. *Plantago altissima* L. hairs: A-E — from a bract; F-L — from a calyx; D — a base of a headless hair; E — an ending of a headless hair; I — a characteristic joining of the headless hair.

Scale bar: A, C, F-L — 0.1 mm; D, E — 0.05 mm; B — 0.2 mm

Psyllium are also lacking here (Andrzejewska-Golec and Świętosławski — in press).

On the other hand, the presence of catapol and morel-like hairs (which characterizes the taxa of sections *Bauphula* and *Arnoglossum*) is regarded as a characteristic feature of some sections of subgenus *Euplantago* (*Plantago*) (Andrzejewska-Golec and Świętek 1984, Andrzejewska-Golec and Świętosławski 1987).

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Fig. 15. *Plantago argentea* Chaix hairs: A-J — from a leaf; J-K — from a scape; J — an ending of a hair; L-O — from a corolla. Scale bar: C-J, L-N — 0.1 mm; A, B, K, O — 0.2 mm

Fig. 16. *Plantago lagopus* L. hairs; A-J — from a leaf; E-G — fragments of the web-like hairs; J — a characteristic "trace" of a headless hair. Scale bar: C, D — 0.1 mm; A, B, E-G, — 0.2 mm

Fig. 17. *Plantago lagopus* L. hairs: A, B — from a stem; C, D — a headless hair from a scape (in two a scape (in two parts); E-J — from a calyx; E, F — a headless hair in two parts; H, I — fragments of headless hairs. Scale bar: E, F, H-J — 0.1 mm; G — 0.2 mm; A-D — 0.05 mm

Fig. 18. *Plantago lagopus* L. var. *lusitanica* (Willd.) Ball hairs: A-D — from a leaf; A — a “trace” of a headless hair; E-G — fragments of a headless hair from a stem. Scale bar: D-G — 0.1 mm; A-C — 0.2 mm

Fig. 19. *Plantago lagopus* L. var. *lusitanica* (Willd.) Ball hairs: A-D — morel-like hairs from the stem; E — a hair from a scape; F-L — hairs (or their fragments) from bracts. Scale bar: A-D, F, G, J-L — 0.1 mm; H — 0.05 mm; I, E — 0.2 mm

Fig. 20. A hair with a unicellular stalk (1) and two-celled head (2) on a leaf of *Plantago amplexicaulis* Cav., surrounding cells (3), a stomatal apparatus (4), $\times 1000$

Fig. 21. A hair with a unicellular stalk (1) two-celled head (2) on a *Plantago amplexicaulis* Cav. leaf, stomatal apparatus (4), smooth surface of the hair, $\times 2000$

Fig. 22. A hair with a unicellular stalk (1) and three-celled head (2) from a leaf of *Plantago amplexicaulis* Cav.: surrounding cells (3), a stomatal apparatus (4), $\times 1000$

Fig. 23. A hair with a unicellular stalk (1) and three-celled head (2) from a leaf of *Plantago amplexicaulis* Cav.: surrounding cells (3), a stomatal apparatus (4), smooth surface of the hair, $\times 2000$

Fig. 24. A "trace" (1) of a headed hair on the stems of *Plantago amplexicaulis* Cav., surrounding cells (2), $\times 2000$

Fig. 25. A morel-like hair on the scape of *Plantago amplexicaulis* Cav., unicellular stalk (1), conical head (2), $\times 2000$

PLATE IV

Figs. 26-27. A morel-like hair on the scape of *Plantago amplexicaulis* Cav., unicellular stalk (1), conical head (2), $\times 2000$

PLATE V

Fig. 28. A "trace" (1) of a headless hair on the scape of *Plantago amplexicaulis* Cav., $\times 1000$

Fig. 29. Combination of two headless hair cells on the calyx of *Plantago amplexicaulis* Cav., $\times 2000$

PLATE VI

Fig. 30. A headless hair with a charactereristic joining (1) on the scape of *Plantago altissima* L., $\times 200$

Fig. 31. A characteristic joining of two cells from a headless hair of *Plantago altissima* L., $\times 2000$

PLATE VII

Fig. 32. A headless hair from a bract of *Plantago altissima* L., 1 — a first cell of the stalk, 2 — characteristic joining of second and third cells of the stalk, $\times 500$

Fig. 33. A base of the headless hair from Fig. 32, $\times 1000$

Fig. 34. The characteristic joining of cells (arrows) of the headless hair from Figs. 32 and 33, $\times 2000$

Fig. 35. A morel-like hair on the bract of *Plantago altissima* L. 1 — a stalk cell, 2 — a head, 3 — surrounding cells, $\times 1000$

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*Morfologia włosków w gatunkach rodzaju Plantago L.,
sekcje: Bauphula Decne i Arnoglossum Decne*

Streszczenie

Zbadano włoski jednego przedstawiciela monotypowej sekcji *Bauphula* oraz siedmiu taksonów sekcji *Arnoglossum*. Przedstawiciele sekcji *Arnoglossum* w odróżnieniu od *P. amplexicaulis* (s. *Bauphula*) mają na łodydze włoski bezgłówkowe o komórkach nakładających się w charaktery-

tyczny sposób. Nie mają natomiast włosków o jednokomórkowym trzonku i główce podzielonej pionowo na dwie komórki, które występują u *P. amplexicaulis* i u przedstawicieli różnych sekcji rodzaju *Plantago*.

Podjęta przez Rahn [1978] decyzja przeniesienia sekcji *Bauphula* i *Arnoglossum* do podrodzaju *Psyllium* wydaje się niesłuszna jeżeli weźmie się pod uwagę wyniki badań morfologii włosków powyższych taksonów.