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VARIATION OF LIGULATE FLORETS IN SOME TAXA OF THE GENUS *ACHILLEA* L.

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ABSTRACT. The author distinguished eight forms of variation of ligulate florets in some species of the genus *Achillea* L. and presented them in figures (Figs 2-9). From them five forms were found in plants of characters intermediate between *A. collina* Becker and *A. millefolium* L. s. str. (Table 1). In forms: *bipetala*, *caliciformis* and *subtubulosa* in some florets also the sex was changed – such florets were bisexual, but of different number of stamina. In form *tubulosa* in all florets the sex was changed, such florets were bisexual, but of different number of stamina. Form *heteropetala* was observed in the nature and also obtained experimentally by the author through selfpollination of a plant of characters intermediate between *A. collina* Becker and *A. millefolium* L. s. str. and *A. asplenifolia* Vent.
It is possible that the described variation of ligulate florets is a result of hybridization especially but may be also the result of some other causes.

Key words: ligulate florets, inflorescence, variability, hybridization, *Achillea*, *Asteraceae,* Poland

Introduction

Capitula of the genus *Achillea* L. are composed of ligulate florets which are female and tubulate florets which are bisexual. Sometimes some morphological variation of ligulate florets can be observed within one plant e.g. margin entire or indistinctly crenate. The variation described below, observed by the author is found less frequently. The aim of this article is not an explanation of causes of variation (author is not a genetist) but describing it for easier communication with other investigators.

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Material and methods

Based on observations in natural conditions and in herbarium collections, carried out especially since 1966, in Poland and in other countries, the author has distinguished eight forms of morphological types of ligulate florets in some taxa of the genus *Achillea* L. (Table 1) and presented them in Figures 2-9*. **The term "form" as applied here does not refer to taxa but describes type of variation,** though the term is used with a Latin adjective. By this way for example genetists describe mutants. In *Antirrhinum majus* mutants were noted as: *graminifolia gracilis*, *marmorata, rubella* etc. (**Malinowski** 1963).

Figures were made by the author using microscope and Abbe apparatus (scale bar = 1 mm). As for receiving self-pollination, parchment isolators were placed on inflorescences with buds (when the plant bloomed, isolators were shaken repeatedly to cause self-pollination).

Crossing of yarrows was performed with the use of the same isolators (tubulate florets), as bisexual, were removed from the plant that was to be pollinated, and the inflorescence which would provide pollen was isolated at bud stage (**Dąbrowska** 1973).

Results and discussion

Forms of morphological types of ligulate florets in some taxa of *Achillea* L. observed by the author are described in Table 1 and presented in Figures 2-9.

Herbarium materials from Sweden (Herbarium WRSL) contain a specimen determined as *Achillea ptarmica* L. for. *tubulosa* C. G. Westerlund, with all the florets tubulate. It is unkown, however if in this form ligulate florets have not been formed at all, or if they have changed into tubulate florets.

According to **Pawłowski** (1971) tubulate florets are more ancestral than ligulate. Hypothetical linies of corolla modifications are presented according to Jeffrey (1977, cit. **Mani** and **Saravanan** 1999): peripheral florets may be derived from the primitive tubular – campanulate corolla (Fig. 1).

Some of them in the last line of Figure 1 are similar to forms which the author observed in yarrows (I_1, I_3).

It follows from the data in the "Flora Polska" (**Pawłowski** 1971) that in some species of *Compositae* forms were noted with inflorescences devoid of ligulate florets (it is unknown, however, if ligulate florets have not been formed at all or if they have changed into tubulate florets – there is no information on the subject).

Besides the above-mentioned forms of variation of ligulate florets, such florets, departing in their shape from most florets in the inflorescence can be encountered almost in any plant and various species of yarrow. These may be single florets changed like in the forms described above, or they may differ only in the ligulate part of the ligulate floret being irregularly crenate, incised at apex or of entire margin.

*Names of districts and voyvodeships at these figures are given according to administration borders actual in Poland in the years 1966-1972.

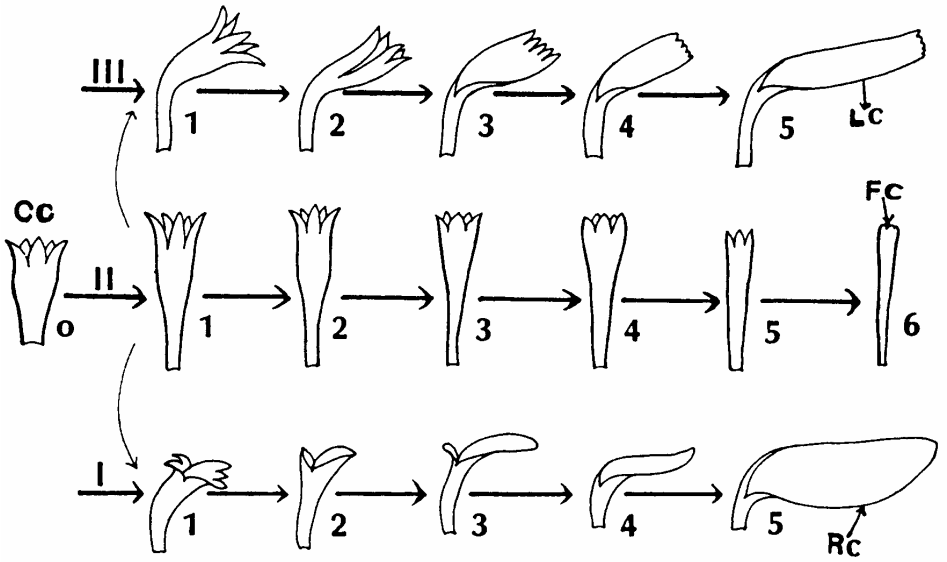

Fig. 1. Reproduction of figures which are cited by **Mani** and **Saravanan** (1999, Fig. 22)
Ryc. 1. Reprodukcja rycin, które cytują **Mani** i **Saravanan** (1999, ryc. 22)

It is noteworthy that I have found five morphological types of ligulate florets (Table 1, *bipetala, caliciformis, heteropetala, subtubulosa, tubulosa*) in the area of frequent occurrence of intermediate forms between *A. collina* Becker (4x, 2n = 36) and *A. millefolium* L. s. str. (6x, 2n = 54). Collecting sites are listed in figure explanations (Figs 2-9).

The area is close to amber tract (Opole and Katowice districts) which was probably the way by which *A. collina* came from the south. The species is abundant in the Moravian Gate, as the author observed on the Czech side. In the Opole district in many places numerous forms are observed of intermediate characters betweem *A. collina* and *A. millefolium* L. s. str. (with respect to leaf morphology). Inflorescences of these forms have characters of one or the other species. The intermediate character of the forms is also manifested as different azulene content in the volatile oil of particular plants; the author found this during her studies on the distribution of these forms in the Upper and Lower Silesia. At that time the author analysed more than 34 000 yarrow plants, using Stahl's EP reagent (**Dąbrowska** 1972). *A. collina* Becker is as a rule azulene-containing, *A. millefolium* L. s. str. is azulene-less. Forms of characters intermediate between the two taxa may hybridize. They have been crossed with a positive result (**Dąbrowska** 1973).

Observing various expressions of variation in *Achillea* L. (n = 9) it should be borne in mind that within some groups of species are di-, tetra-, hexa- and octoploids (and sporadically also penta- and septaploids) characterized by breaking of hybridization barriers at higher ploidy levels. The phenomenon is an important mechanism of transfer of genetic material from lower to higher ploidy levels (**Ehrendorfer** 1959). *Achillea collina* Becker (4x) arose from *A. setacea* W. et K. (2x) and *A. aspelnifolia* Vent. (2x) as experimentally was evidenced by **Ehrendorfer** (1958, 1959). Allopolyploidy has been inferred as a significant aspect of plant evolution (Stebbins 1947, 1959, Grant 1981 – after **Arnold** 1997).

Table 1

Variation of ligulate florets in some taxa of *Achillea*
Zienność kwiatów języczkowatych u niektórych taksonów *Achillea*

Form Forma	Morphology of ligulate florets Morfologia kwiatów języczkowatych	Remarks Uwagi	Figure Rycina	Taxon Takson
1	2	3	4	5
Bipetala	ligulate florets have additionally a smaller ligulate part, some may have an additional pistil (Fig. 6) kwiaty języczkowate mają dodatkowo mniejszą część języczkowatą, niektóre mają dodatkowy słupek (ryc. 6)	(1) (4)	2, 6 – mid row 2, 6 – rząd środkowy	*mill.* *coll.* × *mill.* *A. coarctata* Poir.
Caliciformis	ligulate part accrete has a form of irregular calyx część języczkowata zrośnięta ma kształt nieregularnego kielicha	(1)	2, 8 – top row 2, 8 – rząd górny	*coll.* × *mill.* *A. ptarmica*
Crenatissima	ligulate part distinctly crenate część języczkowata wyraźnie karbowana		4 – top row, two smaller florets 4 – rząd górny, dwa mniejsze kwiaty	*A. salicifolia*
Heteropetala	nearly every ligulate part has a different form and size in one inflorescence, often asymmetric prawie każda część języczkowata ma inny kształt i wielkość w kwiatostanie, często jest asymetryczna	(3)	3, 9	*coll.* × *mill.*
Lobata	ligulate part regular or irregular lobate część języczkowata regularnie lub nieregularnie klapowana		4, 5 – bottom row 4, 5 – rząd dolny	*mill.* *A. ptarmica*
Spathulata	ligulate part has the form of spatula część języczkowata ma kształt łopatkowaty		4 – top row 4 – rząd górny	*mill.*

Table 1 – cont.

1	2	3	4	5
Subtubulosa	ligulate part accrete, similar to florets tubulate, has 2-5 lobes of a different form and size; in this inflorescence may be also some number of ligulate florets of form *lobata* or *bipetala* część języczkowata zrośnięta, podobna do kwiatów rurkowatych, ma 2-5 łatek różnego kształtu i wielkości; w takim kwiatostanie może być także pewna liczba kwiatów formy *lobata* lub *bipetala*	(1) (4)	7, 8 – mid and bottom rows 7, 8 – rząd środkowy i dolny	*coll.* × *mill.*
Tubulosa	ligulate part accrete, similar to florets tubulate but not regular dentate część języczkowata zrośnięta, podobna do kwiatów rurkowatych, lecz nieregularnie ząbkowana	(2) (5)	2 – bottom row 2 – rząd dolny	*coll.* × *mill.*

Remarks:

(1) In some florets the sex was also changed – such florets are bisexual, but of different number of stamina.

(2) In all florets the sex was also changed – such florets are bisexual, but of different number of stamina.

(3) Form *heteropetala* was besides, obtained experimentally (Fig. 9) by the author, through self-pollination of a plant of characters intermediate between *A. collina* × *A. millefolium* L. s. str. and *A. asplenifolia*.

Abbreviations: *coll.* = *A. collina*
mill. = *A. millefolium* L. s. str.
coll. × *mill.* = plant of characters intermediate between these taxa

(4) In this way all ligulate florets in inflorescence are changed or not all of them.

(5) All ligulate florets in inflorescence are changed in this way.

Objaśnienia:

(1) W niektórych kwiatach płeć była także zmieniona – takie kwiaty są obupłciowe, lecz o różnej liczbie pręcików.

(2) Wszystkie kwiaty miały także zmienioną płeć – takie kwiaty są obupłciowe, lecz o różnej liczbie pręcików.

(3) Forma *heteropetala* była ponadto uzyskana eksperymentalnie (ryc. 9) przez autorkę, przez samozapylenie rośliny o cechach pośrednich między *A. collina* × *A. millefolium* L. s. str. i *A. asplenifolia*.

Skróty: *coll.* = *A. collina*
mill. = *A. millefolium* L. s. str.
coll. × *mill.* = roślina o cechach pośrednich między tymi taksonami

(4) Wszystkie lub nie wszystkie kwiaty języczkowate w kwiatostanie są zmienione w ten sposób.

(5) Wszystkie kwiaty języczkowate w kwiatostanie są zmienione w ten sposób.

It is noteworthy that I have found three examples of variation of ligulate florets as single, transformed florets have been found:

– in *Achillea coarctata* Poir. from Bulgaria (diploid of yellow flowers of section *Filipendulinae*). Two florets represent *bipetala* form (**Dąbrowska** 1973, 1982).

– in *A. ochroleuca* Ehrh. from Slovakia (diploid of section *Ochroleuca*), one floret of form *bipetala* (**Dąbrowska** 1973, 1982).

– in *A. ptarmica* L. (diploid of section *Ptarmica*, collected in distr. Zgorzelec, Lower Silesia). Only one ligulate floret represents *caliciformis* form (**Dąbrowska** 1973, 1982).

These two forms (*bipetala, caliciformis*) are not connected with section *Millefolium* only (to which belong *A. collina, A. millefolium*). Taxa of *Achillea* from different sections can hybridize (e.g. **Nedelcheva** et **al.** 1998). The author observed hybrid between *A. coarctata* Poir. and species of section *Millefolium*, *A. asplenifolia* Vent. (unpubl.), in her collection.

Recent studies have confirmed that interspecific hybridization following plant invasions may sometimes lead to rapid evolution of new plant taxa (**Abbot** 1992). Evolutionary significance of hybridization is discussed especially in light of evidence from the analysis of character patterns that suggests that hybrids may do more than simply reshuffle their parents' character (**Mc Dade** 1995). On evolutionary significance of hybridization write many authors (**Abbot** 1992, **Rieseberg** and **Brunsfeld** 1992, **Mc Dade** 1995, **Rieseberg** 1995, 1997).

As regards morphological types of ligulate florets, **Stace's** (1993) words are noteworthy: there are cases when a hybrid displays characters that do not occur in any of the parents; there are also cases when the hybrid has no characters common for both parental species. The author remarks also that there are no universal guidelines for identifying hybrids (**Stace** 1993).

Adler (1995) describing results of cultivar experiments with ornamental plants of *Senecio* × *hybridus* Hyl. informs that in cultivar Mars in 1994 year in all plants (received from seeds) ligulate florets accreted into tubulate florets.In one capitula the most often were changed in this way 3-4 ligulate florets.

It is possible that, besides hybridization (and introgression) between *A. collina* (4x) and *A. millefolium* L. s. str. (6x), also other factors may affect the occurrence of the described forms of variation of ligulate florets. For example, **Mc Clintock** (1984) writes about the significance of stress for evoking genome modifications: "...stress and the genom's reactions to it may underlie many formations of new species". Modification in gene expression may be induced in plants when they are infected with an RNA virus (**Mc Clintock** 1984). Although changes in at least two genes are usually required for speciation (**Coyne** 1992).

The form of variation of florets called by the author *"heteropetala"* and found in natural conditions, was also obtained experimentally through self-pollination of several clones of yarrow for cultivation purposes (**Dąbrowska** 1973). The form appeared in one of the clones in S_1 (first generation after self-pollination). The clone (no 1276) has an array of characters resembling *A. asplenifolia* Vent., *A. collina* Becker and *A. millefolium* L. s. str. and turned out to be tetraploid (2n = 36).

Forcing an allo-pollinating plant to self-pollinate i.e. the method if inbreeding leads to increased homozygosity, which results in many changes. One of the effects is appearance of previously unknown heritable types. Previously recessive characters may come into play. Such plants are often of meagre appearance (**Schmalz** 1969); an example is the inflorescence (but not the whole plant) of the *heteropetala* form.

Conclusions

Considering the reasons for variation of ligulate florets in *Achillea* L. it can be supported that they may be result of different causes, between them of hybridization. It may prove fruitful to accumulate data on the variation of ligulate florets on the background of cytogeography of the genus *Achillea* L., they can be useful for consideration on the importance of hybridization in the history of the genus. Experimentally obtained self-pollination of a allo-pollinating plant resulting in a new quality (form *heteropetala*) may be of interest for researchers in experimental taxonomy.

Clonal biology of *Achillea* taxa shoud be researched, in connection with the somatic mutation theory (**Klekowski jr.** 1997).

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ZMIENNOŚĆ KWIATÓW JĘZYCZKOWATYCH U NIEKTÓRYCH TAKSONÓW RODZAJU *ACHILLEA* L.

S t r e s z c z e n i e

Autorka wyróżniła osiem form zmienności kwiatów języczkowatych u niektórych gatunków rodzaju *Achillea* L. i przedstawiła je na rycinach (ryc. 2-9). Pięć spośród nich znaleziono u roślin o cechach pośrednich między *A. collina* Becker i *A. millefolium* L. s. str. (tab. 1). W niektórych kwiatach form: *bipetala*, *caliciformis* i *subtubulosa* wystąpiła także zmiana płci – takie kwiaty były obupłciowe, lecz o różnej liczbie pręcików, natomiast u formy *tubulosa* wszystkie kwiaty miały zmienioną płeć. Forma *heteropetala* była obserwowana w naturze, jak również uzyskana eksperymentalnie przez autorkę w wyniku samozapylenia rośliny o cechach pośrednich między *A. collina* Becker i *A. millefolium* L. s. str. a *A. asplenifolia* Vent.

Możliwe, że opisana zmienność kwiatów języczkowatych jest głównie wynikiem hybrydyzacji, lecz może są również inne przyczyny tej zmienności.