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THE FLOWERING PATTERN OF *ARNICA MONTANA* L. AND *A. CHAMISSONIS* LESS. UNDER FIELD CULTIVATION CONDITIONS WITH SUCCESSIVE FLOWER HEAD COLLECTION

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S u m m a r y

The research on the flowering of *Arnica montana* L. and *A. chamissonis* Less. was carried out in the years 2005-2006 on two- and three-year plantations on grey-brown podsolic soil with the granulometric composition of heavy clay sand. The aim of the work was to determine the pattern and length of flowering of two- and three-year-old plants under field cultivation conditions with successive flower head collection. The flowering of *Arnica montana* in both years of study lasted 26 days (from the 28th of May to the 22nd of June). In this period, eight collections of flower heads were made. When analyzing the number of inflorescences gathered during particular collections, it was concluded that at the initial stage of flowering it was not great, but it successively increased with the passage of time up to the seventh collection. The pattern of flowering of the two- and three-year-old *Arnica montana* plants was similar. The inflorescences of *Arnica chamissonis* were collected six times, and the most abundant flowering was found in the middle period of this stage, which lasted 20 days.

Key words: *Arnica montana*, *Arnica chamissonis,* flowering, field cultivation

INTRODUCTION

Arnica montana L. (Asteraceae) is a valued medicinal plant (B i l i a et al., 2006; M e r f o r t and W e n d i s c h , 1987, 1992; R e i d e r et al. 2001). Presently, it occurs in few sites in the natural habitat. It is found on mountain meadows of Central Europe, in France, in the Pyrenees, in the Balkans and in Southern Scandinavia, more rarely in the lowlands – in Latvia and Belorussia. In Poland it occurs quite rarely in the Sudety Mountains, East Carpathian Mountains, Suwalszczyzna region, Mazury region and in the Białowieża Primeval Forest (F o r y c k a et al. 2004; K o z ł o w s k i et al. 2001; W o j e w o d a and C y u n e l , 1963; Z a j ą c and Z a j ą c , 2001). This species is subject to total protection, therefore collecting it in its natural state is forbidden (G ó r s k a - Z a j ą c z k o w s k a and W ó j t o w i c z , 1991; K o r n e c k et al., 1996; K a ź m i e r c z a k o w a and Z a r z y c k i , 2001).

For medicinal purposes, it is obtained from special plantations. Due to great difficulties in establishing and maintaining plantations, the crop area of *Arnica montana* is very small (B u ł a , 1993a; 1993b; 1995; K o z ł o w s k i et al. 1999; W e r e m c z u k - J e ż y n a and W y s o k i ń s k a , 2000). It is much easier to cultivate *Arnica chamissonis* which comes from the steppe regions of North America. It provides an equally valuable raw material as *Arnica montana* (N o w a k , 2002). The pharmaceutical raw material comprises flower heads – *Arnicae anthodium*, used for many years in therapeutics, the herbal and cosmetic industry (J a r o n i e w s k i , 1996; K i s i e l , 1995; K o w a l c z y k , 2007a; 2007b). Their quality, and at the same time their value as a pharmaceutical raw material, is dependent on the time and frequency of collection. The aim of this work was to determine the pattern and duration of flowering of two- and three-year-old plants of *Arnica montana* and *Arnica chamissonis* under field cultivation conditions with successive flower head collection.

MATERIALS AND METHODS

The studies were carried out in the years 2005-2006 on two- and three-year plantations of *Arnica montana* and *Arnica chamissonis* grown on grey-brown podsolic soil with the granulometric composition of heavy loamy sand. The soil was characterised by an average content of humus, high phosphorus, very low potassium, low magnesium, and acid reaction. The pioneer crop for *Arnica* was potatoes grown on a full dose of manure (30 t × ha^{-1}). On the plots, phosphorus-potassium fertilisation was applied each year at the following

doses: 24.0 kg P and 66.4 kg K per hectare, whereas 40.0 kg of nitrogen were applied in two equal doses: in the spring, before the beginning of vegetation, and after the collection of flowers. During the vegetation, the plants were three times weeded (by hand), and interrows were cultivated.

In the year 2005 and 2006, the pattern of flowering of *Arnica montana* and *A. chamissonis* was tested under field cultivation conditions. The aim of the experiment was to measure the flowering of the plant, and flower heads were collected from 80 randomly selected plants at three-day intervals. The first collection was carried out when the first inflorescences were in full development. The flowering pattern was presented as a percent of the collected inflorescences during particular collections in relation to the mass of all the inflorescences which were obtained during the entire period of flowering (100%). After each collection, the average diameter of flower heads (n=40) was determined. During the course of the studies on 20 randomly selected plants, counts were made on the number of inflorescence shoots and the number of flower heads per plant. The obtained results were processed using the Statistica program.

RESULTS AND DISCUSSION

In the two-year period of carrying out the experiments, thermal conditions were similar, but the amount and distribution of rainfall were different. Weather conditions in 2005 were more favorable to the growth and development of *Arnica* (Tab. 1). The high temperature and rainfall in May positively affected the growth of the plants. In June, when *Arnica* flowers, it was also noted that there were favorable thermal and rainfall conditions. In 2006 during the flowering period (June), higher temperatures were noted in comparison to 2005, but a lower amount of rainfall. Generally, weather conditions in both seasons could be considered as favourable for the flowering of *Arnica*.

From the two evaluated species, both in 2005 and 2006 *Arnica montana* first entered in the flowering stage, whereas *Arnica chamissonis* began to bloom 6 days later, however the first phase of flowering for *Arnica montana* fell at the end of May, whereas for *Arnica chamissonis* it was in the first days of June. The flowering of both species ended at the same time – at the end of the third decade of June (Fig. 1). The *Arnica montana* in its natural state flowers from June to August (F o r y c k a et al. 2004;

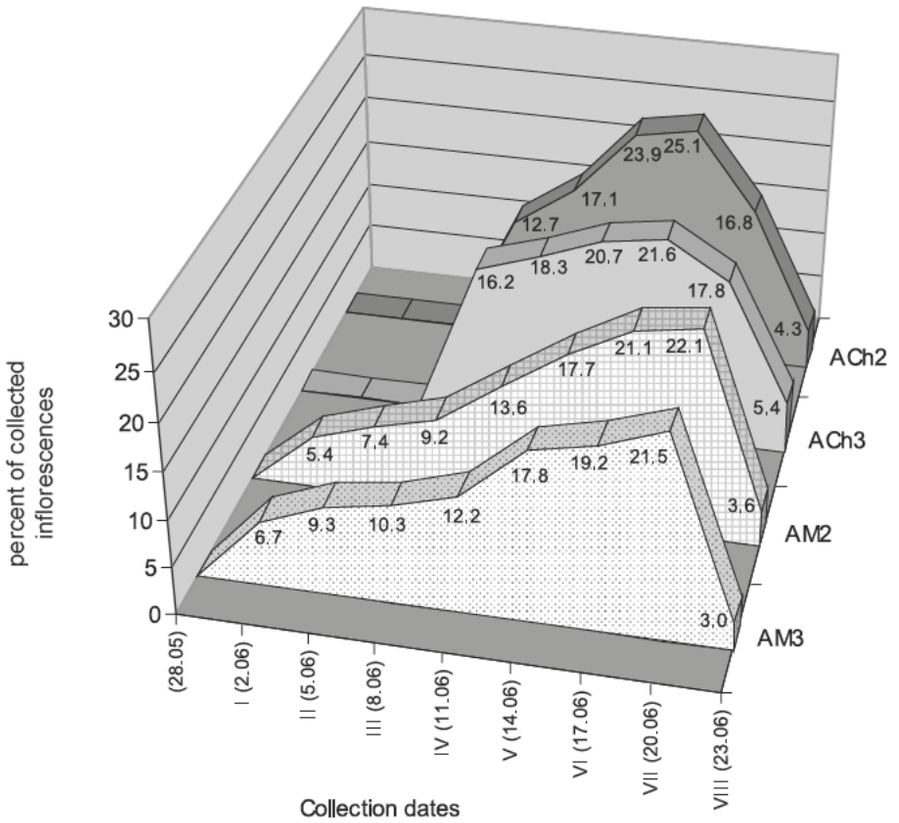

Fig. 1. The pattern of flowering for *Arnica montana* and *Arnica chamissonis;* AM3 – *Arnica montana* (three-year-old plants), AM2 – *Arnica montana* (two-year-old plants), ACh3 – *Arnica chamissonis* (three-year-old plants), ACh2 – *Arnica chamissonis* (two-year-old plants); n=80.

Table 1
Mean air temperature and total precipitation in 2005 and 2006 (after the meteorological station in Felin).

Month	Temperature [°C]		Precipitation [mm]	
	2005	2006	2005	2006
I	0.0	-7.6	41.6	15.7
II	-3.9	-4.1	26.0	26.7
III	-0.1	-1.0	48.0	47.0
IV	9.1	8.7	18.6	30.3
V	13.2	13.6	98.0	59.5
VI	16.0	16.9	55.9	37.9
VII	20.4	21.9	109.8	6.8
VIII	16.9	17.4	108.7	198.3
IX	14.9	15.7	18.0	11.0
X	8.8	10.1	8.6	14.2
XI	2.7	5.3	21.7	41.2
XII	-0.8	3.0	54.5	18.6
Mean or sum	8.1	8.3	609.4	507.2

Senderski, 2004; Jambor, 2006). Galambosi and others (1998) note that *Arnica montana* cultivated in Finland flowers from mid July to the end of June. According to Nowak (2002), in field cultivation, *Arnica chamissonis* flowers from the end of May to the end of June. Rumińska (1991) notes a significantly later time – from June to August. Based on the obtained results, it is concluded that under field cultivation conditions, during the systematic harvesting of heads, the period of flowering for Arnica was considerably shorter.

The flowering of *Arnica montana* in both years of study lasted 26 days (from the 28th of June to the 22nd of July). During this period, eight head collections were carried out. When analyzing the number of inflorescences gathered during particular collections, it was concluded that at the initial stage of flowering it was not great, but it successively increased with the passage of time up to the seventh collection. The flowering pattern for the two- and three-year-old plants of *Arnica montana* was similar. The greatest number of inflorescences was

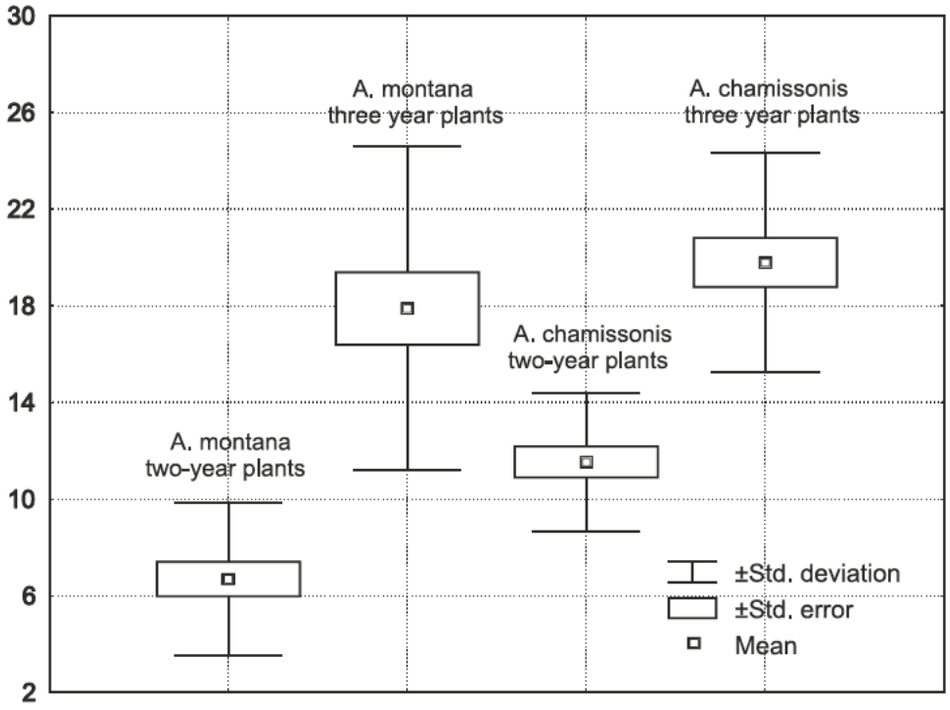

Fig. 2. The number of inflorescent shoots per plant, n = 20.

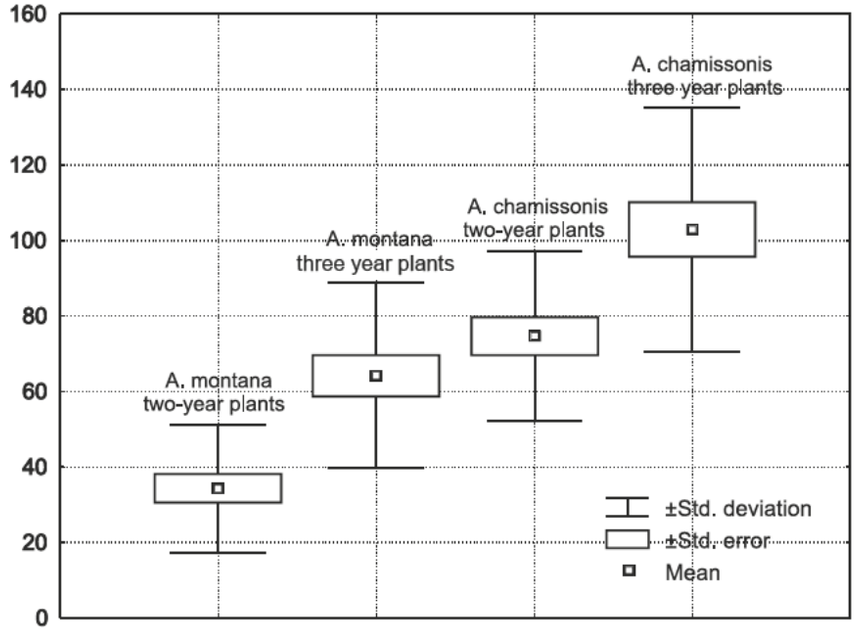

Fig. 3. The number of flower heads per plant, n=20.

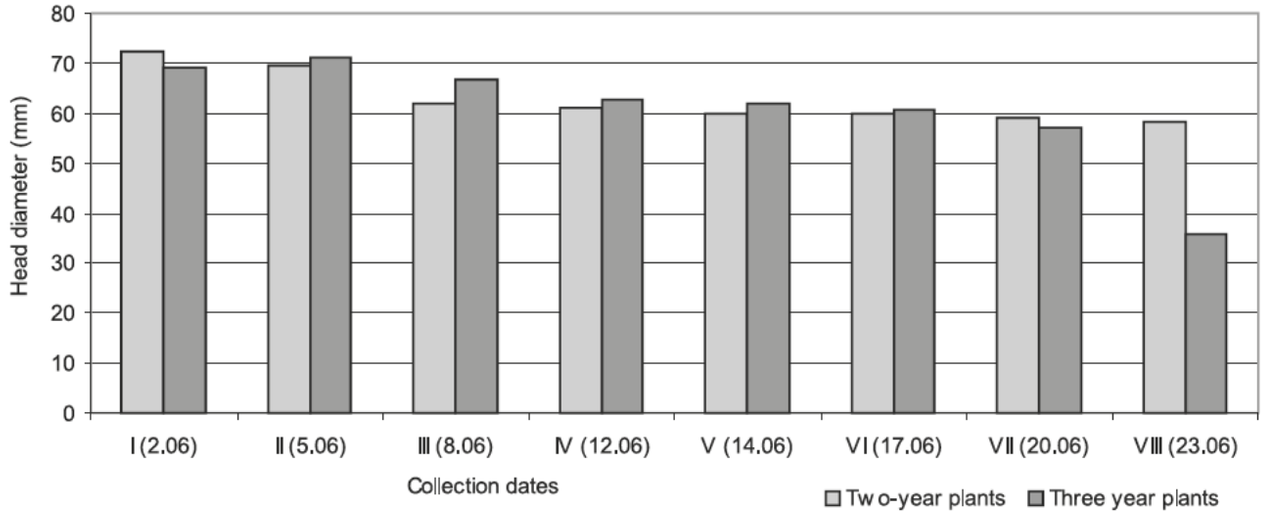

Fig. 4. The diameter of flower heads of *Arnica montana*, n=40.

collected during the sixth and seventh (17th and 20th of July) picking in the two-year-oldplants with the 19.2% and 21.6% mass of all inflorescences, while in the three-year-old plants, it was 21.0% and 22.1%, respectively (Fig. 1). *Arnica chamissonis* inflorescences were collected six times, and the most abundant flowering was found in the middle period of this stage, which lasted 20 days. Both in two- and three-year-old plants, the greatest number of inflorescences was obtained during the third and fourth (14th and 17th of July) picking, while in successive pickings the number of collected inflorescences decreased (Fig. 1).

The number of inflorescent shoots per plant in the studied species was different and depended on the age of the plants. Decidedly fewer shoots were produced by *Arnica montana* (Fig. 2). On average, in the two-year-old plants, their number was 6.7 per plant, whereas in the three-year-old plants it amounted to 17.9. Galambosi et al. (1998) claim that two-year-old plants produce 5-7 shoots, and three-year-old ones 5-35. In available literature, there is no information on the number of inflorescent shoots produced by *Arnica chamissonis*. Based on the observations conducted, it is thought that the two-year-old plants produced from 6 to 16 shoots and the three-year-old ones from 16 to 29 (Fig. 2).

The studied species considerably differed in the aspect of the number of flowering heads per plant. The average number of inflorescences of *Arnica chamissonis* in the two-year-old individuals was 74.6, while in the three-year-old individuals, 121.1 (Fig. 3). The *Arnica*

Fig. 6. *Arnica montana* – three-year-old plants (19.06.2006).

Fig. 6. *Arnica chamissonis* – three-year-old plants (19.06.2006).

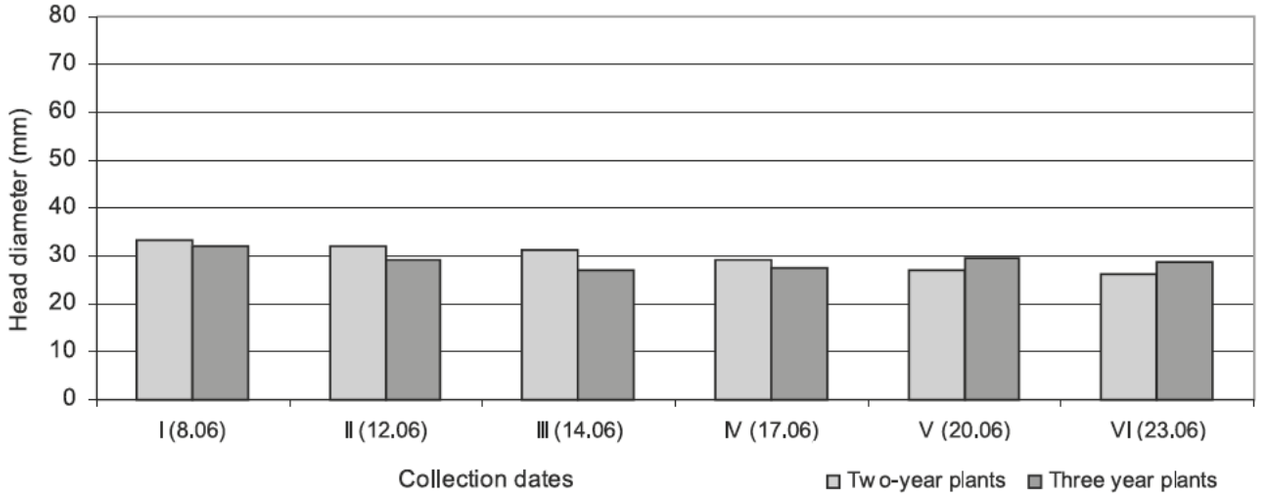

Fig. 5. The diameter of flower heads of *Arnica chamissonis*, n=40.

montana plants produced considerably fewer inflorescences, in both the second and third year of cultivation (34.3 and 64.2 per plant, respectively). According to Galamgosi et al. (1998), a two-year-old *Arnica montana* plant produces on average 28, and a three-year-old one 77 inflorescences.

The next trait in which the evaluated species clearly differed was the diameter of the flower head. The head diameter with open ray florets for the two- and three-year-old plants was similar and was 62.72 and 60.55 mm, respectively. In the study of Forycka et al. (2004) on selected populations of *Arnica montana* occurring in Poland it was shown that the average head is within a very wide range of 46.7 mm to 86.0 mm, so the average value of this trait was 62.8 mm. In the study carried out, *Arnica chamissonis* produced smaller flower heads, on average by 32 mm. Both in *Arnica montana* and *A. chamissonis*, differences were noted in the diameter of flower heads during particular collections. Inflorescences collected at the initial stage of flowering were the largest, and their diameter during further collections decreased smaller (Fig. 5, 6). According to many authors (Rumińska, 1991; Jambor, 2006; Nowak, 2002), *Arnica chamissonis* has smaller flower heads (with the diameter of 20-40 mm), but it produces more of them, which was confirmed in the conducted study.

CONCLUSIONS

1. The period of *Arnica montana* flowering was 26 days. The pattern of flowering of two- and three-year-old plants was similar. In the final period of flowering, under the study conditions the plants formed the greatest number of flower heads.

2. The period of flowering for *Arnica chamissonis* was 20 days. The plants flowered most abundantly in the middle period of this stage.

3. The studied species of Arnica differed in the number of inflorescent shoots, the number of inflorescences and their diameter. *Arnica montana* produced decidedly fewer inflorescent shoots and fewer flower heads, but with a larger diameter.

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Przebieg kwitnienia arniki górskiej *(Arnica montana L.)* i łąkowej (*A. chamissonis* Less.) w warunkach uprawy polowej przy sukcesywnym zrywaniu koszyczków

Streszczenie

Badania dotyczące kwitnienia arniki górskiej (*Arnica montana* L.) i łąkowej (*A. chamission* Less.) przeprowadzono w latach 2005-2006 na dwu- i trzyletniej plantacji, na glebie płowej o składzie granulometrycznym piasku gliniastego mocnego. Celem pracy było określenie przebiegu oraz długości kwitnienia dwu- i trzyletnich roślin arniki górskiej i łąkowej w warunkach uprawy polowej przy sukcesywnym zrywaniu koszyczków. Kwitnienie arniki górskiej w obu latach badań trwało 26 dni (od 28.05 do 22.06). W tym okresie przeprowadzono osiem zbiorów koszyczków kwiatowych. Analizując liczbę kwiatostanów zebranych w poszczególnych terminach stwierdzono, że w początkowej fazie kwitnienia była ona niewielka, a sukcesywnie rosła w miarę upływu czasu aż do siódmego zbioru. Przebieg kwitnienia dwu- i trzyletnich roślin arniki górskiej był zbliżony. Kwiatostany arniki łąkowej zbierano sześciokrotnie, a najobfitsze kwitnienie stwierdzono w środkowym okresie tej fazy, która trwała 20 dni.