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ORIGINAL ARTICLE

Morphology and productivity of tarragon (*Artemisia dracunculus* L.) in Central Polissya (Ukraine)

I. Ivashchenko, L. Kotyuk, A. Bakalova

Zhytomyr National Agroecological University, Stary Boulevard 7, 10008 Zhytomyr, Ukraine
**Corresponding author E-mail: kalateja@ukr.net*

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The aim of the research was to study morphology and productivity of various plant forms of *Artemisia dracunculus* introduced in Central Polissya (Ukraine). We found that the studied forms of *A. dracunculus* in the flowering phase varied in the number of shoots on the average from 59.6 to 76.7 pcs., the shoots length averaged from 103.2 to 141.8 cm, the stem were erect, light green (Form 1), deep green (Form 2) or dark green (Form 3). The leaves had entire margin and were linear-lanceolate or almost linear, while in the lower part of the shoots they were cut into 2-3 segments, their length varied from 6.8 ± 0.32 to 8.3 ± 0.42, and their width – from 0.56 ± 0.03 to 0.79 ± 0.03 cm; the panicle length ranged from 35.2 ± 2.6 to 47.9 ± 3.5 cm. The number of flower heads in the panicle averaged from 814.6 ± 93.7 to 1889 ± 162.7 pcs. The mass of aerial parts varied from 677.2 to 4562 g per plant, the raw material productivity ranged from 1.13 ± 0.23 to 6.87 ± 0.25 kg/m^2. A comparative analysis of the three forms of *A. dracunculus* revealed differences in some biometric parameters: the length of shoots and inflorescences, the number of shoots and flower heads in the panicle of a year-old shoot, and the diameter of the stem. Plants in Form 1 excelled those in Forms 2 and 3 as to the length of shoots 1.37 and 1.27 times respectively, as to the length of inflorescences 1.26 and 1.36 times respectively, and the stem diameter in Form 1 was 1.4 times wider than in Forms 2 and 3. The maximum number of shoots was registered in Form 2, on the average over the years of research it constituted 76.7 pcs. Introduced plants of the studied forms differed significantly in raw material productivity. Over the six years, plants of Form 1 showed the highest average productivity of 4.5 ± 1.2 kg/m^2, which is 2.1 and 1.4 times more higher than in Forms 3 and 2. *A. dracunculus* plants under conditions of Central Polissya undergo an incomplete life cycle: they are able to form vegetative and reproductive organs; however, their seeds do not ripen. Thus, the present research proves that cultivation of tarragon, especially the plants of Form 1 in Central Polissya is rather promising for further use in food industry, pharmacy and cosmetology.

Key words: *Artemisia dracunculus*; Forms; Introduction; Morphological features; Productivity

Introduction

Tarragon (*Artemisia dracunculus* L.) is a valuable food, medicinal, essential oil culture of the Asteraceae family, Anthemideae tribe. The region of origin of tarragon is Southern Siberia and Mongolia (Cherevchenko et al., 2012). The plant is widespread in Mongolia, northern China, Siberia, European Russia, Ukraine, the Balkans, the Baltics, the Mediterranean Region, Central Europe, North Africa, Mexico, South and North America. (Aglarova et al., 2008). In Ukraine, *A. dracunculus* spreads across the Left Bank of the Dnieper; on the Right Bank its localities are, probably, naturalized (Boyko, 2013). In the wild, the plant occurs along riverbanks and in steppe gullies, scattered in the forest-steppe and steppe areas (Visyulina, 1962).

The aerial parts of *A. dracunculus* contain a number of valuable biologically active compounds: essential oil, coumarins, flavonoids, phenolic carboxylic acids, vitamins, tannins, alkaloids, sesquiterpenoids (Fildan et al., 2019; Ivashchenko et al., 2014; Ochur et al., 2013; Petryshyna, 2010). The plant has antipyretic, anti-inflammatory, wound healing, antiulcer, antispasmodic, diuretic, choleretic, anticancer, anticonvulsant, antibacterial, antiprotozoal, and sedative effect. It is used for diabetes, chronic cholecystitis, pulmonary tuberculosis, pneumonia, chronic bronchitis, neurasthenia, impotence, joints diseases, and as a vitamin remedy (Aydin et al., 2019; Kirkin et al., 2019; Manfrinato et al., 2019; Modaresi et al., 2018; Ivashchenko et al., 2015; Korablyova & Rakhmetov, 2012; Rakhmetov et al., 2004). Tarragon is cultivated in the USA, Germany, France, Holland, Bulgaria, Hungary, Belarus, Russia, Central Asia, Iran, India, and Ukraine. The Register of Plant Varieties of Ukraine includes two varieties of tarragon.

Biomorphological features of the species were described by P. P. Polyakov (Komarov, 1961), O. D. Visyulina (Visyulina, 1962), A. M. Aglarova (2006). Biological and ecological features of tarragon were considered by A. V. Boyko (2013). Ontogenesis, types of shoot systems and the structure of *A. dracunculus* synflorescence were under a detailed study by E. S. Geguchadze (2002). Introductory studies of the plant in the Forest-Steppe area of Ukraine were conducted by O. A. Korablyova, D. B. Rakhmetov (2012), and in the Forest-Steppe zone of the Southern Pre-Urals - by I. V. Chernykh (2004); N. M. Petryshyna (2010) studied morpho-biological and commercially valuable features of tarragon, spread in the foothills of the Crimea.

A. dracunculus is a perennial herbaceous polycarpic with aerial orthotropic shoots up to 1.5 m in height, linear-lanceolate or almost linear leaves with entire margin (Boyko, 2013; Geguchadze, 2002). The inflorescence is a panicle with flower heads on very thin, mostly downwardly arched pedicels and pale yellow flowers (Visyulina, 1962), the seeds are small, 0.6 mm long, flat, ovoid, brown (Komarov, 1961). According to C. Raunkiaer's classification, the studied species belongs to the life form of cryptophytes (Petryshyna, 2010). As the adaptive properties of *A. dracunculus* when introduced into the culture in Central Polissya of Ukraine have not been subject to any detailed study so far, the objective of our research was to assess biomorphological parameters and commercial value of the introduced plants depending on their form.

Materials and Methods

The subject of research were plants of three forms of *Artemisia dracunculus*. The introduced population of *A. dracunculus* was created on the basis of planting material obtained from the collection of spicy-aromatic plants of the Department of Cultural Flora of the M. M. Gryshko National Botanical Gardens of the National Academy of Sciences of Ukraine (Form 1), the Botanical Gardens of the Ivan Franko Lviv National University (Form 2) and the Botanical Garden of the Polissya National University (Form 3). Our study was carried out in the experimental plots of the Botanical Garden of Zhytomyr National Agro-ecological University, which belongs to the Central Polissya zone of Ukraine. The soil in the botanical garden is sod-carbonate.

The humus content (according to Tyurin) was 2.39 ± 0.01%, the pH-salt solution of the humus horizon was 7.2 ± 0.10; the P_2O_5 content was 332.67 ± 18.87 mg/kg; the K_2O content amounted to 128.67 ± 26.9 mg/kg (according to Kirsanov), and the Nk content (according to Cornfield) was 63.0 ± 10.1 mg/kg of soil. Ecological conditions in the botanical garden area are typical of Central Polissya, where the temperate-continental climate is generally favorable for growing various species of plants. Tarragon plants were cultivated over the period of 2014–2019 in an open area, well exposed to sunlight, at the 70 × 50 cm scheme in accordance with M. G. Ivanov's recommendations (2002).

The plants were taken care of by removing weeds and inter-row tillage. The following morphometric parameters were studied: shoot length (cm), length of inflorescences (cm), number of shoots (pieces), stem diameter (mm), length and width of the leaf blade (cm), and the number of heads in the panicle of a year-old shoot. To perform biometric measurements we acted on methodological recommendations by V. F. Moiseychenko et al. (1994), B. A. Dospekhov (1985). Morphological description of plants was performed according to A. Novikov and B. Barabash-Krasny (2015).

Assessment of the aerial mass productivity was determined during the period of mass flowering according to Dospekhov (1985). Photos were taken with a Canon DC 8.1V digital camera. We used One-Way ANOVA to process the data. Data in the Tables presented like means and standard errors.

Results and Discussion

The shoot system of *A. dracunculus* is an interconnected system of the parent and partial clumps, connected by a long underground rootstock (Figures 1A-1D). According to the structure of underground shoots, tarragon is a long-rooted plant (Chernykh, 2004; Geguchadze, 2002). The structure of the shoot body of tarragon is represented by orthotropic vegetative and monocarpic shoots as well as anisotropic vegetative and monocarpic shoots, which is consistent with the description of *A. dracunculus* shoot systems given by E. S. Geguchadze (2002) (Figure 1A).

In places of transition of a plagiotropic part to an orthotropic one, there are renewal buds. Anisotropic shoots of all types are the basis for formation of daughter clumps (Geguchadze, 2002). Under conditions of our research, the structural unit of an *A. dracunculus* daughter plant in the flowering phase was a monocarpic shoot with a height of 50 cm to 2 m.

From the practical point of view, it is worth studying what potential the introduced tarragon forms have with respect to the number and length of shoots, which characterizes the power of the plant, determining such a significant marker of productivity as the aerial parts mass. The number of shoots in the studied forms averaged to 68.6 pcs, cf. with 33.6-55.2 pcs reported in other studies (Petryshyna, 2010). There was a natural annual increase in the number of shoots in tarragon plants, which is due to the spreading of the roots and formation of new partial clumps (Figures 2 and 3).

The area occupied by one plant increased annually, location of the shoots being chaotic. The minimum number of shoots occurred during the first year of growth: from 4.7 to 5.4 pcs, the maximum – during the sixth year: from 108.7 to 131.6 pcs. (Figures 2 and 3). In 2014, the average number of shoots in all the forms constituted 4.9 pcs, while in 2019 it was 119.0 pcs, which is 24.3 times greater than in 2014. The largest number of shoots was recorded in plants of Form 2, the average being 76.7 pcs, the smallest – in Form 3, the average constituting 59.6 pcs (Figure 3). In general, plants of all forms showed a significant variability of this trait.

The number of shoots in plants of *A. dracunculus* increased with age, which is of great practical importance. However, in the sixth year of vegetation there appeared signs of aging in all the studied forms, i.e. plants did not bloom, which indicates the beginning of a senile period.

In addition, introduced plants differed in shoots length, which also varied over the years of research. The average value of this indicator in the studied forms was 118.9 cm. The minimum shoots length demonstrated plants of the first year of growth: from 89.9 to 110 cm, the maximum – of the third year: from 109 to 161 cm (Figure 4).

Over the years, plants of Form 1 showed the longest shoots with an average of 141.8 cm, plants of Form 2 with their 103.2 cm – the shortest. In general, the length of shoots in individual plants in 2014, 2015, 2016, 2017, 2018 and 2019 fluctuated in the range of 30–130 cm, 63–160 cm, 50–205 cm, 45–200 cm, 52–184 cm, and 51–160 cm, respectively. Shoots length may vary depending on the conditions of the year. The intensity of the plants growth and development was considerably affected by weather conditions and the plant age.

The leaves of *A. dracunculus* are mostly entire linear-lanceolate or almost linear, only in the lower part of the shoots they are sometimes dissected into 2–3 segments (Figure 1B). The parameters of *A. dracunculus* leaves changed insignificantly over the six years of research. The average length of the leaf blade varied from 6.83 ± 0.32 to 8.3 ± 0.42 cm (Table 1).

The highest values of the leaf blade length and width occurred in Form 1 – 8.3 ± 0.42 cm and 0.79 ± 0.03 cm, respectively. In general, the leaf blade length in the studied forms averaged 7.4 ± 0.73 cm. Moreover, all the forms demonstrated variability of the leaf length. The width of the leaf blade ranged on the average from 0.56 ± 0.03 cm to 0.79 ± 0.03 cm (Table 1). The average value of this parameter in the studied forms was 0.66 ± 0.11 cm. In some plants, the leaf width varied from 0.41 cm to 1.30 cm. Besides, *A. dracunculus* forms differed in the intensity of the leaves and stems color (Table 1). Thus, the studied forms of *A. dracunculus* under conditions of Central Polissya featured various shapes and sizes of the leaf blade. The parameters of the leaf varied even within one form. Dissection of the leaf in the lower part of the shoot is not a stable feature and may change over the years, which is consistent with N. M. Petryshyna (2010).

Figure 1. Morphological features of introduced *Artemisia dracunculus* (Form 1) in Central Polissya. A – monocarpic and vegetative shoots of a plant in the third vegetation year; B – inflorescences; C – leaves; D – roots of plants in the first vegetation year.

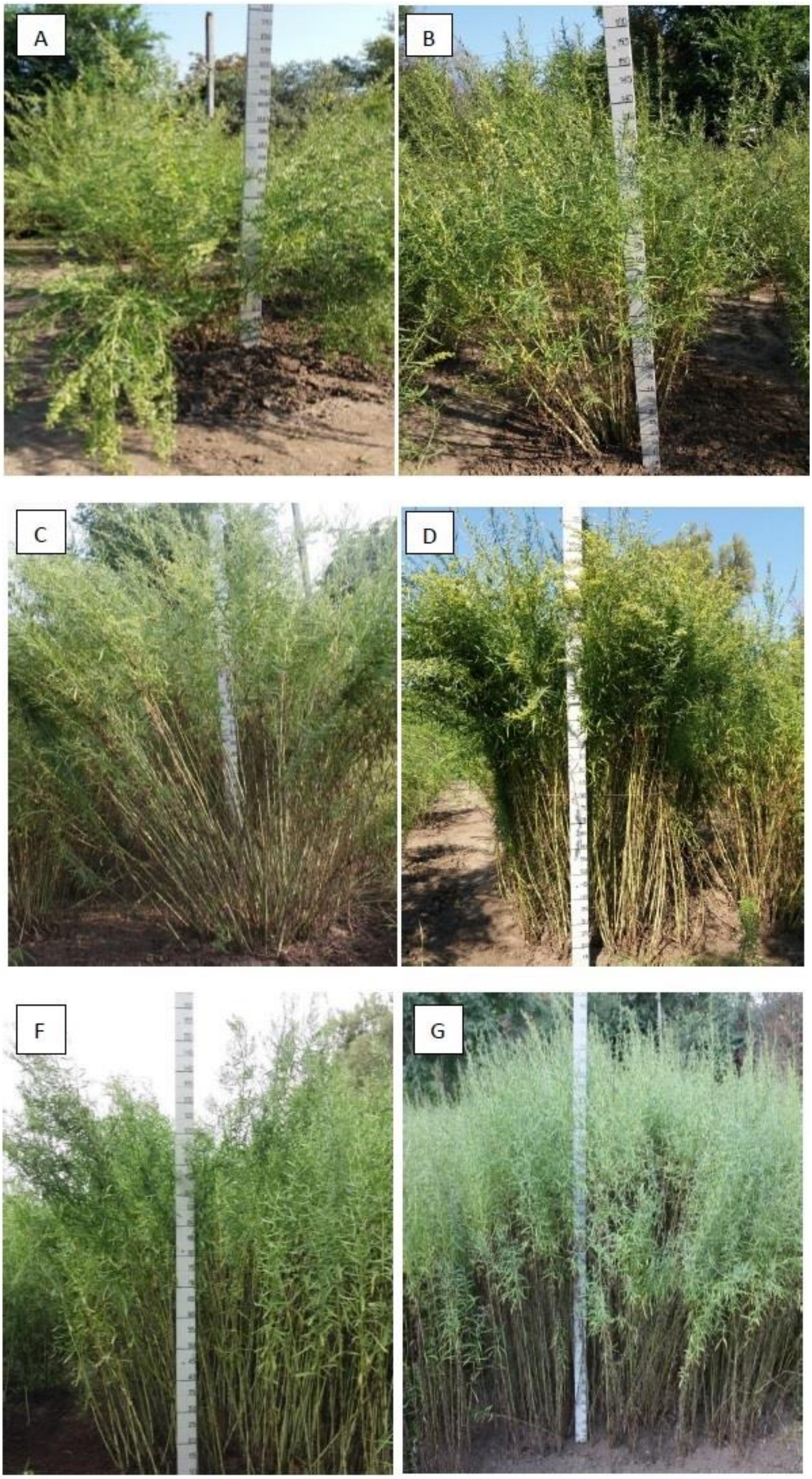

Figure 2. *Artemisia dracunculus* (Form 1) at different stages of maturity. A – the first vegetation year, B – the second year; C – the third year; D – the fourth year; F – the fifth year; G – the sixth year.

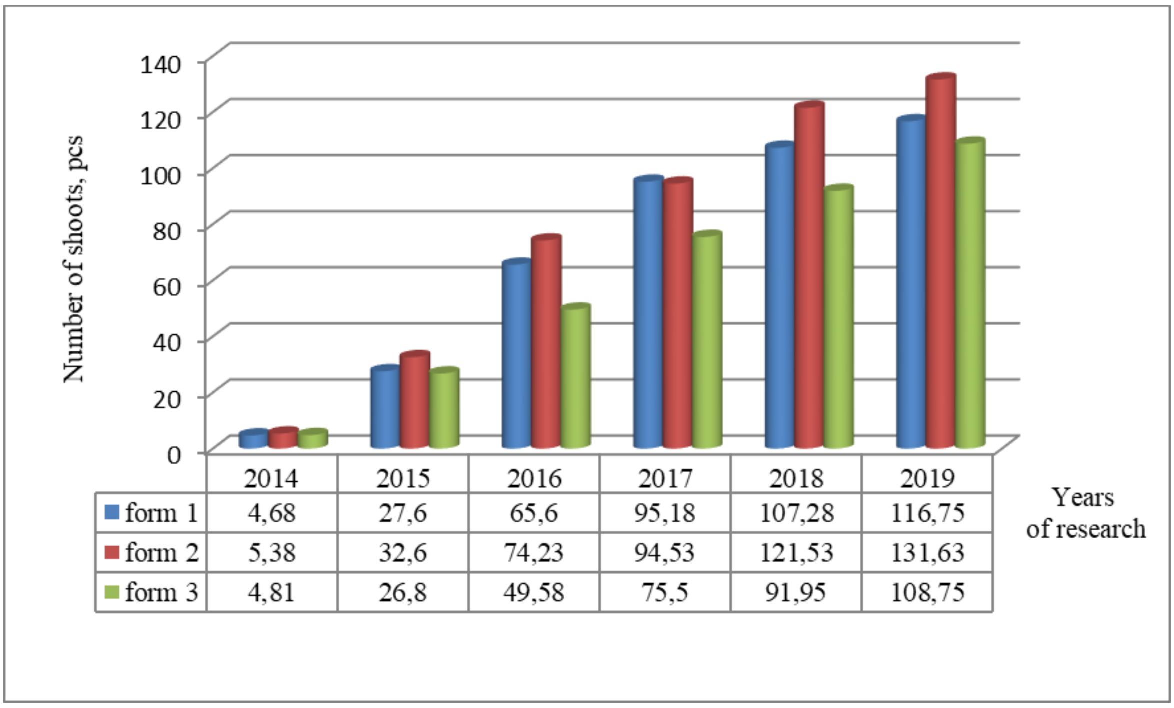

Figure 3. The number of aerial shoots in *A. dracunculus* vs. the plant form and vegetation year, 2014-2019. LSD: 2014 – 0.65, 2015 – 3.37, 2016 – 5.08, 2017 – 5.62, 2018 – 5.32, 2019– 2.75.

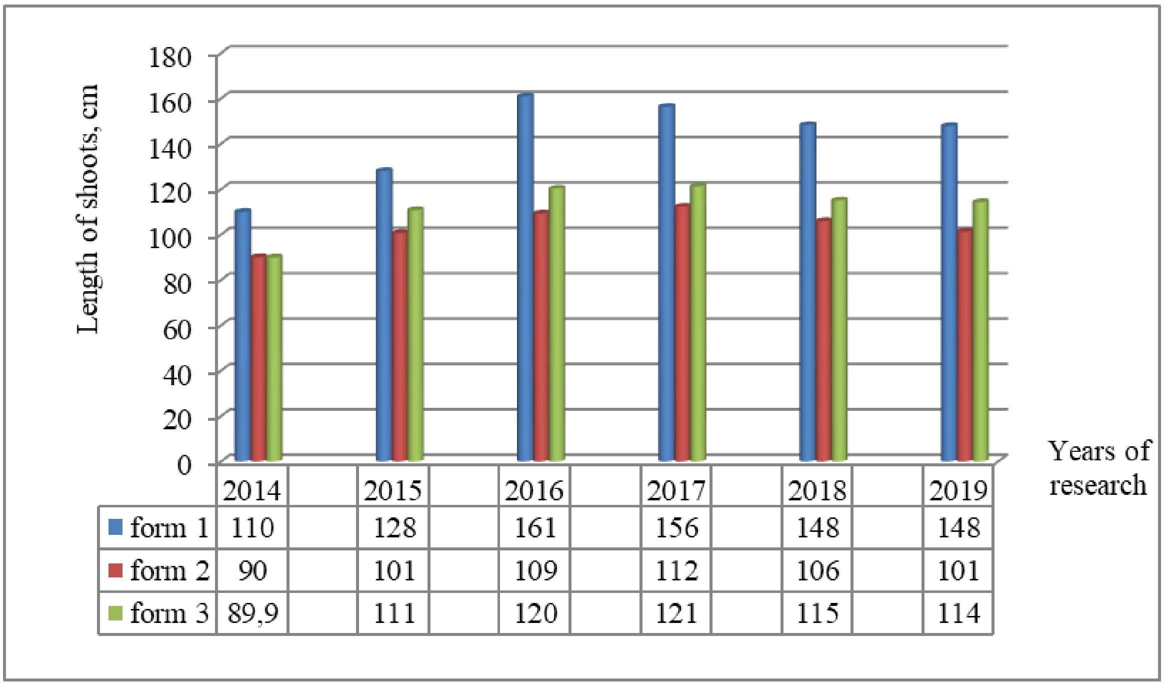

Figure 4. Length of aerial shoots of introduced *A. dracunculus* vs. the plant form and vegetation year, 2014-2019. LSD: 2014 – 2.51, 2015 – 2.29, 2016 – 4.01, 2017 – 6.08, 2018 – 3.35, 2019 – 1.91.

Under conditions of Central Polissya, the individuals of *A. dracunculus* of vegetative origin begin to bloom during the first year of growth, whereas according to Petryshyna (2010), in the foothills of the Crimea they begin to bloom in the second year of life. The inflorescence of *A. dracunculus* is a panicle (Figure 1B). The main and lateral (paraclades) axes of the inflorescence terminate with a floral unit, which is represented by a closed raceme of flower heads. Synfloriscence is a panicle formed by flower heads, and it is consistent with other authors (Geguchadze, 2002; Petryshyna, 2010). The length of flower bearing axes of a year-old shoot decreases with each successive order of branching and ends with a spherical head (Figure 1B). The number of flower heads in a panicle of a year-old shoot varied from 814.6 ± 93.7 to 1889 ± 162.7 pcs. (Table 1). Compound inflorescences differed in size and number of lateral axes. The length of the panicle in the studied forms averaged from 35.2 ± 2.6 to 47.9 ± 3.5 cm (Table 1). Inflorescences in Form 3 (35.2 ± 2.6 cm) had the smallest length and the most compact form. Plants in Form 2 also differed in the compactness of the panicle. Plants in Form 1 had inflorescences of the maximum length 47.9 ± 3.5 cm.

Table 1. Biomorphological parameters of *A. dracunculus* forms (averages for 2014–2019).

Form	Stem diameter, cm	Leaf blade			Panicle length, cm	Heads number in a panicle of a year-old shoot, pcs
		length, cm	width, cm	Color		
1	0.62 ± 0.05	8.3 ± 0.42	0.79 ± 0.03	light-green	47.9 ± 3.5	1567.8 ± 181
2	0.43 ± 0.06	7.0 ± 0.40	0.63 ± 0.04	deep-green	38.1 ± 2.3	1889 ± 162.7
3	0.45 ± 0.06	6.8 ± 0.32	0.56 ± 0.03	dark-green	35.2 ± 2.6	814.6 ± 93.7

Thus, the inflorescence of *A. dracunculus* is a panicle of floral units, which in plants of the studied samples is characterized by different length and compactness of shape. The flowers are pale yellow or atypically reddish-yellow (Form 1) (Figure 5). A relatively stable feature is the diameter of the flower heads (2–4 mm), which is consistent with other studies (Petryshyna, 2010).

Figure 5. Fragments of *A. dracunculus* inflorescences. A – reddish-yellow color of the perianth petals (Form 1); B – typical color of the perianth petals (Form 2).

Successful introduction of different species of essential oil and aromatic plants under non-native growing conditions largely depends on a set of commercially valuable markers, including the mass of raw material and the yield of essential oil. The raw material for obtaining essential oil from tarragon plants is their aerial parts (shoots with inflorescences). Productivity of aerial mass and quantitative content of essential oil depend on a number of factors: growing conditions, i.e. weather conditions during the period of the plant growth and development; agricultural conditions; etc. The present studies have shown that this feature varied significantly in different forms of the introduced plants. The aerial mass of different plant forms averaged from 677.2 to 4562 g per plant (Figure 6). According to N. M. Petryshyna (2010) in the foothills of the Crimea it averaged from 353.4 to 1169.8 g per plant, which is much less.

Consequently, the raw material productivity of tarragon varied over the years of research and averaged from 1.13 ± 0.23 to 6.87 ± 0.25 kg/m^2 (Table 2).

Table 2. Productivity of introduced *A. dracunculus* vs. the plant form and vegetation year, kg/m^2.

Form	2014	2015	2016	2017	2018	2019	2014–2019
1	2.26 ± 0.45	3.87 ± 0.19	6.87 ± 0.25	6.07 ± 0.36	4.0 ± 0.18	3.95 ± 0.24	4.5 ± 1.2
2	2.08 ± 0.28	3.08 ± 0.21	4.15 ± 0.26	3.95 ± 0.24	2.78 ± 0.28	2.75 ± 0.42	3.15 ± 0.57
3	1.13 ± 0.23	1.93 ± 0.25	2.78 ± 0.34	2.35 ± 0.26	2.24 ± 0.22	2.2 ± 0.27	2.11 ± 0.40

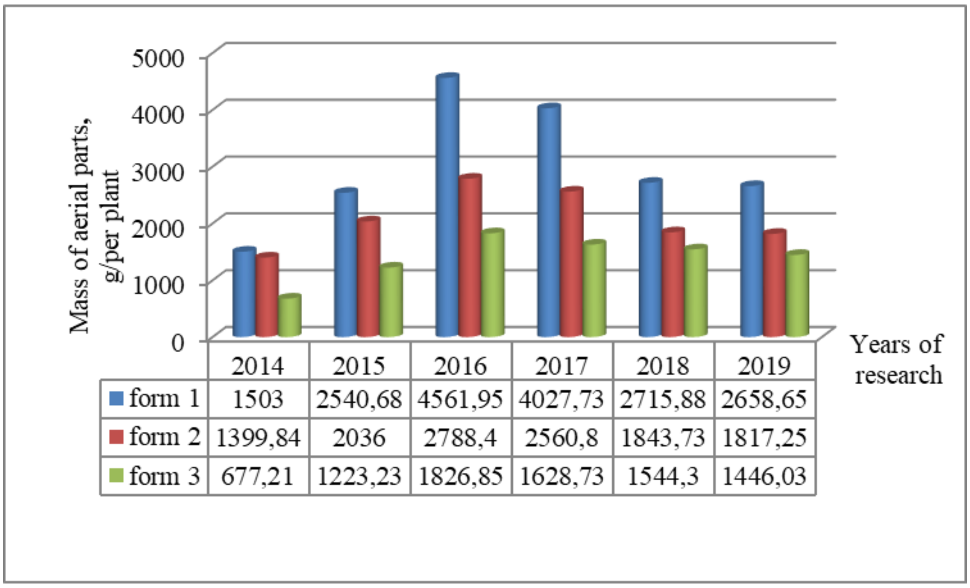

Figure 6. Aerial parts mass of *A. dracunculus* vs. the plant form and vegetation year, 2014–2019. LSD: 2014–69.07, 2015–126.69, 2016–209.71, 2017–179.82, 2018–115.78, 2019– 144.41.

All the studied forms had the lowest productivity in the first year of vegetation, the highest – in the third one. The highest average productivity over the six years was observed in Form 1 and amounted to 4.5 ± 1.2, a much lower average was registered in Form 3, namely 2.11 ± 0.40 kg/m^2 (Table 2). Therefore, the productivity of plants in Form 1 was 2.1 and 1.4 times higher than those in Forms 3 and 2, respectively. The ability of plants under conditions of introduction to form viable seeds is one of the main signs of their successful adaptation to new conditions. In tarragon plants, fruits developed, but seeds did not ripen. Therefore, under conditions of Central Polissya tarragon can only spread through vegetative reproduction (by cuttings or division of the root).

Conclusion

The conducted research showed that, when introduced in Central Polissya of Ukraine, tarragon demonstrated the following parameters during the flowering phase: the number of shoots in different forms ranged from 59,6 to 76,7 pcs, the shoots length averaging from 103.2 to 141.8 cm, the stem being straight, light green (Form 1), deep green (Form 2) or dark green (Form 3). The leaves have entire margin and are linear-lanceolate or almost linear, while in the lower part of the shoots they are cut into 2–3 segments, their length varied from 6.8 ± 0.32 to 8.3 ± 0.42, and their width – from 0.56 ± 0.03 to 0.79 ± 0.03 cm; the panicle length ranged from 35.2 ± 2.6 to 47.9 ± 3.5 cm. The number of flower heads in the panicle averaged from 814.6 ± 93.7 to 1889 ± 162.7 pcs. Over the years of research, the mass of aerial parts varied from 677.2 to 4562 g per plant, the raw material productivity ranged from 1.13 ± 0.23 to 6.87 ± 0.25 kg/m^2.

A comparative analysis of the three forms of *A. dracunculus* revealed differences in some biometric parameters: the length of shoots and inflorescences; the number of shoots and flower heads in the panicle of a year-old shoot; the diameter of the stem. Plants in Form 1 excelled those in Forms 2 and 3 as to the length of shoots 1.37 and 1.27 times respectively, as to the length of inflorescences 1.26 and 1.36 times respectively, and the stem diameter in Form 1 was 1.4 times wider than in Forms 2 and 3. The maximum number of shoots was registered in Form 2, on the average over the years of research it constituted 76.7 pcs. Introduced plants of the studied forms differed significantly in raw material productivity. Over the six years, plants of Form 1 showed the highest average productivity, i.e. 4.5 ± 1.2 kg/m^2, which is 2.1 and 1.4 times more than in Forms 3 and 2, respectively.

A. dracunculus plants under conditions of Central Polissya undergo an incomplete life cycle: they are able to form vegetative and reproductive organs; however, their seeds do not ripen. Thus, the present research proves that cultivation of tarragon in Central Polissya is rather promising for further use in food industry, pharmacy and cosmetology, whereas the plants of Form 1 are the most valuable.

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