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BIOMORPHOLOGY OF ONTOGENETIC PERIODS OF CHRYSANTHEMUM × HORTORUM REPRESENTATIVES IN THE RIGHT-BANK FOREST-STEPPE OF UKRAINE

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Abstract

The studies of the ontogenesis of plants of the genus *Chrysanthemum* L., namely *Chrysanthemum* × *hortorum sp*., ′Gusi lebedi′ and 'Nova era' had been conducted in the conditions of the Right-Bank Forest-Steppe of Ukraine. The aim of the research was to clarify the morphological characteristics of *Ch.* × *hortorum* plants in ontogenesis and to establish the duration of the age periods of plants in the conditions of introduction. The description of age periods was carried out according to the methods of T. Rabotnov, I. Ignatieva and the ontogenetic atlas; the description of seeds was made according to the recommendations of S. Artyushenko to co-authors. Morphological features of plants of various ontogenetic periods were given in accordance with atlases on descriptive morphology of higher plants and an illustrated reference book on the morphology of flower plants edited by S. Zyman et al. Phenological observations were made according to the "Methods of phenological observations in Botanical Gardens of the USSR", and statistical processing of materials was carried out using the Microsoft Excel computer program (2007).

It is stated that the studied plants undergo all periods of ontogenetic development under the conditions of introduction. The duration of these periods was given and the morphological characteristics of plants in each of them were revealed. The most critical period of growth and development of the studied plants was the virginal one.

Keywords: ontogenesis, achene, immature plants, virginal plants, generative plants, morphological features.

Introduction. Knowledge of the patterns of formation of adaptive traits and properties of plants during ontogenesis, under culture conditions, makes it possible to identify critical stages in the life of plants of a particular species [20] and enables systematic management of morphogenetic processes [3], and also allows determining the biological productivity of plants, mechanisms and pathways of their adaptogenesis and features of life strategy [13]. This is especially true for introduced plants, as the success of the mechanisms and pathways of adaptation depends on the internal capabilities determined by the plant genotype and the compliance of the environmental conditions of the new habitat with the biological characteristics of plants [8].

Chrysanthemum varieties united under the general name *Chrysanthemum* ×*horthorum* are complex hybrids obtained by repeated crossing of *Ch. indicum* L. with *Ch. morifolium* Ramat L.. As a result, the plants are heterozygous, so vegetative reproduction prevails over seed reproduction. However, seed propagation allows to obtain more diverse and pure (uninfected) planting material and to study the morphological characteristics of plants at different ontogenetic periods. Also, plants derived from seeds are more durable, have a more developed root system, better tolerate transplantation, and are adapted to the climatic conditions of the area. After all, any variety is not stable and can change significantly when moved to other geographical and environmental conditions [23].

Analysis of the latest research and publications. Plants of the genus *Chrysanthemum* L. are among the least studied in the ontogenetic aspect. The researchers' scientific works are devoted mainly to the elucidation of biological and morphological characteristics of plants of the *Ch.* × *hortorum* selection. The adaptive variability of plants was studied by I.F. Pirko [18], V.F. Opanasenko, Yu. Likholat, E.M. Rudnitskaya [17], N.A. Burmistrova [4] and I.V. Voynyak [23]. Breeding work on the development of new varieties was carried out by R.K. Matiashuk [15], V.F. Gorobets [9], I.A. Zabelin [24], N.V. Smykova [21] and others.

Purpose of the article: to determine the morphological characteristics of the studied plants of *Ch.* × *hortorum* during ontogeny and to establish the duration of age periods in the conditions of the Right-Bank Forest-Steppe of Ukraine.

Materials (objects) and research methods. The research was conducted in the National Dendrological Park "Sofiyivka" of the National Academy of Sciences of Ukraine in 2015-2022. The objects of the study were seeds of *Ch.* × *hortorum* varieties: ′Gusi lebedi′, ′Nova era′, *Ch.* × *hort. sp*. local reproduction of 2015 and the plants themselves at different periods of ontogeny.

The dendrological park is located on the northeastern outskirts of the city of Uman, Cherkasy region. Its geographical location is determined by 48°46' north latitude and 30°14' east longitude according to Greenwich [11]. According to the botanical and geographical

zoning of Ukraine, Uman is located in the central part of the Right-Bank Forest-Steppe of Ukraine and according to the physical and geographical zoning it belongs to the Western Ukrainian Forest-Steppe Province [14]. The climate of the study area is characterized as temperate continental, with an average annual air temperature of +7.3...+9.4°C. According to agrometeorological observations in the zone, the climate is defined by the following features:

- moderately cold winters with a significant amplitude of temperature fluctuations on some days, with little precipitation, light snow cover, and sometimes strong easterly winds;
- moderately warm spring with a significant decrease in air temperature on some days, with cold, sometimes dry winds and uneven distribution of precipitation;
- moderately hot summers, in some years with a dry growing season and uneven distribution of precipitation, often in the form of showers, with predominance of westerly winds;
- moderately warm autumn, sometimes with significant temperature fluctuations at the end of the period [12].

The seeds of the studied plants were sown in March in laboratory conditions and in protected ground. In the laboratory, seeds were germinated on moistened filter paper in Petri dishes, and in protected ground conditions - in sowing boxes with soil mixture (2:1:1 ratio of sod, deciduous soil and peat of neutral acidity). The initial stages of ontogeny were studied in the laboratory and in protected ground, and further research was conducted in experimental plots. Plants were grown by seedling culture.

The description of age periods was carried out according to the methods of T.A. Rabotnova [19], I.P. Ignatieva [10], O.V. Smirnova [21] and according to the ontogenetic atlas [25]. Seeds were described according to the recommendations of S.T. Artyushenko and co-authors [1, 2]. The morphological characters of plants of different ontogenetic periods are given in accordance with the atlases on the descriptive morphology of higher plants [7, 6, 5] and the illustrated guide to the morphology of flowering plants edited by S. M. Ziman et al. [26] Phenological observations were carried out according to the "Methodology of phenological observations in the Botanical Gardens of the USSR" [16]. Statistical processing of the materials was carried out using the computer program Microcoft Excel (2007).

Results of research. The morphological traits of *Ch. × hortorum* plants during ontogenesis were studied and the duration of ontogenetic periods was determined. Each ontogenetic period of plants is characterized by genetically determined traits.

Latency period

The formation and maturation of seeds in the study conditions occurs irregularly, only in years with warm and long autumns. Such an autumn was in 2015 and as a result, we obtained seeds of *Ch. ×hortorum sp* from free crossing and seeds of the varieties ′Gusi lebedi′ and 'Nova era'. The fruit of *Ch. × hortorum* is a small, single-seeded, unopened achene of light, dark brown or black coloring (Table 1, Fig. 1). Seeds are narrowly conical or inversely pyramidal in shape. The surface is ribbed with weakly expressed 5-6 ribs.

Table 1

Morphological characteristics of fruit varieties of Ch.×hortorum

Plant name	Shape of fruit	Colour of the pericarp	Biometric indicators		Weight of 1000 achenes, g
			length, mm	width, mm	
Ch. ×hort. sp.	narrowly conical	brown	2,0±0,06	0,6±0,06	0,19±0,07
′Gusi lebedi′	narrowly conical	dark brown	1,8±0,21	0,4±0,05	0,16±0,02
'Nova era'	inverse pyramidal	brown	1,9±0,12	0,3±0,08	0,17±0,01

In the spring of 2016 (Table 2), the seeds were sown. In the presence of favorable conditions - water, heat, air, viable seeds of *Ch. × hortorum* begin to germinate. During the germination process, there are two main phases: activation of growth processes and seedling growth. The first phase involves swelling, activation of enzyme systems, cell elongation and division. The appearance of the germinal root is the beginning of the second phase of seed germination.

Pregenerative period.

The pregenerative period of ontogeny lasts from seed germination to the beginning of flowering and includes the following age stages: seedlings, juvenile, immature and virginile.

Seedling (p)

Ch. × hortorum cultivars are characteristic by an epigeal type of seed germination. In the studied plants, the seed coat breaks through from the narrowed side of the achene. The germinal root attaches the seedling to the substrate and supplies it with water and minerals. The intensity of germination of the germinal root depends on the plant variety and the conditions of the study (Table 2).

Table 2

Characteristics of seed germination of Ch. ×hortorum cultivars

Stages of Germination	Number of days from sowing		
	Ch.×hortorum	**′Gusi lebedi′**	**'Nova era'**
germination of the germinal root	7 ± 1	9 ± 3	6 ± 1
the appearance of the cotyledonous knee	9 ± 2	12 ± 2	14 ± 2
opening of cotyledon leaves	11 ± 1	13 ± 1	14 ± 1
the emergence of the first pair of true leaves	14 ± 1	18 ± 2	20 ± 2

After 3-5 days, depending on the variety, the hypocotyl appears on the soil surface in protected ground. The hypocotyl stretches out and brings two cotyledon leaves to the soil surface (Table 2). They are whole-edged, elliptical in shape (Table 3, Fig. 1), round at the top, and green in flavor. The central vein of the cotyledon leaf is not clearly defined. The hypocotyl is white in color. Sometimes, at this stage of development, a lateral root appears on the embryonic root. The size of cotyledon leaves and germinal root gradually increases in the seedlings of all the studied individuals.

Fig. 1. Ontogenesis of Ch.×hortorum sp. plants: a - achenes, p - seedling, j - juvenile plant, im. - immature plant, v - virginal plant, g - generative plant

Table 3

Morphological characteristics of Ch.×hortorum seedlings

Plant names	Vegetative organs	Morphological features	
		length, mm	width, mm
Ch.×hortorum sp.	cotyledons	3,2 ± 0,74	2,4± 0,48
	hypocotyl	7,0±0,01	0,5±0,01
	root	4,2±0,12	0,1±0,01
′Gusi lebedi′	cotyledons	2,4 ± 0,8	2,4 ±0,48
	hypocotyl	9,0±0,01	0,5±0,06
	root	2,5±0,14	0,1±0,01
′Nova era′	cotyledons	2,6 ±0,48	2,4 ± 0,48
	hypocotyl	6,0±0,01	0,2±0,01
	root	2,1±0,11	0,1±0,01

The juvenile state (j) is characterized by the activation of growth and organ-forming processes. A sign of transition from a seedling to a juvenile is the appearance of the first genuine leaf.

The first true leaf differs from the leaves of adult plants in the degree of dissection. The first true leaf differs from the leaves of adult plants in the degree of dissection. The appearance of the first genuine leaf occurs on the seventh day from the time the seeds germinate. The leaf emerges directly above the cotyledons, but does not acquire the size and shape of adults. The leaflet is simple, elliptic or obovate-lanceolate (Table 4), the margin is entire, the apex is obtuse or acute, and the base is narrowed. The leaves of the studied plants are petiolate, pubescent. The petiole is 2 mm long. Eight days after the first true leaf appears, the second appears, and the third in another seven days. Starting with the second true leaf, they take on the shape and dissection of adult leaves, but are smaller. A fibrous root system is formed from the embryonic root. The cotyledon leaves remain on the plant for a long time.

Table 4

Characteristics of the juvenile plant

Vegetative organs	Morphological features	Plant name		
		Ch.×hort sp.	**′Gusi lebedi′**	**′Nova era′**
cotyledons	shape	elongated-oval	oval	elongated-oval
	length, mm	10,0±1,5	10,8±2,0	8,4±1,9
	width, mm	5,3±0,60	5,2±0,48	5,8±0,20
real leaf	shape	inverse lanceolate	elliptical	elliptical
	length, mm	7,4±2,0	11,4±1,92	9,5±0,52
	width, mm	3,2±0,43	4,6±0,49	5,4±0,19
hypocotyl	shape	cylindrical	cylindrical	cylindrical
	length, mm	15,2±2,39	15,5±2,34	17,2±0,65
	width, mm	1,3±0,05	1,1±0,06	1,2±0,11
epicotyl	shape	cylindrical	cylindrical	cylindrical
	length, mm	2,5±0,28	2,3±0,45	3,5±0,42
	width, mm	1,2±0,04	1,1±0,05	1,2±0,11
root	length, mm	43,3±2,34	42,2±2,31	38,2±0,57
	width, mm	1,0±0,04	1,1±0,05	1,2±0,04

Immature stae (im) (Fig. 1.). In seedlings, further morphological changes of both underground and aboveground organs were observed. Plants in the immature state have one shoot of monopodial type. Five to eight leaves are formed on it. Leaves have elliptic (′Nova era′, ′Gusi lebedi′) and inversely lanceolate forms (*Ch. × hortorum* sp.), separate partitioning of the leaf plate. As the leaves emerge, their size increases, but their shape remains unchanged (Table 5). The root actively branches, forming lateral roots. The total length of the root system varies from 11.1 cm to 15.4 cm. The beginning of the formation of lateral shoots in axils of the first true leaves and the death of cotyledon leaves on the main shoot indicate the completion of the immature stage and transition to virginal. We observed the immature state of plants from the third decade of April to the second decade of May.

Table 5

Characteristics of immature plants

Vegetative organs	Morphological features	Plant names		
		Ch.×hort sp.	**′Gusi lebedi′**	**′Nova era′**
cotyledons	shape	elongated oval	oval	elongated oval
	length, mm	11,5 ±2,5	11,3 ± 2,0	8,5 ± 0,51
	width, mm	5,5 ± 0,50	5,0 ± 0,52	5,8 ± 0,20
real leaf	shape	inverse lanceolate	elliptical	elliptical
	length, mm	21,6 ± 2,05	25,8 ± 2,0	22,5 ± 0,51
	width, mm	20,3±0,47	18,9 ± 0,52	20,7 ± 0,20
hypocotyl	shape	cylindrical	cylindrical	cylindrical
	length, mm	61,5 ± 2,41	60,7 ± 2,38	54,4 ± 0,65
	width, mm	1,2 ± 0,07	1,1 ± 0,06	1,2 ± 0,12
epicotyl	shape	cylindrical	cylindrical	cylindrical
	length, mm	2,5 ±0,31	2,3 ±0,47	3,5 ± 0,46
	width, mm	1,2 ± 0,07	1,1 ± 0,06	1,2 ± 0,12
main root	length, mm	49,5 ± 2,41	51,3 ± 2,38	47,1±0,65
	width, mm	1,2 ± 0,06	1,1 ± 0,05	1,2 ± 0,06

***Virginal state (v*).** Active growth and development of leaves on the main shoot is a characteristic sign of virginal state of the studied plants. During vegetation, we observed intensive branching of the main shoot. Second and third - order shoots are formed, but generative organs are still absent. Shoots of the second order are placed on the main shoot alternately. The same arrangement is inherent in third-order shoots. Second-order shoots are 19.5±2.76 cm long, and third-order shoots are 12.35±2.93 cm long. The leaves take on the shape and size of adult plants. The size of the leaves of virgin individuals did not differ from the leaves of generative plants, but their number was much smaller. During this period, the growth of the root system continues. Before the beginning of budding, namely the third decade of July, the height of plants ranged from 15.38 cm to 18.75 cm (Table 6). At this stage of development, the plants under study are most vulnerable to diseases, namely septoria, ascochitosis, alternaria, and fusarium. Therefore, preventive treatments of plants with fungicides are necessary.

Table 6

Characteristics of virginal plant

Plant name	Bush		Leaf	
	height, cm	**number of branches of Ⅱ order**	**length, cm**	**width, cm**
′Gusi lebedi′	16,7±0,49	4	3,75±0,83	2,70±0,59
′Nova era′	15,38±0,49	3	4,50±0,5	3,25±0,43
Ch.×hort. sp.	18,75±1,30	4	2,50±0,5	1,58±0,41

Generative period (g). The generative period of the studied *Ch. × hortorum* plants are characterized by the completion of the growth of vegetative shoots of orders 1-4, leaves, and the appearance of reproductive organs. At the end of the Ⅲ decade of July, the phenological phase begins - budding, and flowering - in the Ⅰ decade of September. The timing and duration of flowering of the plants under study depends mainly on the biological characteristics of the variety, but environmental conditions also have a significant impact. For example, high temperature and lack of moisture, under intense light, affect budding and flowering time. The most optimal temperature for bud formation is +18...+20 ºC. Higher air temperatures slow down the formation of buds, or cause them to stop forming altogether. The drop in temperature in September had a positive effect on the plants, which was manifested in flowering. One plant produces 20 to 75 inflorescences (′Gusi lebedi′ - *Ch.×hort*. sp.), which are located at the tops of the main and lateral shoots. The flowers are collected in non-double inflorescences - baskets, which consist of a large number of sessile flowers arranged in a spiral on the peduncle. The reed flowers are yellow, pink and lilac, the tubular flowers are yellow. Young generative plants are characterized by weak flowering compared to plants in a mature generative state. A warm and long autumn with few frosts extended the flowering time of the plants. Flowering continues until the end of October. And an air temperature below -4 ºC causes the death of the above-ground non-lignified part of the bush. This indicates the end of flowering and vegetation of plants in general (Fig. 2).

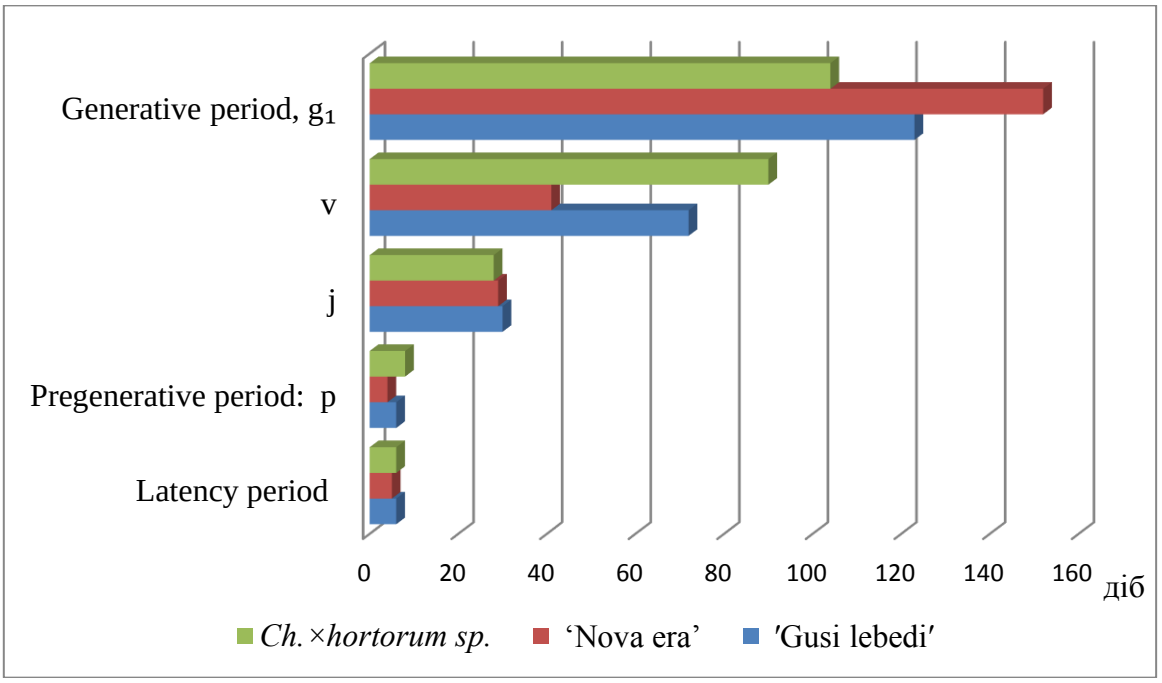

Fig. 2.
Duration of ontogenetic periods and states of Chrysantemum × hortorum cultivars during one growing season

The generative period is the longest (′Gusi lebedi′- 123 days, ′Nova era′- 152 days, *Ch.×hort. sp*. - 104 days) compared to the previously considered ontogenetic periods and states (Fig. 2).

The ontogenetic state, adult generative plants (g2), begins in the 2nd year of vegetation and lasts for 3 years. Plants begin vegetation in the 3rd decade of March. Regrowth of vegetative shoots occurs at the expense of renewal buds. The growth and development of vegetative and generative organs is the same as in the previous growing season. In adult plants of the generative period, vegetative shoots are densely covered with leaves, they have an increased number of branching shoots and reproductive organs (Table 7). In the second year of vegetation, 58 inflorescences were formed on one bush of the ′Gusi lebedi′ variety, 65 inflorescences were formed on ′Nova era′, and 128 inflorescences were formed on *Ch. × hort. sp.* There is no periodicity in seed formation. The life strategy of the plants is aimed at intensive vegetative regeneration.

Table 7

Characteristics of generative plants

Feature		Plant name		
		′Gusi lebedi′	**′Nova era′**	***Ch.×hort. sp.***
Bush	height, cm	21,02±2,18	20,2±1,33	25,0±2,83
	number of branches of II order	6	10	10
Leaf	length, cm	3,75±0,83	4,5±0,5	2,5±0,5
	width, cm	2,7±0,59	3,25±0,43	1,58±0,41
Inflorescence	diameter, cm	5,3±0,17	6,08±0,17	6,18±0,18
	color	yellow	pink	lilac

The ontogenetic state is an old generative individual (g3).

Starting from the 4th-5th year of vegetation, the studied plants showed signs of aging. This condition is characterized by a decrease in the number of shoots, respectively, the number of inflorescences decreases and the size of leaves and inflorescences becomes smaller.

Senile period (s).

Subsenile plants are characterized by the loss of their ability to sprout. As a result, the conditions of existence become unfavorable for plants, contributing to the transition of plants to the so-called quasi senile state. Plants have been in a suppressed state for a long time, being content with a minimal share of environmental resources.

Conclusions.

As a result of the research, it was found that plants of the genus *Chrysanthemum* in the conditions of the Right-Bank Forest-Steppe of Ukraine undergo latent, pregenerative, generative and senile (sub senile stage) periods of individual development. The morphological signs of plants of each ontogenetic period were investigated, and their duration was determined. It was found that the most critical period of growth and development of the studied *Ch. × hort*. plants are in the virginal stage (disease affliction).

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