

# FEATURES OF THE PHENOLOGICAL TIME SERIES OF COMMON ASH (*FRAXINUS EXCELSIOR* L.) AND ITS ORNAMENTAL FORMS IN THE FOREST- STEPPE ZONE OF RIGHT-BANK UKRAINE

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## Abstract

Growth and development of vegetative and generative organs of Common ash and its ornamental forms – 'Albo-Variegata', 'Aurea', 'Crispa', 'Monophylla Pendula' and 'Pendula' were studied. The dates of swelling and bursting of vegetative and generative buds were established; as well as dates of linear growth and lignification of sprouts, budding, flowering; separation, maturation, colouring change and defoliation; fruit set, development, ripening and fruit abscission. Intensity of growth of Common ash annual sprouts and duration of their growth in all studied plants were determined. The results show that *Fraxinus excelsior* and its ornamental forms belong to plants that later begin the vegetation (the second decade of April to the first decade of May), which is characteristic of many heat-loving woody species. It was found that the rhythmic of ornamental forms vegetation corresponds to climatic rhythm of Forest-Steppes of Ukraine and it is an indicator of high adaptability to the conditions in the region.

**Key words:** bud, fruit, leaves, linear growth, phenological phases, sprouts.

## Introduction

Seasonal growth and development play an important role not only in the fields related to agriculture, but also related to landscape gardening (Balčiūnas et al. 2008, Vilčinskas and Dabkevičienė 2009). Life-sustaining activity of plants occurs under conditions of inconstant, variable and dynamic environment. It is reflected on the stages of seasonal plant development. Knowledge of phenological features of a particular plant species, enables to set the most favourable periods

of maturation and seed collection, conducting plant propagation, sowing, planting, etc.

Phenology of species and ornamental forms of *Fraxinus excelsior* L. both in nature and culture, is not enough studied. Hordienko et al. (1996) studied its phenological phases of growth and development in the forest ranges of fresh oak forests. In Donetsk Botanical Garden of NAS of Ukraine, Tereshchenko (2002) studied the growth and development of Common ash and its ornamental form 'Aurea'. The phenological phases of development of vege-

tative and generative organs were investigated in the British islands (Wardle 1961, Thomas 2016), leaf phenology in the Pyrenees mountains, France (Vitasse et al. 2009a), the timing of bud burst and leaf fall in Sheffield, UK (Chih-Wei et al. 2016), the bud burst date and bud development in Oxfordshire, UK (Ella and Ben 2017).

In National Dendrological Park 'Sofievka' five ornamental forms are growing: *F. excelsior* 'Pendula' Boom, which has been cultivating in the park since 1960; *F. excelsior* 'Aurea' Persoon – is introduced from Poland in 1999; *F. excelsior* 'Albo-Variegata' Hayne, *F. excelsior* 'Crispa' Willdenow and *F. excelsior* 'Monophylla Pendula' Aiton, stalks taken from the Botanical Garden named after Academician O. V. Fomin of Kyiv and replicated by V. F. Sobchenko by different methods of transplantation from 1998 to 2001.

Researches of phenological data of growth and development of vegetative and generative organs of Common ash and its ornamental forms in the parkland of the Right-Bank Forest-Steppe of Ukraine were not carried out, therefore their studying is actual.

## Material and Methods

During 2009–2011 were studied phenological rhythms of growth and development of *F. excelsior* and its five ornamental forms at the National Dendrological Park 'Sofievka' NAS of Ukraine and Uman National University of Horticulture by methodology of Botanical Gardens Council of the USSR (Lapin 1975). Vegetative and floral phenological observations were conducted. For this purpose there were selected 7 model exemplars with similar physiological characteristics. Registration of phenological time series was carried

out 2–3 times per week during the vegetative season, and during the period of the fastest development (in the spring) – every day.

The swelling of the vegetative buds was recorded before the scales were opened according to the increase of their size and colour change – from black or brown-black to green. The bursting of the buds was recorded when green tips of primordial leaf which had dark brown or black dots appeared in the places of radial cracks. The beginning of twig growth was observed on the shoots that appeared from the apical bud and placed on elongated shoots of the last year. The beginning of phenological time series was recorded in the period when it was possible to touch with fingers the leaves' hidden apex of the shoots which began to grow. The phase of partial lignification of the shoots was recorded by the formation of cortical layer in shoots' basal part. Their complete lignification was observed when they were covered with cork layer throughout the length and changed the colour to mature shoots. The beginning of separation of leaves was determined on the day when among the young green leaves on the branches there have been seen a few small leaves which were not opened yet. The date when they stopped to grow was recorded by the presence in the crown leaves of normal size with straightened laminas and colour, which are characteristic of the researched plants. The change in the colour of the leaves was recorded when the crown completely changed autumn colours. The defoliation was recorded when 50 % of leaves fell off.

The time of swelling of the generative buds was recorded similarly to the vegetative buds. The bursting of the buds was recorded by the appearance of immature inflorescence from the buds of the scales.

The budding was recorded during the separation of flowers in inflorescences. The beginning of flowering was recorded when pollen released from anther after shaking of the branches. Time of infructescence was recorded during intensive growth of ovary in the days prior to wilting and drying of the flower style. The time when immature fruits reached the size of the mature was determined visually by comparing them with mature fruits. The time of fruits ripening was fixed when the colour of the pericarp and the ash-key changed – they became brown and acquired a light brown colour.

During the determination of vegetative season length we choose the beginning of bud burst as start of the vegetation, and the massive leaf fall as its end.

The dynamics of seasonal shoot growth was determined by the method of Molchanov and Smirnov (1967). For this

purpose on the model trees were selected 10 branches the length of which was measured with a metal ruler every 7 days from the base (crotch or scar of the last year's bud) to the apex with accuracy of 1 mm. The dynamics of the seasonal growth of *F. excelsior* annual seedlings was measured after 3–4 days. The statistical processing of data was conducted with the use of a computer program in accordance with the method of Dospekhov (1985).

The observations of Common ash trees aged about 50 years and of ornamental forms 8–11 years.

The climate of the studied area is moderately continental with relatively warm winters and frequent thaws. The warmest winter was of 2011 when the average temperature in December amounted +1.9 °C, in January – -3.1 °C, February – -5.2 °C (Table 1).

**Table 1. Average temperature (°C) of researches (data by Uman weather-station).**

Years	Months												Average for a year
	1	2	3	4	5	6	7	8	9	10	11	12	
2009	-3.4	-0.8	2.2	10.1	14.6	20.2	21.2	19.2	16.1	9.2	4.6	-2.4	9.2
2010	-7.8	-3.0	0.7	9.3	16.4	20.6	23.0	23.6	14.5	5.9	8.8	-3.8	9.0
2011	-3.1	-5.2	1.4	9.5	15.7	19.7	21.7	18.9	15.0	7.0	1.8	1.9	8.7
Average for 3 years	-4.8	-3.0	1.4	9.6	15.6	20.2	22.0	20.6	15.2	7.4	5.1	-1.4	9.0
Long-term average annual	-5.7	-4.2	0.4	8.5	14.6	17.6	19.0	18.2	13.6	7.6	2.1	-2.4	7.4

The coldest winter was of 2010 – December – -3.8 °C, January – -7.8 °C, February – -3.0 °C. For 2009 and 2010 considerably higher temperatures were typical compared to the long-term average annual data. The highest average monthly temperature on the average over three years of researches was +20.2 °C in July.

Annual amount of precipitations ranged from 500 to 700 mm. Not quite favourable in the amount of precipitations for plant growth were 2009 and 2011 (Table 2). In 2009, the amount of precipitations (523.5 mm) was by 109.5 mm lower in comparison with the long-term average annual, which was 633 mm.

**Table 2. Average amount of precipitations (mm) of researches (data by Uman weather-station).**

Years	Months												Average for a year
	1	2	3	4	5	6	7	8	9	10	11	12	
2009	25.6	73.9	46.8	0.0	38.5	49.0	86.1	4.5	38.8	64.9	14.9	80.5	523.5
2010	108.6	60.2	38.2	43.3	52.6	139.3	59.1	36.4	73.4	29.3	50.0	62.4	752.8
2011	28.8	18.7	3.7	25.2	68.5	129.2	150.7	50.1	12.4	71.6	2.2	32.0	593.1
Average for 3 years	54.3	50.9	29.6	22.8	53.2	105.8	98.6	30.3	41.5	55.3	22.4	58.3	623.1
Long-term average annual	47	44	39	48	55	87	87	59	43	33	43	48	633

Average annual humidity was 75 % (Table 3). Long-term average annual humidity amounts 76 %, the maximum was accounted for November–December (87 %) and minimum – May and June (65 %).

**Table 3. Average humidity (%) of researches (data by Uman weather-station).**

Years	Months												Average for a year
	1	2	3	4	5	6	7	8	9	10	11	12	
2009	88	88	82	54	68	65	72	63	70	81	89	89	76
2010	87	88	79	66	71	71	72	62	71	79	82	89	76
2011	91	77	69	58	66	70	72	70	71	79	79	88	74
Average for 3 years	89	84	77	59	68	69	72	65	71	80	83	89	75
Long-term average annual	86	85	82	68	64	66	67	68	73	80	87	88	76

The dark gray podzolized soils are with humus content from 4.14–4.49 %. By the dry-weight percentage they are heavy loams.

## Results and Discussion

Terms of beginning of passing main phenophases of development give an idea of the progress of seasonal development, so special attention was given to the following phenological phases: swelling and bursting of vegetative and generative

buds, sprouts growth, separation and defoliation, budding, flowering, fruiting and fruit abscission. Phenospectra of seasonal rhythm of development of *F. excelsior* and its ornamental forms are presented in Fig. 1.

### The phases of vegetative organs development

For the vegetative buds in *F. excelsior*, the progression of kidney development is very important for the bud flushing dates (Cun-

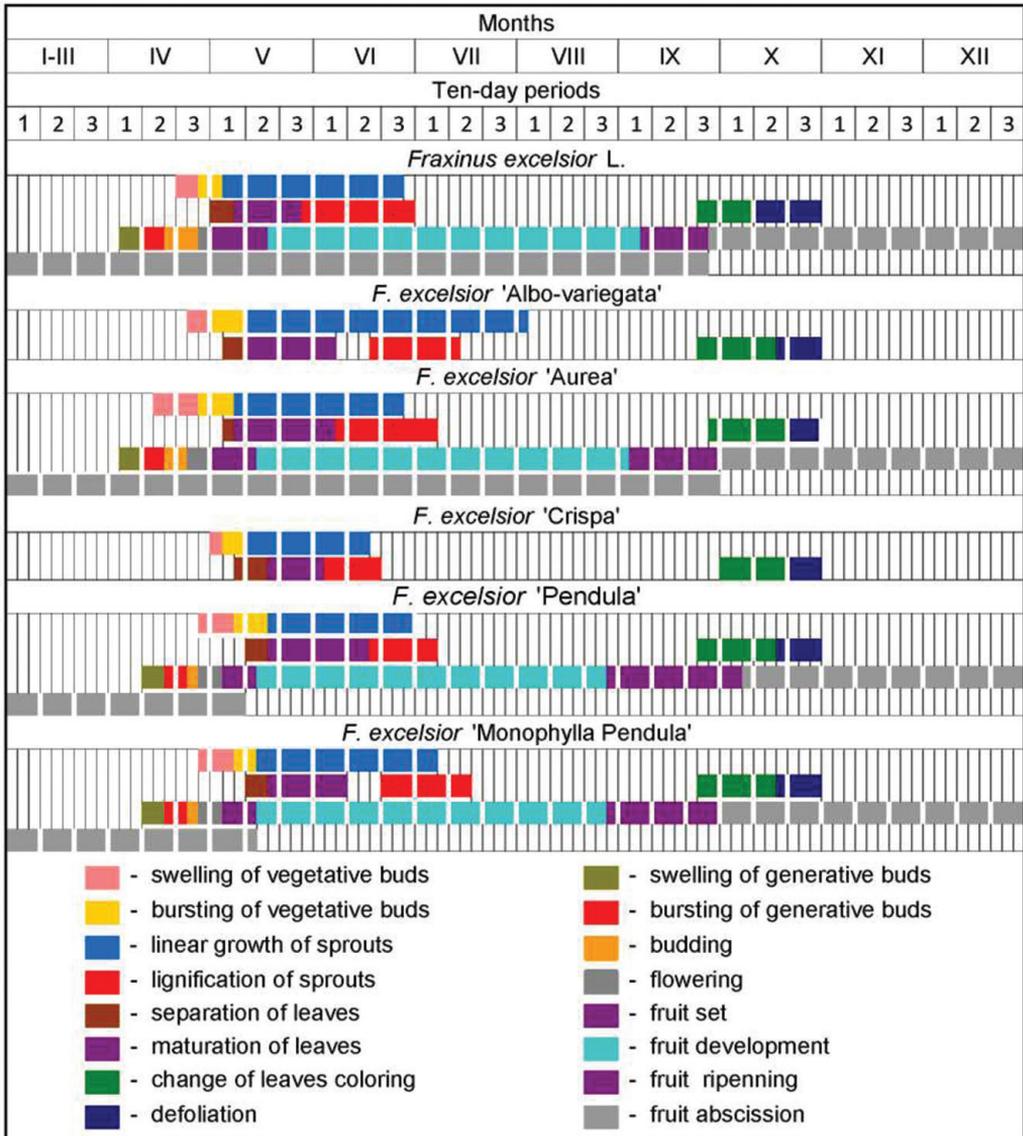


Fig. 1. Phenospectra of seasonal rhythm of development of *Fraxinus excelsior* and its ornamental forms.

dall et al. 2003). The buds' development was observed during the second half of April and sometimes until mid-May in the Vance (Etalle) region of provenance, Belgium (Jouve et al. 2007). The studies of Wardle (1961) showed that vegetative

buds begin to swell in early March and open through May, although understory trees usually begin earlier and can have fully expanded leaves by the beginning of May. The bud burst begins in the first decade of May in Oxfordshire, UK (Ella and

Ben 2017). However, according to data Chih-Wei et al. (2016) for riparian and non-riparian ash it ranged from mid-April to the end of May in Sheffield, UK.

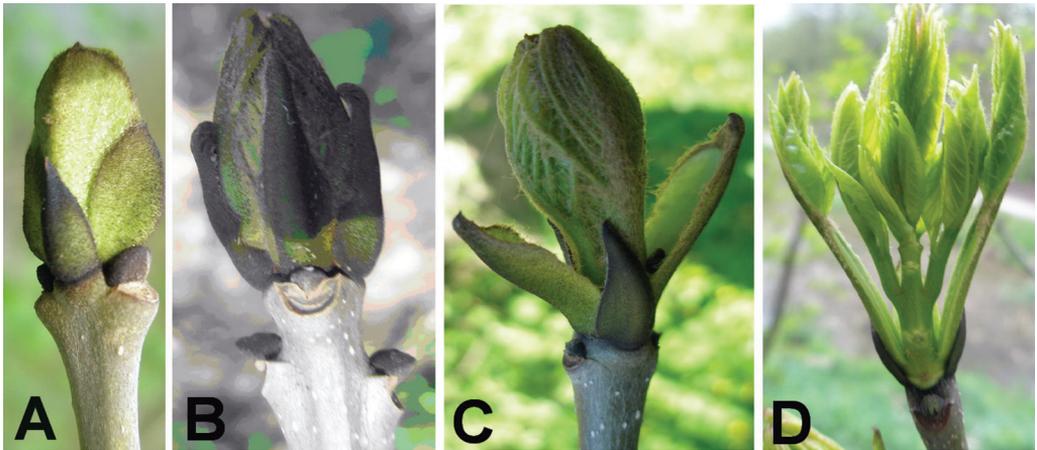
Swelling of buds (Fig. 2A) begins at the end of the second decade of April in Common ash and its forms at an average daily temperature of 8.3–9.4 °C – 'Albo-Variegata' and 'Aurea', and in the third decade – 'Crispa', 'Pendula' and 'Monophylla Pendula' (9.5–9.7 °C). It is the longest in Common ash – 11–12 days, and the lowest in *F. excelsior* 'Crispa' – 3–5 days.

Bursting of buds (Fig. 2B) during the years of our researches in *F. excelsior* and its forms 'Albo-Variegata' and 'Aurea' started in the third decade of April at a temperature of 8.9–9.4 °C, and in *F. excelsior* 'Crispa', 'Pendula' and 'Monophylla Pendula' – in the first decade of May (10.8–16.8 °C). It lasts in Common ash 7–9 days and in its forms – from 5 to 14 days.

Separation of leaves (Fig. 2C) begins at a temperature of 9.2–9.6 °C in *F. excelsior* and *F. excelsior* 'Aurea' at the end of the third decade of April, and in the rest of the forms – in first and second decade of

May (10.6–14.0 °C). The duration of this phase lasts in 'Crispa' – 8–12 days, least – 3–5 days in 'Aurea' and 'Pendula'. In the rest of ornamental forms it varies 4–8 days. Unlike Uman, according to the data in *F. excelsior* under the conditions of Kyiv the leaves appear in the period from 9 to 18 May. In the conditions of Belarus, leaf formation occurs 10–28 May (Hordienko et al. 1996). According to the observations of Vitasse et al. (2009a) the unfolding tree leaves begins on 6–20 of April at a height 150 m a.s.l. of Pyrenees mountains. According to the results of the Marsham Phenological Record, 1736–1947 (Sparks and Carey 1995) the mean date of the beginning of the unfolding leaves of *F. excelsior* is on the third decade of April in central England.

Linear growth of sprouts (Fig. 2D) begins in early May at an average daily temperature of 11.4–17.0 °C in *F. excelsior* and its three forms – 'Aurea', 'Albo-Variegata' and 'Crispa', while in other two – in the second decade of May (13.0–16.9 °C). Completion of this phase begins in the third decade of June in indigenous species, *F. excelsior* 'Aurea' and *F. excelsior* 'Pendula'.



**Fig. 2.** Phases of vegetative organs development of *Fraxinus excelsior*: A) swelling of buds; B) bursting of buds; C) separation of leaves; D) beginning linear growth of sprouts.

la' (19.8–20.5 °C), in the first decade of July – *F. excelsior* 'Monophylla Pendula' and 'Albo-Variegata' (16.9–22.3 °C), the in the second decade of June – *F. excelsior* 'Crispa' (18.5–21.1 °C).

Sprouts under the conditions of Uman have inconsiderable duration of growth – from 34 to 56 days (Table 4). It was established that the longest growth characterized sprouts 'Albo-Variegata' – 56 days. In 2009 their growth did not significantly differ from indices of the growth of annu-

al sprouts of the indigenous species, ornamental forms 'Aurea' and 'Monophylla Pendula', but significantly differed from the indices of duration of seasonal growth in 'Crispa' and 'Pendula', which respectively amounted 37 and 43 days. The same difference from 'Albo-Variegata' in 'Crispa' and 'Pendula' was observed during the following years of researches. On the average, the difference was 20 and 13 days. The smallest duration of growth was observed in 'Crispa' – 36 days.

**Table 4. Duration of growth of *F. excelsior* sprouts and its ornamental forms.**

Species and forms	Days			Average for 3 years
	2009	2010	2011	
<i>F. excelsior</i> L.	55	49	51	52
'Albo-Variegata'	56	55	56	56
'Aurea'	55	51	53	53
'Crispa'	37	34	36	36
'Monophylla Pendula'	52	53	54	53
'Pendula'	43	41	45	43
HIP05	5	6	4	–

According to observations of Hordienko et al. (1996) the growth of shoots lasted 54–58 days in Goloseyevsky forestry of Kiev region, and according to our observations in the plantings of the National Dendrological Park 'Sofievka' – 49–55 days.

The analysis of dynamics of annual sprouts seasonal growth of Common ash (Fig. 3) showed that one-vertex curve that corresponds to one wave of growth was formed. The maximum increase was observed in the third decade of May – 11.3 cm or 34.9 % of total increment. In general, the maximum amount of growth of sprouts lasted from 20.05 to 03.06. So, in the beginning of June the sprouts of indigenous species reached 92.3 %, and during the period from 03.06–24.06 only 7.7 % of the total length. In plantings of Uman, maximum amount of growth was observed dur-

ing the first 22 days and amounts 69.2 % of the total amount of growth.

The studies of Wardle (1961) on the British Isles showed that seedlings growing under a canopy of *F. excelsior* commenced growth at the beginning of May; the growth rate reached a maximum in the latter part of May and declined to zero by the end of June.

Phase of partial fragmentary lignification of sprouts occurred at a temperature of 14.4–15.2 °C in the third decade of May in *F. excelsior*, and in ornamental forms 'Pendula', 'Albo-Variegata', 'Monophylla Pendula' (second and third decades of June) at a temperature of 19.6–20.9 °C, 'Crispa' and 'Aurea' in the first decade of June (18.4–21.4 °C). Full lignification of sprouts occurred in the typical form on the 7–8th day and for *F. excelsior* 'Crispa' on 5–6th day. In the rest of ornamental forms

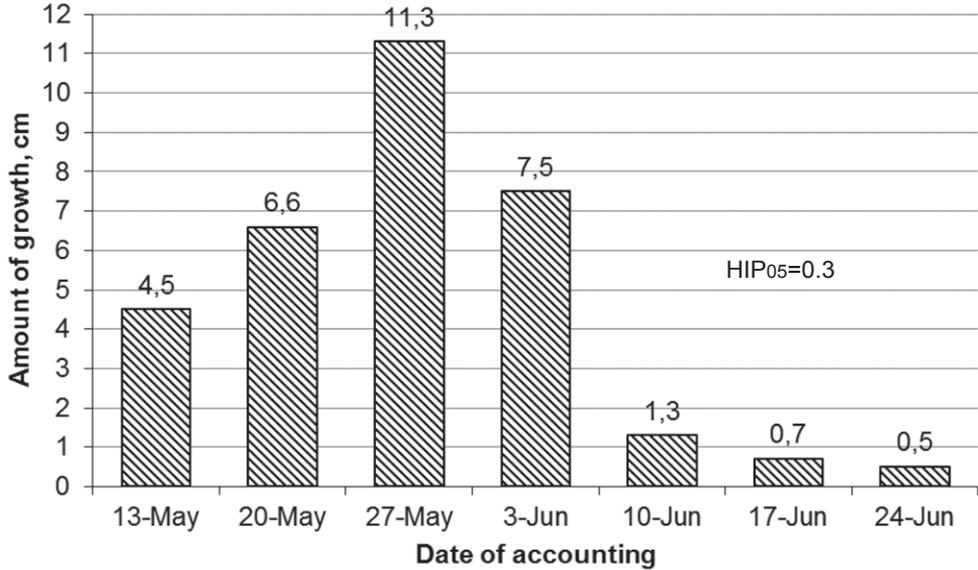


Fig. 3. Dynamics of seasonal growth of annual sprouts of *F. excelsior*.

this phase is observed on the 7–11th day. This phase occurs at an average daily temperature of 20.9–21.6 °C.

Phase of completion of leaf growth in *F. excelsior* and in ornamental form 'Pendula' occurs, respectively, in the third decade of May (14.4–16.1 °C) and in the second decade of June (18.9–21.7 °C). In the rest of forms it occurs in the first decade of June (11.2–16.7 °C). Duration of leaves formation is different. Thus, in *F. excelsior* 'Aurea', it is the longest – 27–38 days, but in 'Crispa', duration is 15–17 days. This phase in *F. excelsior* is 19–22 days, 3–4 days more in 'Monophylla Pendula', 8–10 in 'Albo-Variiegata' and 9–14 in 'Pendula'.

Colour change of leaves could not be observed, because after the first slight frost in late September early October, the green leaves fall off. In indigenous species first simple leaves fall and their stalks – later. Except *F. excelsior*, this phenomenon is observed in 'Albo-Variiegata', 'Aurea', 'Pendula' and 'Monophylla Pendula'.

Under favourable conditions, change of colour occurs in the third decade of September at an average daily temperature of 14.5–16.7 °C, and only in 'Crispa' – at the beginning of the first decade of October (7.6–10.3 °C).

Leaf-fall appears to be a result of declining autumn temperatures, rather than of frost, for the old leaves are quite frost-hardy (Wardle 1961). Leaves are shed during October and the first half of November, though a few persist into December on the British Isles (Wardle 1961, Grime et al. 2007). Leaf fall can be somewhat earlier on polluted sites in or near industrial centers (Thomas 2016).

According to our observations in ornamental forms 'Albo-Variiegata', 'Aurea', 'Pendula' and 'Monophylla Pendula' defoliation starts in the second decade of October and lasts until the first decade of November (6.1–10.2 °C). This phase in 'Crispa' occurs at the beginning of the third decade of October (6.1–10.0 °C).

Concerning indigenous species, it should be noted that the defoliation in certain trees begins in the third decade of September at a temperature of 14.2–15.8 °C, but their majority falls in the first and second decades of October with the beginning of slight frost.

### Phases of generative organs development

Ash begins to flower in early spring (early–mid March in the UK and Ireland) and ends in mid–end May. Anthesis is not always synchronous in adjacent buds (Douglas 2013). Flowers on male trees open earliest and then hermaphrodite trees followed by female trees last of all (Tal 2011, Albert et al. 2013).

Swelling of the buds (Fig. 4A) begins in the first and second decades of April. The first enters this phase *F. excelsior* (05.04–12.04) and its form 'Aurea' (06.04–14.04) at an average daily temperature of 7.0–9.1 °C. The longest lasts in *F. excelsior* 6–7 days, and least in *F. excelsior* 'Pendula' – 3–5 days.

Bursting of buds (Fig. 4B) begins in the second decade of April (7.3–9.4 °C), except 'Pendula' and 'Monophylla Pendula' (beginning of third at a temperature of 7.6–9.7 °C). In *F. excelsior* it lasts 4–6 days, and in its ornamental forms 3–9 days.

Budding (Fig. 4C) occurs at the end of the second or in third decade of April. Simultaneously bud formation begins in *F. excelsior* and *F. excelsior* 'Aurea' – 16.04–23.04 at an average daily temperature of 7.8–9.3 °C, ornamental forms 'Pendula' and 'Monophylla Pendula' – 25.04–28.04 (9.1–9.3 °C).

Beginning of flowering (Fig. 4D) starts in the third decade of April at a temperature of 9.1–10.1 °C. Its duration is 5–6 days. According to the data in the conditions of Kyiv, *F. excelsior* 'Pendula' blossoms from 3–18 May – 16 days, *F. excelsior* 'Aurea' – 8–18 May for 11 days (Rubtsov 1977). Such difference can be explained by the fact that the indices were taken in different phases, because almost simultaneously there is bud formation and flowering on the same tree. The studies of Latorre and Bianchi (1998) on the flowering season of *Fraxinus excelsior* were 34 days long and its principal phase lasted only 21 days in Argentina.

Fruit set in all plants occurs in the first decade of May (10.7–16.8 °C). Immature fruits reach mature sizes in the first decade of June (17.8–21.6 °C), and their ripening – in the last days of the third decade of August and in the beginning of the first decade of September at a temperature of 15.0–23.0 °C. The duration of fruit ripening in *F. excelsior* is 85–89 days. Among the ornamental forms the longest period of ripening is noted in 'Aurea', which is

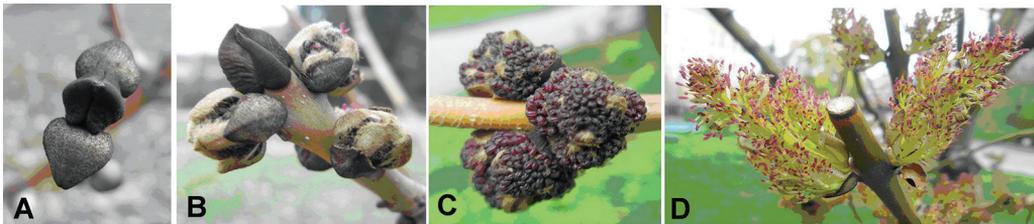


Fig. 4. Phases of generative organs development *Fraxinus excelsior* 'Aurea': A) swelling of buds; B) bursting of buds; C) budding; D) flowering.

88–93 days, and the smallest period in 'Pendula' – 78–81 days. Average indices were recorded in 'Monophylla Pendula' – 84 days.

The samaras are fully grown by the beginning of July, while the enclosed seeds reach their full length by the beginning of August. The embryos grow until August or September (Wardle 1961, Kerr 1995). According to the data in the plantings of Donetsk Botanical Garden of NAS of Ukraine, a fruits ripening of *F. excelsior* begins in the first half of July and lasts for 30 days (Tereshchenko 2002). In the National Dendrological Park 'Sofievka' of NAS of Ukraine in Uman, this phase begins in the third decade of August at an average daily temperature of 18.6–23.5 °C and lasts about 30–40 days, confirming a significant difference in the duration of the formation of seeds in different regions.

According to our observations, maturation of ash-keys begins in late August. On the same tree, seeds ripen not simultaneously. Maturation elongates on a month and sometimes more. The fruits begin to fall off in early July (unfilled and damaged), and most of them falls off on the snow in winter. It also should be noted that some of ash-keys remain on the tree during summer of the next year, and sometimes even till the end of autumn.

The length of vegetative season in the research years is in a range from 167 to 183 days. For *F. excelsior* and *F. excelsior* 'Pendula' and 'Monophylla Pendula' it is 178 days, *F. excelsior* 'Albo-Variegata' – 167 days, *F. excelsior* 'Aurea' – 183 days, *F. excelsior* 'Crispa' – 171 days. According to Tereshchenko (2002) in the plantings of Donetsk Botanical Garden the length of growing season for *F. excelsior* is 197 days, and for *F. excelsior* 'Aurea' – 199 days. According to observations of Vitasse (2009b) under the conditions of Pyr-

enees the length of growing season for *F. excelsior* is 189 days.

## Conclusions

As a result of the conducted phenological observations the growth and development of vegetative and generative organs of Common ash and its ornamental forms – 'Aurea', 'Albo-variegata', 'Crispa', 'Monophylla Pendula' and 'Pendula' were investigated.

The beginning of vegetation of plants of typical species *F. excelsior* and its ornamental forms except 'Crispa' (first decade of May), begins in the second and third decades of April at an average daily temperature of 8.9–16.8 °C.

Linear growth of sprouts begins in early May at an average daily temperature of 11.4–17.0 °C. Completion of this phase begins in the second decade of June – *F. excelsior* 'Crispa' (18.5–21.1 °C), in the third decade of June in indigenous species, *F. excelsior* 'Aurea' and *F. excelsior* 'Pendula' (19.8–20.5 °C), in the first decade of July – *F. excelsior* 'Monophylla Pendula' and 'Albo-Variegata' (16.9–22.3 °C). Duration of growth of annual sprouts *F. excelsior* and its forms are characterized by a short period, duration from 34 (*F. excelsior* 'Crispa') to 56 (*F. excelsior* 'Albo-Variegata') days.

Separation of leaves begins at a temperature of 9.2–9.6 °C in *F. excelsior* and *F. excelsior* 'Aurea' at the end of the third decade of April, and in the rest of forms – in first and second decades of May (10.6–14.0 °C). Phase of completion of leaf growth in *F. excelsior* and in ornamental form 'Pendula' occurs, respectively, in the third decade of May (14.4–16.1 °C) and in the second decade of June (18.9–21.7 °C). In the rest of forms it occurs in

the first decade of June (11.2–16.7 °C).

The colour change occurs in the third decade of September at an average daily temperature of 14.5–16.7 °C, and only in 'Crispa' – at the beginning of the first decade of October (7.6–10.3 °C). The defoliation starts in the second decade of October and lasts until the first decade of November (6.1–10.2 °C).

Beginning of flowering starts in the third decade of April at a temperature of 9.1–10.1 °C. Its duration is 5–6 days. All forms bloom and fructify except 'Albo-Variegata' and 'Crispa'. Trees of *F. excelsior* bloom and fructify not every year.

Fruit set in all plants occurs in the first decade of May (10.7–16.8 °C). Immature fruits reach mature sizes in the first decade of June (17.8–21.6 °C), and their ripening – in the last days of the third decade of August (18.6–23.5 °C) and in the beginning of the first decade of September at a temperature of 15.0–23.0 °C.

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