Received: 06/16/2021; Revised: 07/26/2021; Accepted: 08/20/2021

UKRAINIAN JOURNAL OF FOREST AND WOOD SCIENCE

Journal homepage: https://forestscience.com.ua/en
Ukrainian Journal of Forest and Wood Science, 12(3), 72-79

UDC 582.973:712.25[477]
DOI: 10.31548/forest2021.03.006

Structure and Morphogenesis of Shoots of Species of the *Viburnum* L. Genus in the Right-Bank Forest-Steppe of Ukraine

Olena Demchenko

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Abstract. A study of the growth features and structure of shoots of species of the *Viburnum* L genus was conducted. Determination of features of the structure of shoots of species of the Viburnum genus is relevant because there are substantial differences in the structure and dynamics of growth within the genus. The study of the dynamics of shoot growth was conducted according to the method of A.A. Molchanov and V.V. Smirnov (1967). The studied species belong to three sections of the *Viburnum* L. genus. In the species of each of the sections, the features of the bud structure largely determine the structure of shoots. It is determined that the species of each of the three sections of the genus have a special structure of shoots. The rhythms of growth and development of plants of native and introduced species of the *Viburnum* genus are studied.

The timing of shoot growth of species of the *Viburnum* genus is analysed, and the length of annual shoot growth is determined. Phenodates of the beginning and end of shoot growth were established. It is identified that the onset of individual phenophases quite clearly correlates with the sum of effective temperatures above +5°C. For species of the *Viburnum* genus the following types of shoots are characteristic: tillering, stem, generative. Intensive growth of shoots of all the studied species occurs in May – mid-June. In Lantana section species there are two peaks of shoot growth – May and mid-July. According to the duration of growth, *viburnum* shoots can be divided into two groups: 1) with a short growth period (65-75 days): *V.opulus* L., *V.sargentii* Koehne, *V.prunifolium* L., V.rufidulum Raf., *V.lentago* L.; 2) with a long growth period (100 or more days): *V.lantana* L., *V.carlesii* Hemsl., *V.veitchii* C.H. Wright, *V.rhytidophyllum* Hemsl., *V.buddleifolium* C.H. Wright, *V.burejaeticum* Rgl. et Herd.

The data obtained indicate that the greatest annual growth of shoots of all *Viburnum* species was received at the age of 4-7 years. A decrease in the annual growth of axial shoots signals the need for preliminary rejuvenation of the plant

Keywords: shoots, annual growth, phenophase, phenodate, *Viburnum*

Suggested Citation:
Demchenko, O. (2021). Structure and morphogenesis of shoots of species of the *Viburnum* l. genus in the right-bank forest-steppe of Ukraine. *Ukrainian Journal of Forest and Wood Science*, 12(3), 72-79.

*Corresponding author

Introduction

The growth of plants of introduced species, the ability to give annual growth is one of the indicators of success in the introduction of a species.

Shrubs differ from trees in that they have not one, but several skeletal axes (stems) connected to each other at the base of the bush or in its underground part. The age of individual stems is relatively small, but the total age of the entire plant can be quite substantial, its life is extended due to new axes that grow from aboveground and underground renewal buds, replacing old ones that die off (Mazurenko & Hohryakov, 1977). The stem of perennials, and shrubs as well, consists of separate distinct structural elements called annual shoots (metamers). Annual bush shoots are young central or lateral axes of the stem that have developed during a single growing season from buds located on stems, rhizomes, or roots. Adjacent annual shoots (growths) are separated from each other by scars left over from bud scales, and shortened internodes. Thus, the stem of the shrub consists of a series of generations of shoots that are formed annually, and is characterised by a special type of growth and branching characteristic of this species.

The study of the phase of growth and development of shoots of introduced plants is of particular importance, because the degree of their lignification depends on the time of their growth and development, and therefore the frost resistance and winter hardiness of plants. Simultaneously with the study of the duration of growth of shoots, the dynamics of their growth was also investigated, which is also important for determining the winter hardiness of plants, because it is known that winter-hardy can be not only those shoots that complete growth and development early, but also those that grow for a long time, but rather slowly.

Determining the features of the structure and dynamics of shoot growth is extremely relevant for species of the Viburnum genus because there are substantial differences in structure and dynamics in different species. The dynamics (duration) of growth and development of plant shoots of a certain species is directly related to the annual (phenological) cycle of plant development of a certain species. Information on the phenology of species of the *Viburnum* genus ia submitted in the paper (Demchenko, 2017). Shoots of plants of the genus species as an integral part of the crown of plants directly affect the decorative effect of plants (Demchenko, 2016). Features of the growth of shoots of various types of woody plants on the example of the viburnum genus in the United States are considered in the paper (Donoghue, 1981). Investigation of the reaction of a number of species of forest shrubs, in particular, witherod viburnum (*Viburnum cassinoides* L.), on the bending of the stem is given in the paper (Wilson, 1997). According to the author, the formation of epicormal shoots is the main reaction of the studied species *Cornus amomum* Mill., *V. cassinoides* and *Gaylussacia baccata* (Wang.) K. Koch on bending. Information on the structure of shoots and the formation of the crown structure of *Viburnum* lantana and Viburnum opulus is collected in the paper (Kollmann & Grubb, 2002).

The purpose of the study is a comparative analysis of the features of the structure and dynamics of growth and development of plant shoots of species of the *Viburnum* genus due to their phenological development in the conditions of the Right-bank forest-steppe of Ukraine and their consistency with the natural and climatic conditions of this region.

Materials and Methods

Bioecological, biomorphological, biometric, and statistical research methods were applied.

The objects of the study were plants of the *Viburnum* genus of collections of the NM. M. Hryshko National Botanical Garden of the National Academy of Sciences of Ukraine (NBG of the NASU) and the A.V. Fomin Botanical Garden of the Taras Shevchenko National University of Kyiv (BG of the NUK).

Stationary studies of 11 species and 5 varieties of introduced and native *Viburnum* species were conducted in 2009-2013 in Kyiv on the territory of the NBG of the NASU and BG of the NUK. The studied species belong to 3 of the 9 isolated species in the *Viburnu*m genus sections: *Lantana* Spach. (*V.lantana* L., *V.lantana 'Aureum'*, *V.lantana 'Variegatum'*, *V.carlesii* Hemsl., *V.rhytidophyllum* Hemsl., *V.burejaeticum* Rgl. et Herd., *V.veitchii* C.H.Wright., *V.buddleifolium* C.H.Wright), *Lentago* DC. (*V.lentago* L., *V.prunifolium* L., *V.rufidulum* Raf.), *Opulus* DC. (*Viburnum opulus* L., *V.opulus 'Roseum'*, *V.opulus 'Nanum'*, *V.sargentii* Koehne, *V.sargentii 'Flavum'*).

The dynamics of seasonal shoot growth was determined by the method of A.A. Molchanov and V.V. Smirnov (Molchanov & Smirnov, 1967). Phenological observations were conducted according to the "Technique of phenological observations in botanical gardens of the USSR" (1975). Phenospectors were compiled according to the method of N.E. Bulyigin (Bulyigin, 1985). Field data expressed as ordinary calendar dates were converted to a continuous series of numbers as the number of days from March 1 according to G.M. Zaytsev (Zaytsev, 1981). Statistical processing of research results was conducted according to the methods of G.M. Zaytsev (Zaytsev, 1981, 1984).

Results and Discussion

For *Viburnum* species the following types of shoots are typical.

1. Tillering shoots – vegetative shoots formed most often from the lower or middle part of the crown and delayed for a long time at the second stage of organogenesis. They are characterised by increased growth (in 1-2 years they reach a length corresponding to the habit of the species) and slow development (they enter the generative phase for 2-3 years of growth and development). It was determined that up to 20% of these shoots freeze or stop growing and die off in the first year.

2. Stem shoots – the most numerous among all types of shoots that are distinguished in the crown of the bush. They are formed from lateral buds located at the base of leaf petioles in the middle and upper parts of the crown. They are characterised by slower growth and the rate of transition to the generative phase.

3. Generative shoots – they are characterised by slow growth and rapid development. Such shoots stop growing with the beginning of flowering.

Shoots of the first two types continue to develop even after flowering. Their growth rate slows down during flowering, and after it ends, the shoots activate growth processes. The complexes of conditions necessary for passing a particular phase are determined by the ecological factors in which the species were formed.

The internal rhythm of growth and development, changes in the needs of plants in various complexes of environmental conditions are due to the heredity of organisms and are largely a reflection of seasonal phenomena.

The period from the beginning of bud opening to the beginning of leaf fall or leaf death from autumn frosts in summer green plants can be roughly taken as vegetative, in evergreens – the transition of plants to a state of organic dormancy can be conditionally accepted for the termination of vegetation.

The structure of viburnum shoots, although differs from one another, but also has a lot in common. At the border between adjacent annual shoots, they do not have the typical bud rings consisting of scars of bud scales, as in many trees and shrubs. However, the first internode of the annual shoot in all species of the *Viburnum* genus is usually shorter than the following ones. All nodes on the shoots of viburnum have two opposite leaves. In all species, inflorescences are formed on the tops of shoots.

There is a clear relationship between the structural features of viburnum shoots and their systematic position. The studied species belong to three sections of the *Viburnum* genus, the species of each section have a special structure of shoots.

Among the studied plants, the most distinctive features of their shoots are the species of *Opulus* sections: they usually die and fall off of the tip, the apical bud is not formed. Instead, at the top of the shoot there are two axillary buds of the upper node with a small scar from the dead tip between them. These buds can be either vegetative or generative. In isolated cases, an apical bud is formed on particularly strong shoots, and then a monopodial increase in the axis of the perennial shoot is observed. This occurs more often on intensively growing tillering shoots or in young plants. Sympodial branching is observed in stem shoots. In generative shoots, which usually die off after fruiting, their first metamer remains alive, axillary buds develop on it and give new shoots. In the crown of *Opulus* section species on perennial axial shoots, strongly thickened nodes can be identified, consisting of the first metamers of dead shoots of several orders of branching. Border between adjacent annual shoots of *Opulus* section species, it is easily determined behind the short first internodes of the shoot.

Notably, the dwarf cultivar of Viburnum opulus (*Viburnum opulus 'Nanum'*) it is distinguished by a peculiar form of growth and development of shoots: the vegetation of the plant is conducted at the expense of lateral shoots, apical shoots grow very slowly.

It is much more difficult to establish a boundary between the annual shoots of the *Lantana section*

species. It does not have specialised bud scales, the buds are protected by the outer rudiments of leaves, which are covered with dense pubescence, which forms a dense layer, like felt. Under the outer rudiments there are one or two more pairs of also densely pubescent leaf rudiments. In spring, when the buds open, the outer rudiments unfold and grow into normal green leaves, although slightly smaller in size compared to those located above. The internodes under this first pair of leaves lengthen when the bud opens and become almost as long as the internodes located above. After leaf fall in autumn, the border between adjacent annual shoots is almost impossible to determine. Unlike the *Opulus* section, shoots of *Lantana* section species form an apical bud. Therefore, most perennial axes grow monopodially. Sympodial growth is observed only in generative shoots, the apical bud of which forms the rudiment of the inflorescence.

In *Lentago* section species an apical bud develops on all shoots. From the outside, it is protected by a pair of scales. When the buds open in spring, these scales move apart and their upper parts grow, forming small green leaf blades. These first leaves of the shoot are transitional forms from scales to leaves. The internodes under these leaves lengthen only during the opening of the bud. Therefore, it will not be like the *Lantana* section species, simultaneously the last internodes of the previous summer shoot. This first shortened Internode serves as a well-defined border between adjacent annual shoots.

In most of the studied species of the viburnum genus, stem shoots most often consist of three metamers. Tillering shoots contain much more metamers. For example, in *V.opulus* there can be 7-8 of them, in *V.lantana, V.lentago* – 8-9. Internodes on these shoots are always much longer than on stem shoots.

Thus, a comparison of the structure of shoots of different types of viburnum shows that in the species of each of the sections, the features of shoots are mutually predetermined, that the features of the structure of buds largely determine the structure of shoots, and all this is due to external conditions in the areas of the natural distribution of species.

Intensive growth of shoots of all the studied species occurs in May – mid-June (Fig. 1). In *Lantana* section species there are two peaks of shoot growth – May and mid-July, which is associated with climatic conditions.

It is established that the objects of research on the duration of shoot growth can be divided into two groups (Table 1): 1) with a short growth period (65-75 days) – *V.opulus*, *V.sargentii*, *V.prunifolium*, *V.rufidulum*, *V.lentago*; 2) with a long growth period (100 or more days) – *V.lantana*, *V.carlesii*, *V.veitchii*, *V. rhytidophyllum*, *V.buddleifolium*, *V.burejaeticum*.

Table 1. Average annual phenodates of species of the *Viburnum* genus (average phenodates in days from March 1, Kyiv, 2009-2013)

Species cultivar	Appearance of a green leaf cone	Duration of shoot growth, days	Beginning of November	Duration of vegetation, days
Viburnum opulus	33.13	68.18	213.20	180.07
V. o. 'Roseum'	31.47	67.62	232.27	200.80
V. O. 'Nanum'	42.20	71.14	227.13	184.93
V. lantana	30.60	105.28	234.07	203.47
V.l.'Aureum'	29.67	108.49	247.33	217.66
V. l. 'Varie-gatum'	29, 00	100.35	238.67	209.67
V. sarlesii	29.87	96.14	240.27	210.40
V. rhytidophyllum	30.27	112.36	---	---
V. lentago	37.33	69.32	241.67	204.34
V. rufidulum	34.33	73.24	240.67	206.34
V. prunifolium	36.67	70.76	238.22	201.55
V. veitchii	26.89	115.84	239.22	212.33
V. burejaeticum	25.33	109.28	250.67	225.34
V. buddleifolium	39.33	114.16	---	---
V. sargentii	34.11	68.25	248.33	214.22
V. sargentii 'Flavum'	33.67	69.18	245.22	211.55

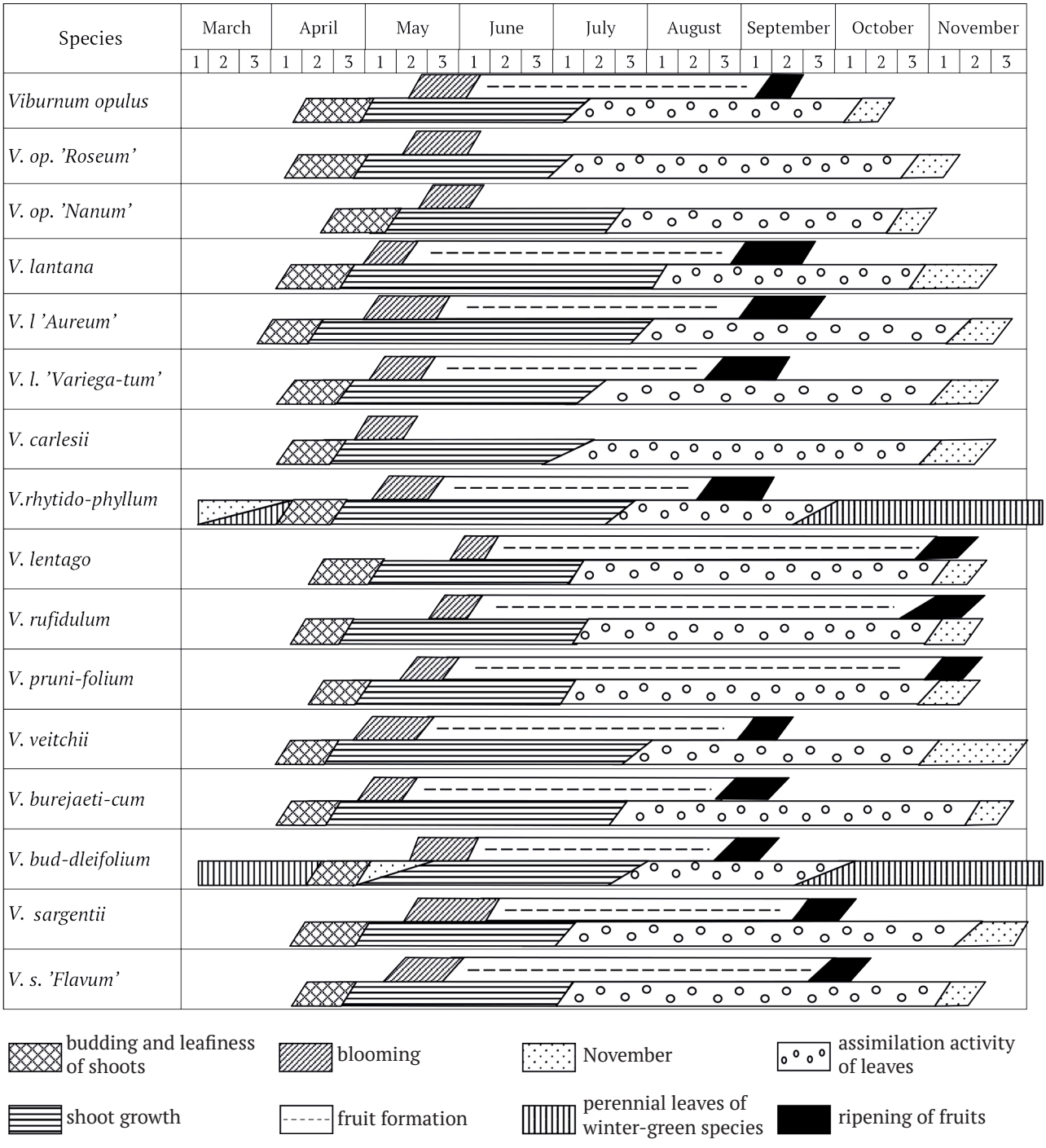

Figure 1. Phenospectre of seasonal development of *Viburnum* species in Kyiv (NBG of the NASU, BG of the NUK)

The average increase per day during the period of intensive growth in *V.lantana* is 10-16 mm, in other viburnums – up to 5 mm. The value of the annual growth of Viburnum ranges from 16.6 cm to 64.7 cm, only in *V.opulus 'Nanum'* it does not exceed 15 cm, more often 5-7 cm.

The greatest length of annual growth of stem shoots is observed in *V.opulus* (21.6 cm), *V.lantana*

(29.4 cm), *V.burejaeticum* (27.8 cm), *V.rufidulum* (19.7 cm).

The greatest annual growth of generative shoots is in *V.opulus* (15.3 cm) and *V.sargentii* (13.9 cm), the smallest – in *V.lantana 'Variegatum'* (2.4 cm) and *V.lantana 'Aureum'* (3.8 cm). The relationship between the timing of the beginning of flowering and the length of generative shoots is determined: the earlier flowering begins, the shorter the length of generative shoots and vice versa.

The data obtained indicate that the largest increase in all *Viburnum* species occurs at the age of 4-7 years. A decrease in the annual growth of axial shoots signals the need for preliminary rejuvenation of the bush: removal of old shoots, crown formation, if necessary – "planting on a stump".

As a result of statistical treatment with phenodate, it was identified that the onset of individual phenophases quite clearly correlates with the sum of effective temperatures (above +5°C) (Table 2).

Table 2. Average dates of occurrence of the main phenophases of *Viburnum* species and the sum of effective temperatures, Kyiv (2009-2013)

Type, cultivar	Budding	Flowering	November	Duration of vegetation
V. opulus	(2.04±4.0) / (70.51±4.41)	(9.05±3,6) / (510.25±18.61)	(29.09±5.8) / (2074.39±27.11)	180.1±4.58
V.o. 'Roseum'	(31.03±5.3) / (64.83±5.25)	(5.05±3.1) / (484.13±17.83)	(18.10±6.3) / (2210.14±30.26)	200.8±3.39
V.o. 'Nanum'	(11.04±4.0) / (98.47±4.37)	(15.05±4.1) / (567.62±21.14)	(13.10±8.1) / (2154.29±32.15)	184.9±3.63
V. lantana	(30.03±5.3) / (61.85±3.49)	(27.04±2.3) / (285.25±20.71)	(20.10±4.1) / (2278.38±34.29)	203.5±4.48
V.l. 'Aureum'	(19.03±4.6) / (54.93±4.68)	(27.04±2.5) / (298.15±20.11)	(2.11±4.9) / (2562.49±40.28)	217.7±4.34
V. l. 'Variegatum'	(29.03±4.0) / (59.94±5.43)	(25.04±2.1) / (229.21±17.16)	(25.10±4.5) / (2400.72±30.29)	209.7±4.08
V.carlesii	(29.03±3.8) / (58.3±3.25)	(20.04±2.6) / (182.31±19.25)	(26.10±3.7) / (2416.67±39.25)	210.4±3.13
V. lentago	(6.04±6.2) / (124.8±5.26)	(22.05±4.1) / (645.73±21.14)	(28.10±5.2) / (2485.51±36.29)	204.3±6.53
V.rufidulum	(3.04±5.2) / (116.2±3.43)	(15.05±3.2) / (559.48±17.28)	(26.10±6.5) / (2462.85±33.28)	206.3±7,78
V.prunifolium	(6.04±5.1) / (124.8±4.01)	(7.05±2.1) / (503.41±18.17)	(24.10±8.1) / (2439.64±34.24)	201.6±5.59
V.veitchii	(27.03±4.5) / (83.1±3.25)	(22.04±2.6) / (195.12±18.28)	(25.10±7.4) / (2445.62±36.33)	212.3±2.12
V.burejae-ticum	(25.03±4,6) / (80.6±4.47)	(22.04±1.2) / (193.25±17.02)	(6.11±7.2) / (2598.26±34.29)	225.3±2.08
V.sargentii	(30.04±4.7) / (69.2±3.73)	(9.05±2.8) / (512.16±17.84)	(3.11±8.9) / (2577.34±32.26)	214.2±4,44
V.sargentii 'Flavum'	(2.04±5.1) / (70.5±4.45)	(2.05±2.2) / (458.25±16.24)	(31.10±7.0) / (2489.74±32.25)	211.6±5.24

Conclusions

The objects of research are divided into two groups according to the duration of shoot growth. By the end of the growing season, the shoots of most species of viburnum have time to lignify. Exceptions are some species with long growth (*V.rhytidophyllum*, *V.buddleifolium*, *V.veitchii*), the shoots of which do not have time to completely lignify. However, the shoots of these species are protected by a thick layer of pubescence, and under the surface covers of the shoot with the onset of cold weather, a sufficient amount of fat is formed that prevents damage to the shoots by low temperatures, so these plants are quite hardy.

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Структура та морфогенез пагонів видів роду *Viburnum* L. у правобережному лісостепу України

Олена Олександрівна Демченко

Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Анотація. Було проведено дослідження особливостей росту та будови пагонів видів роду *Viburnum* L. Визначення особливостей будови пагонів видів роду Viburnum є актуальним, оскільки існують суттєві відмінності структури та динаміки росту в межах роду. Дослідження динаміки росту пагонів проводили за методикою А.А. Молчанова і В.В. Смірнова (1967). Досліджувані види належать до трьох секцій роду *Viburnum* L. У видів кожної з секцій особливості структури бруньок багато в чому визначають структуру пагонів. Установлено, що видам кожної з трьох секцій роду властива особлива будова пагонів. Було вивчено ритми росту та розвитку рослин аборигенних та інтродукованих видів роду *Viburnum*.

Проаналізовано терміни росту пагонів видів роду Viburnum, а також визначено довжину річного приросту пагонів. Установлено фенодати початку і закінчення росту пагонів. Виявлено, що настання окремих фенофаз доволі чітко співвідноситься з сумою ефективних температур вище ніж +5 °C. Для видів роду *Viburnum* характерні такі типи пагонів: кущіння, стеблові, генеративні. Інтенсивний приріст пагонів усіх досліджуваних видів припадає на травень – середину червня. У видів секції *Lantana* спостерігається два піки росту пагонів – травень і середина липня. За тривалістю росту пагонів калини можна розділити на дві групи: 1) з нетривалим періодом росту (65–75 днів): *V.opulus* L., *V.sargentii* Koehne, *V.prunifolium* L., *V.rufidulum* Raf., *V.lentago* L.; 2) з тривалим періодом росту (100 й більше днів): *V.lantana* L., *V.carlesii* Hemsl., *V.veitchii* C.H. Wright, *V.rhytidophyllum* Hemsl., *V.buddleifolium* C.H. Wright, *V.burejaeticum* Rgl. et Herd.

Отримані дані свідчать, що найбільший річний приріст пагонів усіх видів Viburnum отримано у віці 4–7 років. Зниження річного приросту осьових пагонів сигналізує про необхідність робіт із попереднього омолодження рослини

Ключові слова: пагони, річний приріст, фенофаза, фенодата, *Viburnum*