http://dergipark.org.tr/trkjnat
Trakya University Journal of Natural Sciences, 23(2): 185-191, 2022
ISSN 2528-9691
DOI: 10.23902/trkjnat.1073916

Research Article

FORMATION AND MORPHOLOGY OF *Rhus typhina* L. INFLORESCENCE IN CONDITIONS OF THE RIGHT BANK FOREST STEPPE OF UKRAINE

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Cite this article as:

Kovalchuk T., Didenko I., Ishchuk L, Ishchuk H. & Klymenko S. 2022. Formation and morphology of *Rhus typhina* L. inflorescence in conditions of the right bank forest steppe of Ukraine. *Trakya Univ J Nat Sci*, 23(2): 185-191, DOI: 10.23902/trkjnat.1073916

Received: 15 February 2022, Accepted: 26 August 2022, Online First: 23 September 2022, Published: 15 October 2022

Edited by:
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Key words:
Growth
Development
Mixed bud
Shoot
Panicle
Rhus typhina L.

Abstract: Peculiarities of growth and development of shoots of *Rhus typhina* L. in the conditions of the Right-bank forest-steppe of Ukraine are characterized. The morphological description of inflorescences and flowers of the species is carried out. The description took into account the stages of formation of the vegetative component of the inflorescence, the most significant features of its structure, the number of flowers in the inflorescence, and flowering dates. Pistillate and staminate flowers are collected in complex, botric, botanical, bractose, pyramidal inflorescences - panicles. The studied plants are characterized by acropetal type of inflorescence flowering. Abundance and level of flowering are estimated. In the research conditions generative individuals of *R. typhina* bloom annually. We estimated the abundance of *R. typhina* flowering in 4 points that corresponds to a high level.

Özet: Ukrayna'nın Sağ Yaka orman-step bölgesi koşullarında yetişen *Rhus typhina* L. sürgünlerinin büyüme ve gelişme özellikleri karakterize edilmiştir. Türün çiçek salkımlarının ve çiçeklerinin morfolojik tanımlaması yapılmıştır. Tanımlamada, çiçek salkımlarının en önemli özelliği olan çiçeklenmenin vejetatif bileşeninin oluşum aşamaları, çiçeklenme dönemindeki çiçek sayısı ve çiçeklenme tarihleri dikkate alınmıştır. Pistillat ve staminat çiçekler karmaşık, botric, botanical, braktoz, piramidal salkımlarda toplanmıştır. İncelenen bitkiler, akropetal tipte çiçeklenme ile karakterizedir. Bolluk ve çiçeklenme seviyesine dair bir tahmin ortaya konmuştur. *Rhus typhina*'nın üretken bireylerinin çalışmanın yapıldığı koşullarda yıllık olarak çiçek açtıkları tespit edilmiştir. *Rhus typhina*'nın çiçeklenmesinin 4 farklı dönemde yüksek bir seviyeye ulaştığı tahmin edilmektedir.

Introduction

The study of the structure of generative organs is an urgent issue, as it provides seed regeneration of plants, in particular plants of the species of the genus *Rhus* L. in the conditions of the Right-bank forest-steppe of Ukraine. For the conditions of Ukraine, most species of the genus *Rhus* are introduced plants that were brought to its territory in the XIX century (Kovalchuk 2011). The result of the success of plant introduction is the acclimatisation and naturalisation of plants, which is manifested in the ability to naturally regenerate plants and ensures the continuity and succession of life. Under the conditions of introduction, vegetative regeneration of *Rhus typhina* L. plants predominates over seed regeneration. Due to vegetative regeneration, plants of this species pose a potential invasive threat and negative consequences for local species and ecosystems (Kovalchuk 2018). This phenomenon was also noted by scientists from different regions in the world, in particular in Luxembourg (Pfeiffenschneider *et al.* 2014), Poland (Bomanowska *et al.* 2019), Romania (Sîrbu & Opera 2010), China (Guangmei *et al.* 2008, Du *et al.* 2017), in addition to some other countries. Seed regeneration of the studied plants and the formation of generative organs in terms of introduction is poorly studied. Knowledge of the biology of flowering plants of the genus *Rhus* is covered in the national literature in fragments (Bobrov 1949, Barbarych 1955, Misnik 1962, 1976) and mainly in encyclopedic nature.

Rhus typhina plants are monoecious (Misnik 1962) or dioecious (Misnik 1976, Kohno 1986, Aksenova & Frolova 1989) with heterosexual flowers. Pistillate flowers are collected in dense pyramidal panicles 10-20 cm long, staminate– in large and sparse inflorescences

with linear bracts, up to 30 cm long (Bobrov 1949, Kohno 1986). The axes of the inflorescence are densely pubescent (Bobrov 1949, Aksenova & Frolova 1989). Sepals of flowers are round-quadrangular, 1.5 mm long and 0.5 mm wide, hairy on the outside, which remain on the fruit. The flowers are small, greenish, inconspicuous, unisexual, on short pedicels (Barbarych 1955). According to Schmalhausen's data, flower petals are yellow-white, 2 mm long (Schmalhausen 1895). Misnik (1976) notes that the staminate flowers are greenish in color, and the pistillate flowers are pink-carmine by the end of flowering, collected in inflorescences up to 21 cm long and bloom and bear fruit in the Trostyanets arboretum in Chernihiv region (Misnik 1976). Pistillate flowers are slightly smaller than staminate (Misnik 1962). Flower petals are lanceolate, 3.5 mm long and 1.5 mm wide, pubescent. Stamens are longer than petals. The plants bloom in early summer. In the forest-steppe zone of Russia the average date of flowering is (4.VI–9.VI), lasting 15–20 days (Misnik 1962), in Moscow– in VII-VIII months (Borodina 1970), in Kyiv the plants bloom in III decade of June–I decade of July (Olekseychenko *et al.* 2014), according to Kohno– in April-May (Kohno 1986), in the conditions of the Southern coast of Crimea-in May-June (Wulf *et al.* 1948). The description of flowers of the studied species is reflected in foreign publications (Rehder 1949, Bogacińsky & Molski 1969, Göritz 1973, Krüssmann 1986, Gallant *et al.* 1998) and others. According to Rehder, petals of *R. typhina* are green (Rehder 1949). A detailed description of the growth and development of flowers and biometric indicators of the sterile and fertile part of the flower was made by a group of authors in Canada (Gallant *et al.* 1998). The researchers found signs of sexual dimorphism during the growth and development of pistil and stamen of flowers.

Problems of morphological description of inflorescences, formulation of their structural features, selection and classification of the main types are considered to be one of the most difficult directions in modern botanical morphology (Kuznetsova *et al.* 1992). The aim of our research was to find out the features of growth and development of shoots from mixed buds and morphological features of vegetative and generative parts of *R. typhina* inflorescences, to establish the timing of phenological phases of growth and development of vegetative and generative organs and to estimate abundance and level of flowering in the conditions of the Right-bank forest-steppe of Ukraine.

Materials and Methods

The study was conducted during 2009-2020. The objects of our research were generative individuals of *R. typhina*, which are cultivated in the research and exhibition areas of the National Dendrological Park Sofiyivka of the National Academy of Sciences of Ukraine. Dendrological Park is located on the northeastern outskirts of Uman, Cherkasy region. Its geographical position is determined by 48º46' North latitude and 30º14' East longitude from Greenwich (Ishchuk 2006). The city of Uman, according to the botanical and geographical zoning of Ukraine, is located in the central part of the Right-bank forest-steppe of the country according to the physical-geographical zoning, Uman belongs to the Western Ukrainian forest-steppe province (Marynych 2005). The climate of the zone in which the experiments were conducted is characterized as temperate-continental, with an average annual air temperature of 7.3-9.4ºC. According to the summary data of agrometeorological observations in the area, the climate is characterized by the following features:

- moderately cold winter with a significant amplitude of fluctuations in air temperature on some days, with little precipitation, light snow cover, sometimes with strong eastern 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 summer, in some years with a dry growing season and uneven distribution of precipitation, often in the form of showers, with a predominance of western winds;

- moderately warm autumn, sometimes with significant temperature fluctuations at the end of the growing season (Lipinsky 2003).

However, over the years of research (2009-2020), the average annual temperature fluctuated between 8.8-9.9°C, which is higher than the long-term average by 0.4-1.5°C (Fig. 1). During the research period, the winter seasons of 2012, 2013 and 2018 with the minimum air temperature of -25.4°C were the coldest ones, whereas the overall maximum temperature was 32.9°C (Ishchuk *et al.* 2020).

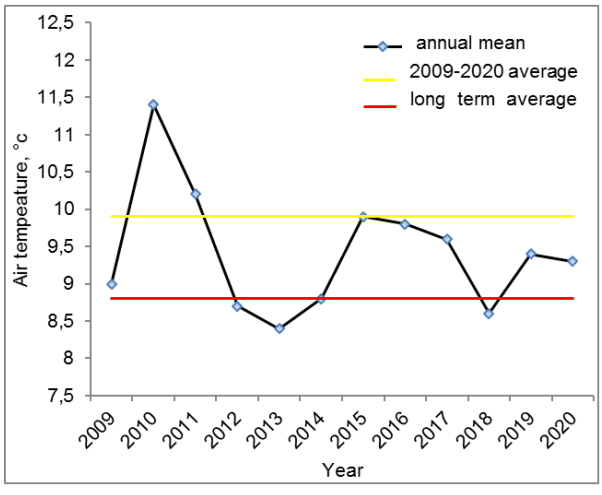

Fig. 1. Average annual temperature over the years of the study.

In the course of the study, the sums of effective temperatures (above +5°C) were determined, at which the phenological phases of plant growth and development took place (Rubtsov 1998, Ishchuk *et al.* 2021). Phenological observations of *R. typhina* plants were

performed according to the recommended methods for botanical gardens The swelling dates of mixed buds were noted as their volume increased. The bud-burst phase was recorded when the young leaves that protect the rudimentary shoot begin to open. The beginning of leaf separation was determined on the day when the opened leaves were still folded, and complete separation-when the leaves acquired their characteristic shape, but did not acquire the normal size characteristic of this species. The phase of completion of leaf growth was determined by the presence of normal size leaves in the crown of the tree with straightened leaf blades of dark green color, characteristic for *R. typhina*. The date of flowering was fixed by full disclosure of pistillate and staminate flowers (Lapin 1975). Morphological description of inflorescences and flowers was carried out according to the illustrated reference book on morphology of flowering plants (Ziman *et al.* 2004), atlases on descriptive morphology of plants (Fedorov & Artyushenko, 1979) and according to the recommendations of Kuznetsova *et al.* (1992). The dimensions of the vegetative part of the inflorescence and the sterile part of the flower were measured by a caliper and graph paper.

The abundance and level of flowering of plants were investigated according to the guidelines for reproduction of woody ornamental plants of the Botanical Garden of the National University of Life and Environmental Sciences of Ukraine (2008) (Maurer & Kushnir 2008), where for the convenience of accounting, the investigated plants belong to 4 groups corresponding to high, medium, low and zero levels. Level: 4-5 points- high, 3 points-medium, 1-2 points- low and zero.

Results

The growth and development of introduced plants of *Rhus* species in the conditions of the Right-bank forest-steppe of Ukraine are influenced by both endogenous factors determined by genotype and exogenous factors of the introduction area (Kovalchuk 2019). The main adaptation of plants to the seasonal rhythm of climatic conditions is the alternation of the active phase and the dormant phase. The transition of plants to a state of autumn-winter dormancy is due to lower air and soil temperatures, reducing the length of daylight and depends on providing the plant with moisture. As soon as these factors change in a favorable direction, growth processes resume. Thus, in plants of *R. typhina* there is a phenophase of mixed buds swelling, which are located at the top of the main and lateral shoots of generative plants and vegetative buds. This phenophase begins on the territory of the Right-bank forest-steppe of Ukraine mainly in the I-II decades of April, at the sum of effective temperatures from 116.9 ± 60.51ºC and is characterized by an increase in the volume of buds (Table 1).

The beginning of apical growth of shoots of the studied plants begins mainly in the II–III decades of April at the sum of effective temperatures– 278.5±45.69ºC. At the exit of the shoot from the bud, during the spring period, there is a development of the laid elements of the shoot, elongation of the stem and leaf growth. The intensity of linear growth of shoots had certain features.

The growth of *R. typhina* shoots is orthotropic and isotropic. Reaches its peak in the period from I to II decade of May and is 90.23±4.51% of the annual growth. Then the growth rate of shoots gradually decreases. Thus, by the second decade of June, 98.17% of the annual growth of plant shoots is formed.

In parallel with the development of the shoot is the development of leaves of the studied species. The post-bud phase of leaf development occurs after bud development, mainly in the third decade of April. This phenophase is characterized by almost steady surface growth, during which the shape of the leaf is fully preserved, only the linear dimensions increase due to the steady growth of cells (mainly stretching) over the entire area of the leaf. The shape, size and presence of the leaf denticles are genetically determined. In the second decade of May, the leaves acquire the appropriate shape, but do not yet reach their inherent size. The leaves of *R. typhina* are imparipinnate and consist of 11-31 leaflets. The leaves of the species are oblong-elliptic or lanceolate, finely serrated at the edges. Leaf growth is limited in time and stops when it reaches a genetically determined size and shape. Thus, the leaves of *R. typhina* grow for 31±2.5 days to 50–60 cm in length. The size of the leaves varies from 6 to 1 cm long and from 2 to 4.3 cm wide. Leaf area 701.81± 23.15 cm², leaf area 30.51±10.87 cm².

In parallel with the growth and development of the shoot, the vegetative part of the inflorescence– panicles and flowers develop. Panicle is a complex, much branched inflorescence with long growth of the main axis and intensive development of lateral axes and is classified as botric (Kovalchuk 2017). The inflorescence of *R. typhina* is formed because of repeated branching of the main axis, as a result of which the axes of the first, second and third orders are formed. The final branch is the pedicel. The number of such branches is greater when the lateral axis that carries them is lower. The number of branching axes decreases from the axis of the third order to the main axis in the direction from the base of the inflorescence to the apex.

Table 1. Phenological phases of development of a vegetative shoot from mixed buds of *R. typhina.*

Swelling buds, date		Shoot growth				
	Σtef., °C	Beginning, date	Σt ef., °C	End, date	Σtef., °C	Duration, day
27.03.-16.04	116.9±60.51	22.04.-30.04	282.1±42,92	11.07.-24.07	1832.42±88.75	82.6±3.06

We observed the same tendency at research of axes lengths of the first order (from 5.9±1.25 cm), the second order (from 2.3±0.10 cm), the third order (from 1.6±0.51 cm), which decrease in the same direction to the length of the pedicel. The length of the main axis is 18.83±4.54 cm. The lateral axes are placed on the main axis in a spiral, forming a spiral panicle, and reducing of the lateral axes' length forms a pyramidal panicle. The inflorescence of this species bears modified leaves, bracts– apical leaves, which are the basis of branching of the lateral axes (Fig. 2). Therefore, the inflorescence is bracteous. The size and shape of the bracts is significantly different from the stem leaves. Leaf blade is entire, narrow, pointed at the apex. The size depends on the location of the inflorescence. Bracts, which are located on the main axis 0.4±0.12 cm wide, 6.1±1.22 cm long, and in the branches of the axes of the second and third orders, their size decreases. Bracts fall off before flowering.

Vegetative parts of the inflorescence are generative organs– flowers. Terminal flowers are always placed at the ends of the branches. Boutoning in plants occurs at the sum of effective temperatures of 710.20± 3.00ºC, in the second– third decades of May (Table 2).

Table 2. Phenological phases of development of a generative shoot from a mixed bud of *R. typhina.*

Boutoning, date	Σtef., °C	Flowering				
		Beginning, date	Σtef., °C	End, date	Σtef., °C	Duration, days
17.05.-30.05	710.20±73.00	06.06.-19.06	06.06.-19.06.	16.06.-05.07	1427.28±97.36	14.0±2.55

Staminate and pistillate flowers begin to bloom at the same time. An important indicator in describing the flowering of plants is the order of opening the flowers in the inflorescence. The investigated plants are characterized by acropetal type of inflorescence flowering. The first to bloom are the flowers that are on the lateral axes located at the lowest part on the main axis, in particular in the direction from the base to the terminal flower of the lateral axis (Fig. 3).

We took this stage of plants flowering of the studied species as the beginning of flowering (Table 2). Then the flowers opened in an ascending direction. Blooming of the terminal flower of the main axis indicates the end of flowering. The average end dates of flowering for plants of *R. typhina* are 16 June-05 July with the sum of effective temperatures 1439.06 ± 94.48ºC.

The flowers of *R. typhina* are unisexual. The flowers have pedicels 2.47±0.92 mm long and 0.43±0.05 mm wide.

Staminate flower formula of *R. typhina* is $K_5C_5A_5$.

The flowers are collected in a sparse inflorescence (Fig. 5). In one inflorescence there are 453±57.32 of flowers that are greenish-white in color (Fig. 4). Calyx is leaf separate, sepals are elongated: 1.5±0.06 mm long, 0.5±0.10 mm wide. The corolla is formed by five integral, hairy petals of lanceolate shape: 3.5±0.21 mm long, 1.5±0.25mm wide and bent at the end inwards. Androecium is formed by five stamens, anthers are located on the side of the stamen filament, which is 1.3±0.30 cm long. Staminate flowers have a rudimentary ovary.

The formula of the pistillate flower of *R. typhina* is $K_5C_5G_3$

Pistillate flowers are collected in dense inflorescences. In one inflorescence there are 231±47.57 of flowers that have a white-green color (Fig. 6). After fertilization, they acquire a carmine color. The shape, size of the calux and corolla are similar to staminate flowers. Gynoecium monocarp. According to the location of the pistil in the flower, the studied plants have pistillate flowers. The ovary of the pistil is upper, the column is apical, stigma is triple-cutted. The flowers have reduced stamens with underdeveloped anthers.

Fig. 2. Bracts of *R. typhina.*

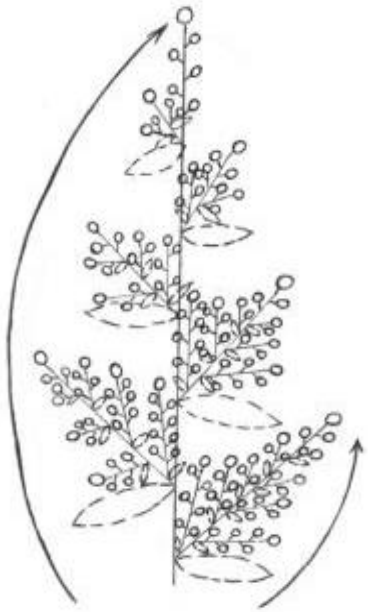

Fig. 3. The scheme of the inflorescence of *R. typhina*.

**Note:* — *terminal flower,* — *flower,* — *fallen bract*

Fig. 4. Staminate flower of *R. typhina*.

Fig. 5. Inflorescences with staminate flowers of *R. typhina*.

Fig. 6. The pistillate flower of *R. typhina*.

Discussion

Linear growth of R. typhina shoots begins at a total effective temperature of 282.1±42.92°C by apical growth and cell expansion during May – the first half of June in an orthotropic and isotropic manner. The formation of botrytal inflorescences of R. typhina results from multiple branching of the main axis, into first, second and third order axes. However, the number of branching axes decreases from the third-order axis towards the main axis. Thus, the model of formation of vegetative shoots and generative inflorescences presented by us and the sequence of flowering coincides with the concept of Lovett & Lovett (1988). Studies by Misnik (1976) and Gallant *et al.* (1998) on the study of signs of sexual dimorphism in the development of pistillate and staminate flowers are confirmed by our data.

The first flowering of *R. typhina* under the introduction in the National Dendrological Park Sofiyivka was recorded by us after 5 years, which coincides with the research of Chepik (1981), indicating that the first flowering occurs after 4-6 years. The timing of *R. typhina* flowering, (start of flowering is 06 June-19 July and end of flowering is 16 June-05 July) coincides with that of Olekseychenko *et al.* (2014) and differ significantly from the older data of Kohno (1986), who also conducted studies in the Right-bank forest-steppe of Ukraine. The difference in flowering terms between our results and those of Kohno (1986) is obviously explained by the phenomenon of global climatic warming, which we have observed in recent years (Ishchuk *et al.* 2020). However, it is more accurate to determine the timing of flowering, as well as the timing of other developmental phases, by the sum of the effective temperatures. Thus, the sum of effective temperatures 710.20±73.00°C is required for budding and 1427.28±97.36°C for flowering.

Conclusions

In the research conditions, generative individuals of *R. typhina* bloom annually. We estimated the abundance of flowering in 4 points, which corresponds to a high level. The ability of *R. typhina* plants in the conditions of the Right-bank forest-steppe of Ukraine to form generative organs testifies to the success of introduction. Pistillate and

staminate flowers are collected in complex, botric, botanical, bractose, pyramidal inflorescences-panicles. The obtained data of morphology and phenology of *R. typhina* in terms of introduction can be used to identify this species.

Ethics Committee Approval: Since the article does not contain any studies with human or animal subject, its approval to the ethics committee was not required.

Author Contributions: Concept: T.K., L.I., H.I., Desing: T.K., L.I., H.I., Execution: T.K., L.I., H.I., Material supplying: I.D., Data acquisition: S.K., Data analysis/interpretation: I.D., Writing: I.D., Critical review: I.D.

Conflict of Interest: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

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