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RESEARCH ARTICLE

BBCH model of seasonal growth of *Cydonia oblonga* Mill. in Ukraine

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Abstract

Phenology has not lost its relevance, especially now, when the global warming is making itself known more and more clearly. Phenological data obtained according to the BBCH system have a wide range of application: from the biological identification of global and regional weather and climate changes to the use in the selection of new cultivars of plants adapted to modern living conditions. We found out the BBCH model of phenological growth of 19 cultivars of *Cydonia oblonga* Mill. (Rosaceae) of the collection of the M.M. Gryshko National Botanical Garden, National Academy of Sciences of Ukraine (NBG). In the climatic conditions of Ukraine, quince goes through an entire cycle of seasonal growth. Codification of the phenological phases of growth according to the BBCH system showed that for quince, as for other fruit plants of the Rosaceae family, is characterized by eight of the ten principal stages of seasonal growth, in particular: the development of buds (principal growth stage 0: bud development), leaves (principal growth stage 1: leaf development), shoots (principal growth stage 3: shoot development), inflorescence (principal growth stage 5: inflorescence emergence), flowering (principal growth stage 6: flowering), fruit development and ripening (principal growth stage 7: fruit development; principal growth stage 8: maturity of fruit) and senescence and onset of dormancy (principal growth stage 9: senescence, beginning of dormancy). *Cydonia oblonga* has vegetative and vegetative-generative buds. It differs from some other fruit plants of the Rosaceae family by the specific course of the principal growth stage 5. Quince flowers are initiated from the apical meristem of one-year shoots, therefore they do not have phenophase 51, and at the stage of development 53 they are visually invisible due to the fact that they are tightly wrapped by leaves. The studied quince cultivars of the NBG collection are similar to each other in the course of most phenophases of seasonal development. The BBCH model of the seasonal growth of quince in Ukraine corresponds to two other comparable models that record the seasonal growth of this species in Spain (Murcia region) in a semi-arid Mediterranean climate with very mild winters and hot summers and Brazil (Pelotas region) in a warm tropical climate. These facts confirm the ecological plasticity of the species and its high adaptive and reproductive capacity, which can be the key to the expansion of the region of quince cultivation in Ukraine, including through the creation of industrial plantations.

Keywords: quince, seasonal growth, BBCH system, Ukraine

Authors' contributions: Svitlana Klymenko – conceptualization of the study, conducting experiments, writing and editing the manuscript. Antonina Ilyinska – conducting observations, analyzing the obtained data and literary sources, photographing phenophases, creating figures and table, and writing the manuscript.

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Introduction

Phenological data have a wide range of uses. They serve as a biological indicator of global and regional weather and climate changes (Woodcock, 1992; Menzel et al., 2020; Gallinat et al., 2021; Inouye, 2022), reflect the response of plants to abiotic stress (Denisow & Malinowski, 2016; Iler et al., 2021; Baidya et al., 2022), make it possible to assess the adaptive properties of introducers (Chmielewski et al., 2004), important and widely in demand in agriculture and horticulture (Ruml & Vulić, 2005; Chmielewski, 2013; Yang et al., 2020). Phenological observations are relevant even now, when climatic changes, in particular, temperature stresses, are becoming more and more pronounced.

Phenology has a very ancient history. Different approaches and methods have been used to characterize the seasonal growth of plants at various times (Meier et al., 2009). In Europe, for example, until 1994, Fleckinger's classification of phenophases was widely used, which the author developed initially for seeded fruits (Martínez-Valero et al., 2001; Meier et al., 2009). The creation of a new codification of plant phenological phases, BBCH (Biologische Bundesanstalt für Land- und Forstwirtschaft, Bundessortenamt und Chemische Industrie), started from the numerical decimal scale of Zadoks et al. (1974). The expanded BBCH scale is the result of the joint work of scientists from several institutions: the German Federal Biological Research Center for Agriculture and Forestry (BBA), the German Federal Office of Plant Cultivars (BSA), the German Agrochemical Association (IVA) and the Institute for Vegetables and Ornamentals (Meier et al., 2009). The modern BBCH system is a classification for unified coding of phenologically similar growth stages of all monocots and dicots (Hack et al., 1992; Meier, 1997, 2003). Applying this scale, the phenological stages of development of an increasing number of species are described, including fruit from the genera *Malus* Mill., *Pyrus* L., *Prunus* L. s.l., *Crataegus* L. s.l., etc. (Meier et al., 1994; Atay, 2013; Maghlakelidze et al., 2017; Sakar et al., 2019; Martínez et al., 2019; Drepper et al., 2020; Srivastava et al., 2020; Perju et al., 2022; Salmasi et al., 2023).

Cydonia oblonga Mill. (Rosaceae), the quince, belongs to the oldest fruit crops and has been widely known for its nutritional and healing properties since ancient times (Abdollahi, 2019; Hussain et al., 2021; Mirabdulbaghi et al., 2023; Najman et al., 2023; Kostecka-Gugała, 2024).

The genus name originated from the name of a Greek city on the island of Crete, Cydonea (Kydonia; ancient Greek Κŭδωνία), now Canea (Kafkas et al., 2018). The primary natural range of *C. oblonga* is located in Transcaucasia (from Dagestan to Talysh and Turkestan) and in the north regions of Iran (Abdollahi, 2019).

Quince was first cultivated about 4000 years ago in the Caucasus and in the Middle East in Mesopotamia between 5000 and 4000 years ago (Khoshbakht & Hammer, 2006). About 2500 years ago, the species was first introduced from Persia to the Chinese province of Xinjiang (Xie et al., 2023). The authors believe that quince has become naturalized on the slopes of Mount Baozhong (Hunan Province, China), as indicated by the structure and dynamics of its populations.

Quince first came to Europe, in particular to the Mediterranean basin (Greece, Rome), from the centers of its diversity in Persia in the period from the sixth to the second century B.C. (Zohary & Hopf, 2000; Khoshbakht & Hammer, 2006; Abdollahi, 2019). Later, there were other ways of introducing quince to Europe. The germplasm of quince cultivars of Eastern Europe, including Ukraine (Crimea), probably originates from introduction of this species from Western Asia (Abdollahi, 2019). Now quince is cultivated in many countries in Western and Eastern Europe, Middle and Central Asia, North, Central and South America, Africa, Australia, New Zealand, etc. (Kafkas et al., 2018; Hussain et al., 2021; POWO, 2024; Xie et al., 2023). Turkey is the world leader in quince production (Kafkas et al., 2018; Abdollahi, 2019).

The range of the species is characterized by long, hot summers with maximum temperatures of +30 °C to +40 °C and harsh winters. Therefore, wild quince genotypes are adapted to high summer and minus (−26 °C) winter temperatures and acidic soils but are less tolerant to low temperatures, especially to sharp changes in night and day temperatures (Hunter & Dunster, 2014; Abdollahi, 2021). Although quince does not require intensive care in the culture, it belongs to underutilized crops, which are regularly used only as rootstock for pears (Klymenko, 2011).

Quince has been known in Ukraine for over 200 years. For the Crimea, it was suggested by Pallas (1792) and Marschall von Bieberstein (1808). Marschall von Bieberstein (1808, p. 391) believed that quince is a wild plant not only in the South Caucasus but also in the Crimea: "Spontanea nascitur in Tauriae meridionalis et Caucasi australiorus sylvius (It grows spontaneously in the forests of South Tauria and the South Caucasus)". In 1809, botanist-acclimatizer Karazin described a 60-year-old quince grown in his garden, and in 1900, he showed quince fruits on a branch from his acclimatization garden (Klymenko, 1993). In 1912, Kashchenko started the introduction of quince in the acclimatization garden of Kyiv. After transferring the collection to the M.M. Gryshko National Botanical Garden, National Academy of Sciences of Ukraine (NBG) in 1975, selection work was continued by Klymenko (1993, 2009, 2011). Now in Ukraine, cultivars of *C. oblonga* are zoned in eight regions of Ukraine – Zakarpattia, Chernivtsi, Odesa, Kherson, Khmelnytskyi, Vinnytsia, and Chernihiv, as well as in the Crimea, and small plantations exist practically throughout the country (Volkodav et al., 2004; Klymenko, 2009, 2011).

The collection of *C. oblonga* in NBG includes over 20 cultivars of different origins, including 14 cultivars of NBG selection, three cultivars of Nikita Botanical Garden selection, two Middle Asian cultivars, etc.

The beneficial properties of the fruits have stimulated extensive comprehensive research on *C. oblonga*, in particular, the biochemical composition and medicinal uses of the fruits, flowers and leaves (Al-Snafi, 2016; Blanda et al., 2020; Hanan et al., 2020; Abed et al., 2022; Baroni et al., 2023; Kostecka-Gugała, 2024), of the morphological and anatomical structure of the fruit, leaf and pollen (Ganeva, 2009; Koçyiğit et al., 2015; Radovic et al., 2016; Pinar et al., 2016; Klymenko & Ilyinska, 2019; Kokaj, 2021; Hussain et al., 2021), molecular and biological aspects (Yüksel et al., 2013; Pinar et al., 2016; Abdollahi, 2019; Kokaj, 2021; Soyturk et al., 2021); dynamics of species populations (Xie et al., 2023), reactions of the species to water stress (Griñán et al., 2019), features of selection, domestication and productivity of cultivars under different ecological growing conditions (Hussain et al., 2021; Ozturk et al., 2022), as well as the use of molecular markers to analyze the genetic basis of important traits and carry out selection using genomics, etc. (Pinar et al., 2016; Kafkas et al., 2018; Abdollahi, 2019; Soyturk et al., 2021; Sadeghnejad et al., 2024). The rhythm of seasonal development of quince cultivars was also studied using different methods and under various environmental conditions, but such studies are still insufficient for widespread use in agricultural practice (Klymenko, 1993, 2011; Gordo & Sanz, 2005; Ozturk et al., 2022). In Spain, Martínez-Valero et al. (2001) compared the phenological growth stages of quince according to the BBCH scale with the Fleckinger phenological code based on the study of two cultivars, and Manica-Berto (2009) described, according to the BBCH scale, the phenological growth phases of 21 Brazilian cultivars of quince.

We found out the BBCH model of seasonal development of quince cultivars of the NBG collection (Kyiv, Ukraine).

Material and methods

Research region, weather, and climatic conditions

The research was conducted in 2021–2023 in the NBG, which is located on the right bank of the Dnipro River in the southeastern part of Kyiv on the low Pechersky slopes of the Kyiv Highlands (197 m above sea level) in the Zvirynets tract (50°27' N, 30°31' E). The climate is moderately continental; the winter is mild, the summer is warm. The average monthly temperature in January is −3.8 °C, and in July it is +21.5 °C. The average annual temperature is +7.7 °C. Average annual precipitation is about 640 mm; fall throughout the year (https://en.climate-data.org/, accessed June 17, 2024).

Research objects

Cydonia oblonga cultivars of the NBG selection ('Akademichna', 'Hrushovydna Shaidarovoi', 'Hrushovydna Shums'koho', 'Hrushka', 'Darunok doli', 'Darunok onuku', 'Dyvyna Svitlany', 'No. 8 Kashchenka', 'No. 18 Kashchenka', 'Mariya', 'Melodia dlya mene', 'Novynka', 'Orange', 'Studentka'), selection of the Nikita Botanical garden ('Kryms'ka aromatna', 'Uspikh', 'Myr') and Middle Asian selection ('Seredn'oaziys'ka' and 'Uzbets'ka aromatna'). The plants were planted at the collection site on April 14–16, 1986. To describe the morphological profile of *C. oblonga*, the structural morphological descriptors of the cultivars of the NBG collection and literature data were used (Gu & Spongberg, 2003; Catling & Mitrow, 2015; Abdollahi, 2021; etc.).

Phenological monitoring

Observation started on 01.03.2021. Two to three times a week, the state of the plants was recorded by means of textual and photo documentation from the beginning of vegetation to December and the beginning of winter dormancy. The course of seasonal development was codified according to the expanded BBCH scale (Hack et al., 1992; Meier et al., 1994, 2009) with particular attention to sympodially growing shoots.

Results and discussion

Morphological profile of the species

Cydonia oblonga can be a small deciduous tree up to 8 m tall or a bush. Young twigs are purple-red, old purple-brown, round, with lenticels. Juvenile stems, leaves, stipules, buds, ovaries, peduncles, and unripe fruits are densely pubescent, but ripe ones easily lose their pubescence. The leaves are simple, with petioles up to 2.0 cm long. Leaf blades are about 10 cm long, obtuse or leathery, broadly ovate or oblong, and entire, with a rounded or barely heart-shaped base and a pointed or blunt apex. Stipules are rounded or ovate, glandular-serrate on the edge, deciduous. Flowers develop on the tops of annual shoots. Pedicels are almost absent or about 5 mm long. Hypanthium is bell-shaped. Sepals are ovate or broadly lanceolate, green, glandular-serrate on the edge, pointed at the apex, five to seven mm long. The petals are white or pink, almost 20 mm long. Stamens 20; anthers are yellow, filaments are white or purple. Carpels five, connate with the hypanthium, ovary five-nest, column five, almost equal to or shorter than the stamens. The fruit is a fleshy pome, multi-seeded pseudocarpium. Ripe fruits are fragrant, yellow, nearly orange or greenish-yellow, spherical, oblong or pear-shaped with a diameter of three to seven cm or more; sepals in fruit bent downwards; peduncles almost absent or about five mm, thick, gradually thickening and growing with the fruit in many cultivars. The weight of the fruit varies widely, depending on the cultivar. The range of fruit weight variability in different quince cultivars of the NBG collection is 200–800 g (Klymenko & Ilyinska, 2019). In some cultivars of *C. oblonga* of Iran, the weight of the fruit can reach 1.5 kg (Abdollahi, 2021).

Quince is characterized by monopodial and sympodial growth of shoots. Their ratio in the crown of one cultivated plant depends on a complex of factors, including the age and features of tree pruning. Monopodial and sympodial shoots of *C. oblonga* differ morphologically: in the former, the largest leaves develop in the lower part of the shoot (Fig. 1 A), and in the latter, at its apex under the flower (Fig. 1 B). Vegetative shoots actively develop in young plants, as well as after rejuvenating pruning of old trees (Fig. 1 C), but in cultivars during the period of active fruiting, they are few.

Vegetative shoots develop from May to October. Their length varies, but they can reach 100 cm or more under favorable conditions. Generative shoots (sympodial growth) significantly predominate in the crown of trees during active fruiting. Such shoots form a system of fruit branches and it is on them that the main crop of fruits is formed. Their growth continues for a short time, before the beginning of fruit development. The spore-like structures of the old parts of the plant, on which the fruits also develop, are also sympodial, which distinguishes quince from apple and pear trees (Klymenko, 2011; Abdollahi, 2021).

Seasonal rhythm of plant growth

The annual life cycle of *C. oblonga*, like other seasonal climate species, includes a complex of phenological stages of growth, in particular, swelling and opening of buds, leaf development and shoot growth, flower development, flowering, fruiting and senescence, and a dormant period. The codification of the phenological phases of growth, according to the BBCH model, showed that in the climatic conditions of Ukraine, the quince goes through a complete cycle of seasonal development (Table 1; Fig. 2). The quince cultivars of the NBG collection studied by us are similar in the onset of most phenophases of seasonal growth.

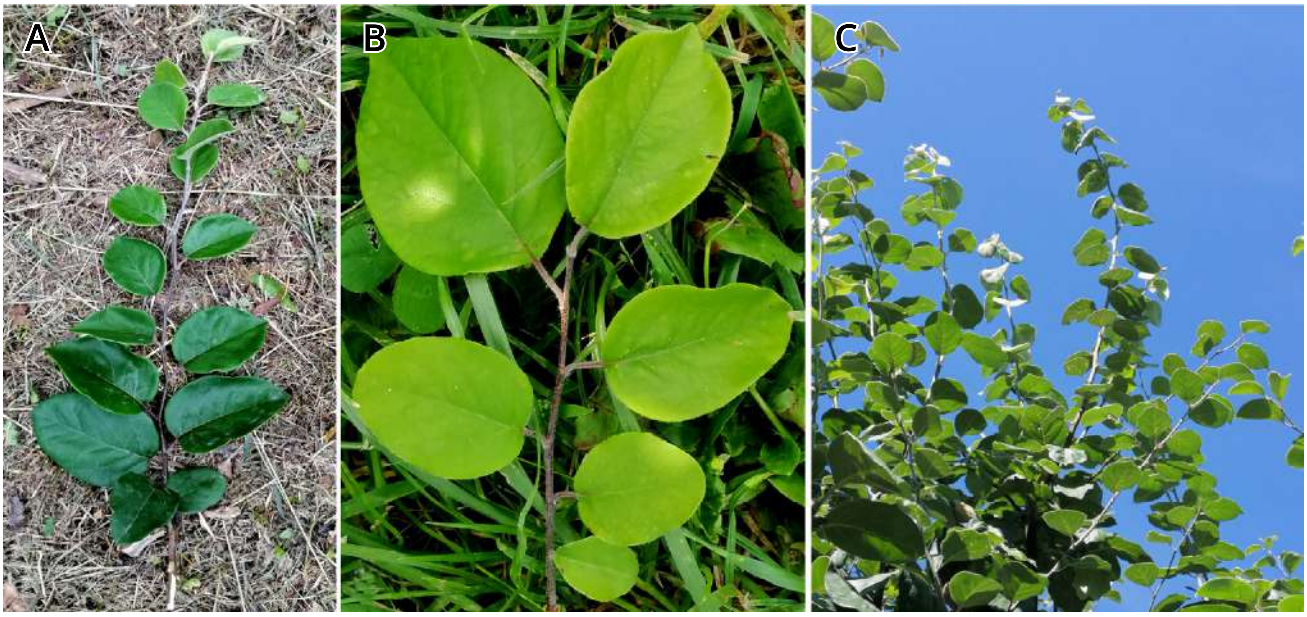

Figure 1. Shoots of *Cydonia oblonga*: **A** – vegetative (monopodial) and **B** – generative (sympodial) in the period of active fruiting; **C** – vegetative shoots after rejuvenating tree pruning.

Differences between cultivars are observed in the beginning of fruit ripening, as well as in their shape and biochemical composition (Klymenko, 2011).

Principal growth stage 0: bud development. Quince has two types of buds: vegetative and vegetative-generative. During the rest period, the buds are very small and it is difficult to distinguish them visually. Later (phenophase 01), it becomes noticeable that vegetative buds are slightly smaller compared to vegetative-generative ones, and develop somewhat more slowly. On adult trees in full fruiting, vegetative buds occupy a small percentage. Therefore, in our study, the primary attention is paid to vegetative-generative buds.

The first stages of development of vegetative and vegetative-generative buds are practically the same. In the final phases of buds of quince development, stipules are clearly visible (phenophases 07 and 09). In contrast to the very densely pubescent and, therefore, whitish leaves at this stage, the stipules are green and, hence, actively perform the function of photosynthesis, and also serve as additional protection of the leaves from adverse environmental factors.

Principal growth stage 1: leaf development. The shape and size of the leaves are variable and determined by several factors, in particular, the type of shoots, the age and condition of the tree, as well as species and cultivar characteristics of quince.

The first few leaves on monopodial and sympodial shoots differ from others in shape and size (very small). The following leaves of vegetative shoots have a shape and size typical for the species or cultivar; the largest of them are developed at the beginning or in the middle part of the length of the shoot (Fig. 1 A). On generative shoots, the largest in size are those leaves that are formed last, that is, under the flower (Fig. 1 B). Stipules are characteristic of young leaves of both vegetative and generative shoots (Fig. 3). They function near the five or six youngest leaves and then fall off. During this development phase, some of the leaves are unfolded, and others are folded and tightly surround the flower bud (phenophases 11–19, Fig. 2).

Principal growth stage 3: shoot development. Vegetative and generative shoots of quince differ among themselves in the nature and duration of growth. The first grow monopodially; their length is determined by a complex of factors, in particular weather conditions (temperature, amount of precipitation), as well as the position of the plant. Small trees (five to eight meters tall) of wild quince genotypes form numerous root sprouts and root shoots that grow monopodially (Abdollahi, 2021). In cultivars, especially those actively fruiting, the growth of vegetative shoots is insignificant, including due to pruning. Robust growth of monopodial vegetative

Table 1. Seasonal growth of *Cydonia oblonga* according to the BBCH model (Kyiv, NBG).

Stage	Characteristics
Principal growth stage 0: bud development	
00	Dormant: buds closed and covered by two outer dark brown leathery scales
01	Beginning of swelling of the buds: the buds are swollen, the outer scales are noticeably enlarged, and they begin to separate
03	The end of bud swelling: the outer scales are separated, and the inner scales are visible
07	Beginning of bud opening: all scales are rejected; the first light green stipules are visible
09	The tips of the leaves are whitish from dense pubescence, about 5 mm long
Principal growth stage 1: leaf development	
10	The tips of the leaves are whitish from dense pubescence, about 10 mm long
11	The first leaves are unfolded, the following are unfolding
15	More leaves have unfolded, but have not yet reached full size
19	The first leaves are fully unfolded
Principal growth stage 3: shoot development	
31	The beginning of the growth of one-year shoots: the axes of the developing shoots are visible; about 10% of the expected length
37	One-year shoots about 70% of the final length
39	One-year shoots about 90% of the final length
Principal growth stage 5: emergent inflorescence	
53	Flower buds are tightly surrounded by developing leaves
54	Emergence of flower buds: a conspicuous calyx formed by five closed sepals protecting the structural elements of the flower
55	Opening of the buds: the sepals begin to open, and the top of the corolla becomes visible
56	Green flower bud stage: sepals slightly open, folded petals green
57	Dark pink flower bud stage: folded petals pink, sepals rejected
59	Most flowers with petals forming an ‘airy’ hollow sphere
Principal growth stage 6: flowering	
60	The first flowers have opened
61	Beginning of flowering: about 10% of opened flowers
65	Full bloom: at least 50% of the flowers are open, the petals of the first flowers fall
67	Fading of most flowers: petals of most flowers fall
69	End of flowering: petals of all flowers have fallen
Principal growth stage 7: fruit development	
71	Beginning of fruit set; fruits about 10 mm long; fall of ovaries after flowering
72	Fruits about 20 mm long
73	The second fall of fruits
75	Fruits have reached almost half their final size
77	Fruits about 70% of final size
79	Fruits have reached their final size, green
Principal growth stage 8: maturity of fruit	
81	The beginning of ripening: the fruits begin to be colored in the characteristic color of the cultivar
85	Increase in color intensity specific to the cultivar; reduction of pubescence of fruits
87	Technical ripeness of fruits
89	Fruits are ripe for consumption: they have a typical taste and firmness

Table 1. Continued.

Stage	Characteristics
Principal growth stage 9: senescence, beginning of dormancy	
91	The growth of the shoots is complete; the leaves are still green; the terminal bud is developed
92	Leaves begin to change color
93	The beginning of falling leaves
95	Half of the leaves have changed color or fallen
97	All the leaves have fallen
99	The beginning of the winter rest period

shoots is observed after the rejuvenation pruning of trees (Fig. 1 C).

We studied quince generative shoots developing from vegetative-generative buds. They are sympodial, short, about 10–15 cm long, have five to eight nodes, and end the primary growth after flowering (phenophase 39) (Klymenko, 2011; Abdollahi, 2021). The next year buds are laid in late May or early June. Fruit branches formed by a system of sympodial generative shoots are observed on adult trees of quince cultivars.

Principal growth stage 5: emergent inflorescence. Cydonia oblonga has a specific development of flower buds (Table 1; Fig. 2). Flower buds develop on the tops of one-year shoots, and are also formed on old parts of the crown of the tree, different in age, which distinguishes quince from apple and pear trees (Klymenko, 2011; Abdollahi, 2021). According to Esumi et al. (2007a), in Japan (Omachi, Nagano, Japan), their differentiation begins in late October – early November or approximately 160–180 days after full flowering. At first, six scales are slowly formed, and eight leaf primordia begin to develop (Esumi et al., 2007a; Abdollahi, 2021). After that, the apical meristem produces sepal primordia. In this undifferentiated state, the buds remain during the winter, and then, the following spring, the entire apical meristem is transformed into a single flower meristem, while in pear (*Pyrus pyrifolia* (Burm.f.) Nakai 'Housui'), it forms an inflorescence (Esumi et al., 2007a). Therefore, the corolla, androecium, and gynoecium of quince flowers begin to form in the spring, almost simultaneously with the further development of the leaves.

Quince flower buds are not characterized by phenophase 51, and at stage 53, flower buds are tightly surrounded by rolled leaves that protect them and are an advantage of quince over other fruits.

Flower buds become visually visible (with closed sepals; phenophase 54) when several leaves have already unfolded (phenophase 19) and the growth of annual shoots begins (phenophase 31). The development of buds is accompanied by a change in the orientation of the sepals and the color of the petals. First, the sepals begin to deviate, and the corolla tip becomes visible (phenophase 55). Distinctly deviated sepals and the green color of rolled petals are characteristic of phenophase 56. Phenophase 57 is characterized by sepals deviated by 45° or almost horizontally and pink petals (pink bud stage). The last phenophase (59) of the development of flower buds is characterized by downward-sloping sepals and light pink or almost white petals that form an 'airy' hollow sphere.

The beginning and duration of the floral organogenesis determine endogenous and exogenous factors. Among the latter, geographical, meteorological, and climatic conditions of plant existence play an important role. In the Republic of Moldova, for example, quince flower differentiation begins at the end of September – beginning of October, and in Crimea in October – November (Klymenko, 2011). Endogenous regulation of flower bud differentiation is studied not only in *C. oblonga*, but also in other species of Rosaceae fruit plants by molecular-biological and genetic methods (Esumi et al., 2007b, 2008; Chen et al., 2013; Kurokura et al., 2013; Jiang et al., 2022, 2024). It is assumed (Esumi et al., 2007b, 2008), in particular, that *TFL1* gene homologs are involved in the formation of dome-shaped apical meristems during the early reproductive development of quince (*C. oblonga*) and Japanese pear (*P. pyrifolia*).

Figure 2. Phenological phases of development of *Cydonia oblonga* cultivars: **A** – 'Mariya'; **B** – 'Studentka'; **C** – 'Akademichna'; **D** – 'Novynka'; **E** – 'Darunok onuku'; **F** – 'Seredn'oaziys'ka'; **G** – 'No. 18 Kashchenka'; **H** – 'Oranzheva'; **I** – 'Hrushovydna Shums'koho'; **J** – 'Uspikh'; **K** – 'Uzbets'ka aromatna'.

Figure 2. Continued.

Principal growth stage 6: flowering. In quince, as in other fruit plants, the flowering phenophase is important for monitoring and evaluating the features of plant development and is also used to predict future fruiting productivity, determine the number of days from full flowering to harvest, etc. (Manica-Berto, 2009; Ozturk et al., 2022). The advantage of this species over other fruits is late flowering. Thanks to this, the flowers are less damaged by late spring frosts. At the same time, quince is a cross-pollinated,

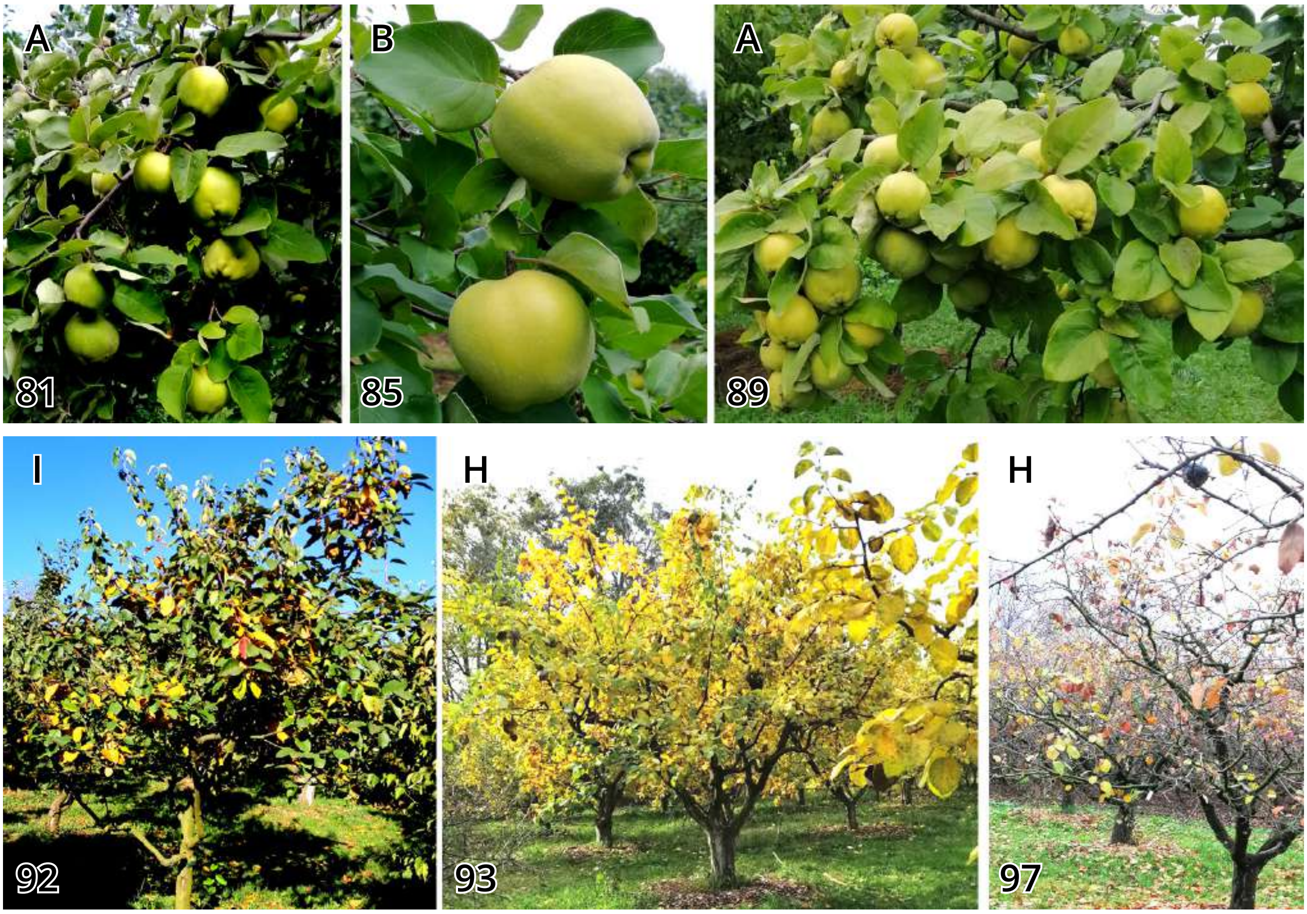

Figure 2. Continued.

entomophilous plant. Therefore, there is a problem of better pollination of plants, which is solved in different ways (Benedek et al., 2000; Halász et al., 2009; Tatari et al., 2018; Tatari & Abdollahi, 2021; Sadeghnejad et al., 2024). Information on quince self-fertility is also discussed in the literature (Abdollahi, 2021).

Principal growth stage 7: fruit development. Quince is similar to other fruit plants in some characteristics of fruit development. In particular, her ovaries also fall twice (phenophases 71 and 73). Unfertilized flowers are known to drop first about four weeks after flowering, and then, in June, about eight weeks after flowering, fruits with underdeveloped seeds drop (Abdollahi, 2021). Quince, like other seed-bearing fruit plants, is characterized by three stages of fruit development and ripening (Costa & Ramina, 2014; Abdollahi, 2021). At the first stage (S1), active cell division takes place and fruits have very dense pubescence. In the middle of summer, the second (S2) stage of fruit development begins, during which active fruit growth is observed due to an increase in the size of cells, the thickness of the cell membrane, the volume of vacuoles and intercellular spaces, etc. Also, the density of the pubescence decreases due to the death of hairs and due to the rapid growth of the fruits, and the first green, and then characteristic for one or another cultivar, the color of the fruits becomes noticeable. The third stage of development (S3) covers the period of fruit ripening.

A distinctive feature of quince is a long period of fruit development. In Ukraine (NBG), quince fruits grow from May to October, but active fruit growth (stage S2) begins in August (Klymenko, 2011; Klymenko & Ilyinska, 2019). In Spain, quince fruit development lasts about 175 days (Martínez-Valero et al., 2001; Abdollahi, 2021).

Principal growth stage 8: maturity of the fruit. At the fruit ripening stage (S3), the diameter of the fruit increases slightly. The signs of ripe fruits include skin color (from yellowish-green to pale yellow to golden), sepals pressed to the fruit, easy rubbing of hairs by hand, distinct aroma, as well as brown

Figure 3. Stipules of *Cydonia oblonga* cultivars: **A** – 'Akademichna'; **B** – 'No. 18 Kashchenka'.

color of seeds (Klymenko, 2011; Abdollahi, 2021; Ozturk et al., 2022). Some cultivars of quince that we have studied differ in the color of the fruits. The cultivar 'Mariya' has green fruits, the cultivar 'Oranzheva' is characterized by orange-yellow fruits, and the cultivars 'Darunok onuku', 'Studentka' and 'Akademichna' have a 'red blush' on the fruits in certain years (Klymenko, 2011). Fruits are usually harvested at the stage of technical (physiological) ripeness. During storage, they turn yellow in all cultivars. Ripe fruits of *C. oblonga* are rich in biologically active substances, due to which they are widely used in the food industry and in pharmaceuticals (Khoubnasabjafari & Jouyban, 2011; Blanda et al., 2020; Al-Zughbi & Krayem, 2022; Najman et al., 2023; Ňorbová et al., 2024). Ripe fruits remain hard, so they are used most often in the culinary processing, in particular, jam, jelly, marmalade, juice, and other sweets are made from these fruits (Hunter & Dunster, 2014).

Principal growth stage 9: senescence, beginning of dormancy. Autumn phenology has a more significant influence on the duration of the growing season than spring, but this phase of seasonal plant development is little studied, which is due to specific difficulties in determining standard methods for its identification (Gallinat et al., 2015; Estiarte & Peñuelas, 2015; Xie et al., 2015; Liu et al., 2016; Gao et al., 2023).

In the zone of seasonal climate, senescence and the beginning of plant dormancy (phenophase 9 according to the BBCH scale) begin with a gradual inhibition of growth processes, degradation of chlorophyll, and later with leaf fall (Gallinat et al., 2015; Xie et al., 2015; Dox et al., 2021). The dynamics of autumn phenology are also influenced by various climatic factors, including temperature, precipitations, and wind (Dox et al., 2021; Gao et al., 2023).

Phenophase 9 of *C. oblonga* has also been studied much less compared to the flowering and fruiting phase. Our data confirm that the visually visible signs of plant dormancy are determined mainly by temperature, as in other woody plants in a temperate climate. According to our three-year observations, the beginning of November in quince correlated, to some extent, with the onset of meteorological autumn. According to the data of the B. Sreznevsky Central Geophysical Observatory, meteorological autumn came on September 19, the second of September, and the second of October (2021, 2022, and 2023, respectively). Based on the meteorological observations, the autumn of 2023 in Kyiv became one of the warmest ever. In these years, the first fallen leaves of quince were observed on October 13, 16, and 30.

Conclusions

The BBCH model of seasonal growth of *Cydonia oblonga* is described based on the analysis of cultivars of the NBG collection (Kyiv, Ukraine). During the three-year observation period (2021–2023), all cultivars of C. *oblonga*, went through a full cycle of seasonal development. The codification of phenological phases according to the expanded BBCH system showed that C. *oblonga* cultivars, like other fruit plants of the Rosaceae family, are characterized by eight out of ten main stages of seasonal growth, in particular: principal growth stages 0, 1, 3, 5, 6, 7, 8, and 9. Quince differs from other fruit plants of the Rosaceae family in the specific course of the principal growth stage 5. The flowers of C. *oblonga* develop from the apical meristem of one-year vegetative-generative shoots, so they lack phenophase 51, and at the stage of development 53, flower buds are visually invisible because they are tightly wrapped by leaves. The quince cultivars of the NBG collection we studied are similar in the course of most phenophases of seasonal growth. Differences between cultivars are most clearly observed in the duration of development, the ripening period, and the shape of the fruits. The phenological BBCH model of the seasonal growth of quince in Ukraine corresponds to two other similar BBCH models that capture the seasonal growth of this species in Spain (Murcia region; semi-arid, Mediterranean climate with very mild winters and hot summers – Martínez-Valero et al., 2001) and in Brazil (Pelotas region; warm tropical climate – Manica-Berto, 2009). The obtained data confirm the clear ecological plasticity of C. *oblonga*, and the high adaptive and reproductive capacity of the species, which can be a guarantee for the expansion of the region of quince cultivation in Ukraine, including through the creation of industrial plantations, especially now, when climate changes, in particular abnormally high temperatures, are becoming increasingly more frequent.

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BBCH модель сезонного розвитку *Cydonia oblonga* Mill. в Україні

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Фенологія не втрачає своєї актуальності, особливо тепер, коли глобальне потепління стає все очевиднішим. Фенологічні дані, що отримані за системою BBCH, мають широкий спектр використання: від біологічної ідентифікації глобальних і регіональних змін погоди і клімату до використання в селекції нових сортів рослин, адаптованих до сучасних умов існування. Ми з'ясували BBCH модель фенологічного розвитку 19 сортів *Cydonia oblonga* Mill. (Rosaceae) колекції НБС (Київ). У кліматичних умовах України айва проходить повний цикл сезонного росту. Кодифікація фенологічних фаз росту за системою BBCH показала, що для айви, як і для інших плодових рослин родини Rosaceae, характерні вісім із десяти основних фаз сезонного розвитку, зокрема: розвиток бруньок (основна стадія росту 0: розвиток бруньок), листків (основна стадія росту 1: розвиток листків), пагонів (основна стадія росту 3: розвиток пагонів), суцвіття (основна стадія росту 5: поява суцвіть), цвітіння (основна стадія росту 6: цвітіння), розвиток і достигання плодів (основна стадія росту 7: розвиток плодів; основна стадія росту 8: достигання плодів) і старіння та початок спокою (основна стадія росту 9: старіння, початок спокою). *Cydonia oblonga* має вегетативні та вегетативно-генеративні бруньки. Від деяких інших плодових рослин родини розоцвітих айва відрізняється специфічним перебігом основної стадії росту 5. Квітки айви ініціюються з верхівкової меристеми однорічних пагонів, тому не мають фенофази 51, а на стадії розвитку 53 візуально непомітні через те, що щільно оповиті листками. Досліджені сорти айви колекції НБС схожі між собою за перебігом більшості фенофаз. ВВСН модель сезонного розвитку айви в Україні відповідає двом іншим аналогічним моделям, які фіксують сезонний розвиток цього виду в Іспанії (регіон Мурсія) у напівпосушливому середземноморському кліматі з дуже м'якою зимою та жарким літом і в Бразилії (регіон Пелотас) у теплому тропічному кліматі. Ці факти підтверджують екологічну пластичність виду, його високу адаптивну та репродуктивну здатності, що може стати запорукою розширення регіону вирощування айви в Україні, у тому числі через створення промислових насаджень.

Ключові слова: айва, сезонний розвиток, система ВВСН, Україна