Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 15(2), 18-31
Received: 24.01.2024 Revised: 26.04.2024 Accepted: 29.05.2024

UDC 633.861:581.14(292.485)(477.4)
DOI: 10.31548/plant2.2024.18

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Phenological observations on the growth and development of saffron (*Crocus sativus* L.) in the conditions of the Right-Bank Forest-Steppe of Ukraine

Abstract. There is a need to summarise information using phenological models to develop a sustainable saffron production technology with further regulation of flowering at a certain phenological stage and determination of the appropriate flowering period to improve yield and

Suggested Citation:

Komar, O., Bobos, I., Fedosiy, I., Shemetun, O., & Havrys, I. (2024). Phenological observations on the growth and development of saffron (*Crocus sativus* L.) in the conditions of the Right-Bank Forest-Steppe of Ukraine. *Plant and Soil Science,* 15(2)*,* 18-31. doi: 10.31548/plant2.2024.18.

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quality under different environmental conditions. The purpose of the study is to establish the course of phenological phases of saffron growth and development in the conditions of the Right-Bank Forest-Steppe of Ukraine. Phenological observations and biometric measurements were performed in the study. According to field observations, there are a total of 6 phenological stages of saffron development. The rest period lasts from the third ten days of May to October and is divided into primary and secondary dormancy. During the primary dormant period, corms do not show external morphological changes and growth, but internal physiological and morphogenetic changes occur. In the secondary dormant period, the initial emergence of leaves and flowers and their differentiation take place. During the dormant period, saffron plants were left without aboveground organs. The flowering period falls in October. The passage of this phenological stage may be affected by changes in environmental conditions or agricultural technology. The growth of the root system began with the appearance of flowers and leaves. During the growing season, the growth of the leaf apparatus and the development of the root system continue. During this period, daughter corms are also formed from the buds of the mother corm. During the winter, the replacement corms continue to grow using the nutrient reserves of the mother corm. In early March, the development of the root system slows down and the daughter corms reach almost the final size. At the end of the growing season, the root system of the mother corm stops growing. The leaves begin to age from the top to the base. By the end of May, the daughter corms are fully developed and are preparing for the transition to a dormant state. The number of corms produced per unit area depends on the age of the plot, nutrient supply, and the level of agricultural technology. Older fields produce more corms. Due to the higher density, a larger yield of stamens is formed. Therefore, understanding the phenological reactions and influence of climatic factors on the stages of saffron growth and development in certain soil and climatic conditions is useful for future forecasting of harvest time

Keywords: phenological phase; BBCH; flowering; corms; cataphylls

INTRODUCTION

In the modern world, there is a need to investigate the phenological features of saffron, since this determines the key aspects of crop rotation optimisation and rational use of land resources. Analysis of saffron phenology is also important for the development of effective agrotechnical approaches that promote high-quality cultivation of this valuable plant species. Consideration of these features is a critical element in ecosystem management aimed at preserving the diversity and sustainability of natural environments. The study of saffron phenology is strategically important for scientific cooperation, contributing to the development of innovative agricultural methods and sustainable management of natural resources.

According to D. Kothari *et al.* (2021), saffron is one of the most valuable and expensive spices in the world. It is sold for EUR 30 thousand per kilogramme is due to its unique organoleptic properties and difficulties associated with its cultivation and harvesting. It is mainly grown in Iran, India, Afghanistan, Greece, Morocco, Spain, and Italy. Global saffron production is estimated at 418 t per year on 121 thousand ha.

E. Gupta *et al.* (2021) described how saffron is obtained from dried flower stigmas. About 150 thousand flowers are needed to produce 1 kg of saffron, as each stigma weighs about 2 mg. It has many uses in pharmaceuticals and folk medicine as a preservative, dye, and food ingredient. The main components responsible for the bitter taste and aroma of saffron are picrocrocin and safranal. Contrary to its many health benefits, a high dose of saffron can cause toxic effects on the human body, according to S. Sharma & D. Kumar (2022).

Results of chemical analysis of saffron stigmas along with the main components of saffron (crocins, picrocrocin, and safranal). L. Jarukas *et al.* (2020) found the presence of about 150 volatile and non-volatile compounds. These include carotenoids, individual polyphenols, flavonoids, and terpenes, whose particles vary depending on the place of origin, collection time, drying process, and storage conditions. Dried stigmas contain from 5 to 7% minerals, from 5 to 8% lipids, from 12 to 13% proteins, up to 20% reducing sugars, from 6 to 7% pentosans, from 9 to 10% gum and dextrins, and up to 0.3% essential oil.

Sparsely distributed vegetable crops and plants have become a new trend in the development of Ukrainian agribusiness. Understanding the economic advantages of high purchase prices and the availability of free niches in the market for the sale of their products, many farms became interested in their cultivation, as noted by S. Koliadenko *et al.* (2020) and N. Tretiak *et al.* (2021). Attracting educated and knowledgeable people to agribusiness can play a significant role in improving sales and export markets for this sector. The vast majority of companies that produce saffron use their own experience, without applying the scientific principles of marketing and trade. A. Karbasi *et al.* (2022) found that saffron's marketing margin is directly related to the retail price, and marketing costs such as wages and transportation costs increase the retail price.

N. Moratalla-López *et al.* (2019) proved that the petals of the saffron perianth account for 78.4% of the weight of the entire flower, stamens – 13.4%, stigmas – 7.4%, and the rods – 0.7%. Approximately 86 to 93% of the weight of saffron flowers is not used and is discarded after harvesting. Thus, given that saffron is delivered to the market by hundreds of kilogrammes annually, the production generates several hundred tonnes of waste. D. Cerdá-Bernad *et al.* (2023) note that saffron flower residues are high in fibre, and among the nutrients, carbohydrates are the most common, followed by proteins, and a small content of fat. They have high concentrations of glucose, fructose, lactic and malic acids, and minerals, in particular, K, Ca, and Mg. Polyunsaturated fatty acids also prevailed; of which linoleic acid was the most common. Agribusiness is constantly looking for innovative solutions to produce waste-free products. In particular, saffron flower waste can be considered as high-value-added ingredients that can be used in the food, nutraceutical, and cosmetics industries. Z. Khadfy *et al.* (2023) reviewed the use of bioactive compounds derived from saffron stigmata (*Crocus sativus* L.) and its by-products n nutraceutical and cosmetic applications. They investigated the use of bioactive compounds derived from saffron stigmas in skin care products. The antioxidant properties of these compounds can be used to protect the skin from oxidative stress, help to control the signs of ageing, and support skin health. Thus, a deep understanding of plant behaviour at different stages of growth is of paramount importance for improving quality, regulating production cycles, and reducing production costs.

The purpose of the study was to establish the course of phenological phases of saffron growth and development in the conditions of the Right-Bank Forest-Steppe of Ukraine.

MATERIALS AND METHODS

The research was conducted in a field experiment of the Department of Vegetable Crops in the "Fruit and Vegetable Garden" training laboratory of the National University of Life and Environmental Sciences of Ukraine during 2021-2023. The study was part of the state project "Development of innovative technologies for growing rare vegetable crops" (state registration number: 0122U001637) and the initiative project "Substantiation and development of innovative technologies for growing new vegetable crops" (state registration number: 0120U105682).

The experimental site was located in the Right-Bank Forest-Steppe of Ukraine. The soils of the experimental site were sod-medium podzolic coarse sandy-loam. Saffron was planted on September 1, 2021. Corms were planted in 20×10 cm spacing. The planting depth was 10 cm. A local species of saffron was used as planting material. The repetition of the experiment was threefold.

The phenological development of saffron plants was determined on the BBCH scale (Lopez-Corcoles *et al.*, 2015). According to the BBCH scale, the life cycle of saffron goes through 6 phases of development, each of which differs in its duration and recognition, where 0 – germination, 1 – leaf development, 4 – development of corms replacement, 5 – appearance of flower cataphylls, 6 – flowering, 9 – plant senescence. Stages of development 2, 3, 7, and 8 in saffron plants according to the extended BBCH scale are not observed. The presence of only the main phases is not an exhaustive criterion in the process of establishing specific phases of development. Therefore, for a more detailed description of the development stages, 10 subphases were used for each phase. They were indicated by two digits from 00 to 09.

The growth and development phases of saffron were determined visually simultaneously throughout the experiment. To determine the individual stages (the appearance of roots, the beginning of corm germination, the beginning of flower cataphil formation, etc.) that occur under the soil surface, the assessment was carried out on randomly excavated plants. The beginning of the phase was recorded when it was observed in 10% of plants on the site, in mass – in 75%.

This territory was characterised by a temperate continental climate with mild winters and warm summers. The sum of temperatures over 5°C for the warm period in 2021 was 2,334.4°C, in 2022 – 2,322.3°C, and in 2023 – 2,623.7°C, which is 1.0%, 0.5%, and 13.5% more than long-term norms, respectively (Fig. 1).

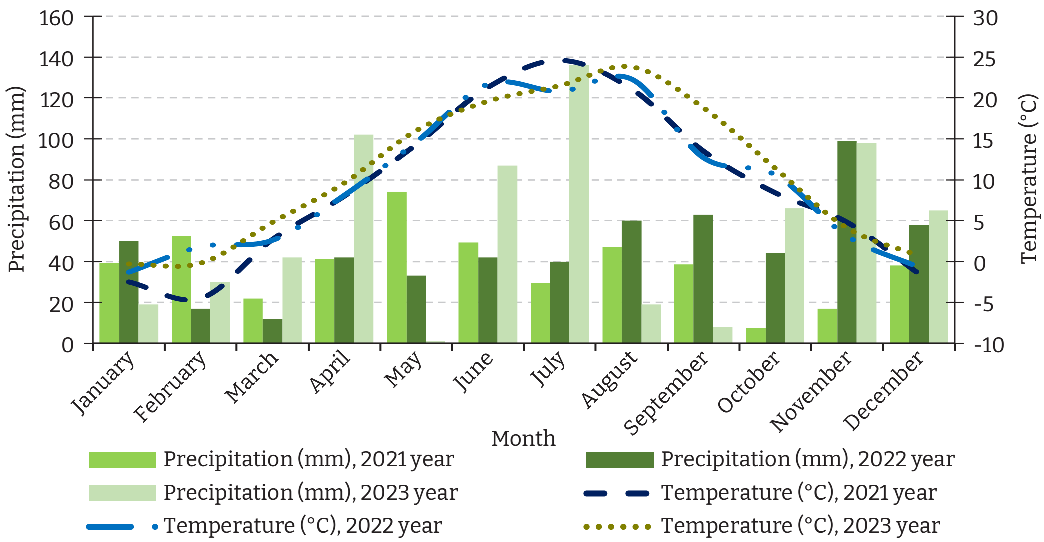

Figure 1. Average monthly air temperature and precipitation in the study area
Source: based on data from the weather station of the Borys Sreznevsky Central Geophysical Observatory

There was an uneven distribution of precipitation over the years from 456 mm in 2021 to 673 mm in 2023, which respectively amounted to -26.2% and 8.9% deviation from the norm of long-term data. In addition, the nature of precipitation is changing, namely, the number of inefficient heavy rains increases, which after long dry periods often cause more harm than good. In the winter months of 2021, 28.5% of annual precipitation fell, in 2022 – 22.3%, in 2023 – 16.9%; in the spring months – 30.1%, 15.5%, 21.5%; during the summer months – 27.6%, 25.4%, 36.0%; and in the autumn months – 13.8%, 36.8%, 25.6%, respectively. The study was conducted in compliance with the Convention on Biological Diversity (1992) and the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973).

RESULTS AND DISCUSSION

Saffron has 6 main phenological phases: germination, leaf development, corm replacement development, appearance of flower cataphylls, flowering, and plant senescence (Table 1). The development period of saffron without aboveground organs lasted 182 days: from June 5 to October 2; while with aboveground organs it lasted 244 days: from October 3 to June 4. The corms became dormant after the leaves wilted. At the beginning of the dormant period, the mother corm showed no morphological changes or external growth. Saffron corm is marked by the ability to accumulate reserves of nutrients. Therefore, the nutrient reserves in the mother corms determine the growth and development of saffron, especially in the early stages.

Table 1. Phases of growth and development of saffron according to the extended BBCH scale

Phenological phase	International BBCH scale
Macro stage 0: germination	00-10
Mother corm is dormant. Apical and lateral sprouts are not yet developed	00
Beginning of bud swelling	01
Bud swelling is complete	03
Roots appear from the corm	05
Beginning of bud germination	07
Shoots are visible below the soil surface	08
Emergence: shoots (cataphylls) break through the soil surface	09
Macro stage 1: leaf development (assessed at the plant level)	1-19
Leaves begin to break through and develop from cataphylls	10
Leaf growth by 10% of the final length	11
Leaves reach 20% of the final length	12
Leaf growth by X...% of the final length, continues according to the same pattern until stage 18	1...
Leaves reach 90% of the final length	19
Macro stage 2: –	20-29
Macro stage 3: –	30-39
Macro stage 4: Corm replacement development	41-49
Corm replacement growth by 10% of the final size	41
Corm replacement growth by 20% of the final size	42
Growth of corms replacement up to X... % of the final size, continues according to the same pattern until stage 48	4...
Corm replacement growth up to 90% of the final size	49
Macro stage 5: Appearance of flower cataphylls	50-59
Beginning of the development of flower cataphylls. Stigmas are visible on the basal part of the stem	50
Appearance of flower cataphylls	55
Flower cataphylls are visible above the ground, wrapped in bracts	57
Flower cataphylls are still closed	59
Macro stage 6: Flowering	60-69
First perianth flowers are visible	60
10% of the maximum flower weight is reached	61
30% of the maximum flower weight is reached	63
50% of the maximum flower weight is reached	65
70% of the maximum flower weight is reached	67
End of flowering	69
Macro stage 7: –	70-79
Macro stage 8: –	80-89
Macro stage 9: Plant senescence	91-99
Leaf development is complete, the leaves are still green	91
Tops of the leaves begin to discolour	93
50% of the leaves turn yellow	95
Roots are dry and can easily fall off	96
Leaf senescence. Leaves are completely discoloured and the plant begins to go to a dormant state. Mother corm is completely dry	97
Leaves fall off the corm	98
Replacement corms are fully developed	99

Source: developed by the authors based on the conducted research

At the end of August, all parts of the flower were already differentiated. Despite the fact that important ontogenetic processes that determine the differentiation of vegetative (early August) and flower (late August) buds took place, no external signs of saffron development were observed. As soon as the buds swell, the corms begin to emerge from dormancy. Further, the appearance of roots at its base was observed, and subsequently, after the shoots (cataphylls) broke through the soil surface, seedlings appeared under the study conditions, plant shoots were observed from October 3 to October 8.

The flowers appeared simultaneously with the leaves or after the leaves appeared, usually depending on the weather conditions, in particular, on the temperature. Elevated air temperatures delayed flowering and caused leaves to appear earlier. Flower ontogenesis was observed from October 8 to October 28. The main stages of flower ontogenesis are shown in Figure 2. Studies have shown that the development of flowers is directly dependent on the size of the corm, and a quantitative relationship between these two parameters was found. In general, the heavier the mother corms, the more energy they transfer to the daughter corms, and before they became completely independent, the mother corm had a significant impact on their development. Accordingly, mother corms with optimal weight improved the growth process by increasing the leaf surface area and saffron yield due to the accumulation of more carbohydrates. It was noted that fewer flowers and daughter corms developed on the lateral buds relative to the apical buds.

Figure 2. Phenological stages of saffron growth and development according to the extended BBCH scale (0-67)

Note: macro stage: germination (0: 00, 05, 08, 09); leaf development (1: 10, 11, 12, 19); appearance of flower cataphylls (5: 57, 59); flowering (6: 60, 61, 63, 65, 67)

Source: developed by the authors based on the conducted research

The leaves and roots continued to grow during flowering. The growth of daughter corms decreased during the flowering period, as most of the energy was used for flowering and initial growth. After flowering, increased leaf growth was noted, and the first daughter corms began to appear on the mother corms. The development of daughter corms was observed throughout the entire vegetative growth of the plant.

The growth of the root system, leaves and corm development are interrelated. On the one hand, leaf development stimulated root growth, which, in turn, stimulated increased absorption of water and nutrients. On the other hand, due to the greater development of the roots, plants developed a larger number of daughter corms. The rate of vegetative growth of saffron in the first year was slower compared to subsequent years.

Each year, the plants repeated their phonological stages of growth and development. At the same time, the development of daughter corms on the mother corm was observed, which affected the annual increase in plant density.

In the third ten days of May, the leaves began to discolour, which indicated that the plant was beginning to pass into a dormant state of yellowing leaves (Fig. 3). The daughter corms were separated from the mother corms after the leaves dried, which was observed on June 4. Over the next year, each daughter corm continued to grow as a mother corm. From June to October, the absence of saffron vegetation cover was observed at the experimental site. The life cycle of saffron in the conditions of the Right-Bank Forest-Steppe of Ukraine is shown in Figure 4.

Figure 3. Phenological stages of saffron growth and development according to the extended BBCH scale (69-99)

Note: macro stage: flowering (6: 69); plant senescence (9: 91, 95, 96, 97, 99)

Source: developed by the authors based on the conducted research

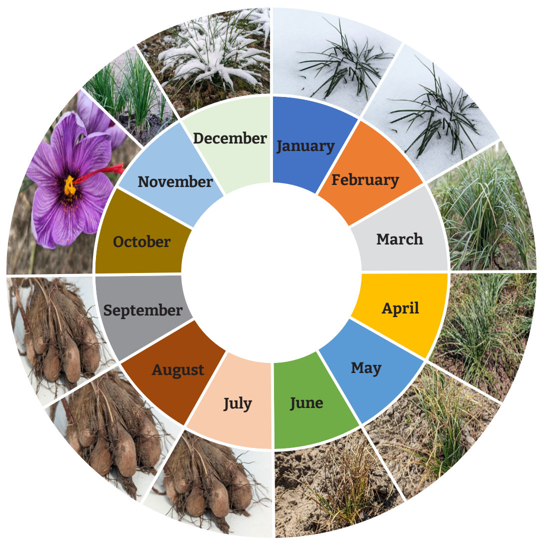

Figure 4. Biological cycle of saffron development

Source: developed by the authors based on the conducted research

The choice of flowering time is crucial for the plant, which directly affects the adaptability of plants to a particular environment. The physiological process of saffron flowering is very complex and depends on many external and internal factors. Flowering directly affects yield and productivity, so it is the most important stage in the development of saffron. J. Jose-Santhi *et al.* (2023)

found that flowering in saffron depends on environmental conditions, in particular, temperature and humidity levels. Since saffron has an annual growth and dormancy cycle, its flowering occurs in autumn, before that there is a summer period during which flowering induction occurs (Koocheki & Seyyedi, 2020). Indeed, over the years of research, it has been observed that higher water availability of plants affected the development of daughter corms in years with more precipitation, which allowed increasing the length, area and productivity of leaf photosynthesis, and obtaining daughter corms with a larger diameter and weight.

Saffron is a plant with a wide temperature range depending on the growing season, high ambient temperatures of 23 to 27°C are required to start flowering, and then the temperature drops to 10-17°C to develop flowers (Wang *et al.*, 2021). Autumn temperatures contribute to the development of the crop in the current year, and spring – in the next. It was found that the optimal temperature for the appearance of flowers is significantly lower compared to the temperature of flower development. This explains the difference in the time of flowering in places with excellent climates. H. Pirasteh-Anosheh *et al.* (2023) noted that excessively high autumn temperatures delay flowering, and in such regions, flowering occurs when the air temperature drops below 17°C. The current study also confirms that ambient temperature is crucial for saffron to come out of dormancy and stimulate the onset of flowering. Accordingly, during the period of flower development, the average air temperature was 8-11°C.

Light levels regulate plant growth, development, physiology, and metabolism (Klem *et al.*, 2019). The growth of flowers, roots, and corms improves when the proportion of blue and red light increases. The grown saffron in blue light had the highest photosynthetic activity with a high level of efficient electron transport and a lower level of energy dissipation. According to S. Moradi *et al.* (2021), blue light contributes to the development of corms and flower organs, while red light contributes to the development of leaves. Saffron needs partial shading at the level of 30% to achieve maximum growth and especially yield of stigmas. In addition, saffron can adjust its metabolism and adapt to stronger shading with an increase in shading up to 50% and especially 70% significantly improved morphological parameters, leaf surface area, aboveground biomass, weight and diameter of daughter corms (Mzabri *et al.*, 2021; 2022). Similar research results were also obtained, namely, the reaction of saffron plants to shading in the form of changes in growth and development Growing some saffron plants in the row spacing of asparagus, it was found that plants grown in the open ground without shading showed a lower intensity of green leaf colour compared to those grown in partial shading conditions. Probably, the degradation of chlorophyll was responsible for the change in green colour.

In addition, lower temperatures and higher soil moisture may have contributed to early flowering, which was observed in soils with a higher clay and silt content compared to sandy soils. Given that the corm is the main site of nutrient accumulation for stigma development, soil characteristics partially affected the number of flowers on the corm. Calcareous soils with phosphorus deficiency are considered the main difficulties on saffron-growing lands and can seriously affect plant growth and development, which will ultimately affect the stability of production (Daneshmandi & Seyyedi, 2019). Premature plant senescence on soils with a high clay content is explained by the increased synthesis of ethylene, which is caused by the possibility of limiting the development of the root system. In addition, the early plant senescence in the second year of cultivation is conditioned by climatic conditions, that is, less precipitation during the growing season than in the first year.

The results of morphological observations indicate that the process of transition to flowering in saffron is divided into 3 stages: 1) undifferentiated period (flower bud ≤1 mm long, and the apical growth point acquired a semi-conical shape); 2) period of early differentiation of flower buds (flower bud 1.5-2.0 mm, the growth point is raised, the rudiments of the perianth appear, reflecting the transition from vegetative to reproductive growth; 3) period of late differentiation of flower buds (flower buds >3 mm, the rudiments of the pistil began to differentiate, and the area of differentiation of the inner bud expanded and lengthened). The content of sugar, gibberellin, auxin, and zeatin continuously increased, while the content of starch and abscisic acid gradually decreased, which is consistent with the results of J. Hu *et al.* (2020).

Getting more flowers by extending the duration of flowering is the main task of saffron breeding. Accordingly, stimulating the expression of flowering-related genes by plant growth regulators is one of the possibilities for achieving this goal (Haghighi *et al.*, 2023). Along with other factors, the date of planting corms is an important factor determining the growth and yield of saffron. Under Yazd conditions, the early timing of saffron planting accelerated the plant development phases, so corms planted in early October sprang up earlier and observed a faster appearance of flowers and early full flowering (Pirasteh-Anosheh *et al.*, 2022).

There is a close relationship between the size of the mother corms and the productivity of saffron (Hassanzadeh Aval *et al.*, 2015). According to the study, with an increase in the size of mother corms, there is a decrease in the number of small corms weighing from 0.1 to 4 g, but the percentage of medium corms weighing from 4.1 to 8 g and large ones weighing more than 8 g increased (Koocheki & Seyyedi, 2016).

The use of iron nanochelate at a rate of 10 kg/ha increases the yield of dry stigmas by 133%, and the application of cow manure at a rate of 20 t/ha^{-1} – by 100%. It is also noted that the use of vermicompost (10 t/ha) and humic acids (10 kg/ha) in combination with biofertilisers provides an increase in the quantitative and qualitative yield of saffron (Hourani, 2023). It is obvious that the application of organic fertilisers plays an important role in improving the vegetative growth of saffron, the distribution of nutrients, which leads to an increase in the number of corms and their weight (Jami *et al.*, 2020).

L. Cardone *et al.* (2021) found that the saffron ecotype significantly affects all phenological and productive traits. The origin of corms had a significant association with early ripening and flowering interval. Before the beginning of flowering, 40.4 days usually passed from planting corms, and flowering lasted about 20 days. The ecotype from Italy (Sardinia) bloomed almost 6 days earlier than from Greece (Kozani), and had a longer flowering period. The flowering period of saffron in Italy is several weeks, usually between late October and early December. The results obtained in this study are consistent with findings of F. Gresta & G. Avola (2016), who reported that the daily flowering, and therefore, the yield of stigmas during this period is not constant, but shows from 1 to 4 peaks, during which there is a significant increase in the number of flowers.

Under Pampore conditions, the longest stage of ontogenesis in saffron is the vegetative phase, which lasted 142 days, followed by flower ontogenesis – 60 days, dormant period – 55 days, reproductive phase – 41 days, bud germination phase – 36 days, and plant senescence – 30 days (Yasmin & Nehvi, 2018). For the semi-arid territories of Iran, the leaf drying period falls at the end of spring. Recovery from dormant state is observed in mid-July – early August. Flowering is observed in the first half of August and lasts up to 1 month. Shoots appear at the end of flowering.

In April-May, when the dry period begins, the leaves age and wither, and the corms fall into a dormant state (Dewir *et al.*, 2022). F. Nehvi (2022) noted that during the dormant period, saffron corms show no morphological changes or external growth, and the tip looks like a dormant bud with protective cataphylls. The development of stamens, which precedes the laying of the perianth and the development of gynaecium, is observed in the period from the end of July to the beginning of August, regardless of whether the corms came from the field or were stored at a constant temperature. As of the beginning of September, all the organs of the flower are fully differentiated. The growing period of saffron varies in different countries and can be either annual or perennial: Italy (part of the South, Abruzzo and Tuscany) – 1 year; Spain and Italy (Sicily and Sardinia) – from 3 to 4 years; Morocco – from 5 to 6 years, Iran – from 6 to 8 years, Greece – from 10 to 12 years; India – from 10 to 15 years (Cardone *et al.*, 2021).

Phenological studies at various stages of plant growth and development are important for mitigating the negative effects of climate change, to which saffron is very susceptible, and for planning elements of the production system that include agrotechnical operations and flower harvesting processes. Harvesting flowers at optimal times is a very important step in saffron agribusiness, so the phenology of flowering in relation to climatic conditions is essential for a proper understanding of this process.

CONCLUSIONS

Saffron, compared to other widely cultivated crops, is a plant with numerous differences in ecological, physiological, and phenological terms. Among these differences, it is worth highlighting the following: the development of flowers precedes the development of other parts of the plant. The course of this process is conditioned by the reserves of nutrients accumulated in the corms. The onset of the flowering phase is accompanied by a decrease in air temperature in autumn, unlike the vast majority of agricultural crops, for which this period coincides with the period of warm and humid seasons. For saffron, only the stigma, which makes up 7.4% of the flower's weight, is considered a commercial product. Saffron development can generally be divided into three phases: generative, vegetative, and dormant. The physiological process of the generative phase occurs well in advance of visible flowering. The appearance of flowers was noted in the period from October 8 to October 28. The flowers may appear simultaneously with the leaves or sometimes after their emergence. The vegetative phase, which begins immediately after flowering, is the longest stage (244 days) in the annual saffron cycle. During this phase, leaves and corms develop. The leaves currently play the role of an assimilation resource for the development of corms and roots. During autumn and winter, corms develop slowly, and closer to spring, they begin to grow actively. The size of the mother corm significantly affects the development of daughter corms. The dormant phase occurred with the beginning of senescence (3rd 10 days of May) and leaf death (1st 10 days of June) and lasted until the beginning of autumn.

A detailed description and coding of the stages of saffron development is a useful and convenient tool for identifying the various stages of plant growth and development, which is necessary for implementing effective crop management methods that will ensure the high quality of the crop.

The main areas of further study should be aimed at creating and optimising new methods of growing saffron, such as hydroponics and vertical farming, due to which it would be possible to achieve an increase in the yield, quality, and efficiency of saffron production, and minimise dependence on climatic conditions and soil factors.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

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Фенологічні спостереження за ростом та розвитком шафрану (*Crocus sativus* L.) в умовах Правобережного Лісостепу України

Анотація. Існує потреба в узагальненні інформації з використанням фенологічних моделей з метою розробки стійкої технології виробництва шафрану з подальшим регулюванням цвітіння на певній фенологічній стадії та визначенням відповідного періоду цвітіння для покращення врожайності та якості за різних умов навколишнього середовища. Метою досліджень було встановлення перебігу фенологічних фаз росту та розвитку шафрану в умовах Правобережного Лісостепу України. Проводили фенологічні спостереження та біометричні вимірювання у дослідженні. Згідно з польовими спостереженнями, існує загалом 6 фенологічних стадій розвитку шафрану. Період спокою триває з третьої декади травня до жовтня і розділяється на фазу первинного та вторинного спокою. Під час первинного періоду спокою бульбоцибулини не проявляють зовнішніх морфологічних змін та росту, але внутрішні фізіологічні та морфогенетичні зміни відбуваються. У фазі вторинного спокою відбувається початкове зародження листків та квіток і їх диференціація. У період спокою рослини шафрану залишились без надземних органів. Період цвітіння припадає на жовтень. На проходження цієї фенологічної стадії можуть впливати зміни умов навколишнього середовища або агротехніки. Ріст кореневої системи розпочинався разом з появою квіток і листків. Під час фази вегетації продовжується наростання листового апарату та розвиток кореневої системи. Також у цей період з бруньок материнської бульбоцибулини утворюються дочірні бульбоцибулини. Протягом зими бульбоцибулин заміщення продовжують рости використовуючи запаси поживних речовин материнської бульбоцибулини. На початку березня розвиток кореневої системи сповільнюється і дочірні бульбоцибулини досягають майже остаточного розміру. Під час закінчення вегетаційного періоду коренева система материнської бульбоцибулини припиняє ріст. Листки починають старіти від верхівки до основи. На кінець травня дочірні бульбоцибулини повноцінно розвинені та готуються до переходу в стан спокою. Кількість бульбоцибулин, що утворюється з одиниці площі, залежить від віку ділянки, забезпеченості поживними речовинами та рівня агротехніки. Старіші поля дають більшу кількість бульбоцибулин. Завдяки більшій густоті формується більший врожай тичинок. Тому, розуміння фенологічних реакцій та впливу кліматичних факторів на етапи росту та розвитку шафрану у певних ґрунтово-кліматичних умовах корисний для майбутнього прогнозування термінів збору врожаю

Ключові слова: фенологічна фаза; BBCH; цвітіння; бульбоцибулини; катафіли