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Bioecological features of *Nigella sativa* L. in different conditions of Uzbekistan

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Abstract

The article is devoted to the study of bio-ecological features of black caraway (kalonji) in different conditions of introduction. The analysis of the periods of ontogenesis, the biology of flowering, fruiting (seed productivity) in different conditions of Uzbekistan was carried out. By results of phenological researches the differences of terms of phases of the vegetative period and its turn, by morphometric parameters are revealed. Emergence of buds in *Nigella sativa* under conditions of introduction is observed in the first decade of May, sometimes in the middle of May, depending on weather conditions of the year. The earliest flowering was on 18.05, the latest on 29.05. Fruiting takes place in early June to late June. The end of the growing season is observed in late June-early July. The duration of vegetation in Malguzar is 130-35 days, while in Botanical Garden it is 135-145 days. The real seed production per plant averages 51.9±3.94 in Botanical Garden conditions and 42.5±2.10 in Malguzar.

Keywords

Nigella sativa, introduction, ontogenesis, seedling, juvenile, virginile, generative, phenology, flowering biology, seed production

Introduction

The overall prevalence of patterns, co- and counter gradients is crucial to plant phenology as this will determine the extent to which local adaptation will strengthen or weaken phenological responses to temporal shifts in climate (1). Depending on the environmental gradients in space, the relative dominance of countervailing gradient variation in spring compared to autumn will be critical. In general, geographic variation in the period of activity will be maximized when events in autumn and spring differ in terms of whether they follow patterns of co- or counter gradient variation (1). Climate change is changing the structure of biodiversity around the world among the key responses to spatial and seasonal changes in environmental temperature are changes in phenology, that is, changes in seasonal life cycle events. In the middle and high latitudes in the Northern Hemisphere, spring events usually occur. earlier, whereas autumn events occur later, mainly due to an increase in temperature. In general, responses are expected to be faster and more distinct the higher the latitude or altitude, i.e. the lower the average temperatures (2).

Recently, global climate change has accelerated considerably, which has opened up the possibility of increasing the biodiversity of cultivated crops by introducing warm-loving crops to more northern latitudes. Among

a wide range of promising new and less common crops, *Nigella sativa* which is native to the Mediterranean, occupies an important position (3). It is widely known in the southern countries since biblical times as a medicinal and aromatic herb, which is characterized not only by a high content of biologically active compounds, but also the ability to remove radionuclides and salts of heavy metals from the human body (3). Nowadays, its unique properties for human health are widely studied all over the world (4).

The genus *Nigella* belongs to the buttercup family (Ranunculaceae), which comprises about 25 species distributed in Western Europe, North Africa and Western Asia. 10-11 species occur in Russia and adjacent countries (5). There are two species of corms in the flora of Uzbekistan: *Nigella bucharica* Schipcz. and *Nigella integrifolia* Regel (6).

In the Mediterranean countries, black caraway (kalonji) is regarded as a highly profitable crop in organic farming (7). The chemical composition of corm seeds varies widely depending on the place of cultivation and cultivation conditions and has been most extensively studied in the Arab world. In the CIS such studies are most developed in Dagestan, Stavropol Territory, Crimea, and Belarus. It was found that numerous pharmacological effects of nigella are in close correlation with a great diversity in the seeds of black caraway biologically active compounds (over 100 compounds) (8). Nigella sown seeds contain fat (up to 53%), protein (16-28.3%), carbohydrates (24.9-33.9%), essential oils (up to 1.4-1.9%) and other classes of compounds [9]. Bilberry essential oil contains: p-cymene (7-41.8%), thymoquinone (10.3-57%), thymohydroquinone, dithymoquinone, ethylinoleate (9.4%), a-pinene (9.3%), a-thujene 5.6-13.9%), ethyloleate (2.7%), β-pinene (2.2-2.96%), limonene (1.6-2.11%) carvacrol (2.85-12%), camphor (0.06%), longifolene (1-8%), 4-terpineol (2-7%), t-anethol (0.25-4%), sabinene (1.18-1.50%), 4,5-epoxy-1-isopropyl-4-methyl1-cyclohexene (1.80%), 4-terpineol (1.22%), etc. (10).

The essential oils of *Nigella sativa* contain over 40 compounds, but up to 99.0% are represented by 16 compounds. The most common component of the essential oils of all samples is paracymol. Its content is 38.2-52.0%. A significant part (16.2-23.9%) is represented by monoterpenes - hydrocarbons formed by a combination of two isoprene fragments with the common gross formula C10H16 (136 Da). Thymol, which is a hydroxy derivative of para-cymol, was detected at 2.5-4.9%. The proportion of thymoquinone in the essential oils ranged from 10.1 to 22.9% (11).

In the composition of black caraway (kalonji) essential oil a rather high thymoquinone content is noted, which is due to the fact that thymoquinone is the final oxidation product in this chain of terpene transformations, so it accumulates in the oil in the greatest quantity. Thymoquinone can undergo further transformations, for example, it dimerises in light to form dithymoquinone, which indicates that it is photosensitive. Dithymoquinone, the dimerization product of thymoquinone, is less well studied and presumably, like thymoquinone, may have anti-tumour effects (12, 13).

Nigella sativa L. is a member of the Ranunculaceae family and a well-known medicinal and aromatic plant. It has other names: black cumin, calindji, seidena, cedena, Roman coriander, bread cumin, etc. It is an annual herbaceous plant. Annual herbaceous plant with upright, branched, light green, slightly glaucous stem, 20 to 70 cm high. Leaves double- to triple-pinnately dissected with numerous linear segments. Flowers are solitary, regular, ovipotent, 2-4 cm in diameter. Sepals are blue, corolla consists of 5-6 nectar-like petals. The anthers are obtuse, slightly pointed. The fruit is a swollen multi-partite leaflet, with usually 3 to 7 leaflets. Seeds are small, triangular, wrinkly tufted, black. They contain 20 to 49% fatty oils, 0.8-1.5% essential oil, the enzyme lipasunyhedase, saponins, the glycoside nigellin, thymoquinone, tannins and bitter substances, alkaloids, and aromatic hydrocarbons (14).

Major pharmacological studies have been conducted in well-known research centres in Egypt, Turkey, Saudi Arabia, Iran, Pakistan, India, Israel, USA, which confirmed the unique medicinal properties of nigella. The seeds and the oil extracted from them have been found to possess numerous pharmacological properties, including: analgesic, antiatherosclerotic, antihyperlipidemic, antifungal, antidepressant, antidiabetic, antioxidant, analgesic, bronchodilator, gastroprotective, hepatoprotective, hypotensive, anthelmintic, choleretic, immunomodulatory, hemostatic, pulmonary protection, diuretic, neuroprotective, nephroprotective, analgesic, anti-allergic, anti-asthmatic, anti-inflammatory, antihelminthic, anti-tumor, reparative, laxative, sleeping pills, antispasmodic, tonic. Black cumin oil is a source of essential oils and polyunsaturated fatty acids that have the following effects in the body: protect cells from damage, improve brain cell metabolism, has a stimulating effect on the bone marrow, normalize blood viscosity and other blood parameters. Nigella preparations are effective in the treatment of opioid and nicotine addiction (15).

This research is conducted within the framework of the state applied project No. A-FA-106 "Establishment of *Nigella sativa* L. (Ranunculaceae), *Linum ussitatissimum* L. (Linaceae) and *Elwendia persica* (Boiss.) Pimenov & Kljuykov.) (Apiaceae) plantations in rainfed areas of the Republic". The aim of this project is to establish plantations of black caraway (kalonji) – (*Nigella sativa*), Flaxseed (Linseed) – (*Linum ussitatissimum*) and Black cumin – (*Elwendia persica*), which are in high demand in pharmaceutics and the national economy. On the basis of the obtained results, a peculiar innovation technology of cultivation in the regions, a technology of production in ready for export packaged form (oil, capsules, seeds) will be developed.

Materials and Methods

The study of phenological features of Black caraway (kalonji) is carried out in two conditions: in rainfed areas of the republic (Malguzar ridge - in Jizzakh region, altitude 900 m) and in the Tashkent Botanical Garden named after Acad. F.N. Rusanov (Fig. 1).

Malguzar district of Kuhistan district is situated in the south of Jizzakh region and includes the Malguzar ridge

Fig. 1. Study areas

(2,620 m). Malguzar is a north-western spur of the Turkestan ridge, about 80 km long, separated from the Turkestan ridge by the Zaaminsu river valley in the east and the Sanzar river valley in the south. The "Tamerlane's Gate" gorge separates Malguzar from the Nurata Range. Arid and semi-arid foothill and mountainous landscapes (except highlands) are represented here. Vegetation cover of Malguzar is very similar to the vegetation of the northern slopes of Turkestan ridge. As on Turkestan ridge, foothills are covered with ephemeroid and wormwood-ephemeroid vegetation, low belt is formed by motley grass-grass communities and shrub sparse woodlands, and above 1500 m begins a belt of juniper, which is combined with blackwood, couch grass and steppes.

Tashkent Botanical Garden is located in the north-eastern part of the city of Tashkent (altitude 473.3 m above sea level). The Tashkent Botanical Garden is the largest in the Central Asian region, and in Uzbekistan it is registered as a unique natural object. Its area of 68 hectares of land is divided into 5 plots: plants of the East Asian, Indochinese, circumborial (Crimea, Caucasus, Europe), North American and Central Asian floristic regions. Our study was conducted at the experimental plot of the Laboratory "Introduction of Medicinal Plants" of the Tashkent Botanical Garden.

Seeds were sown in the Malguzar area during the first decade of February. Seeds were sown 1.5-2 cm deep, and under Botanical conditions in mid-February. Phenological observations were carried out every 3 days during the period from early February to the end of June according to the generally accepted method for annual plants (16). The study of flowering biology was conducted according to the method of A.P. Ponomarev (1960), as well as the seed production of plants by T.T. Rakhimova (2009) (17,18).

Results

Phenological observations were made during the growing season in different conditions of the republic. The studied species reached the generative stage during the observation period. In the middle of March, the emergence of sprouts, with a difference of 4-5 days, is noted. Formation of rosette plants is observed on the first decade of April, with difference of 3-4 days. Accordingly, these differences (timing) are noted in the phases of budding, flowering and fruiting.

Periods of ontogenesis

We have identified latent (*se*), virginile (*v*) and generative (*g*) periods of plant ontogenesis as a result of our research.

se – period is represented by resting seeds. Mass seed maturation in Malguzar conditions at the end of February and in the Botanical Garden at the first decade of March. By the time of full maturity, the seeds have formed a dense seed coat.

According to M. Schlash (2004), this period usually lasts 7-8 months: from May to January of the following year, when the seeds begin to germinate under natural conditions; if the seeds are stored, the latent period lasts until they lose germination for 2 to 5 years (19).

v - period in *Nigella sativa* under Malguzar conditions from late February to the second decade of March averages 36-40 days, this period is shifted to earlier dates in the Botanical Garden, from the second decade of February to the end of March: 40-44 days. During this period, we studied: seedlings (*p*) juvenile (*j*) and virginile (*v*) plants.

p – this stage is observed 10-12 days under Malguzar conditions and 8-12 days after sowing at the Botanical Gardens. Emergence of the first leaf is observed 8-9 days later, with differences of 2-3 days under Botanical Garden conditions. Appearance of the second leaf was observed 3-5 days after the first. The first leaves are tricompartmental, the buds are suproposed. The duration of the seedling state is short, i.e. 10-12 days in Malguzar conditions and 10-15 days in the Botanical Garden.

j - the stage observed by the plant after the beginning of the development of the 3rd leaf in the seedlings. In this state, plants are characterized by underdeveloped underground and above-ground organs and leaves that differ in size and shape from those of adult plants. The juvenile plants of Cormorant seedlings continue forming leaves, reaching a height of 12-16 cm in Malgusar conditions and 15 -20 cm in Botanical Garden. The duration of the condition under Malguzar conditions is 13-15 days and 15-20 days in the Botanical Garden (Fig. 2).

The *v* - stage of the plant is characterized by the rapid beginning of the growth of lateral shoots, intensive accumulation of vegetative mass, growth of the root system (the main root has 4-5 lateral roots), and the beginning of the appearance of cambium in the main root. Plant height at this time is 18-25 cm in Malguzar and 25-30 cm in Botanical Gardens. The duration of the adult vegetative state is up to 6-10 days, with differences of 2-3 days under Botanical Garden conditions (Fig. 3).

The *g*-stage is observed in the seed black caraway (kalonji) with the development of buds at the ends of the shoots. The onset of flowering in celandine starts at the end of the first decade of May. At that time, the height of the plant reaches 25-28 cm in Malguzar, 34-36 cm in Botanical Garden. The number of leaves averages 10-12. The root

Fig. 2. *p-j* states of *Nigella sativa*

Fig. 3. *v*-states of *Nigella sativa*

system consists of a main root, 14-22 cm long, and 6-8 second- and third-order lateral roots. The time from emergence to bud development is 10-12 days, from green to colored buds. The onset of flowering was noted, in mid-May. During this period, plant height averaged 30.8-42.7 cm. Under Malguzar conditions, 8 to 14 flowers were formed on a single plant, while in the Botanical Garden the number of flowers was 15-22. Mass flowering was observed in Malguzar at the end of May and in Botanical Garden at the beginning of June. The entire flowering period lasts up to 25-30 days. Fruiting in Malguzar is observed in early June and in the Botanical Garden in the second decade of June. Fruit ripening correlates with the process of seed formation. The time for seed formation is about 10-12 days. Each box contains approximately 75-90 seeds, 0.1-0.2 mm in size (Fig. 4).

Phenological studies

The results of phenological research revealed differences in the timing of the phases of the growing season and, in turn, in morphometric parameters. Emergence of buds in *Nigella sativa* under the conditions of introduction is observed in the first decade of May, sometimes in the middle of May, depending on weather conditions of the year. The earliest

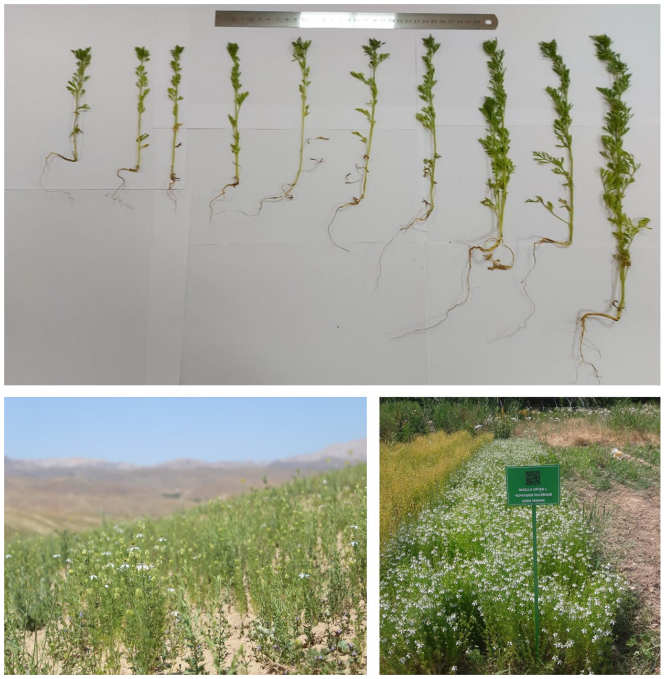

Fig. 4. *g*-states of *Nigella sativa*

flowering was on 18.05, the latest on 29.05. Fruiting takes place in early June to late June. The end of vegetation is in late June or early July. The duration of vegetation in Malguzar conditions is 130-35 days, and in Botanical Garden 135-145 days (Fig. 5).

The biology of flowering

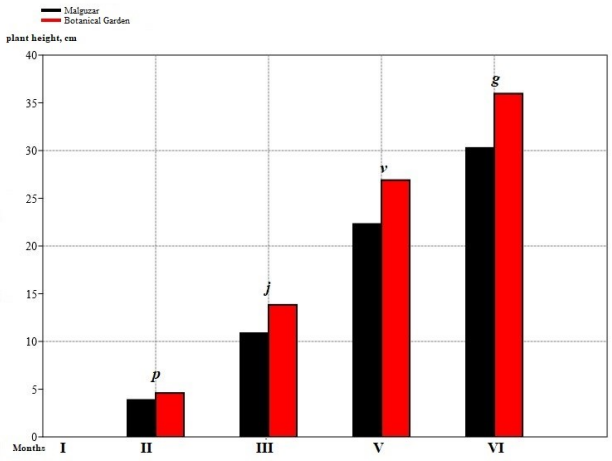

Fig. 5. The rhythm of development of *Nigella sativa* in different conditions Uzbekistan

During the growing season, introductory trials of *Nigella sativa* were conducted under different conditions in Uzbekistan. The species under study underwent a complete development cycle during the entire observation period, reached the generative stage, set fruit and produced viable seeds.

When studying the biology of *Nigella sativa* flowering under different conditions, the optimum air humidity, air temperature and soil surface temperature were determined. Including at the Botanical Garden, the norm for the average monthly temperature during flowering (in May) was noted to be 21.10 C°. The actual monthly temperature according to observations was 24.60 C°. The

lowest temperature was recorded in May 1 at 13.40 C°, while the highest was recorded in May 31 at 37.80 C°. Soil surface temperature was 30-40 C° lower than air temperature. In addition, a rainfall of 18-22 mm was recorded during flowering (Fig.6).

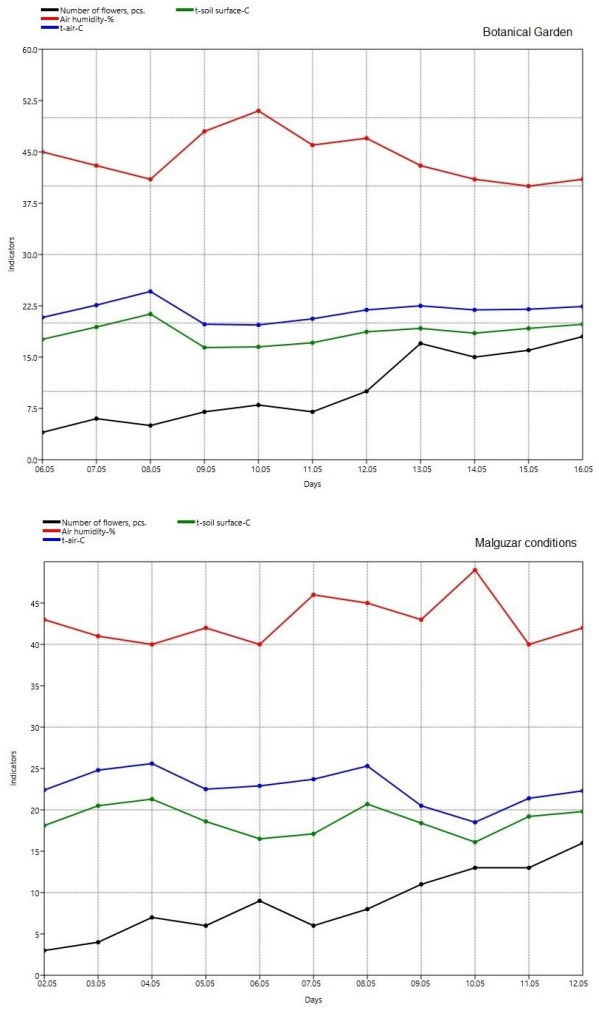

Fig. 6. Biology of flowering of *Nigella sativa* in different conditions of Uzbekistan.

The composition of the soil

The concentrations of humus and macro elements, the pH, the conductivity and humidity of the soil solutions from the Botanical Garden and Malguzar were carried out. The obtained data show that humidity was 11±1.0 and 10±0.84 %, respectively. The pH value varied between 8-8.1. The concentration of the nitrogen was 0.085±0.01 and 0.14±0.015 %, respectively. The soil of Botanical garden consists the 0.1±0.01 % phosphorus and Malguzar soil 0.16±0.01%. concentration of potassium in Botanical garden soil was 1.4±0.1 % and in Malguzars' soil was 1.2±0.1 % (Table-1).

Discussion

During the growing season, introduction tests of *Nigella sativa* were carried out in different conditions of Uzbekistan. During the entire observation period, the studied species underwent a full development cycle, reached the generative stage, tied fruits and formed viable seeds.

Table 1. The composition of the soil of Malguzar and Botanical garden

Soil indicators	Malguzar	Tashkent Botanical garden
Humidity (%)	10,0 ± 0,84	11,0 ± 1,0
pH	8,0 ± 0,05	8,10 ± 0,1
Conductivity (μS/см)	0,408 ± 0,017	0,324 ± 0,017
Humus (%)	4 ± 0,12	4,1 ± 0,2
Total nitrogen (%)	0,085 ± 0,01	0,14 ± 0,015
Total phosphorus (%)	0,16 ± 0,01	0,1 ± 0,01
Total potassium (%)	1,2 ± 0,1	1,4 ± 0,1

In turn, on Malguzar, the norm of the average monthly temperature during flowering (in May) was 21.80 C°. The actual temperature of the month according to observations is 24.50 C°. The lowest air temperature was recorded in May 14 – 9.90 C°, in turn, the highest in May 31 – 39.50 C°. The temperature of the soil surface differed by 30-40 C° lower than the air temperature. In addition, the observation noted the amount of precipitation in the amount of 15-17 mm (Fig. 5).

Seeds form by the third decade of June, but under Malguzar conditions this is pushed back to an earlier date (4 -6 days). The time for seed formation is about 10-12 days.

Table 2. Seed productivity of *Nigella sativa* in different conditions of Uzbekistan (2021) n=10

Parameters	condition	
	Botanical garden	Malguzar
Plant height, cm	37,51±2,77	24,63±1,70
The length of the shoot	7,23±0,29	6,76±0,28
Socket length, cm	2,84±0,19	2,55±0,13
Quantity socket, pcs.	2,8±0,29	2,6±0,22
The length of the boxes, cm	1,47±0,10	1,36±0,06
Diameter of the boxes, cm	1,08±0,07	1,04±0,07
PSP, %	68,6±4,52	58,8±2,48
RSP, %	51,9±3,94	42,5±2,10
EC, %	75,7±1,64	72,3±1,85

Each boll produces about 75-90 seeds of 0.1-0.2 mm in size. Biometric indicators of seed production are shown in Table 2.

It is well known that medicinal plants need adequate amounts of nutrients, organic matter and other elements in the soil to ensure good growth and optimal quality. Optimal soil conditions, including soil type, moisture and fertility, will be an important factor in the cultivation of selected medicinal plant species or medicinal plant parts.

In addition, humus, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, silicon, trace elements in the soil are the main chemicals that determine soil fertility. The presence of certain amounts of these chemicals in the soil determines their yield depending on the type of crop grown. When the balance of these substances in the soil is disturbed, the yield of crops changes. In this work, Tashkent Botanical garden and Malguzars' soil composite components were analyzed. All chemical properties were similar in the two soil samples. Obtained data are presented in Table 1.

Conclusion

The results of the phenological studies revealed differences in the timing of the phases of the growing season and, in turn, in morphometric parameters.

The appearance of buds in *Nigella sativa* under introduction conditions is observed in the first decade of May, sometimes in mid-May, depending on the weather conditions of the year. The earliest flowering was on 18.05, the latest on 29.05. Fruiting occurs in early June to late June. The end of vegetation is in late June or early July. The duration of vegetation in Malguzar is 130-35 days, while in Botanical Garden it is 135-145 days. The real seed production per plant averages 51.9±3.94 in Botanical Garden conditions and 42.5±2.10 in Malguzar.

This is due to the difference in climatic factors in the two conditions, as, optimum air humidity, air temperature and soil surface temperature during the growing season of the plant. Thus, the results have shown that *Nigella sativa* can be cultivated in rainfed areas of our republic, to obtain quality raw plants.

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Authors contributions

All the authors together conducted fieldwork, data collection, data analysis, data generation and manuscripts. All authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: The author declares that the provided information has no conflict of interest.

Ethical issues: None.

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