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RESEARCH ARTICLE

Seed productivity of *Linum usitatissimum* L. in different ecological conditions of Uzbekistan

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Abstract

The article reports influence of different environmental conditions on the productivity of *Linum usitatissimum* L. (flax or flaxseed) in Uzbekistan. Analyses of the plant productivity were carried out on the rainfed lands and in the conditions of the Tashkent Botanical Garden. Phenological studies revealed differences in various phases of the growing period. Morphometric parameters that determine yield of *L. usitatissimum* seeds under different conditions were determined. The seed yield per plant on average in the Botanical Garden was 79.4 ± 4.00, and at various regions in the rich lands such as Malguzar 76,8±4,33, Pishagar 74,2±4,54 and Khatyrchi district was 76,5±4,28. The results of the studies can be used by farms in cultivating *L. usitatissimum* in the Republic of Uzbekistan.

Keywords

Linum usitatissimum, phenology, flowering biology, seed productivity, yield

Introduction

Climate change is changing the biodiversity around the world and among the key responses to spatial and seasonal changes in environmental temperature are changes in phenology, that is, changes in seasonal life-cycle events (1, 2). In the middle and high latitudes in the Northern Hemisphere, spring events usually occur earlier, while autumn events occur later, mainly due to rising temperatures (3). In general, responses are expected to be faster and more distinct, the higher the latitude or altitude, the lower the average temperatures (4).

Global climate change has recently accelerated significantly, opening the way for mankind to increase the biological diversity of cultivated crops by introducing heat-loving crops in the northern latitudes (5).

Linum usitatissimum L. (Linaceae) is a valuable crop having multilateral use. Area of its cultivation extends to 2.5-3.2 million ha and the gross seed harvest reaches 1.9-2.7 million tons worldwide (6). This is an annual herb with a shallow root system. Common names such as flax and flaxseed are used in North America and Asia respectively, for *L. usitatissimum*. Oilseeds and fibrous varieties are available for this species (7).

The uniqueness of *L. usitatissimum* oil lies in the high content of polyunsaturated α-linolenic acid, which is part of almost all cell membranes. It is an indispensable fatty acid in the human diet, which is involved in the regeneration of the cardiovascular system and in the growth and development of the brain (8-9).

In 2004, flax was grown in 47 countries with a seed production of 1.903 million tons (9). Canada has the highest area and flax production in the world, followed by China, USA, India and EU. In 2006, Canada produced 1014 million tons of flax seeds with an area of about 800 thousand ha (10).

L. usitattisimum L. grown as oilseeds, or as a fiber crop and is one of the oldest plants cultivated (11). In the Indian subcontinent, this plant is mainly grown as an oil crop in vast areas. Nevertheless, ordinary flax is one of the most natural and ecological pure fibrous crops, the fourth largest commercial fibrous crop in the world (12). Linseed fiber is stronger, crunchier and harder to handle because it is a more crystalline cellulose polymer (13).

The healing properties of the linseed were known to the ancient Greeks. Hippocrates recommended using it for inflammation of the mucous membranes. The medicinal raw material used is flax seed, which is collected during full maturity. Flax seeds with hot water give thick mucus, which has a mild laxative, enveloping, mild, anti-inflammatory and analgesic effect and are used in the treatment of inflammation of the esophagus and peptic ulcer. The pharmaceutical industry produces the drug Linetol, obtained from linseed oil, which is used inside for the treatment and prevention of atherosclerosis, as well as externally for the treatment of chemical and thermal burns and radiation lesions of the skin. *Oleum lini* linseed oil is used as a laxative and also as a diuretic (14).

In a recent study with 3 grades of a flax olive (Northern, LM 98 and Norlin) the earliest maturing variety was the Northern, vegetative period of which makes 98 days whereas the most late-ripening - LM 98 needs 107 days. The Norlin variety occupied an intermediate position with a growing period of 100 days (15). Studies on the productivity and yield of *L. usitatissimum* in Belarus were conducted (18).

In the conditions of the southern zone of the Rostov region, with the highest yield, the largest amount of energy was accumulated on options with waste processing in *L. usitatissimum* products. The energy efficiency ratio was compared to the minimum tillage and No-till technology which suggests that No-till technology is more efficient than other processing options from an economic and bioenergy point of view. It was lower by 0.9-1.9 for the Heavenly variety and 0.8-1.1 for the VNIIMK 620 variety (16-17).

For olive flax, significant variability in the seed productivity (number and mass of seeds per plant and mass of 1000 seeds) and the biochemical composition of the seeds was revealed, however, information on the genotypic potential of the plant is limited. Thus, the influence of weather conditions and geographical factors on the content and quality of the oil is described. Depending on the environmental conditions, fluctuations in grade oiliness can be 36.4-52.0%, and sharp temperature fluctuations during ripening cause a relatively greater accumulation of unsaturated fatty acids (19).

Unfortunately, there are no specific studies reported on the cultivation of *L. usitatissimum* in the conditions of the Republic of Uzbekistan. Since, more than 900 tons of *L. usitatissimum* raw materials are imported per year in the value of 1 million US dollars, thus such a study is highly significant.

In this regard, it seems important to determine agrotechnological measures for the cultivation of *L. usitatissimum*, based on the study of growth and development, flowering biology and seed productivity in different growing conditions of Uzbekistan.

This research was carried out as part of the state applied project №. 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 purpose of this project is to create the *Nigella sativa, Linum ussitatissimum* and *Elwendia persica* plantations, which are in high demand in pharmaceuticals and the national economy and based on the results obtained, unique innovative technologies will be developed for growing these crops in the regions, which will create a technology for manufacturing products in ready-for-export packaged form (oil, capsules, seeds).

Materials and Methods

The study of the bioecological features of *Linum usitatissimum* L. was carried out under two conditions: on the rainfed lands of the republic (on the territory of the Jizzak region: The Malguzar ridge and the Pishagar forestry; Khatyrchi district of Navai region) and in the conditions of the Tashkent Botanical Garden named after Acad. F.N. Rusanov (Fig. 1).

The Malguzar district of the Kuhistan district is located in the south of the Jizzak region and includes the Malguzar ridge (2620 m N). Malguzar is a northwestern spur of the Turkestan ridge with a length of about 80 km, separated from the Turkestan ridge by the valley of the Zaaminsu River in the east and the valley of the Sanzar River in the south. The gorge "Tamerlane Gate" separates Malguzar from the Nurata ridge. Here are arid and semiarid foothill and mountain landscapes (except for highland) (20). The vegetation cover of Malguzar is very similar to the vegetation of the northern slopes of the Turkestan Range. As on the Turkestan ridge, the foothills are covered by ephemeroid and wormwood-ephemeroid vegetation, and the low mountain belt is formed by variegated-dust communities and shrub redwood forests, and above 1500 m the belt of archovniks begins, which are combined with blackberries, anthers and type steppes (20).

Tashkent Botanical Garden is located in the north-eastern part of Tashkent (473.3 m above sea level). 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 ha of land is divided into 5 plots: plants of East Asian, Indochina, circumborial (Crimea, Caucasus, Europe), North American and Central Asian floristic regions. Our research was carried out at the experimental

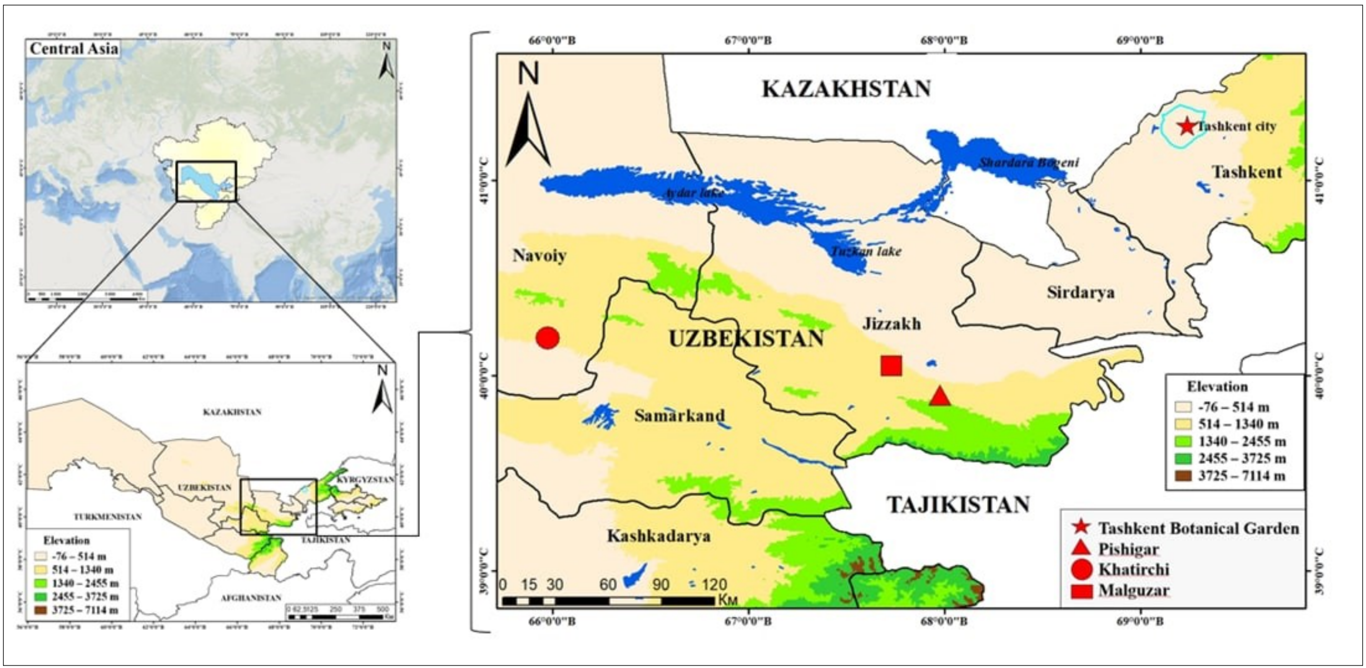


Fig. 1. Study area

site of the laboratory "Introduction of medicinal plants" of the Tashkent Botanical Garden (21).

Forestry Pishagar is located in the southeastern part of the Malguzar ridge of the Kuhistan district (h-2432). The vegetation cover is very similar to the Malguzar Range. The foothills are covered by ephemeroid and wormwood-ephemeroid vegetation, the low mountain belt is formed by variegated-dust communities and shrub redwood forests.

Khatyrchi district is located in the eastern part of the Navoi region (h-900). It borders on Kazakhstan, Dzhizak, Samarkand and Bukhara regions. The northwestern part of the region is occupied by the Kyzylkum plateau, the Nurata mountain ranges stretched in the east, the Zerafshan River borders the south of the region. The climate is sharply continental, desert, and arid (23).

Results

During the growing season, phenological observations were made in different conditions of the republic. The studied species in the observation period reached the generative stage. In mid-March, the appearance of seedlings is noted, with a difference of 4-5 days. The formation of a plant rosette is observed in the first part of April, with a difference of 3-4 days. Accordingly, these differences (timing) are noted in the phases of budding, flowering and fruiting.

Phenological studies

Mass ripening of seeds in the rainfed lands was noticed at the end of February and at the Botanical Garden in the first part of March. By the time of complete maturity, the seeds form a soft seed peel. The appearance of buds in *L. usitatissimum* under conditions of introduction is observed in the first part of May, sometimes in mid-May, depending on the weather conditions of the year. The height of the plants at this time reaches almost the same 30-34 cm under the conditions of the rainfed and 40-45 cm in the Botanical Garden (Fig. 2).

The lowest indicators were noted in Pishagar conditions, since in this area the degree of weed coverage is high. The number of leaves is on average 30-40. The root system is represented by the main root, the length of which is 10-14 cm and 6-8 lateral roots of the second and third orders. Fruiting occurs in early June - at the end of June. The end of vegetation is observed in late June - early July. Duration of vegetation in boharas 134-138 days, as well as in the Botanical Garden 140-145 days (Fig. 3).

Flowering biology

When studying the biology of flowering *L. usitatissimum* under different conditions, the optimal air humidity, air temperature and soil surface temperature were determined. Including, at the Botanical Garden, the average monthly temperature during flowering (in May) was noted 21°C. The actual temperature of month according to observations was 24.6°C. The lowest air temperature was noted in May 1 – 13.4°C, in turn, the highest in May 31-37.8°C. The surface temperature of the soil was 3-4°C lower than the air temperature. In addition, during flowering, the amount of precipitation in the amount of 18-22 mm was noted. In turn, in Malguzar and Pishagar were almost the same, the norm of the average monthly temperature during flowering (in May) was noted 21.8°C. The actual temperature of month according to observations was 24.5°C. The lowest air temperature in this region was noted in May 14-9.9°C, in turn, the highest in May 31-39.5°C. The surface temperature of the soil was 3-4°C lower than the air temperature. In addition, the amount of precipitation in the amount of 15-17 mm was noted during observation. Also, in the Khatyrchi district, the average monthly temperature during flowering (in May) was noted as 20.5 °C. The actual temperature of month according to observations 22.7°C. The lowest air temperature was noted in May 11-8.3 °C,

Fig. 2. Flowering *L. usitatissimum* in different conditions of Uzbekistan: **A** – Rainfed areas; **B** - Botanical Garden.

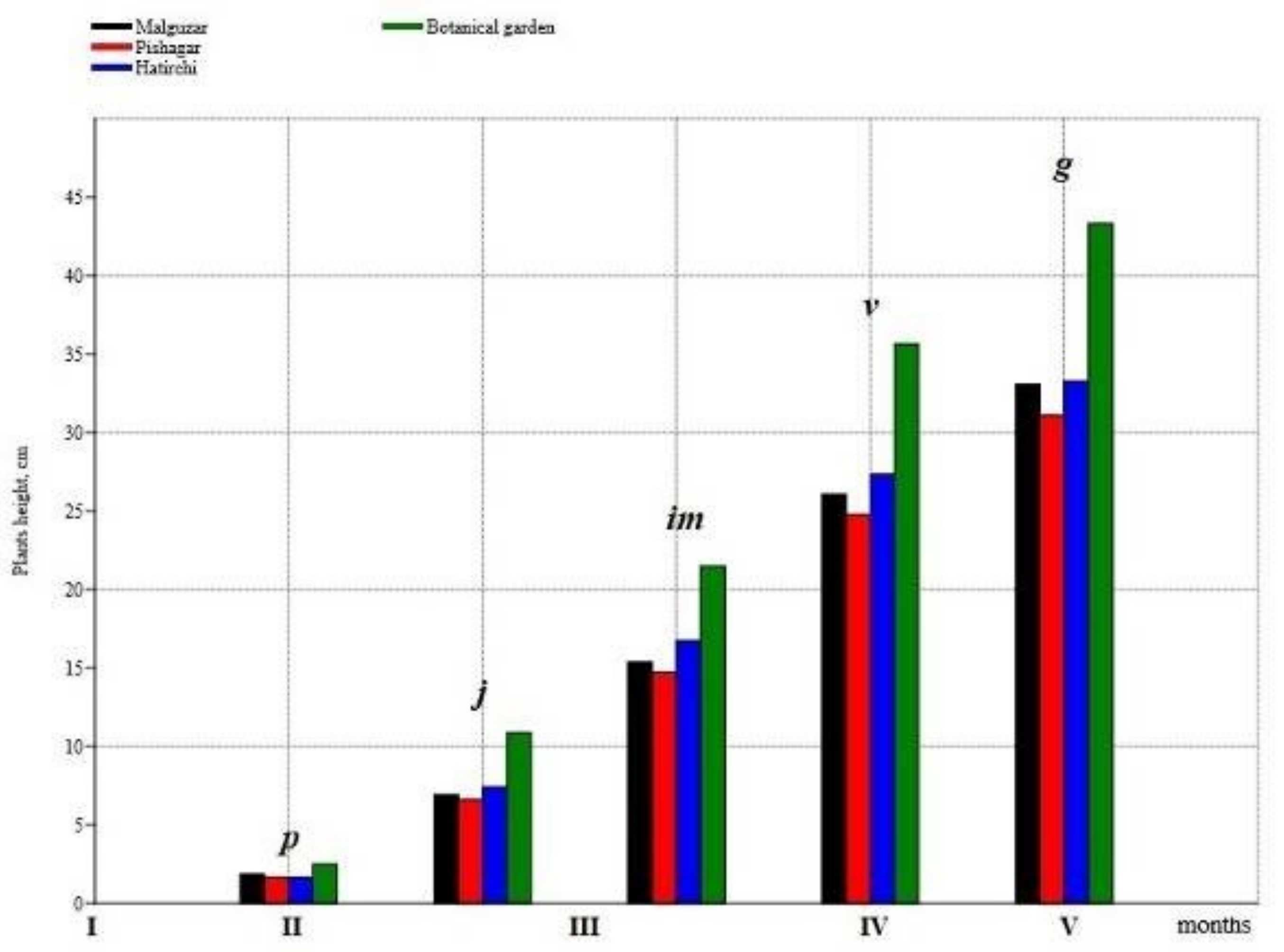
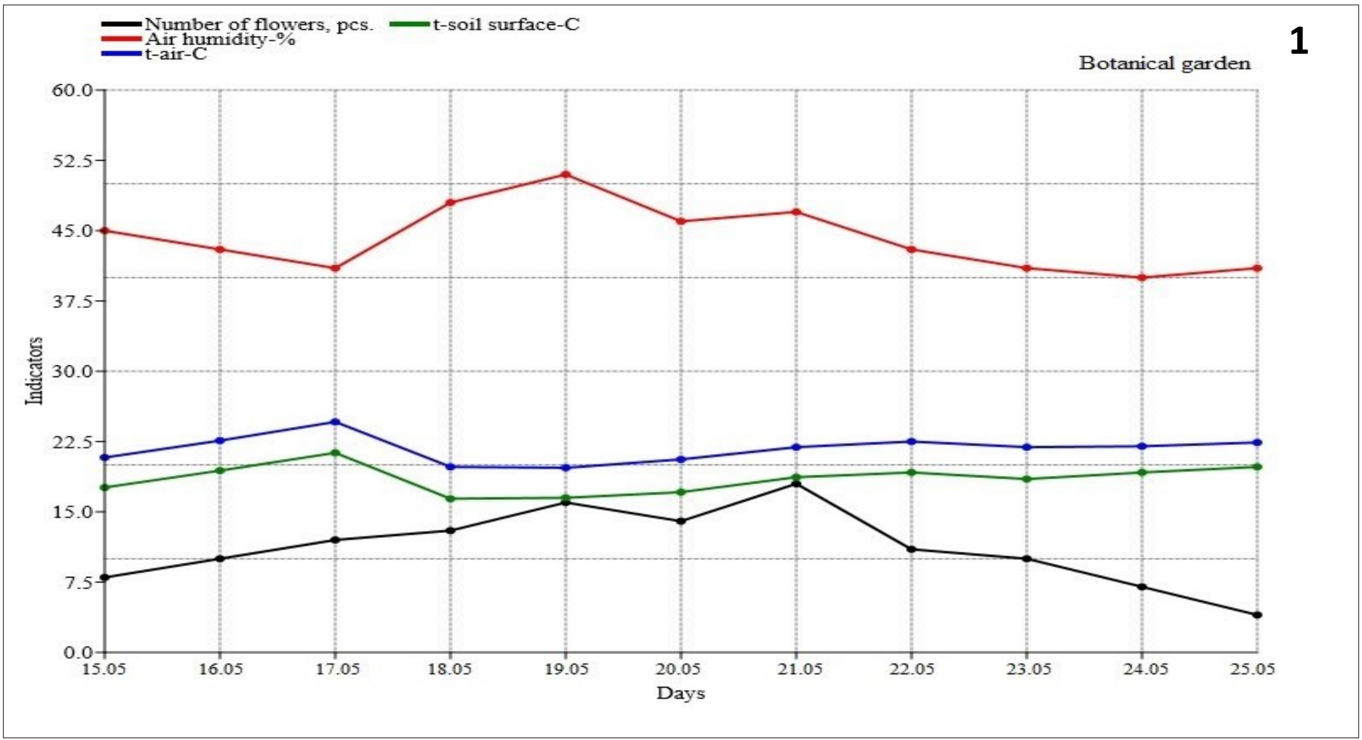


Fig. 3. The rhythm of development of *L. usitatissimum* in different conditions of Uzbekistan.

in turn, the highest in May 31-39.3°C. The surface temperature of the soil was 3-4°C lower than the air temperature. In addition, the amount of precipitation in the amount of 9.7-11.6 mm was observed (Fig. 4).

Fruiting in *L. usitatissimum* in fainfed was observed in early June and in the Botanical Garden in the second part of June. Ripening of fruits correlates with the process of seed formation. The seed formation period is about 8-11 days. About 10-15 seeds are formed in each fruit (Fig. 5).



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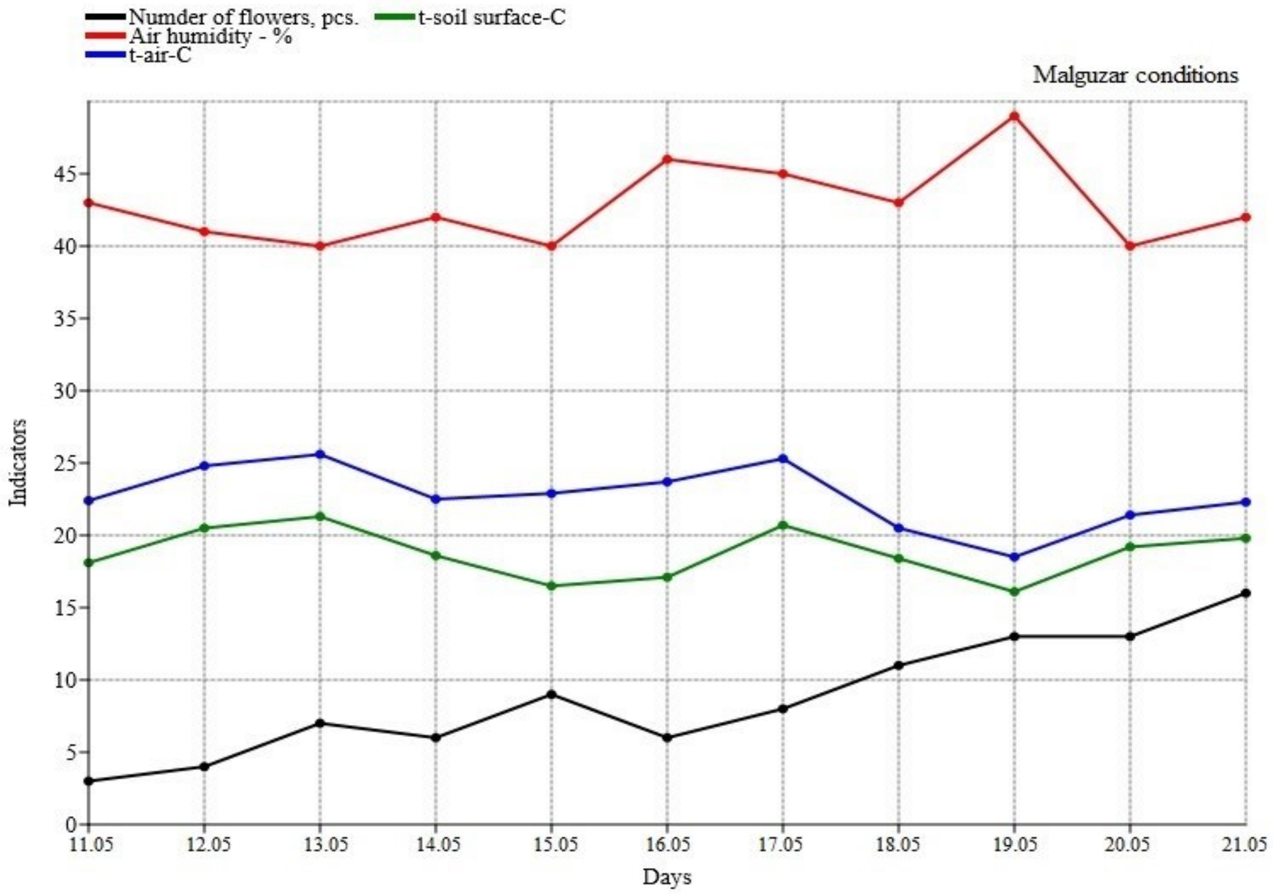
Numder of flowers, pcs.
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Air humidity - %
t-air-C
Malguzar conditions
Indicators
Days
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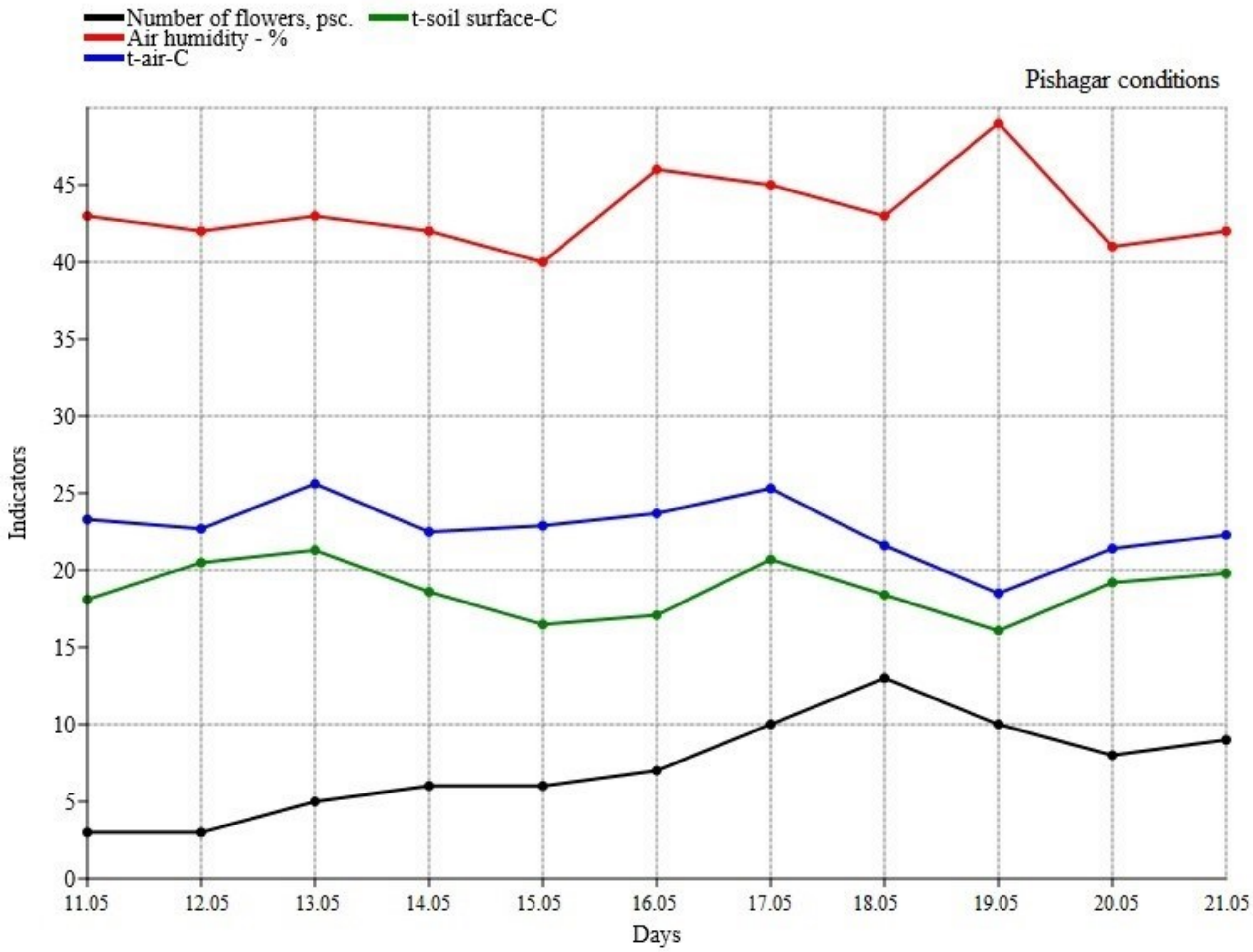
3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Pishagar conditions
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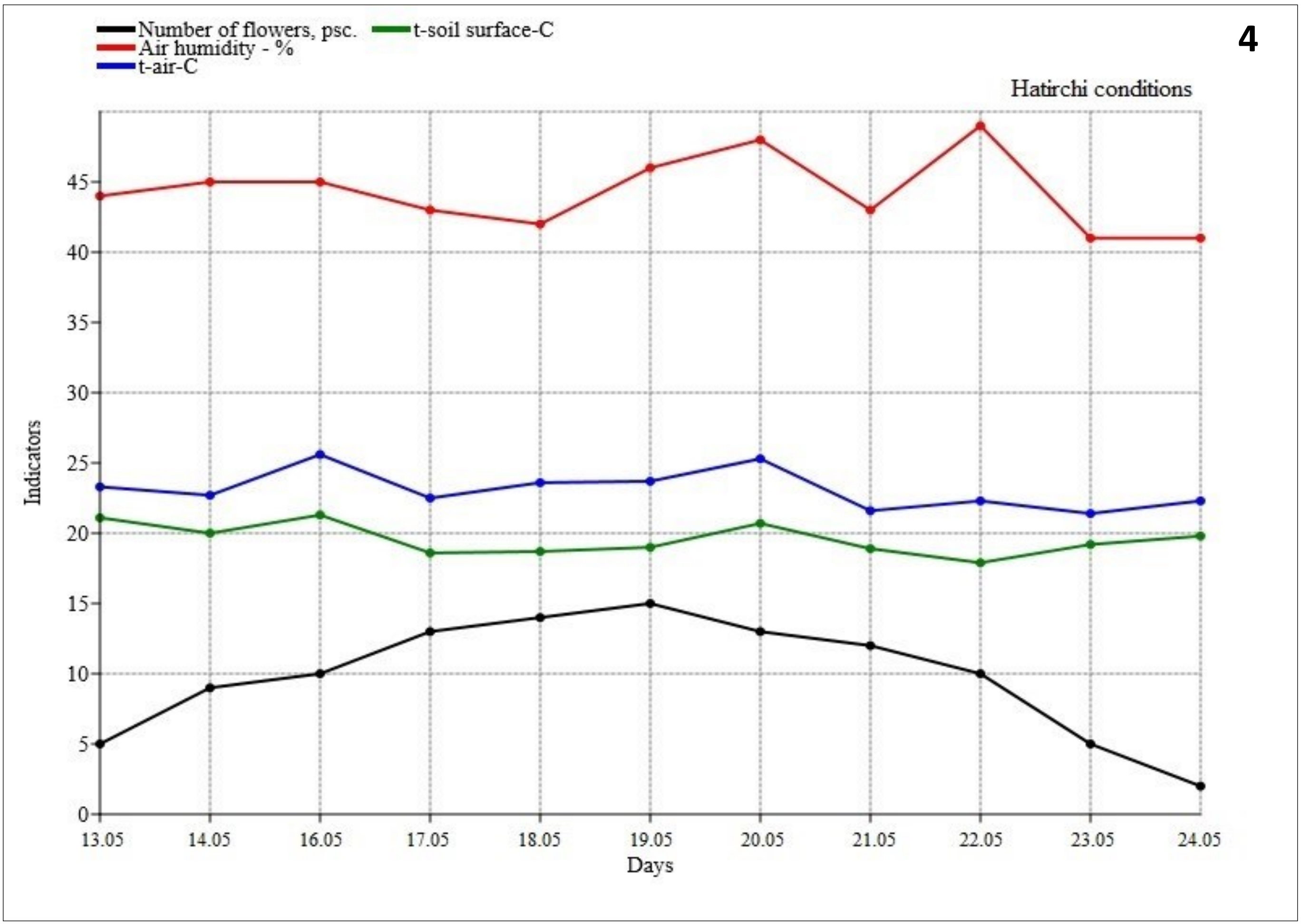

Fig. 4. Flowering biology *L. usitatissimum* in different conditions Uzbekistan.


A2


B1

Fig. 5. Fruiting *L. usitatissimum* in different conditions of Uzbekistan: **A** – Rainfed areas; **B** - Botanical Garden.

Soil composition of the studied areas

Our studies analyzed the concentration of humus, macro-elements, pH, conductivity and moisture of the soil. The obtained results show that soil moisture in the Botanical Garden was 11±1.0% and in the rainfed zones: Malguzar 10±0.84%, Pishagar 12.5±0.8% and the Khatirchi district 11.6±0.72% at the time of measurement. The pH value showed in the Botanical Garden was 8.10 ± 0.1 and rainfed zones respectively 8.0±0.05; 8.15±0.04; and 8.22±0.04. The nitrogen concentration in the Botanical Garden was 0.14±0.015 and on soil samples of the rainfed areas respectively 0.085±0.01; 0.12±0.01; and 0.08±0.01. The concentration of phosphorus in the Botanical Garden was 0.1±0.01 and in the rich lands, respectively 0.16±0.01; 0.08±0.01; 0.05±0.01. The concentration of potassium in the Botanical Garden was 1.4±0.1 and in the rich lands respectively 1.2±0.1; 0.8±0.1; and 3±0.2 (Table 1).

Under the conditions of Botanical Garden *L. usitatissimum* seeds are formed in the first part of June, and on the rich lands this period is shifted to 4-6 days earlier terms. The real seed productivity of one plant on average was 8.1±0.43 in the conditions of the Botanical Garden and in the rich lands: in Malguzar 7.3±0.42; Pishagar 6.9±0.43; Khatyrchi district 7.5±0.40. This is due to the difference in climatic factors between the two conditions (RHA (relative humid air), t^0-air, t^0-soil surface temperature) and weed coverage (Fig. 6).

Discussion

The highest productivity ratio was noted in the conditions of the Botanical Garden. This is due to the difference in climatic factors, such as air temperature, air humidity and the amount of annual precipitation. Indicators on rich con

Table 1. Soil composition of study areas *L. usitatissimum*

Soil indicators	Botanical garden	Malguzar	Pishagar	Khatirchi
Humidity (%)	11,0±1,0	10,0±0,84	12,5±0,8	11,6±0,72
pH	8,10±0,1	8,0±0,05	8,15±0,04	8,22±0,04
Conductivity (µS/см)	0,324±0,017	0,408±0,017	0,306±0,02	0,342±0,014
Humus (%)	4,1±0,2	4,0±0,12	4,2±0,1	4,0±0,1
Total nitrogen (kg ha^{-1})	0,14±0,015	0,085±0,01	0,12±0,01	0,08±0,01
Total phosphorus (kg ha^{-1})	0,1±0,01	0,16±0,01	0,08±0,01	0,05±0,01
Total potassium (kg ha^{-1})	1,4±0,1	1,2±0,1	0,8±0,1	3,0±0,2

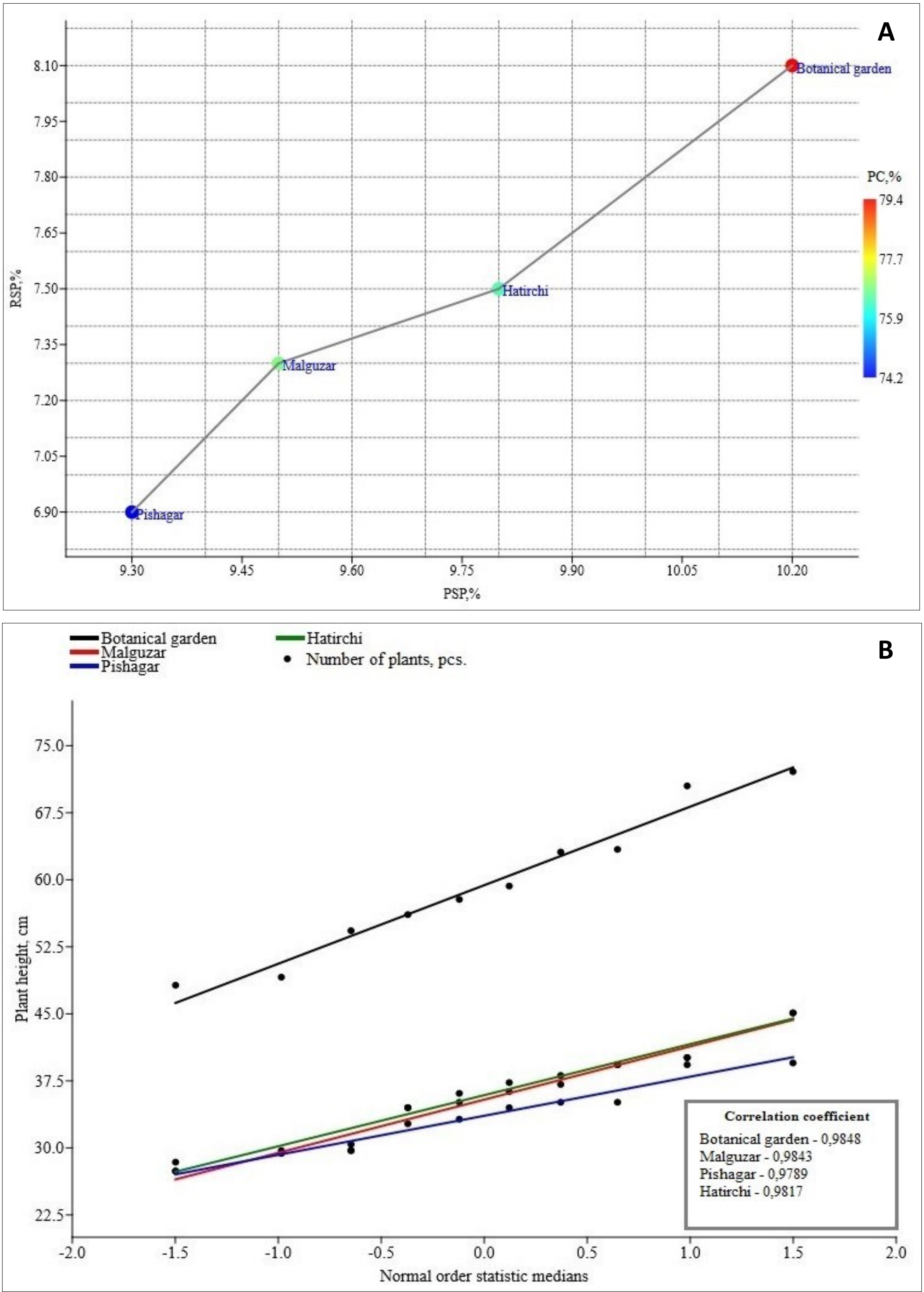

Fig. 6. Indicators of *L. usitatissimum* during the fruiting period in Uzbekistan: **A**-Seed productivity; **B**-Biometric indicators.

ditions, revealed that the main influencing factors on the productivity of the plant are the environmental factors. This can be explained by the coefficients of seed productivity in the regions: in the botanical garden it was 79.4±4.00% and in the rainfed zones: Malguzar 76.8±4.33%, Pishagar 74.2±4.54% and the Khatirchi district 76.5±4.28%.

The appearance of buds in *L. usitattisimum* after planting was observed in the first part of May, sometimes in mid-May, depending on the weather conditions of the year. The earliest flowering was noted at 18.05 days after planting, the most recent at 29.05. Fruiting occurs in early June - at the end of June. The end of vegetation is observed in late June - early July. The duration of vegetation in Malguzar conditions is 134-138 days, as well as in the Botanical Garden 140-145 days. The real seed productivity of one plant on average is in the conditions of the Botanical Garden 8.1±0.43 and in the rich lands: Malguzar 7.3±0.42; Pishagar 6.9±0.43; Khatyrchi district 7.5±0.40.

Conclusion

During the growing season, planting experiments of *Linum usitatissimum* L. were carried out in different environmental conditions of Uzbekistan. The species studied over the entire observation period underwent a full development cycle, reached the productive stage, tied fruits and formed viable seeds. According to the results of phenological studies, differences in the timing of the seasons of the growing period and its turn were revealed, according to morphometric parameters.

Thus, the obtained results showed that it is possible to grow *L. usitattisimum* in the rich zones of Uzbekistan, to obtain high-quality raw materials of the highly important crop plant. The results of the studies are recommended for use by farms in growing *L. usitatissimum* in the conditions of the Republic of Uzbekistan.

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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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