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Impact of Sowing Dates on the Variability of Different Traits of Fenugreek

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Abstract. The article presents the results of studies of two samples of fenugreek: blue (*Trigonella coerulea* (Desr.) Ser.) and hay (*Trigonella foenum graecum* L.) on the set of economic, biological and biochemical parameters. The researched samples of fenugreek have a wide range of variability of indicators depending on the terms of sowing and weather conditions. More rapid development was shown by fenugreek species on the summer sowing dates (III decade of June) with a vegetation period of 36–37 days. To obtain a high yield of green mass of fenugreek plants, the early spring (II–III decade of April) and late spring (I decade of May) sowing terms were more suitable. The obtained green mass yield was: 5.7–6.9 t·ha^{-1} – blue fenugreek, and 7.3–9.3 t·ha^{-1} – hay fenugreek, with the content of the dry matter being 12.4–28.4%, the sum of sugars 2.5–5.0% and vitamin C – 38.0–51.8 mg·(100 g)$^{-1}$. To obtain spices called "mushroom grass", it is promising to use hay fenugreek with early spring (II–III decade of April) and late spring (I decade of May) terms of sowing, as a more developed vegetative mass is formed with the dry weight yield of plants 1.3–1.4 t·ha^{-1}. An increase in the amount of precipitation by 1 mm resulted in fluctuations of green mass yield from 15.0 to 77.3 kg·ha^{-1} and dry mass yield from 0.693 to 25.9 kg·ha^{-1}.

Key words: fenugreek, sowing, beans, productivity, biochemical parameters.

Introduction

At the current stage of vegetable production there are many unresolved problems, among which some stand out, such as the lack of species diversity of vegetable crops, low yields and quality of vegetable products. There are also acute problems with regard to providing the population with protein–rich food, which is lacking in the daily diet of each person (Bobos *et al.,* 2019; Bobos & Kokoyko, 2013; Fernandez–Aparicio, Emeran & Rubiales, 2008).

The most common crops are hay or Greek fenugreek (*Trigonella foenum–graecum L.*) and blue fenugreek (*Trigonella caerulea L.*). The folk names of fenugreek are also known as fenugreek, mushroom grass, shamballa, chelba, camel grass, etc. (Bobos & Kokoyko, 2013; Bobos, 2015; Shelyuto, 2013). Fenugreek is considered to be native to the eastern part of the Mediterranean. It is widespread, and the greatest diversity of species is found in Asia Minor and Central Asia. The plant is recognised worldwide and is actively cultivated in many countries (Abramchuk, 2013; Acharya, Thomas & Basu, 2008; Fernandez–Aparicio, Emeran & Rubiales, 2008; Thirunavakkarasu & Anuradha, 2006).

Fenugreek is cultivated for spicy and aromatic mixtures, as fodder and as a greenhouse crop. Plants in fresh form do not have a pronouncedly intense smell, which only appears after drying during storage. Dried and powdered young shoots during flowering are used as seasoning in meat dishes and for cheese–making. Powdered seeds also smell like dried mushrooms and are used for flavouring in cooking and baking. Fenugreek seeds are indispensable in many dishes. In addition, fenugreek seeds are used for sprouts.

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Young plants are used to make salads, which are very beneficial for health as they contain biologically active substances (Bobos, 2015; Shelyuto, 2013; Fernandez–Aparicio, Emeran & Rubiales, 2008; Premanath, Sudisha & Aradhya, 2011; Thirunavakkarasu & Anuradha, 2006).

Fenugreek is especially valued by the peoples of the Caucasus, where it is widely used as a spice that gives a unique flavour and mushroom aroma to meat and vegetable dishes. It is also used as a spice for seasoning mixes such as hops-suneli, curry, and the chaman mixture used to coat basturma (cured meat loin). In Latvia, fenugreek is used to produce various sorts of cheese. In the United States, fenugreek is flavoured with rum and maple beverage, and sometimes added to dough. In India, roasted seeds are used to make a surrogate coffee (Acharya, Thomas & Basu, 2008; Thirunavakkarasu & Anuradha, 2006). Despite their importance in some Asian and North African countries, fenugreek is cultivated in many countries: yet data on the genetic diversity, intra- and inter-specific variability, and cultivation techniques are limited (Bobos, 2015; Beyzi & Gürbüz, 2020; Dangi *et al.,* 2004; Shelyuto, 2013; Xalxo & Keshavkant, 2020). This crop also has fodder value and is promising, but until recently it has been insufficiently studied and too poorly distributed to increase the production of fodder and plant protein in EU countries, including Latvia. The agronomic importance of fenugreek for increasing soil fertility due to the ability of this plant to form nitrogen–fixing nodules is known (Bobos, 2015; Shelyuto, 2013; Plechishchik *et al.,* 2010; Randhaw *et al*., 1996; Tonkha *et al.,* 2020; Pavlista & Santra, 2016; Xalxo & Keshavkant, 2020). In this regard, the study of the economic features of Greek fenugreek and blue fenugreek as crops, recently introduced and little studied in Ukraine and Latvia, is of great scientific and practical interest. The technology of growing fenugreek for spices in Ukraine and Latvia has not been developed. The main method of technology implementation, first of all, is the adaptation of species to growing conditions. For these species there are no domestic varieties created, and the vegetable growers grow local forms. The diversity of local samples in Ukraine is quite large. Moreover, the local varieties are not yet collected and are not systematised (Bobos *et al.,* 2019; Bobos & Kokoyko, 2013; Shelyuto, 2013; Plechishchik *et al.,* 2010). However, the problem of the impact of the sowing time on the growth and development of the fenugreek species in order to spread this diversity of crops remains relevant (Bobos et al., 2019; Bobos & Kokoyko, 2013; Pavlista & Santra, 2016; Xalxo & Keshavkant, 2020; Bulgakov *et al.,* 2020).

The aim of the study is to identify the adaptive properties of the fenugreek species, based on the study of the sowing time for conveyorised production.

Materials and Methods

Studies were conducted at the National University of Life and Environmental Sciences of Ukraine and Latvia University of Life Sciences and Technologies. Two local samples of fenugreek were studied: blue fenugreek (*Trigonella coerulea (Desr.) Ser.*) and hay fenugreek (*Trigonella foenum graecum L.*). The studies were carried out in three repetitions according to the method of two-factor experiments (Bondarenko & Yakovenko, 2001). Factor A is the fenugreek species, factor B is the sowing date. The total size of the study area was 120 m^2, one plot was 5 m^2. Four variants of sowing dates of Greek fenugreek and hay fenugreek were included in the experiment scheme. The species were sown simultaneously with four terms of sowing: early spring – II–III decade of April (10.04 – 2012, 24.04 – 2013, 10.04 – 2014); late spring the 1st term – III decade of April – I decade of May (25.04 – 2012, May – 10.06 – 2013, 04.04 – 2014); late–spring the 2nd term – II decade of May (15.05 – 2012, 17.05 – 2013, 14.05 – 2014); summer – I decade of June (10.06 – 2012, 04.06 – 2013, 05.06 – 2014). The seeds of early–spring and late–spring of the first term in 2013 had to be sown later because of the prolonged cold spring. Control – the early–spring sowing date (II–III decade of April). The cultivation technology of the fenugreek species is generally accepted under production conditions for leguminous crops (Sych, 2010). The seeds were sown manually in a 45 × 15 cm pattern. The sowing depth of blue fenugreek was 1.0–1.5 cm; that of hay fenugreek was 2.0–3.0 cm. After sprouting, thinning was carried out so that the distance in the row between the plants was 15 cm regardless of the sowing time. We formed the density of 150 thousand plants per hectare for all sowing dates.

Phenological phases were observed during the growing season: the beginning (10%) and mass (75%) sprouts; the beginning and mass flowering; and bean maturation. Sprouts were observed when the cotyledons appeared on the soil surface. The beginning of bean maturation was observed when 60–70% of the beans turned yellow. The duration of the growing season was calculated from the appearance of seedlings to the beginning of bean ripening.

The area of the site is located in the forest–steppe in Ukraine, in the Kiev Region. The climate of the zone is moderately continental, with warm summers and mild winters. According to long-term data, the annual air temperature is 7.0 °C. Average long-term temperature of the coldest month of January is minus 6.5 °C, and

the warmest month of July +19.8 °C. The minimum temperature according to long-term observations is –36 °C, and the maximum temperature is +39 °C. The sum of active temperatures above 10 °C within (total sum of temperatures – 2440 – 2700 °C), indicating high thermal resources for the cultivation of various types of leguminous vegetable crops. The soil of the site is dark grey medium-podsolised light loam, the reaction 5.1 pH of the soil environment is slightly acidic. The thickness of the humus horizon is 24–28 cm. The experimental plot is characterised by a low content of humus – 1.5–2.2%, average content of hydrolysed nitrogen – 26–38 mg·kg^{-1}, available phosphorus – 43–61 mg·kg^{-1} and potassium – 28–34 mg·kg^{-1} (Bobos *et al.,* 2019; Zavadska *et al.,* 2020). The depth of the arable layer is 20–22 cm. Black fallow was used as a precursor in 2012 and cucumber in 2013–2014. The main tillage of the crop included the autumn destruction of crop residues of the predecessor and weeds, deep autumn ploughing. Seven days before seeding, a mixture of N60 P40 K90 (ammonium nitrate, superphosphate, and potassium chloride) fertiliser was applied. In the first decade of April and before sowing, soil cultivation was carried out on the experimental plot according to the requirements (Novakovska I., *et.al.*, 2018). During the period of mass flowering, the vegetative mass of plants was cut from an area of 60 m^2. We analysed the yield of green mass during the period of mass flowering. At the same time, the sprouts of the 4th sowing date of 13.06 had not yet been revealed. The collected vegetative mass was dried for 7 days in a Shellab HF10 – 2 dry-air oven at +35 °C. The moisture content in the samples was 80.2–80.5%. After the plants had dried, the leaves and inflorescences were separated from the stems and weighed separately to determine the percentage content of different parts of the plant in relation to the plant as a whole. The content of leaves and inflorescences in the plants was within the range of 31.6–40.2%. The dry weight yield of the plants was analysed.

The green mass of the fenugreek species was analysed according to generally accepted methods (Zavadska *et al.,* 2020). The dry matter content was determined according to DSTU ISO 751 by thermogravimetric drying in a desiccator at 100–105 °C to constant weight; the sugar content (sum) – by Bertrand method; vitamin C – using a solution of 2.6 dichlorophenolindophenol. For the study, 3 replications of 100 g of fresh green mass of each species were taken and immediately analysed for the content of the main biochemical parameters.

Analysis of variance (ANOVA) and correlation and regression were performed using the XLSTAT add–in in MS Excel. Differences were considered significant when the value α = 0.95 (Kwanchai A. *et al.,* 1984; Nageswara Rao, 2007).

Results and Discussion

It was found that the growth and development of plants of the fenugreek species depends on the sowing dates. On the early spring sowing dates, the

Table 1

Impact of the sowing dates on the duration of phenological phases of growth and development of the fenugreek species (average for 2012–2014)

Time of sowing (factor B)	Duration of periods, days			
	Seeding – mass sprouting	mass sprouts – beginning of flowering	beginning of flowering – beginning of bean ripening	mass sprouting – beginning of bean maturation
Fenugreek blue (factor A)				
Early spring (II–III decade of April) (control)	12	40	10	50
Late spring the 1st term (III decade of April – I decade of May)	9	37	9	46
Late spring the 2nd term (II decade of May)	8	32	8	40
Summer (I decade of June)	6	29	7	36
Fenugreek hay				
Early spring (II–III decade of April) (control)	13	38	14	52
Late spring the 1st term (III decade of April – I decade of May)	11	35	14	49
Late spring the 2nd term (II decade of May)	9	32	13	45
Summer (I decade of June)	8	28	9	37

vegetation period of species increased by 14–15 days in contrast to the summer sowing dates on average, for three years. At the same time, species with summer sowing dates sprouted 5 days faster after sowing. Mass sprouting of the fenugreek species was longer at the early spring sowing dates. This is due to lower temperatures during this period. On the following sowing dates, the fenugreek species sprouted 7–9 days earlier compared to the control species. The duration of the inter-phase periods differed for the fenugreek species, and depended on the sowing date (Table 1). The duration of the period from sowing to mass sprouting was revealed in species with the summer sowing dates – 6–8 days, which is 4–6 days less than for the control species. This is due to increased air and soil temperatures during this period, which accelerated the passage of all the phases of plant growth and development.

The results showed that the sowing dates influenced the duration of the phase from mass sprouting to the beginning of flowering, which in the species ranged from 28 to 40 days. The fenugreek species, sown on the summer sowing dates, developed faster, with a period of 28–29 days, which is 10–11 days less than for the control species. This is due to the hot weather and rapid heating of the soil surface in summer, which accelerates the start of all the phases of growth and development of the fenugreek species.

The productivity and average yield of the green mass of the fenugreek species depended on the sowing date (factor B). A significant difference was found between the control option of late spring (2 dates) and summer sowing dates. No significant difference was found between economic indicators of blue fenugreek and hay fenugreek (Table 2). Plant productivity determines the yield and the yield of green mass, as a whole. The hay fenugreek plants are characterised by a more developed vegetative mass, with the formation of leaves of a larger size and more shoots, which affected their productivity (Fig. 1 a). At the same time, plant productivity was 62.7 g for the early spring sowing dates and decreased by 87.3% for the summer sowing dates.

For the early spring sowing dates, plant productivity was higher, on average, over three years for both – hay fenugreek and blue fenugreek, and it was 46.7–62.7 g. The summer sowing dates reduced plant productivity to 7.1–8.0 g. This is due to the cold resistance of the species for which optimal conditions for growth and development of the plants set in at moderate temperatures.

Table 2

Impact of sowing dates on indicators of green mass of fenugreek species (average for 2012–2014)

Times of sowing (factor B)	Average productivity, g	Yield of green mass a year, t·ha^{-1}			Average yield of green mass, t·ha^{-1}	Increase of yield		Stability factor (S.F.)
		2012	2013	2014		t·ha^{-1}	%	
Fenugreek blue (Factor A)								
Early spring (II–III decade of April) (control)	46.7	9.5	6.0	5.1	6.9	0	100	1.9
Late spring the 1st term (III decade of April – I decade of May)	38.5	8.2	4.6	4.4	5.7	–1.2	–17	1.9
Late spring the 2nd term (II decade of May)	26.9	4.9	3.6	3.4	4.0	–2.9	–42	1.4
Summer (I decade of June)	7.1	1.4	0.9	0.9	1.1	–5.8	–84	1.6
Fenugreek hay								
Early spring (II–III decade of April) (control)	62.7	10.2	9.0	8.7	9.3	0	100	1.2
Late spring the 1st term (III decade of April – I decade of May)	47.9	8.8	7.0	6.1	7.3	–2.0	–21	1.4
Late spring the 2nd term (II decade of May)	29.0	5.4	3.8	3.7	4.3	–5.0	–54	1.4
Summer (I decade of June)	8.0	1.7	1.0	0.9	1.2	–8.1	–87	1.9
HCP_{05}	–	1.5	1.2	1.1	–	–	–	–
Factor A	–	0.8	0.7	0.5	–	–	–	–
Factor B	–	1.1	1.1	0.9	–	–	–	–



a b

Figure 1. The plants during flowering on early spring sowing dates: (a) hay fenugreek; (b) blue fenugreek.

The yield of green mass of plants depended significantly on both – the species and the sowing date. The highest yield of green mass was found for early spring sowing, which during three years was, on average, 6.9 t·ha^{-1} for blue fenugreek and 9.3 t·ha^{-1} for hay fenugreek. At the same time, blue fenugreek was found to be less adaptive to growing conditions, with a stability coefficient of 1.9. The fenugreek blue plants are characterised by less developed vegetative mass, with the formation of leaves of a smaller size and fewer shoots compared to fenugreek, which influenced their lower productivity (Fig. 1 b). The low yield was characterised for the fenugreek species in the dry spring of 2014, which affected the formation of less developed vegetative apparatus and the more intense passage of all phases of plant growth and development.

The low yield of green mass of the fenugreek plants for the late spring (II decade of May) and summer (I decade of June) sowing dates is due to the less developed vegetative apparatus of the plants. High air and soil temperatures contributed to the rapid passage of all the phases of the plant growth and development. However, the intensity of growth of the aboveground mass of the fenugreek species was weaker. Therefore, these dates are not suitable for growing the fenugreek species in the forest–steppe of Ukraine. Sowing with summer terms reduced the yield of green mass of the fenugreek species by 84–87% compared to the control species. At the same time, blue fenugreek was found to be more adaptive to the summer growing conditions with a stability coefficient of 1.6. At the same time, no significant difference was found from the control species for the first late spring sowing date. The average green mass yield of the species on this sowing date was, on average, 5.7–7.3 t·ha^{-1} during three years, which was 17–21% lower than the control yield. Considerably low green mass yield was obtained with the summer sowing dates for fenugreek from 0.9 to 1.7 t·ha^{-1}, and for blue fenugreek from 0.9 to 1.4 t·ha^{-1} (Fig. 2).

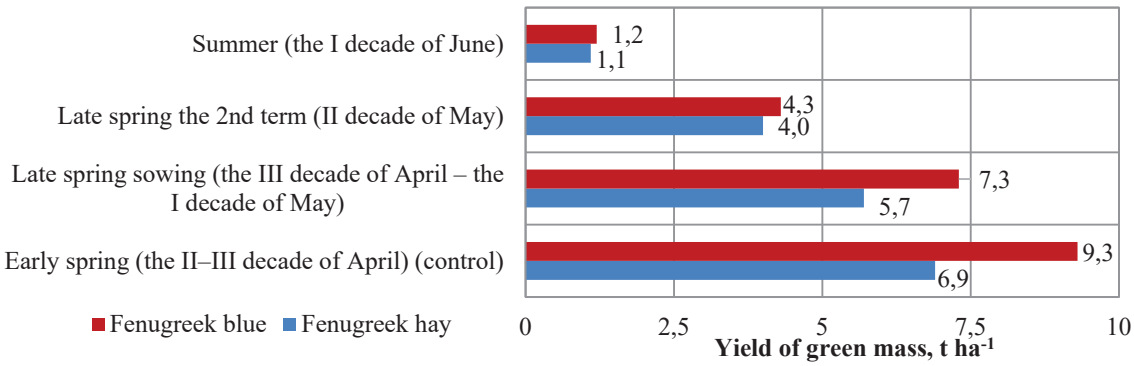


Figure 2. Dynamics of yield formation of green mass of fenugreek species.

Table 3

Impact of sowing dates on biochemical indicators of green mass of fenugreek species (average for 2012–2014)

Times of sowing (factor B)	Dry matter, %	Sum of sugars, %	Vitamin C, mg (100 g)$^{-1}$
Fenugreek blue (factor A)			
Early spring (II–III decade of April) (control)	12.4	2.5	45.4
Late spring the 1st term (III decade of April – I decade of May)	18.8	4.0	38.0
Late spring the 2nd term (II decade of May)	16.0	2.8	26.0
Summer (I decade of June)	15.5	2.2	19.7
Fenugreek hay			
Early spring (II–III decade of April) (control)	18.0	2.6	51.8
Late spring the 1st term (III decade of April – I decade of May)	28.4	5.0	49.7
Late spring the 2nd term (II decade of May)	20.4	3.4	26.7
Summer (I decade of June)	18.5	2.7	20.1
HIP_{05}	4.9	0.7	6.5
Factor A	2.4	0.4	3.3
Factor B	3.4	0.5	4.6

Table 4

Impact of sowing dates on indicators of dry weight of fenugreek species (average for 2012–2014)

Timing of sowing (factor B)	Average coefficient of moisture loss	Yield dry weight by years, t·ha^{-1}			Average dry matter yield, t ha^{-1}	Yield increase		Stability factor (S.F.)
		2012	2013	2014		t·ha^{-1}	%	
Fenugreek blue (factor A)								
Early spring (II–III decade of April) (control)	6.5	1.3	1.2	1.0	1.2	0	100	1.3
Late spring the 1st term (III decade of April – I decade of May)	5.7	1.3	1.1	0.9	1.1	–0.1	–8	1.4
Late spring the 2nd term (II decade of May)	4.0	1.2	0.9	0.8	1.0	–0.2	–17	1.4
Summer (I decade of June)	1.8	0.7	0.6	0.5	0.6	–0.6	–50	1.5
Fenugreek hay								
Early spring (II–III decade of April) (control)	6.7	1.5	1.4	1.3	1.4	0	100	1.1
Late spring the 1st term (III decade of April – I decade of May)	5.9	1.4	1.3	1.1	1.3	–0.1	–7	1.3
Late spring the 2nd term (II decade of May)	4.0	1.4	0.9	0.9	1.1	–0.3	–21	1.6
Summer (I decade of June)	1.5	1.0	0.7	0.6	0.8	–0.6	–43	1.7
HIP_{05}	-	0.5	0.5	0.4	-	-	-	
Factor A	-	0.2	0.1	0.1	-	-	-	-
Factor B	-	0.3	0.3	0.2	-	-	-	-

Studies have found that the biochemical composition of green mass of the fenugreek species significantly depended on both – the species and the sowing date (Table 3).

According to the results of biochemical analyses it was found that the quality indices of fresh green mass of the fenugreek species improved with late spring sowing (III decade of April – I decade of May). At the same time, the content of the dry matter was 18.8–28.4%. A higher content of dry matter was revealed in the green mass of hay fenugreek. Such a tendency was also noted for other indicators. This is explained by the greater height of blue fenugreek, which leads to the shading of plants, slowing down the process of photosynthesis, and less accumulation of dry matter and sugars.

For the early spring sowing dates the quality indicators deteriorated, the dry matter and sugar content of fenugreek was 18.0 and 2.6%, respectively, and that of blue fenugreek was 12.4 and 2.5%. This is explained by slower photosynthesis in the plants at lower temperatures. However, the content of vitamin C increases for the early spring sowing date. This index was higher in the control samples, and it was 51.8 in hay fenugreek and 45.4 mg·(100 g)$^{-1}$ raw weight in blue fenugreek. For later dates, the vitamin C content decreases and for summer sowing this figure was lowest, amounting to 19.7–20.1 mg·(100 g)$^{-1}$ of crude weight. The dried upper part of the leaves and inflorescences of the plants of fenugreek species are more often used for food needs. Therefore it became necessary to determine the economic indicators of dried products. On average, for three years it was found that the dry weight yield of the fenugreek species significantly depended on the sowing date (Factor B) (Table 4).

The yield of the dry mass of fenugreek depended on the coefficient of moisture loss, which is lower with summer sowing terms, and was 1.5–1.8. This is due to high temperatures in summer and the loss of turgor due to the intensive breathing of plants. The high coefficient of moisture loss is characterised for the species with early spring terms of sowing (6.5–6.7). Moreover, this index is lower for blue fenugreek. Meanwhile, blue fenugreek was found to be less adaptive on early spring sowing dates compared to hay fenugreek with a stability coefficient of 1.3.

High dry matter yields were obtained for early–spring and late–spring sowing dates due to the high yield of the green mass of plants, which was 1.1–1.2 for blue fenugreek and 1.3–1.4 t·ha^{-1} for hay fenugreek. The species with summer sowing dates (0.6–0.8 t·ha^{-1}) were characterised by a low dry matter yield (Fig. 3).

This is due to the low yield of green mass, despite the lower moisture loss (1.5–1.8). On average, on the summer sowing dates the dry matter yield decreased by 43–50% compared to the control in three years.

The dry matter yield of fenugreek was higher for all the sowing dates (0.8–1.4 t·ha^{-1}) compared to blue fenugreek (0.6–1.2 t·ha^{-1}). Moreover, no significant difference was found between the dry weight yield of early spring and the 1st late spring sowing dates, which was 1.3–1.4 t·ha^{-1} for fenugreek. The late spring sowing dates (II decade of May) and the summer sowing dates (I decade of June) proved to be unsuitable for growing the fenugreek species, which produced the lowest yield of green mass and dry mass of plants, which was 0.6–0.8 t·ha^{-1} for fenugreek. During the 2012–2014 growing season for fenugreek, depending on the sowing times, the sum of effective air temperatures (>10 °C) ranged from 316 to 508 °C, and the amount of precipitation from 36 to 195 mm. The green matter yields ranged from 0.9 t·ha^{-1} to 10.2 t·ha^{-1}, depending on the sowing time, the physico-mechanical properties of the soil and the meteorological conditions. This makes it possible to determine the criterion of yield level variability for each 1 °C of the sum of the effective air temperatures and 1 mm of precipitation. There is also a direct strong relationship between the fenugreek green mass yield and the dry mass yield (r = 0.88 to 0.99). There is a direct clear relationship (r = 0.66 to 0.99) between the fenugreek dry matter yield by sowing dates and the sum of effective temperatures.

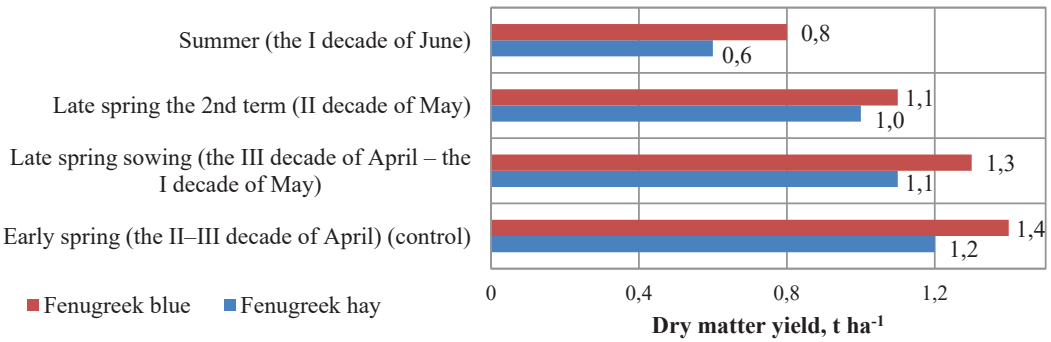


Figure 3. Dynamics of formation of dry weight yield of fenugreek species.

Table 5

Simulation of yield formation of fenugreek species

Times of sowing	Regression equations	
	green mass yield (y)	dry mass yield (y)
Fenugreek blue		
Early spring (II – III decade of April) (control)	$y=71.408+0.1277*x_1+0.1465*x_2$	$y=2.3375+0.0061*x_1+0.0054*x_2$
Late spring the 1st term (III decade of April – I decade of May)	$y=21.5585+0.0533*x_1+0.0283*x_2$	$y=0.6787+0.0039*x_1+0.000145*x_2$
Late spring the 2nd term (II decade of May)	$y=18.8633–0.0111*x_1–0.0967*x_2$	$y=4.1151–0.0018*x_1–0.0225*x_2$
Summer (I decade of June)	$y=4.2259–0.0048*x_1–0.0161*x_2$	$y=1.0105–0.0004*x_1–0.034*x_2$
Fenugreek hay		
Early spring (II–III decade of April) (control)	$y=0.2199+0.0141*x_1+0.015*x_2$	$y=0.4699+0.0016*x_1+0.0011*x_2$
Late spring the 1st term (III decade of April – I decade of May)	$y=11.5108+0.0339*x_1+0.0227*x_2$	$y=0.3536+0.0022*x_1–0.0007*x_2$
Late spring the 2nd term (II decade of May)	$y=13.8269+0.0212*x_1+0.0773*x_2$	$y=4.7949+0.0066*x_1+0.0259*x_2$
Summer (I decade of June)	$y=4.0142+0.0102*x_1+0.0184*x_2$	$y=1.3691+0.0043*x_1+0.0068*x_2$

Note: x_1 – the sum of effective temperatures (>10 °C); x_2 – the sum of precipitation, mm^{-1}.

An average and pronounced inverse relationship (r = – 0.48–0.99) was found between the dry mass yield of fenugreek by the sowing dates and the precipitation sum (Table 5).

In order to establish the direction and nature of influence of the parameters of the sum of effective air temperatures (>10 °C) and the amount of precipitation on the yield of the fenugreek species by sowing dates, we calculated regression equations. According to the results of the regression equations, it was found that an increase in the sum of effective temperatures by 1 °C contributed to the variation of the yield of blue fenugreek by the sowing dates of the green mass from 4.82 to 128 kg·ha^{-1}, and of the dry mass from 0.401 to 6.06 kg·ha^{-1}. An increase in the precipitation amount by 1 mm contributed to the variation of the green mass yield from 16.1 to 146 kg·ha^{-1} and dry mass from 0.145 to 22.7 kg·ha^{-1}. Increase in the sum of effective temperatures by 1 °C caused a variation of hay fenugreek yield by sowing dates from 10.25 to 33.9 kg·ha^{-1} of the green mass, and from 1.58 to 6.63 kg·ha^{-1} of the dry mass. An increase in the precipitation amount by 1 mm led to fluctuations of the green mass yield from 15.0 to 77.3 kg·ha^{-1}, and of the dry mass from 0.693 to 25.9 kg·ha^{-1}.

Conclusions

The fenugreek species have a wide range of variability of morphological and economically valuable features depending on the sowing dates. The fenugreek species had more rapid development with the summer sowing dates, with a short duration of the growing season of 36–37 days. On the early spring sowing dates the vegetation period of the fenugreek species became longer, and it amounted to 50–52 days.

To obtain a high yield of green mass of fenugreek plants, the early spring (II–III decade of April) and late spring (I decade of May) sowing terms were more suitable. The obtained green mass yield was: 5.7–6.9 t·ha^{-1} – blue fenugreek, and 7.3–9.3 t·ha^{-1} – hay fenugreek, with the content of the dry matter being 12.4–28.4%, the sum of sugars 2.5–5.0% and vitamin C – 38.0–51.8 mg·100 g^{-1}.

To obtain spices, such as “mushroom grass”, it is more appropriate to use fenugreek with the early spring (II–III decade of April) and late spring (I decade of May) terms of sowing, which forms a more developed vegetative mass with the dry weight yield of plants 1.3–1.4 t·ha^{-1} and seed yield of 0.9–2.0 t·ha^{-1}, with 1000 seeds weighing 9.0–9.7 g.

Increasing the sum of effective temperatures by 1 °C caused a variation of the fenugreek yield with the sowing dates from 10.25 to 33.9 kg·ha^{-1} of green mass, and from 1.58 to 6.63 kg·ha^{-1} of dry mass. An increase in the precipitation amount by 1 mm contributed to fluctuations of the green mass yield from 15.0 to 77.3 kg·ha^{-1} and of the dry mass from 0.693 to 25.9 kg·ha^{-1}.

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