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Research into properties of blue melilot and fenugreek cultivated using different sowing times

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Abstract. The paper presents the results of the research into the properties of blue melilot (*Melilotus caeruleus* (L.) Desr.) and fenugreek (*Trigonella foenum graecum* L.) with regard to the set of their economy-and-biology and biochemical indices in relation to the dates of their sowing. It has been established that the two species under consideration feature wide ranges of index variability depending on the sowing term and the weather conditions. The earliest ripening terms have been recorded for species in case of summer sowing dates (decade I of June), when short growing season lengths of 36–37 days were observed. At the same time, in terms of heavy plant herbage yield obtained from species in the green conveyor system, the early spring (decades II–III of April) and late spring (decade I of May) sowing terms are more suitable providing a herbage yield of 5.7–6.9 t ha^{-1} in case of blue melilot and 7.3–9.3 t ha^{-1} for fenugreek, with a solids content of 12.4–28.4%, total sugars of 2.5–5.0% and vitamin C - 38.0–51.8 mg $(100\ g)^{-1}$. For the purpose of obtaining the spice named 'Greek hay' (foenum Graecum), a better choice is to cultivate fenugreek with early spring (decades II–III of April) and late spring (decade I of May) sowing times, as in this case a greater vegetation mass develops, resulting in a plant dry weight yield of 1.3–1.4 t ha^{-1}. An increase in the total precipitation by 1 mm has contributed to the variation of the herbage yield within the range of 15.0 to 77.3 kg ha^{-1}, dry matter yield - 0.693 to 25.9 kg ha^{-1}. High seed yield has been noted in case of sowing the species in early spring (decades II–III of April), where the seed yield of blue melilot was equal to 0.4 t ha^{-1}, fenugreek - 2.0 t ha^{-1}, their 1,000 seeds having a weight of 0.71 and 9.7 g, respectively.

Key words: blue melilot, fenugreek, sowing time, herbage and dry weight, pod, yield.

INTRODUCTION

The current stage of development in the vegetable farming industry features multiple unresolved problems, the most marked ones being the insufficient vegetable crop species diversity, the low yield capacity and the low quality of the output vegetable products. At the same time, supplying the population with the food products that are rich with protein, a nutrient that is deficient in everyone's daily diet, remains a high priority topic (Pandian et al., 2002; Fernandez-Aparicio et al., 2008; Bobos, 2013; Bobos & Kokoyko, 2013; Bobos et al., 2019; Tonkha et al., 2020).

Legumes (*Fabaceae* Lindl.) are of high nutritional value. They are recognized, first of all, as a source of easily digestible proteins and vitamins. The global diversity of arable vegetable legumes is huge and includes over 40 species (Yakovlev, 1991; Pandian et al., 2002; Fernandez-Aparicio et al., 2008; Bobos, 2013; Bobos & Kokoyko, 2013; Bobos et al., 2019).

In cultivation, fenugreek (*Trigonella foenum graecum* L.) is the most commonly encountered species, but blue melilot (*Melilotus caeruleus* (L.) Desr.) is the most commonly not encountered species (Pandian et al., 2002; Bobos, 2013; Bobos & Kokoyko, 2013; Bobos, 2015; Shelyuto, 2013).

It is generally assumed that *Trigonella* species come from the eastern part of the Mediterranean. They are widely present and have the greatest diversity of species in Asia Minor and Central Asia. The value of the plant is recognized all over the globe and it is actively cultivated in many countries (Thirunavukkarasu & Anuradha, 2007; Acharya et al., 2008; Fernandez-Aparicio et al., 2008; Bobos, 2013; Abramchuk & Karpuhin, 2018).

Trigonella and blue melilot species are cultivated for obtaining spice and flavour mixtures and as fodder and green manure crops (Ates, 2016). Fresh herbage does not produce any pronounced intense flavour, it appears only after its drying in the process of storage. Young shoot apices harvested in the blooming period, dried and beaten to powder are used as a spice for meat dishes and in cheese-making. Moreover, ground seeds fenugreek and blue melilot powder plant smell like dried mushrooms and are used in gastronomy and the bread baking industry. Trigonella seeds are an irreplaceable component in the cooking of many dishes. Apart from that, trigonella seeds are used to obtain sprouts. Young plants are used for making salads, which are very good for health due to the biologically active substances contained in them (Thirunavukkarasu & Anuradha, 2007; Fernandez-Aparicio et al., 2008; Premanath et al., 2011; Bobos, 2013; Shelyuto, 2013; Bobos, 2015; Zemzmi et al., 2017).

In the USA, *Trigonella* is used for flavouring rum and maple drinks, sometimes it is added to dough. In India, coffee substitutes are made from its roasted seeds (Thirunavakkarasu & Anuradha, 2006; Acharya et al., 2008).

These crops ~~is~~ are also recognized as having medicinal properties. Fenugreek seeds gathered at the stage of biological ripeness are used in the capacity of drug raw materials. They contain alkaloids (trigonelline), essential oils, steroidal saponins, flavonoids, coumarins, polysaccharides, proteins (amino acids: alanine, arginine, glycine, methionine and other), carbohydrates (45–60%), vitamins (A, C, B, P), mineral salts (Ca, Mg, P, Fe, K, S and other) (Pandian et al., 2002; Devasena & Menon, 2003; Acharya et al., 2008 Premanath et al., 2011; Shelyuto, 2013; Arslan et al., 2016; Abramchuk& Karpuhin, 2018). The polyphenols of the plant possess pronounced antioxidative, hepatoprotective and antibacterial properties (Srinivasan, 2006; Kaviarasan et al., 2007; Al-Timimi, 2019).

The highest pharmacological activity is typical for the plant's steroidal saponins, which are used both for the preventive care and the treatment of cardiovascular diseases and atherosclerosis (Premanath et al., 2011; Shelyuto, 2013; Al-Timimi, 2019). Steroidal saponins are effective in the treatment of rheumatic diseases, hemolitic anemia, bronchial asthma, gastric ulcer (Devasena & Menon, 2003; Srinivasan, 2006; Plechishchik et al., 2010; Abramchuk & Karpuhin, 2018). In many countries, fenugreek seeds are included in the contents of the combined pharmaceuticals that have antidiabetic, antisclerotic, diuretic, laxative, anti-inflammatory effects (Srinivasan, 2006; Kaviarasan et al., 2007; Bafadam et al., 2019).

Despite the high importance of the above-mentioned species for a number of Asian and North African countries and the fact that they are cultivated in many countries, the data on their genetic diversity, the intraspecies and interspecies variation and the agronomic practices of their cultivation are limited (Dangi et al., 2004; Shelyuto, 2013; Bobos, 2015; Beyzi & Gürbüz, 2020; Xalxo & Keshavkant, 2020).

The crops under consideration are also of importance for feeding purposes and is a promising one in that sector. However, until recently it has been inadequately researched into and of limited occurrence for the purposes of increasing the production of fodder and plant proteins in the territories of the EU and other countries, including Ukraine. It is well-known that *Trigonella* species and blue melilot have agronomic importance in the improvement of soil fertility due to the ability of the plant to form nitrogen-assimilating tubercles (Randhawa et al., 1996; Plechishchik et al., 2010; Shelyuto, 2013; Bobos, 2015; Pavlista & Santra, 2016; Xalxo & Keshavkant, 2020).

In view of the above, research into the economically valuable properties of fenugreek and blue melilot as crops only recently introduced and little researched in the conditions of Ukraine is of great scientific and practical interest. No technology has been developed for cultivating *Trigonella* species in the conditions of Ukraine for the purpose of spice production. The primary method of technology implementation is the adaptation of species to the cultivation conditions. No domestic varieties has been bred for these species and vegetable growers just cultivate local forms. The varietal diversity of local specimen in Ukraine is rather large. At the same time, the local varieties have not until know been set in collections and systematised (Plechishchik et al., 2010; Bobos, 2013; Bobos & Kokoyko, 2013; Shelyuto, 2013; Bobos et al., 2019).

The authors have been carrying out work on research into the production methods and the development of the green conveyor for the cultivation of *Trigonella* and blue melilot as a valuable medical and spice-and-flavour crop. Therefore, the problem of the effect that the sowing terms have on the growth and development of *Trigonella* species and blue melilot in the context of widening the green crop species diversity remains a topical one (Bobos & Kokoyko, 2013; Sych & Bobos, 2013; Pavlista & Santra, 2016; Bobos et al., 2019; Xalxo & Keshavkant, 2020).

The aim of the completed study was to determine the properties of fenugreek and blue melilot in terms of exploring the sowing times for the purpose of delivering products in conveyor in the conditions of the Forest Steppe Region. The research into the economically valuable properties of the crop species would enable the development of technologies for the cultivation of a spice named 'mushroom grass', which would result in expanding the legume species diversity and improving the supply of cheap digestible protein to the population. The research target was in summary to determine the following: the timing of phenological stages, the growing season duration, the yield of fresh and dried leaves, their biochemical composition and the seed productivity of the plants.

MATERIALS AND METHODS

The research had been carried out for 3 years (2018–2020) in the National University of Life and Environmental Sciences of Ukraine (NUBiP) in the collection field of the Horticultural Garden situated in the Kiev Province, without watering. Two local specimen were under investigation: blue melilot and fenugreek (*Trigonella foenum graecum* L.). The investigations were carried out with three replicates using the two-factor experiment technique (Bondarenka & Yakovenka, 2001). Factor A - trigonella species, factor B - sowing date. The total recorded area was 120 m^2, one plot - 5 m^2.

The experimental design included four sowing time options for blue melilot and fenugreek. Both the species were sown simultaneously at the following four sowing terms: early spring - decades II–III of April (10.04. - the 1st year, 24.04. - the 2nd year, 10.04. - the 3rd year); late spring, term 1 - decade III of April - decade I of May (25.04. - the 1st year, 08.05. - the 2nd year, 29.04. - the 3rd year); late spring, term 2 - decade II of May (15.05. - the 1st year, 17.05. - the 2nd year, 14.05. - the 3rd year); summer - decade I of June (10.06. - the 1st year, 04.06. - the 2nd year, 05.06. - the 3rd year). The early spring sowing term (decades II–III of April) was assumed to be the reference case in the study.

The study employed the generally accepted approach, according to which *Trigonella* species should be cultivated in the production conditions suitable for legumes (Sych et al., 2010). The seeds were drilled manually following the 45×15 cm pattern. The sowing depth was 1.0–1.5 cm for blue melilot; 2.0–3.0 cm for fenugreek. After the appearance of seedlings, thinning was carried out with a target of setting the distance between the plants in a row at 15 cm, irrespective of the sowing time. At all sowing dates, the density of stand was arranged at 15 plants per m^2 (Maletić & Jevdjović, 2007).

During the growth of the plant, the following phenological stages were marked: start of (10%) and massive (75%) seedlings; start of and massive flowering; ripening of pods. Seedlings were recorded, when the seed lobes appeared on the surface of the soil. The beginning of pod ripening was recorded, when 60–70% of the seedpods had been yellowed. The duration of the vegetation period was counted from the appearance of seedlings to the beginning of pod ripening.

The territory of the research field is situated in the Forest Steppe Region. The climate of the area is moderately continental, with warm summer and not cold winter. According to the long-term data, the annual mean temperature is equal to 7.0 °C. The long-term mean temperature of the coldest month of January is equal to minus 6.5 °C, the warmest one, July + 19.8 °C. In accordance with the long-term monitoring data, the minimum temperature is equal to -36 °C, the maximum one - to +39 °C. The sum of effective temperatures above 10 °C is within the range of 2,440–2,700 °C, which is the evidence of high calorific resources available for growing various species of leguminous vegetable crops.

The soil in the field is medium-podzolic, roughly dusty, easy loamy soil, the reaction of the soil medium is slightly acid. The humus horizon thickness is equal to 24–28 cm. The experimental field features low humus content 4 - 1.5–2.2%, moderate contents of hydrolysable nitrogen - 26–38 mg kg^{-1}, labile phosphorus - 43–61 and potassium - 28–34 mg kg^{-1} (Bobos et al., 2019; Zavadska et al., 2020).

The depth of top soil is 20–22 cm. The preceding backgrounds were as follows: black fallow in the 1st year, in the 2nd and 3rd years - cucumber plantings. The primary tillage of the soil for the crop involved autumnal eradication of the plant residues from the preceding crop and weeds, deep autumn ploughing. 7 days prior to seed sowing, the N60P40K90 fertiliser mixture (German saltpetre, superphosphate and potassium chloride) was applied. In the first decade of April and prior to sowing, the experimental field was tilled to depths of 12–15 cm and 6–8 cm, respectively, with the use of a KPSP-4 tiller unitised with a DT-75 tractor, then levelled off with a harrow and the seeds were sown. In the massive plant flowering period, the plants' vegetative mass was cut for hay in an area of 60 m^2. The herbage output in the massive flowering period was analysed.

The harvested vegetative mass had for 7 days been dried in the Shellab HF10-2 dry-air drying cabinet at a temperature of +35 °C. The moisture content in the specimen was equal to 80.2–80.5%. After drying the plants, the leaves and flower heads were separated from the stems and were weighed separately in order to determine the per cent content of different plant components in the plant as a whole.

In order to determine the seed productivity, the plants were harvested at a seed moisture content of 18–20%. After harvesting, the seeds had been finally dried for 7–10 days in the Shellab HF10-2 dry-air drying cabinet at a temperature of +35 °C, then they were sieved through a set of sieves with gauges of 1.0–2.5 mm. The variability was analysed for the following main economically valuable properties of the reproductive organs: the number of seedpods on a plant, the seedpod length, the seed productivity and yield, also the mass of 1,000 seeds. The seed productivity indices were determined at the seedpod biological ripening stage.

The analysis of the herbage obtained from species was carried out in the conditions of the research-and-study laboratory under the Department of Storage, Processing and Standardization of Crop Products named after Prof. B.V. Lesik, NUBiP, in accordance with the standard practices (Zavadska et al., 2020). The content of solid matter was determined in accordance with DSTU ISO 751 with the use of thermal gravimetric analysis by drying the sample in the drying cabinet at a temperature of 100–105 °C until the mass became constant. The content of sugars (total) was determined with the use of Bertrand's method; vitamin C - with the use of 2,6-dichlorophenolindophenol solution. For the purposes of research, 100 g of fresh herbage were sampled for each species with 3 replicates and immediately analysed with regard to the contents of the main biochemical components.

The obtained research results were statistically analysed with the use of the methods of the analysis of variance and the correlation and regression analysis (Rao, 2007).

The analysis of variance was applied in the form of the statistical research into the probable effect that the involved factors (species and sowing time) and their interaction had on the resulting property. The significance of the difference between means was estimated by the least significant difference (*LSD*). This statistical value was compared with the difference between arithmetic means (d). If $d \geq LSD$, the difference between the alternatives was significant, but if $d < LSD$ - it was not significant, inessential. The difference between the means that exceeded *LSD*, was calculated with a 5% significance level. The analysis was carried out for each year.

For the purpose of measuring the closeness and form of the relationship, the special statistical methods called correlation analysis and regression analysis were used.

RESULTS AND DISCUSSION

It has been established that the growth and development of species depend on the sowing terms. In case of early spring sowing times, the vegetative season increases by 14–15 days as compared to summer sowing dates, on the average for three years. At the same time, in case of summer sowing terms, the earlier massive emergence of seedlings has been recorded for the researched species - on the 5th day after drilling. In case of early spring sowing terms, the massive emergence of seedlings becomes a lengthier process. That is due to the lower temperatures in the respective period. In case of the next sowing terms, fenugreek and blue melilot seedlings emerge 7–9 days earlier as compared to the reference case.

The duration of interstage periods differs for species under consideration and depends on the sowing date (Table 1). When the species are sown in summer, the duration of the period from seeding to massive seedlings is 6–8 days, according to the records, which is 4–6 days shorter, than in the reference case. This is due to the increased temperature of the air and soil in this period, which promotes the accelerated completion of all stages of plant growth and development.

Table 1. Impact of sowing terms on duration of phenological stages of growth and development for fenugreek and blue melilot species

Sowing term (factor B)	Duration of periods [days]			
	Seeding - massive seedlings	Massive seedlings - start of flowering	Start of flowering - start of seedpod ripening	Massive seedlings - start of seedpod ripening
Blue melilot (factor A)				
Early spring (decades II–III of April) (reference case)	12	40	10	50
Late spring, term 1 (decade III of April-decade I of May)	9	37	9	46
Late spring, term 2 (decade II of May)	8	32	8	40
Summer (decade I of June)	6	29	7	36
Fenugreek				
Early spring (decades II–III of April) (reference case)	13	38	14	52
Late spring, term 1 (decade III of April-decade I of May)	11	35	14	49
Late spring, term 2 (decade II of May)	9	32	13	45
Summer (decade I of June)	8	28	9	37

According to Güzel & Özyazıcı (2021), the time until the emergence of seedlings, the time until the 50% flowering of the plants and the growing period of various *Trigonella* genotypes vary within the ranges of 16.0 to 19.9 days, 160.9 to 170.4 days, 202.0 to 209.3 days, respectively. However, the highest values of these indices have been observed for the genotypes grown in Iraq and Afghanistan.

According to the results of investigations, it has been established that the sowing terms have effect on the duration of the stage from massive seedlings to the start of flowering, which has varied for the species within the range of 28 to 40 days. The earliest completion of it is typical for the species sown on summer sowing terms. Their stage duration is 28–29 days, which is 10–11 days shorter, than in the reference case. That results from hot weather and the rapid warming of the soil surface in the summer season, which accelerates the initiation of all species growth and development stages.

The economically valuable indices of the species that had been researched for 3 years are shown in Table 2.

Table 2. Impact of sowing terms on economically valuable indices of fenugreek and blue melilot herbage

Species (factor A)	Sowing terms (factor B)	Mean productivity, g	Herbage yield in years t ha^{-1}			Mean yield, t ha^{-1}	Yield increase		Stability factor (S.F.)
			1st year	2nd year	3rd year		t ha^{-1}	%	
Blue melilot	Early spring (decades II–III of April) (reference case)	46.7				6.9	0	100	1.9
	Late spring 1st term (decade III of April-decade I of May)	38.5	8.2	4.6	4.4	5.7	-1.2	-17	1.9
	Late spring 2nd term (decade II of May)	26.9	4.9	3.6	3.4	4.0	-2.9	-42	1.4
	Summer (decade I of June)	7.1	1.4	0.9	0.9	1.1	-5.8	-84	1.6
Fenugreek	Early spring (decades II–III of April) (reference case)	62.7	10.2	9.0	8.7	9.3	0	100	1.2
	Late spring 1st term (decade III of April-decade I of May)	47.9	8.8	7.0	6.1	7.3	-2.0	-21	1.4
	Late spring 2nd term (decade II of May)	29.0	5.4	3.8	3.7	4.3	-5.0	-54	1.4
	Summer (decade I 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				

The species plant productivity and mean herbage yield capacity depend on the sowing term (factor B). That said, a significant difference has been detected between the reference, late spring (2 terms) and summer sowing term cases. As regards the economically valuable indices of blue melilot and those of fenugreek, no significant difference has been found.

The plant productivity defines the herbage yield and overall harvest. Fenugreek features a more developed vegetative mass, forming large size leaves and greater numbers of shoots, which has effect on its productivity. That said, the plant productivity amounts to 62.7 g in case of early spring sowing terms and decreases by 87.3% in case of summer seeding.

On the average for three years, the plant productivity has been higher in case of early spring sowing terms both for fenugreek and blue melilot, being equal to 46.7–62.7 g. The summer sowing terms result in reducing the plant productivity down to 7.1–8.0 g. This is related to the cold tolerance of the species, which have optimum conditions for their plant growth and development at moderate temperatures.

The yield of plant herbage to a significant extent depends on both the species and the sowing terms. The highest herbage yield capacity has been detected for early spring sowing terms, in which case it is equal to 6.9 t ha^{-1} on the three years average for blue melilot, 9.3 t ha^{-1} - for fenugreek. That said, blue melilot has been found to be less adaptable to the growing conditions, with a stability factor of 1.9. Blue melilot plants feature less developed vegetative mass, forming smaller size leaves and smaller numbers of shoots as compared to fenugreek, which results in their lower productivity. That said, species had low yield in dry spring of 2014, the dry conditions inflicting the formation of an underdeveloped vegetative apparatus and the more intensive progress of all the plant growth and development stages.

The low herbage yield of species plants in case of the late spring (decade II of May) and summer (decade I of June) sowing terms is due to the less developed vegetative apparatus of the plants. The high air and soil temperatures have contributed to the rapid completion of all plant growth and development stages. However, the intensity of the species' tops build-up has been recorded at lower levels. Therefore, such dates are not suitable for the cultivation of species in the Forest Steppe Region of Ukraine. The sowing on summer dates has resulted in the species herbage productivity decreasing by 84–87% in comparison with the reference case. At the same time, blue melilot has been found to be more adaptive to summer growing conditions with a stability factor of 1.6.

Meanwhile, no appreciable difference from the reference case has been revealed for the species in case of the first late spring sowing term. When sowing on this term, the three-year average herbage productivity of the species becomes equal to 5.7–7.3 t ha^{-1}, i.e. 17–21% less than in the reference case. Significantly lower herbage productivity is obtained with the summer sowing terms: fenugreek 0.9 to 1.7 t ha^{-1}, blue melilot - 0.9–1.4 t ha^{-1} (Fig. 1). Muhammad et al. (2020) have found that IAA and GA_3 can be applied for increasing the foliage biomass output and the yield.

Saxena et al. (2019) have revealed that the fatty oil content in the seeds of various trigonella genotypes varies within the range of 2.62 to 5.33%. Beyzi et al. (2021) have reported about the fatty oil content in trigonella within the range of 4.75% to 5.54%. Ciftci et al. (2011) have stated that the oil content in trigonella varies within the range of 5.8 to 15.2% and the main fatty acids are: linolic acid (45.1–47.5%), α-linolenic

(18.3–22.8%), oleic (12.4–17.0%), palmitic (9.8–11.2%) and stearic (3.8–4.2%) acids. The ratios between the n-6 and n-3 fatty acids vary within the range of 2.1 to 2.7. Seeds of the plant contain also 35% of alkaloids, 10% of flavonoids (100 mg per gram of *Trigonella* seeds), 4.8% of saponins and 0.2–0.9% of diosgenin (Jani et al., 2009; Meghwal & Goswami, 2012; Vaidya et al., 2013). Alkaloids, together with some other volatile compounds, are the primary cause of the bitter taste and the typical flavour of *Trigonella* (Kumar et al., 2012, Faeste et al., 2009).

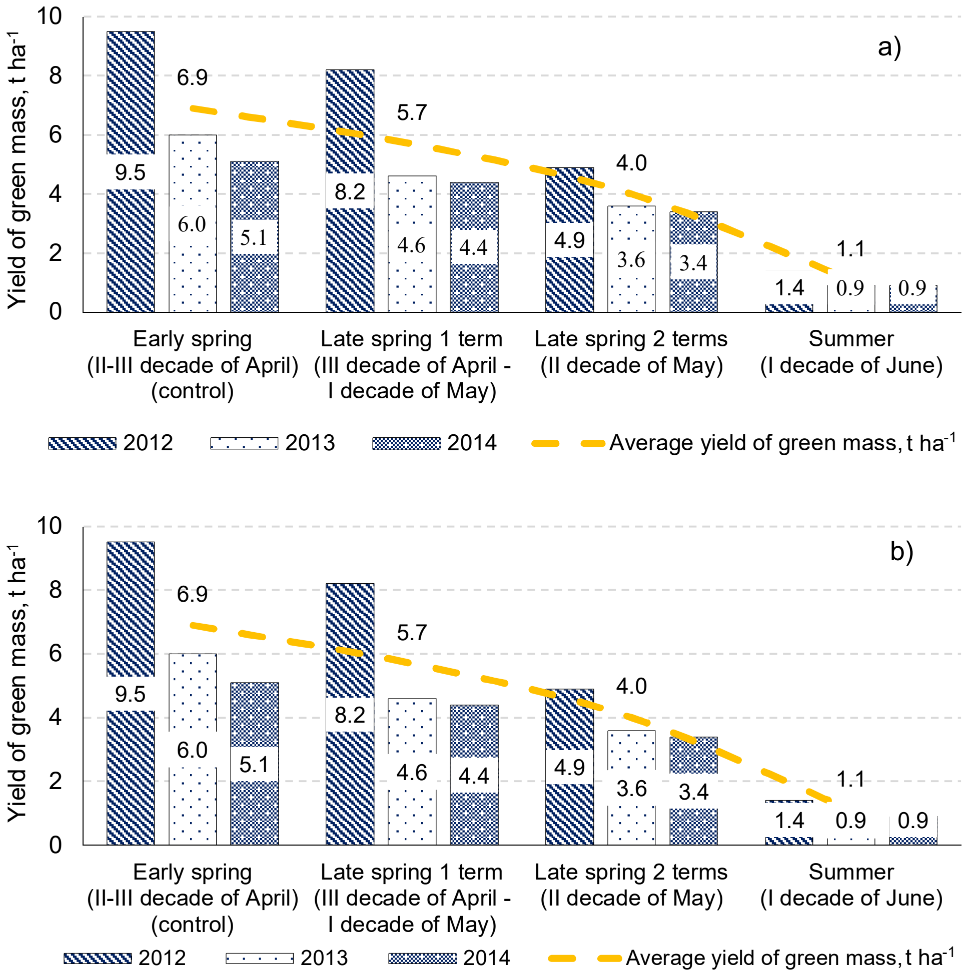

Figure 1. Herbage yield development dynamics: a) blue melilot; b) fenugreek.

It has been established in the research that the biochemical composition of the species herbage to a significant extent depends on both the species properties and the sowing terms (Table 3).

Table 3. Relation between sowing terms and biochemical indices of fenugreek and blue melilot herbage

Species (factor A)	Sowing terms (factor B)	Solid matter, %	Sum of sugars, %	Vitamin C, mg (100 g)$^{-1}$
Blue melilot	Early spring (decades II–III of April) (reference case)	12.4	2.5	45.4
	Late spring, term 1 (decade III of April- decade I of May)	18.8	4.0	38.0
	Late spring, term 2 (decade II of May)	16.0	2.8	26.0
	Summer(decade I of June)	15.5	2.2	19.7
Fenugreek	Early spring (decades II–III of April) (reference case)	18.0	2.6	51.8
	Late spring, term 1 (decade III of Aprisl-decade I of May)	28.4	5.0	49.7
	Late spring, term 2 (decade II of May)	20.4	3.4	26.7
	Summer (decade I of June)	18.5	2.7	20.1
HIP_{05}			4.9	0.7
factor A			2.4	0.4
factor B			3.4	0.5

According to the results of the biochemical analysis, the fresh herbage quality indices of species improve in case of late spring sowing terms (decade III of April-decade I of May). The solid matter content in this case is equal to 18.8–28.4%. The higher index values have been obtained for the herbage of fenugreek. The same trend is observed also in other indices. That can be explained by the great height of blue melilot plants, which results in the shading of the plants, the slowing down of the photosynthesis process and the reduced accumulation of solid matter and sugars.

With early spring sowing terms, the quality indices go down - in these cases, the solid matter and sugar contents in fenugreek species have been equal to 18.0 and 2.6%, respectively, in blue melilot species - 12.4 and 2.5%. That can be explained by the slowing down of photosynthesis in plants at lower temperatures. However, in case of early spring sowing terms, the vitamin C content in species increases. This index has been found to reach the highest level in the reference case, where it is equal to 51.8 mg (100 g)$^{-1}$ of raw matter for fenugreek, for blue melilot - 45.4 mg (100 g)$^{-1}$. With later sowing terms, the vitamin C content decreases, reaching the lowest level in case of summer seeding, where it has been equal to 19.7–20.1 mg (100 g)$^{-1}$ of raw matter.

The loss of vitamin C, when boiling in water or cooking in steam and frying, amounts to 10.8 and 7.4%, respectively, while the action of β- and γ-radiation on germinating seeds reduces the vitamin content as well (Khorshidian et al., 2016).

For the food purposes, the dried upper part of leaves and flower heads is the most frequently used part of these species. Accordingly, it is necessary to determine the economically valuable indices of dried output. It has been found on the average for three years that the dry matter yield capacity of blue melilot and fenugreek depends to a considerable extent on the sowing term (factor B) (Table 4).

Table 4. Relation between sowing terms and economically valuable indices of blue melilot and fenugreek dry matter

Species (factor A)	Sowing terms (factor B)	Average water loss factor	Dry matter yield in years t ha^{-1} 1st year	2nd year	3rd year	Average dry matter yield, t ha^{-1}	Increase of yield t ha^{-1}	%	Stability factor (S.F.)
Blue melilot	Early spring (decades ii–iii of april) (reference case)	6.5	1.3	1.2	1.0	1.2	0	100	1.3
	Late spring 1st term (decade iii of april - decade i of may)	5.7	1.3	1.1	0.9	1.1	-0.1	-8	1.4
	Late spring 2nd term (decade ii of may)	4.0	1.2	0.9	0.8	1.0	-0.2	-17	1.4
	Summer (decade i of june)	1.8	0.7	0.6	0.5	0.6	-0.6	-50	1.5
Fenugreek	Early spring (decades ii–iii of april) (reference case)	6.7	1.5	1.4	1.3	1.4	0	100	1.1
	Late spring 1st term (decade iii of april- Decade i of may)	5.9	1.4	1.3	1.1	1.3	-0.1	-7	1.3
	Late spring 2nd term (decade ii of may)	4.0	1.4	0.9	0.9	1.1	-0.3	-21	1.6
	Summer (decade i of june)	1.5	1.0	0.7	0.6	0.8	-0.6	-43	1.7
HCP_{05}			0.5	0.5	0.4				
factor A			0.2	0.1	0.1				
factor B			0.3	0.3	0.2				

It has been established that the dry matter yield of two species depends on the water loss factor, which has been found to be lower, at a value of 1.5–1.8, in case of summer sowing terms. That is due to the high temperatures of the summer season and the loss of turgor because of the intensive plant breathing. Higher water loss factors among the two species are observed in case of early spring sowing terms (6.5–6.7). That said, this index is lower for blue melilot. At the same time, blue melilot has been found to be less adaptive in case of early spring sowing terms, comparing to fenugreek, with a stability factor of 1.3.

Higher dry matter yield has been observed in case of early spring sowing terms and late spring term 1, which is due to the high plant herbage yield: it is equal to 1.1–1.2 t ha^{-1} for blue melilot, for fenugreek - 1.3–1.4 t ha^{-1}. Lower dry matter yield is obtained from species in case of summer sowing terms (0.6–0.8 t ha^{-1}) (Fig. 2). That is due to the low herbage yield, despite the lower water loss factor in this period (1.5–1.8). On the average for three years, the dry matter yield in case of summer sowing terms has been reduced by 43–50% in comparison with the reference case.

The dry matter yield has been higher in case of fenugreek at all the sowing terms (0.8–1.4 t ha^{-1}), as compared to blue melilot (0.6–1.2 t ha^{-1}). At the same time, no significant difference with regard to the dry matter yield has been observed between the cases of the early spring and 1st late spring sowing terms - in both cases it has been equal to 1.3–1.4 t ha^{-1} for fenugreek. It has been established that late spring sowing term 2 (decade II of May) and the summer sowing terms (decade I of June) are impractical for the cultivation of species, since with these terms the lowest plant herbage and dry matter yields have been reached.

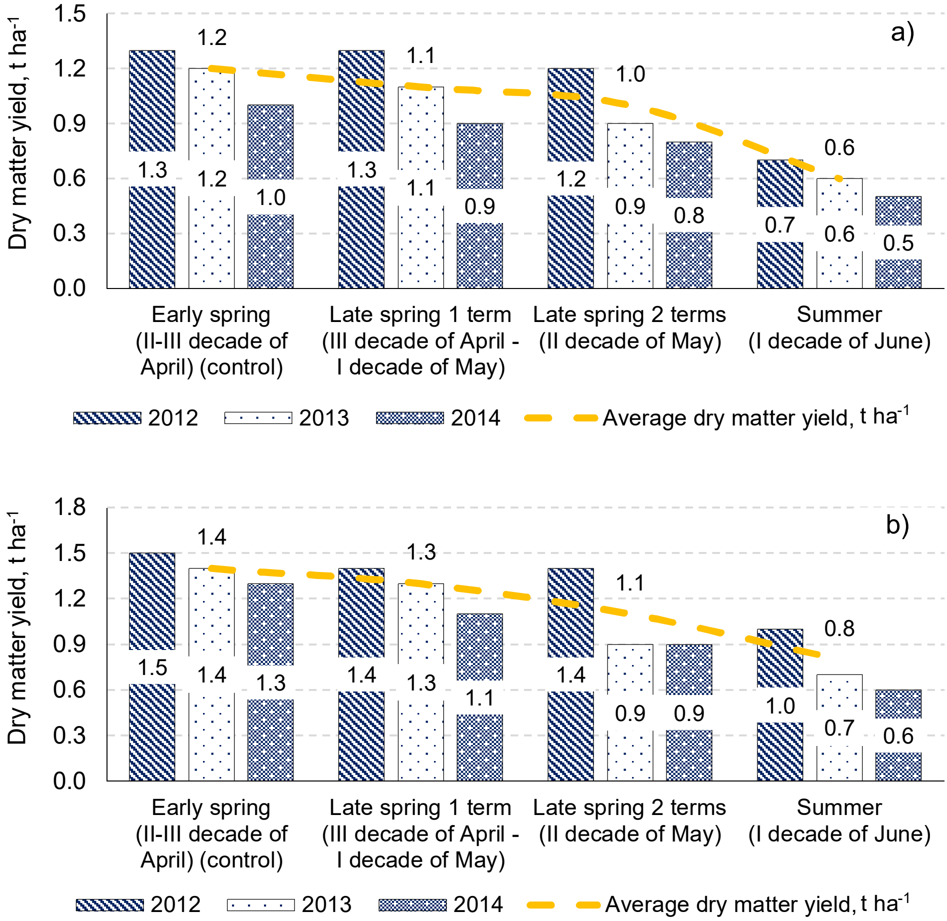

Figure 2. Dry matter yield development dynamics: a) blue melilot; b) fenugreek.

The above-mentioned results align with the data obtained in the state of Alberta for the production of hay from blue melilot and fenugreek. In this area, the recommended sowing term is from the middle of April to the middle of May (Acharya et al., 2008). In Kansas, Obour et al. (2015) have reported that the timing of sowing within the period from the 1st of April through the 22nd of May has no effect on the fodder yield. In Poland, Bieńkowski et al. (2016) have reported that the highest seed yield per plant was reached in case of the earliest sowing terms in spring, while the maximum recorded seed yield was equal to 840 kg ha^{-1}.

Although the cultivation of blue melilot and fenugreek are concentrated mostly in some countries of Africa and Asia, it is grown throughout the world in different environmental conditions, where the annual rainfall varies within the range of 300–1,500 mm and the average yearly temperature - within the range of 7.8–27.5 °C (Solorio-Sánchez et al., 2014; Ahmad et al., 2016). *Trigonella* is considered a drought-resistant plant and its relatively low requirement to precipitation makes it suitable for the semi-arid conditions of the Great Plains, for example, in Alberta, Canada (Acharya et al., 2008), Kansas (Obour et al., 2015) and western Nebraska. *Trigonella* is sensitive to moisture deficiency, especially immediately after sowing (Żuk-Gołaszewska et al., 2015). That is supported by the results of the research into blue melilot by Akhalkatsi & Losch (2005). They have proved that shortage of water in the period of seed germination limits the germinating capacity and development of the plants. Seasonal irrigation is needed to achieve the maximum yield. In Iran, Dadrasan et al. (2015) have reported that insufficient irrigation (75%) not meeting the plants' demand reduces the seed yield by 27% and the fodder yield by 40%. In India, where *Trigonella* sp. were grown in winter with small amounts of rainfall, the irrigation resulted in an increase in the seed yield to a maximum of 1,300 kg ha^{-1} (Kumar et al., 2000).

Plants need certain quantities of heat for their development (Reshma & Samir 2021). It is difficult to forecast the growth of plants by the calendar, because the temperature can greatly vary from year to year (Abou-Shleel, 2014). Instead of that, the 'Growing Degree Days' (GDD) method can be applied. The method is based on the actual temperatures, it is a simple, but accurate way of predicting when a certain plant development stage will be reached. Moreover, according to the paper (Ionescu & Roman, 2013), the maturity was reached in the third ten-day period of July, that is, after 95 days of growth, when the accumulation of the above-mentioned heating units totalled 922.2 GDD (St > 10 °C).

Within the recorded three years of cultivation, the sum of effective air temperatures (> 10 °C) in the species growth season varied, depending on the sowing terms, within the range of 316 to 508 °C, the precipitation total - within the range of 36 to 195 mm. At the same time, the herbage yield varied from 0.9 t ha^{-1} to 10.2 t ha^{-1}, the dry matter yield - from 0.5 t ha^{-1} to 1.5 t ha^{-1}. The above-mentioned data make it possible to determine the yield variability criterion per degree °C of the sum of effective air temperatures and per mm of the precipitation total. A strong direct relation between the species herbage yield and its dry matter yield has been established (r = 0.88 to 0.99). A strong direct relation exists between the species dry matter yield at different sowing terms and the sum of effective air temperatures (r = 0.66 to 0.99). Intermediate and strong inverse relations have been found between the species dry matter yield at different sowing terms and the precipitation total (r = -0.48 to -0.99) (Table 5).

In order to establish the direction and type of the effect that the parameters of the sum of effective air temperatures (> 10 °C) and the precipitation total have on two species yield value at different sowing terms, the authors have generated and analysed the regression equations.

Basing on the results of the regression equation analysis, it has been established that an increase in the sum of effective air temperatures by 1 °C results in the variation of the blue melilot yield at different sowing terms: herbage yield - within the range of 4.82 to 128 kg ha^{-1}, dry matter yield - within the range of 0.401 to 6.06 kg ha^{-1}. Increasing the precipitation total by 1 mm results in the variation of the herbage yield within the range of 16.1 to 146 kg ha^{-1}, the dry matter yield - within the range of 0.145 to 22.7 kg ha^{-1}.

Table 5. Modelling of blue melilot and fenugreek yield development

Sowing term	Regression equations	
	Herbage yield (y)	Dry matter yield (y)
Blue melilot		
Early spring (decades II–III of April) (reference case)	$y = -71.408+0.1277 \cdot x_1+0.1465 \cdot x_2$	$y = -2.3375+0.0061 \cdot x_1+0.0054 \cdot x_2$
Late spring. term 1 (decade III of April-decade I of May)	$y = -21.5585+0.0533 \cdot x_1+0.0283 \cdot x_2$	$y = -0.6787+0.0039 \cdot x_1+0.000145 \cdot x_2$
Late spring. term 2 (decade II of May)	$y = 18.8633-0.0111 \cdot x_1-0.0967 \cdot x_2$	$y = 4.1151-0.0018 \cdot x_1-0.0225 \cdot x_2$
Summer (decade I of June)	$y = 4.2259-0.0048 \cdot x_1-0.0161 \cdot x_2$	$y = 1.0105-0.0004 \cdot x_1-0034 \cdot x_2$
Fenugreek		
Early spring (decades II–III of April) (reference case)	$y = 0.2199+0.0141 \cdot x_1+0.015 \cdot x_2$	$y = 0.4699+0.0016 \cdot x_1+0.0011 \cdot x_2$
Late spring. term 1 (decade III of April-decade I of May)	$y = -11.5108+0.0339 \cdot x_1+0.0227 \cdot x_2$	$y = 0.3536+0.0022 \cdot x_1-0.0007 \cdot x_2$
Late spring. term 2 (decade II of May)	$y = -13.8269+0.0212 \cdot x_1+0.0773 \cdot x_2$	$y = -4.7949+0.0066 \cdot x_1+0.0259 \cdot x_2$
Summer (decade I of June)	$y = -4.0142+0.0102 \cdot x_1+0.0184 \cdot x_2$	$y = -1.3691+0.0043 \cdot x_1+0.0068 \cdot x_2$

Note: x_1 – sum of effective air temperatures (> 10 °C); x_2 – precipitation total in mm.

An increase in the sum of effective air temperatures by 1 °C results in the variation of the fenugreek yield at different sowing terms: herbage yield - within the range of 10.25 to 33.9 kg ha^{-1}, dry matter yield - 1.58 to 6.63 kg ha^{-1}. Increasing the precipitation total by 1 mm results in the variation of the herbage yield within the range of 15.0 to 77.3 kg ha^{-1}, dry matter yield - within the range of 0.693 to 25.9 kg ha^{-1}.

The research into the cultivation of blue melilot and fenugreek has revealed a difference between their seed productivities (Table 6).

It has been established that the early spring (decades II–III of April) and late spring (decade III of April-decade I of May) sowing terms are the most favourable ones for the growth and development of species, that is, the optimal amount of precipitation in April and the increased temperatures during the second part of summer have positive effect on the seed productivity of species. In case of these terms, the plants develop the greatest amounts of pods and seeds in them. That results in the improved seed productivity of species, as compared to the summer sowing terms.

In the conditions of semi-arid high-altitude plains in the USA, the variation of the sowing terms within the range of the first ten-day period in May to the first ten-day period in June had no effect on the plant height (Pavlista & Santra, 2016). The heights of *Trigonellas* varied within the range of 33 to 41 cm for two varieties within the range indicated for *Trigonella* in Turkey, 36 to 44 cm (Tuncturk et al., 2011) and for *Trigonella* in India, 25 to 54 cm, depending on the genotype, 38 cm on the average (Chandra et al., 2000). In Canada, the height of the *Trigonella* in the time of flowering was equal to about 40 cm (Acharya et al., 2008).

Table 6. Relation between sowing terms and seed productivity of blue melilot and fenugreek

Sowing terms (factor B)	Number of pods per plant, pcs	Length of pod, cm	Number of seeds per pod, pcs	Mean productivity, g	Seed yield, t ha^{-1}	Mass of 1,000 seeds, g
Blue melilot (factor A)						
Early spring (decades II–III of April) (reference case)	133.5 ± 25.3	2.4 ± 0.4	27.3 ± 5.7	2.6 ± 0.4	0.40 ± 0.2	0.71 ± 0.24
Late spring, term 1 (decade III of April-decade I of May)	81.8 ± 12.7	1.8 ± 0.1	16.2 ± 4.3	0.9 ± 0.2	0.10 ± 0.05	0.65 ± 0.13
Late spring, term 2 (decade II of May)	56.3 ± 12.5	1.5 ± 0.3	13.5 ± 5.6	0.5 ± 0.3	0.07 ± 0.03	0.60 ± 0.09
Summer (decade I of June)	31.0 ± 8.6	1.3 ± 0.4	11.7 ± 4.8	0.2 ± 0.1	0.03 ± 0.01	0.52 ± 0.05
Fenugreek						
Early spring (decades II–III of April) (reference case)	65.7 ± 14.7	15.0 ± 2.8	21.0 ± 4.5	13.3 ± 4.8	2.0 ± 0.7	9.7 ± 1.5
Late spring, term 1 (decade III of April-decade I of May)	46.5 ± 13.8	10.7 ± 1.5	15.3 ± 2.3	6.4 ± 2.4	0.9 ± 0.3	9.0 ± 1.1
Late spring, term 2 (decade II of May)	35.1 ± 10.2	9.5 ± 1.2	12.8 ± 3.1	3.9 ± 1.3	0.6 ± 0.2	8.7 ± 0.9
Summer (decade I of June)	21.0 ± 9.8	8.0 ± 0.9	10.8 ± 2.7	1.7 ± 0.8	0.2 ± 0.09	7.5 ± 0.6

Fenugreek produces low plants - up to 40 cm, with lower numbers of pods per plant (21.0–65.7 pcs). Moreover, in the years with the increased sums of effective air temperatures the productivity of fenugreek decreases. Another distinctive feature of fenugreek is that it produces long pods with a length of 8.0 to 15.0 cm, which contain small numbers of seeds (10.8–21.0 pcs per pod).

Özyazıcı (2020) has established that the seed yield positively and significantly correlated with the number of pods per plant ($r = 0.70$), the pod length ($r = 0.33$), the number of seeds per pod ($r = 0.51$), the mass of one thousand seeds (r = 0.57). Increases in these indices result in significant increases in the plant seed yield. The highest coefficients of correlation for the seed yield have been found in its relationships with the number of pods per plant, the number of seeds per pod and the mass of one thousand seeds. Parchin et al. (2019) have stated that there is a positive correlation between the number of pods per plant and the seed yield.

A positive and significant correlation has been determined between the plant height and the height of the first pod. Positive and significant correlations have been revealed between the number of pods per plant and the pod length as well as between the number of seeds per pod and the mass of one thousand seeds. Positive and significant interrelations have been found between the mass of one thousand seeds and the number of pods per plant as well as between the pod length and the number of seeds per pod. Many papers state that the number of seeds per pod, the number of pods per plant and the mass of one thousand seeds are the primary factors that have a direct effect on the seed yield (Patahk et al., 2014; Singh et al., 2019a; Singh et al., 2019b).

In the conditions of West Bengal, India, the number of seeds per pod varies within the range of 14.67 to 16.38 pcs for different times of sowing (Bhutia et al., 2017). Nandre et al., (2011) have established that the *Trigonella* plants sown on the 1st of November yield considerably greater numbers of seeds per pod. Bhutia & Sharangi (2016), Sultana et al. (2016) obtained the highest numbers of seeds per pod in case of sowing on the 23rd of November.

Blue melilot grows higher reaching plant heights of up to 100 cm. It blossoms with small blue flowers on the stem apices. The seeds are smaller comparing to fenugreek (approximately by a factor of 3–5). The scent is less pronounced. At the same time, blue melilot produces greater numbers of pods per plant at all sowing terms (31.0–133.5 pcs). However, blue melilot features short pods, in which small seeds develop, 1,000 seeds weighing 0.52–0.71 g. That results in the low seed productivity of the species, which is equal to 0.2–2.6 g per plant, despite the greater number of seeds per pod. Overall, the seed yield of blue melilot varies within the range of 0.03–0.40 t ha^{-1}.

Tuncturk et al. (2011) have reported that 1,000 seeds weigh 18 g in Turkey, which is heavier than in western Nebraska (12 g) for fenugreek. In Poland, the variation of the 1,000 seed weight within the range of 14 to 15 g has been recorded (Bieńkowski et al., 2016). The difference between seed masses is probably caused by the germinal plasma, because different germinal plasmas differ as regards the seed mass even for the plants grown close to each other in the same year (Pavlista & Santra, 2015).

Fenugreek produces seeds with greater sizes, 1,000 seeds weighing 7.5–9.7 g, which results in the higher seed productivity of its plants. The average seed productivity was recorded at higher levels in case of early spring sowing terms, where it was equal to 13.3 g per plant, resulting in the improvement of the seed yield, which reached 2.0 t ha^{-1} for fenugreek. Moreover, its seeds after their grinding emitted intense pleasant mushroom aroma.

In the tropics, species for seed production is usually sown in the winter season. The maximum seed yield was obtained in case of sowing on the 30th of October (1.45 t ha^{-1}), the lowest one – when sowing on the 30th of December (0.93 t ha^{-1}) (Bhutia et al., 2017). According to the data by Nandre et al. (2011), the highest species seed yield per hectare was obtained in case of sowing on the 1st of November. Lal et al. (2003) have also revealed similar results for *Trigonella*. Bhutia & Sharangi (2016) and Sultana et al. (2016) obtained the highest seed yield after sowing on the 2nd of November. The possible cause of the low productivity in case of late sowing can be related to the insufficient time for vegetative growth due to the plant entering the reproductive phase more rapidly. Delays in harvesting increase the risk of pod dehiscence and seed loss. Petropoulos (2002) has also reported that the late sowing in spring has resulted in a reduced seed yield.

Lower seed yield was recorded in case of summer sowing terms, where it was equal to 0.2 t ha^{-1}, which was lower by 1.8 t ha^{-1}, as compared to the reference case. Moreover, with each succeeding sowing term fenugreek produced lower numbers of pods per plant, shorter pods, smaller numbers of seeds per pod and lower weights of 1,000 seeds, which resulted in lower seed yields as compared to the early spring sowing terms.

The time of sowing is of critical importance for the vegetative growth of plants and the procurement of the highest possible yield. Early or late seeding can impair the growth, the yield capacity and also the quality of the harvest (Al-Dalain et al., 2012). In case of *Trigonella*, early sowing results in early flowering, but then the plants are vulnerable to damage in the event of severe cold and frost. Overall, the crop needs a cool climate during its vegetative growth and a warm dry climate at the ripening stage (Aggarwal et al., 2013). Plants sown on an optimal day have better chances of achieving the correct phenological development (Bieńkowski et al., 2016).

CONCLUSIONS

Blue melilot and fenugreek species have a wide range of variability as regards their morphologic and economically valuable properties, depending on the time of their sowing. The earliest ripening of two species has been recorded in case of summer sowing terms - the vegetative season duration was equal to 36–37 days. In case of early spring sowing dates, the species growth period became longer and was equal to 50–52 days.

It has been established that the early spring sowing terms (decades II–III of April) and the late spring sowing terms (decade I of May) are more suitable for obtaining high herbage yields from the plants of blue melilot and fenugreek in the green conveyor system - with these sowing terms, the herbage yield is equal to 5.7–6.9 t ha^{-1} for blue melilot and 7.3–9.3 t ha^{-1} - for fenugreek, the herbage containing dry matter at levels of 12.4–28.4%, total sugars - 2.5–5.0% and vitamin C - 38.0–51.8 mg $(100\ g)^{-1}$.

For the purpose of obtaining the spice named 'mushroom grass', the promising development trend is to use fenugreek sown at the early spring terms (decades II–III of April) and the late spring terms (decade I of May), as it produces better developed vegetative mass and delivers a plant dry matter yield of 1.3–1.4 t ha^{-1} and a seed yield of 0.9–2.0 t ha^{-1}, 1,000 seeds weighing 9.0–9.7 g.

It has been revealed that an increase in the sum of effective air temperatures by 1 °C results in the variation of the fenugreek yield at different sowing terms as follows: the herbage yield – within the range of 10.25 to 33.9 kg ha^{-1}, the dry matter yield – within the range of 1.58 to 6.63 kg ha^{-1}. An increase in the precipitation total by 1 mm results in the variation of the herbage yield within the range of 15.0 to 77.3 kg ha^{-1}, the dry matter yield – within the range of 0.693 to 25.9 kg ha^{-1}.

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