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Original article

Yield Potential of Newly Introduced Energy and Fodder Crop *Galega orientalis* Lam. on Marginal Heavy Soils under Moderate Central European Continental climate

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This research verifies the production potential of *Galega orientalis* Lam. grown on marginal heavy soils with the following intensities of mineral nutrition: (1) 245.0 kg/ha NPK, (2) 122.5 kg/ha NPK and (3) 0.0 kg/ha NPK. A large-scale pilot experiment with the cultivar Gale was carried out on two sites under a semi-humid to humid temperate climate in Central Europe for 4 years. Overall, 14.56 t/ha of dry matter yield on average was achieved, with 10.92 t/ha in the first cut and 3.65 t/ha in second cut; the yields varied from 4.61 t/ha to 24.65 t/ha for both the cuts, and 2.69 – 21.30 t/ha and 1.05 – 9.06 t/ha for the first and second cuts, respectively. In the year of establishment (2017), the crop reached an average yield of 0.52 t/ha; due to slow development. The yield during the three productive years (2018 – 2020) was affected mainly by the cuts (F-ratio 218.97, *P*-value <0.01), then by years (F-ratio 178.38, *P*-value <0.01), followed by nutrition (F-ratio 4.81, *P*-value <0.01), sites (F-ratio 1.34, *P*-value >0.05), and finally by replications (F-ratio 0.17, *P*-value >0.05). In general, eastern galega productivity increased as the nutrition increased and the utility year approached, but the impact of nutrition seems to be more complicated due to the legume crop's biological specifics. The study includes no sites with arid or semi-arid climate, where the productivity may be different, especially on light soils with drying water regime, which can be assumed as a limiting factor for the crop with slow initial growth.

Key words: eastern galega, nutrition intensity, crop coverage, plant height, dry matter content at harvest

The eastern galega (*Galega orientalis* Lam.) is a perennial forage legume crop with high yield potential and is rich in crude protein and fiber; it can be an alternative option to alfalfa *Medicago sativa* L. cultivation mostly under the more difficult agroecological conditions (Symanowicz *et al.* 2019; Ignaczak *et al.* 2022; Samoilova *et al.* 2022). Due to its high yield potential, unusual adaptability to different environmental conditions, and useful characteristics of the green phytomass, the crop has a great potential for agricultural development (Žarczynski *et al.* 2021; Lang *et al.* 2022). The main advantages of the eastern galega cropping are as follows: (1) its low requirement for nutrition; (2) it cannot be easily damaged by specialized pests; (3) its positive impact on soil fertility; and (4) its suitability for all farms, such as conventional, organic, or extensive ones (Žarczynski *et al.* 2021). Although eastern galega has been introduced and cultivated for about half a century in some suitable pioneer countries, especially in Northern and Eastern Europe (Halling *et al.* 2004; Meripõld *et al.* 2017; Vasbieva & Zavyalova

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2021), it has not yet been introduced in other countries and probably in very suitable countries such as Slovakia in Central Europe.

Eastern galega is an impressive dark green perennial herb growing to a height of 0.6 – 1.5 m; some are even higher. Similar to a more widely known plant and botanically similar species, the traditional European pharmaceutical *G. officinalis* L., it is a medicinal and honey-bearing plant, which can also be used to fertilise the soil as a green manure (Symanowicz *et al.* 2019; Kshnikatkin *et al.* 2022). Eastern galega proves itself particularly valuable as a protein fodder suitable for all types of farm animals under certain conditions. Fresh fodder, particularly from young plants, is characterized by very good biochemical parameters because it can be used as feed for animals including poultry (Žarczynski *et al.* 2021). Currently, the possibility of this crop for energy use is also being recognized, as because of the long durability of its stands, exceptional yield potential, and certain suitability for some marginal soil conditions. This is appreciated in several countries; however, the task must be studied in more detail as agronomically as concerning to specify the chemical composition of the phytomass, which should be recognized for choosing the most appropriate conversion process (Povilaitis *et al.* 2016; Symanowicz *et al.* 2019; Cerempei *et al.* 2023). Particularly, because of the widening exploration of the energy use possibilities of the eastern galega in later years, the crop has been obtaining popularity as one of the newly discovered and promising crops worldwide under moderate climate conditions. So, with the cultivation of the crop, there is little knowledge and experience not only in the non-traditional countries, but in general too.

One of the disadvantages of eastern galega is the hard shell of the seeds, which causes increased seed consumption, prolonged germination, and a lower emergence, due to an irrevocable loss of a part of the sown seeds (Khasanov *et al.* 2020). Studies of Eryashev *et al.* (2019) showed that the eastern galega had a higher dry matter (DM) yield and phytomass quality on a non-pesticide background than on a pesticide background in the phenophase of spring after growing and budding. For Shevchenko *et al.* (2022), the energy potential of eastern galega plant is related to the amount of the nutrients, as the crop's growth depends on the photosynthesis activity of the plant and the quick rate of trimmed root system regeneration, which can succeed by the satisfactory mechanism of the skilled machines operating during the cultivation process. It was found that the crop development varied according to soil cultivation, agrophysical conditions of the soil during cultivation, sowing quality, processing, and seed condition, which all affect the growth of the stem mass of the crop.

Since the lack of experience with eastern galega cultivation in Slovakia, a phytotechnically designed large-scale pilot open-field trial was conducted. The main aim of the experiment was to approximate the yield potential of the crop under semi-humid to humid subclimate in marginal heavy soils, where the suitability of the crop is expected, and the full production potential could be targeted.

MATERIAL AND METHODS

The Trial Sites, Plant Material and Agronomy

The large-scale pilot experiment with the newly introduced eastern galega was established on two sites, both with marginal heavy soil conditions, under a moderate continental climate in Central Europe. The pilot field experiment was performed in cooperation with two local farmers not far distant from the departmental place in Michalovce:

- Site 1, village of Pozdišovce, altitude 115 m, total flat, Gleyic Fluvisol − heavy soil (64.14% of clay content) and semi-humid climate,
- Site 2, village of Košický Klečenov, altitude 340 m, slope, Stragnic Cambisol − heavy soil (48.88% clay content) and humid climate.

Prior to the trial, the soil analyses were done, based on samples taken from the topsoil layer (depth of 0 – 30 cm) in autumn of 2016. The crop stand was established by sowing in the spring of 2017 and was carried out up to 2020. In autumn, the soil tillage was done to a depth of 24 cm on both sites and was followed by high-quality pre-sowing preparation in spring with an aim to achieve an optimal soil bed for successful germination and emergence. The sowing date of April 03, 2017, was agreed on at both sites, as well as the sowing rate of 1.35 million of germinating seeds per hectare (MGS/ha),

Table 1

The annual dose of NPKCa (kg/ha, P, K and Ca in oxide form) according to treatments (following Tóth 2023)

Treatment/ NPKCa dosage	N	P	K	Σ NPK	Ca
T1: intensive nutrition	125.0	60.0	60.0	245.0	24.0
T2: semi-intensive nutrition	62.5	30.0	30.0	122.5	12.0
T3: untreated control	0.0	0.0	0.0	0.0	0.0

and sowing depth of 1.5 cm. In the trial Gale cultivar was tested, the seed had a bulk density of 768.8 g/L, a germination rate of 52.5%, and a weight of thousand seeds of 6.8 g. Immediately before sowing, the seed was inoculated dry in the seed drill, *Rhizobium galegae* was applied. As the main treatment, the intensity of mineral nutrition was differentiated, so that intensive nutrition, semi-intensive nutrition, and untreated control were included in the trial (Table 1). The doses of NPKCa were applied regularly every year in early spring, at the beginning of the main vegetation period, at the end of March. The experimental layout was a randomized block design, which was described in more detail in previous papers (Tóth *et al.* 2023).

Because the sites differ mainly in the above sea level and the subsequent sub-climate, while presenting data of weather conditions related to the main growing season, the average values are given according to the cuts as well. Soil-climate was monitored too; besides the soil temperature and soil humidity, the soil electrical conductivity was measured twice a day, recording the data from a topsoil (depth of 15 cm) and subsoil (depth of 45 cm) as well. The time development of soil moisture is displayed as well.

The Harvest and the Laboratory Analyses

The crop was not harvested during the year of establishment, while in subsequent years, it was harvested by cutting twice in a year according to the optimal mowing stage; however, the dates of harvest were the same for both sites (Table 2). During the harvest, samples of the fresh green phytomass (approximately 3 kg per sample) were taken to determine the DM content, which was measured gravimetrically by laboratory analyses.

Immediately after the final harvest, the second cut in 2020, soil samples were taken to monitor the development of the soil's main chemical properties. Both soil sample sets came from (1) the beginning (autumn 2016, the initial set) and (2) the end of the trial (autumn 2020, the final set), and refer to a topsoil layer (depth of 0−30 cm); each of the six plots was sampled (the 2 sites × the 3 nutrient treatments). Soil sampling, as well as the sample storage and processing, were done in relevant accordance with Slovak Law No. 151/2016, Law Digest. For the laboratory analyses of the soil samples, the Mehlich 3 (method for P, K, Ca, and Mg), Kjeldahl method (Nt), Tjurin's method (C-ox, humus), potentiometric method (pH/KCl), and the Novak method (soil texture parameters) were applied, respectively (Tóth 2023).

Statistics

Totally, 596 authentic crop data, 216 soil chemical properties data, 5,760 weather data, and further 17,280 soil-climate and conductivity data were recorded, processed, and statistically evaluated. Moreover, a set of 96 yield data was obtained regarding the cuts, when the sum of the two authentic cuts per year was calculated. As the main statistics, the multifactorial analysis of variance (MANOVA) with subsequent post-hoc Fisher's least significant difference (*LSD*) test was performed to identify significant factors having influence on influencing the crop yield variability, using Statgraphics 15.2.14. That test was performed at first with the aim to include the cuts into the main effects, and secondarily with the aim to compare the authentic cuts in a more de-

Table 2

Dates of the crop harvest

Cut	2018	2019	2020
1st	May 28	June 20	June 16
2nd	September 25	September 23	September 7

tailed manner, including both cuts. In addition, some correlation analysis and second-order polynomial lines in the case of trend analyses were also applied, whereby the reliability index was also calculated.

RESULTS

Dry Matter Yield and the Main Effects

The authentic data on the yield of green phytomass of eastern galega are integrated in Figure 1A–C, while presenting them as converted to DM yield. The statistical outputs of the multivariate analysis of variance (MANOVA) are summarized and displayed as well (Tables 3 and 4). Overall, the average DM yield was 14.56 t/ha, was 10.92 t/ha in the first and 3.65 t/ha in the second cut, whereas the yields ranged from 4.61 to 24.65 t/ha for the cuts together, and 2.69 − 21.30 t/ha and 1.05 − 9.06 t/ha in the first and second cuts, respectively.

The evaluation of the crop yield is more difficult than usual because the stand was mowed down regularly with two cuts per year, except in the year of establishment (2017), when the crop was not harvested due to slow plant development, and the aboveground parts of the crop stand remained low. During the next three productive years (2018 − 2020), the crop yield was affected mainly by the cuts (*F*-ratio 218.97, *P*-value <0.01), followed by years (*F*-ratio 178.38, *P*-value <0.01), then by nutrition (*F*-ratio 4.81, *P*-value <0.01), sites (*F*-ratio 1.34, *P*-value >0.05), and finally by replications (*F*-ratio 0.17, *P*-value >0.05). In general, eastern galega productivity increased with the approaching utility year, and with rising nutrition intensity; however, the effect of the sites and nutrition seems to be of quite a different impact if first and second cuts are evaluated separately and compared with each other. In addition to the fact that the assessment is complicated by the two cuts, the yield forming formation of the

Table 3

Outputs of MANOVA for the yield data, including the cuts as the main factor

IO	Main effect	Sum of squares	*DF*	*F*-ratio	*P*-value	Homogenous groups		LS Mean	LS Sigma
5.	Replications	5.02829	3	0.17	0.9198	A	IV	9.5399	0.4336
						A	I	9.5708	0.4336
						A	II	9.8488	0.4336
						A	III	9.8699	0.4336
4.	Sites	13.5841	1	1.34	0.2487	A	Site 1	9.4566	0.3066
						A	Site 2	9.9582	0.3066
2.	Years	3,480.14	2	171.38	0.0000	A	2018	4.0536	0.3755
						B	2019	12.0944	0.3755
						A	2020	12.9741	0.3755
3.	Nutrition	97.5909	2	4.81	0.0091	A	T3: Control	8.7569	0.3755
						B	T2: semi-intensive	10.1702	0.3755
						B	T1: intensive	10.1950	0.3755
1.	Cuts	4,446.5	2	218.97	0.0000	A	1st cut	3.6460	0.3755
						B	2nd cut	10.9151	0.3755
						C	The cuts together	14.5611	0.3755
	Residual	2,081.42	205	10.15*					
	Total	10,124.20	215						

* − sum of squares (for residual). *DF* − degree of freedom; IO − impact order, an order according to *F*-ratio; LS Mean − the average value; LS Sigma − the least significant difference.

crop relates to the symbiosis of the plants with root nodule-forming bacteria for nitrogen fixing, whose optimal activity can be conditioned by different soil conditions and weather patterns as well. Most probably, this can also be one of the key sources that changes the impact of nutrition treatments, and the sites and years as well. The DM yield order in the three productive years was as follows: (1) 19.46 t/ha in 2020, (2) 18.14 t/ha in 2019, and (3) 6.08 t/ha in 2018, where ranking was according to the mean average; significant differences were achieved when they were compared with each other (Table 4). The yield order by nutrition treatment was the same as in nutrition intensity; the highest DM yield of 15.29 t/ha was found under intensive nutrition, 15.26 t/ha under semi-intensive, and the lowest yield of 13.14

A: 1st cut

	Site - Pozdišovce			Site - Košický Klečenov			average		
	intensive	semi-intensive	control	intensive	semi-intensive	control	intensive	semi-intensive	control
1st C, 2018	4.265	3.138	2.690	5.106	5.317	3.966	4.686	4.228	3.328
1st C, 2019	12.500	10.450	10.700	21.300	16.450	16.700	16.900	13.450	13.700
1st C, 2020	14.093	16.436	12.407	12.017	16.169	12.767	13.055	16.303	12.587

B: 2nd cut

	Site - Pozdišovce			Site - Košický Klečenov			average		
	intensive	semi-intensive	control	intensive	semi-intensive	control	intensive	semi-intensive	control
2nd C, 2018	1.689	2.145	1.920	2.842	2.356	1.048	2.266	2.251	1.484
2nd C, 2019	2.850	3.750	5.550	2.750	3.850	2.000	2.800	3.800	3.775
2nd C, 2020	9.058	8.215	5.808	3.285	3.256	3.256	6.172	5.736	4.532

C: 1st and 2nd cut together

	Site - Pozdišovce			Site - Košický Klečenov			average		
	intensive	semi-intensive	control	intensive	semi-intensive	control	intensive	semi-intensive	control
2018	5.954	5.283	4.610	7.948	7.673	5.014	6.951	6.478	4.812
2019	15.350	14.200	16.250	24.050	20.300	18.700	19.700	17.250	17.475
2020	23.151	24.651	18.215	15.302	19.425	16.023	19.227	22.038	17.119

Figure 1. The dry matter yield according to site, year and treatment in the first cut (A), second cut (B), and the first and second cuts together (C); standard deviation added.

t/ha was found under the untreated control. The mutual difference was significant in general, except for the intensive and semi-intensive treatment comparison. The average DM yield on Site 1 was 14.18 t/ha, and on Site 2 was 14.94 t/ha, but the difference was not significant for the cuts together (Table 3), although the difference was significant according to the cuts, but even opposite if ranking the yield of the first and second cuts by site (Table 4).

The crop stand was not mowed down three times per year in any of the years, not even in the most productive year 2020, when the second cut was carried out earlier by 16 or 18 days compared with the 2 previous years. The regrowth after the second cut and further development of the crop stand were present, but the crop grew slowly under the moderate continental climate with the cooling autumn and the formed aboveground phytomass was left maybe as it can be necessary for good wintering.

Plant Height and Crop Coverage

The eastern galega plant's height and crop coverage had the following average values by year and treatment in the order of intensive–semi-intensive– untreated control: 2017: height: 26.0−29.0−26.0 cm, coverage: 24.0−26.0−25.0%, 2018: height: 57.5 − 53.5 − 41.8 cm,coverage: 77.8−65.3−56.8%, 2019: height: 105.0−92.0−87.0 cm, coverage: 85.8 − 87.3 − 88.3%, and 2020: height:110.8 − 113.8 − 100.0 cm, coverage: 96.0−92.5−92.3%.

Overall, in the year of establishment, the crop stands reached the plant height of 27 cm and crop coverage of 25%, both on average. Values of both parameters differed according to the site and treatment and achieved maximal values on Site 1 under semi-intensive nutrition treatment (Table 5). During the three productive years, the height of eastern galega was 84.6 cm on average, ranging 25−170 cm, and the coverage was 82.4% on average, ranging 10−100%, while the DM content at harvest was 27.9% on average, ranging 15.4−39.8%.

The yield of eastern galega was in a middle correlation with crop coverage ($r=0.483$, $R^2=0.2332$ for first cut; and $r=0.368$, $R^2=0.1352$ for the second cut), and in a strong correlation with plant height ($r=0.935$, $R^2=0.8742$ for the first cut; and $r=0.846$, $R^2=0.7161$ for the second cut). Adequate reliability indexes (R^2 values displayed in Figure 2) presented by the cuts are related to the second-order polynomic course of the dependence of crop yield on plant height and crop coverage, so both subfigures (AB) are optimised to show the whole data cluster for the sets by the cuts.

DM Content at Harvest

The crop stands were harvested based on an optimal harvest maturity, mainly in terms of high phytomass green yield, and at the same time with respect to the suitability of the harvested phytomass for ligno-cellulose quality, and with an effort to keep good regrowth and overwintering ability of the stands. Therefore, the cuts were done primarily focusing on the phenophase of full flowering initiation (BBCH 65). Although variable mowing down dates during the productive years occurred, mainly concerning the second cuts, no third cut was done so the phytomass regrowth in autumn was left to stay entirely on the field. Overall, the crop contained 27.9% of DM at harvest in total average, ranging from 15.4% to 39.8% (Table 6), while it achieved 30.9% at Site 1 and 24.9% at Site 2 on average. DM content at harvest had the following values on average according to the productive years and nutrition treatments in the order of intensive–semi -intensive–control: 2018: 31.3−32.0−33.3%, 2019: 26.1−27.5−29.8%, 2020: 22.6−24.5−24.0%. The obtained results on DM content at harvest indicate that the fresh phytomass of eastern galega contains high amounts of moisture. Concerning the mowing down, the second cut seems to be of higher DM content at harvest (30.2% in average) and more variable (15.4−39.8%) in comparison with the first cut with lower DM content (25.6%) and less variability (19.9−30.2%), contrary to DM yield, plant height and crop coverage (Figure 2).

Weather and Soil – Climate Conditions

The crop was sown in early spring of 2017 on the same day of April 3 on both trial sites. In 2017, the weather and soil-climate conditions were different on the sites (Table 6); during April–September, the precipitation was 288 mm on Site 1 and 363 mm on Site 2. Although the weather was typical for the continental moderate climate, being quite similar on both sites all over the trial period, it also varied over the years on the sites. Therefore, a marked differen-

T a b l e 4

Ouputs of MANOVA for the yield data, according to the cuts separately

Main effect	1st cut							2nd cut							The cuts together						
	IO	F-ratio	P-value	Homogenous groups		LS Mean	LS Sigma	IO	F-ratio	P-value	Homogenous groups		LS Mean	LS Sigma	IO	*F*-ratio	*P*-value	Homogenous groups		LS Mean	LS Sigma
Replications	4.	0.16	0.9254	A	IV	10.7127	0.5117	4.	0.05	0.9858	A	IV	3.5854	0.6163	4.	0.15	0.9310	A	IV	14.3225	0.6708
				A	II	10.7710	0.5117				A	II	3.5869	0.6163				A	II	14.3543	0.6708
				A	III	11.0673	0.5117				A	III	3.7060	0.6163				A	III	14.7731	0.6708
				A	I	11.1093	0.5117				A	I	3.7063	0.6163				A	I	14.7943	0.6708
Sites	2.	25.19	0.0000	A	Site 1	9.6310	0.3066	2.	32.96	0.0000	B	Site 1	4.5539	0.2236	3.	1.26	0.2663	A	Site 1.	14.1849	0.4732
				B	Site 2	12.1991	0.3066				A	Site 2	2.7381	0.2236				A	Site 2.	14.9372	0.4732
Years	1.	179.07	0.0000	A	2018	4.0803	0.4431	1.	40.70	0.0000	A	2018	2.0000	0.2739	1.	161.13	0.0000	A	2018	6.0803	0.5809
				B	2019	13.9815	0.4431				B	2019	3.4583	0.2739				B	2019	18.1417	0.5809
				B	2020	14.6833	0.4431				C	2020	5.4797	0.2739				C	2020	19.4612	0.5809
Nutrition	3.	4.22	0.0191	A	T3	9.8717	0.4431	3.	1.57	0.5155	A	T3	3.2637	0.2739	2.	4.52	0.0147	A	T3	13.1353	0.5809
				B	T2	11.3267	0.4431				A	T2	3.7457	0.2739				B	T2	15.2553	0.5809
				B	T1	11.5468	0.4431				A	T1	3.9287	0.2739				B	T1	15.2925	0.5809

IO – impact order, an order according to F-ratio; Main effect – source of variability; MANOVA – multivariate analysis of variance

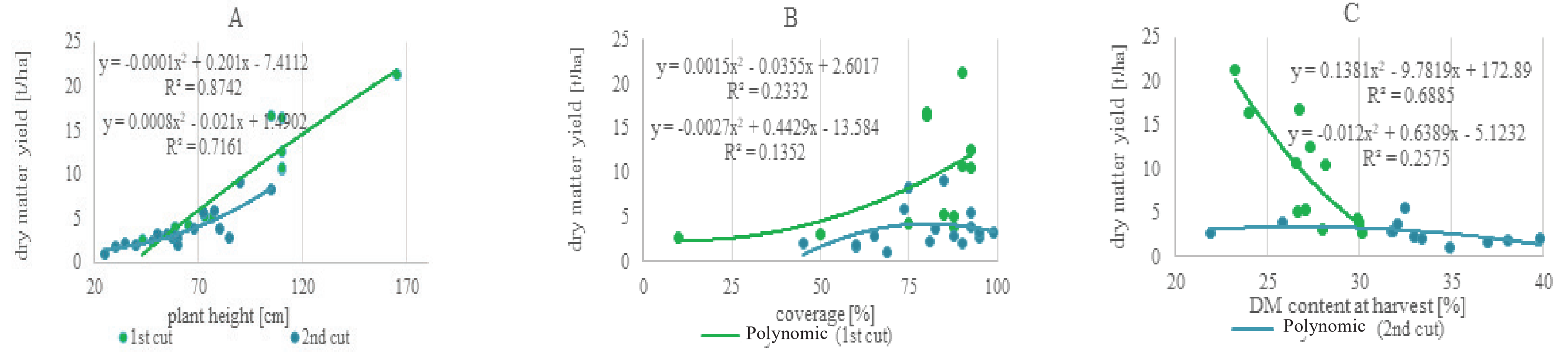

Figure 2. The polynomic trend lines of the yield dependence on crop height (A), crop coverage (B), and dry matter content at harvest (C) by the cuts.

ce between the semi-humid versus humid sub-climate was manifested on the sites, so it is displayed as it was present considering the soil moisture of topsoil and subsoil as well (Figure 3AC vs Figure 3BD, respectively). Due to the obtained differences, the dependence of the crop yield on weather conditions can be evaluated, as performed by polynomial relations presented separately according to treatments (Figure 4). Similarly, the yield relations on weather and soil-climate indicators are presented too, displaying them separately according to the cuts and nutrition treatments (Figure 5).

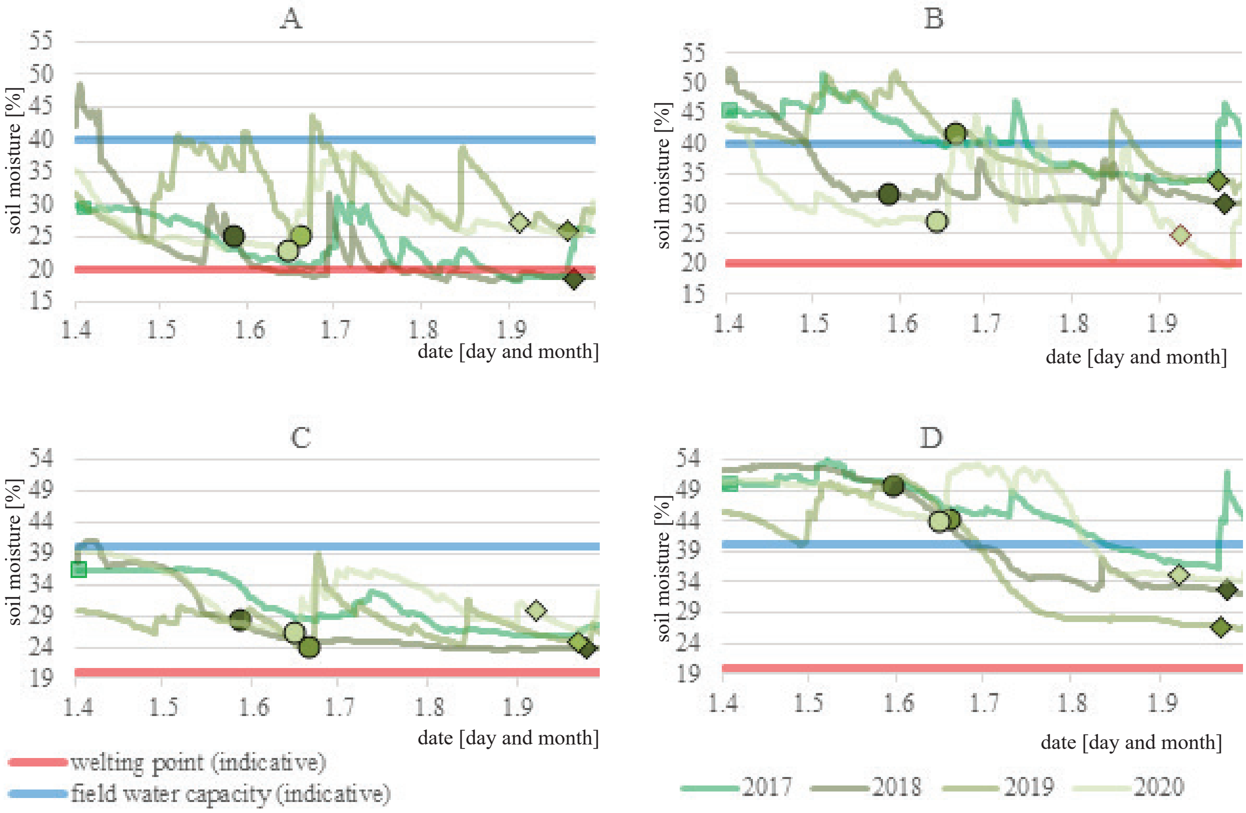

Figure 3. The time development of soil moisture in depths of 15 cm (AB) and 45 cm (CD), according to sites (Site 1: AC; Site 2: BD); added sowing (cube point) and cutting days (round for first and rhombus for second cut); and the indication of hydro-limits of field water capacity (~40%) and wilting point (~20%), which for clay-loamy heavy soils range from 35% to 46% and 17 – 23%, respectively.

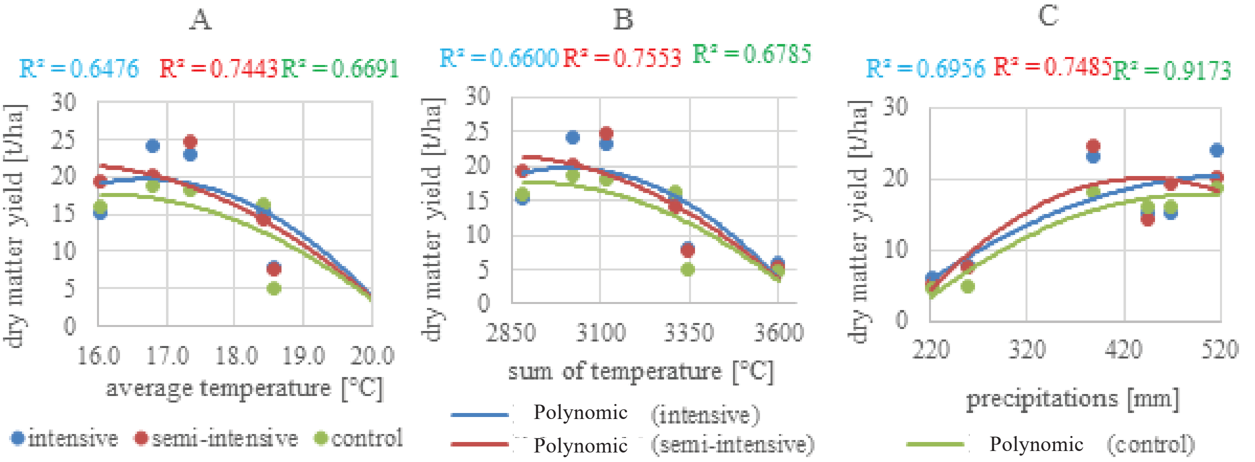

Figure 4. The polynomial course of dependence of yield on average air temperature (A), sum of air temperature (B), and sum of precipitation (C), according to treatments (intensive, semi-intensive, control). DM − dry matter.

There is a strong negative correlation between the eastern galega yield and the average day air temperature which increased from 16.0°C to 20.0°C ($R^2 = 0.6476$, 0.7443 and 0.6691, in the order of treatments T1 – T2 – T3), and a similar strong negative correlation is noted with the sum of temperature that increased in range from 2,850°C to 3,600°C ($R^2 = 0.6600$, 0.7553 and 0.6785, in the same order, respectively). Contrary to the temperature impact, there is a strong positive correlation between the crop yield and the increase in the sum of precipitation, which ranged between 221 and 516 mm ($R^2 = 0.6956$, 0.7485 and 0.9173, in the same treatment order). If the DM yield of the two cuts together is taken into account, it can also be concluded that the highest DM yield seems to be associated with average temperature range of 17.0 – 18.0°C, the temperature sum of 3,100°C, and precipitation amount of 420 mm (Figure 4). The correlations (Figure 5) performed separately by the cuts probably may prove, whereas the crop yield dependence on air temperature and precipitation confirms the rank of the cuts as a change factor. On the other hand, nutrition intensity is an important factor that mitigates some of the weather's adverse effects or increases some of its favorable effects. The same can be stated based on following the rank of the cuts by nutrition intensity, where the impact of the yield's relations with the soil–climate parameters is tracked.

Soil's Main Chemical Properties and Nutrient Content

The highest change status (471.6 ppm) was counted at soil calcium (Ca) content, followed by total nitrogen (Nt, 53.5 ppm), then by magnesium (Mg, −50.9 ppm), phosphorus (P, 41.2 ppm), potassium (K, −15.1 ppm), humus content (0.286 %), and C/N ratio (0.743), whereas values of C-ox content (0.166 %) and pH (0.350 pH/KCl) were changed at the least (Table 7). The change is an impact of the complex processes of the soil environment including the soil-plant system and availability changes, as well as the result of the soil's non-homogeneity, especially within the large-scale trials, as it is in the given case. The changes related to nutrition treatments are

Table 5

Plant hight, crop coverage and dry matter content at harvest

Site/cultivar Year/treatment		1st cut						2nd cut					
		Site 1			Site 2			Site 1			Site 2		
		T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Plant height [cm]	2017*	29	34	31	23	24	21	–	–	–	–	–	–
	2018	65	58	43	77	73	59	30	35	40	58	48	25
	2019	110	110	110	165	110	105	60	68	73	85	80	60
	2020	130	125	122	165	170	150	90	105	78	58	55	50
Crop coverage [%]	2017*	27	29	29	21	23	21	–	–	–	–	–	–
	2018	75	50	10	88	85	88	60	45	60	88	81	69
	2019	93	93	90	90	80	80	65	83	93	95	93	90
	2020	100	100	100	100	100	100	85	75	74	99	95	95
DM cont. at harv. [%]	2017*	35.6	37.3	36.4	32.3	33.4	33.9	–	–	–	–	–	–
	2018	29.8	28.0	30.2	26.6	27.1	30.0	37.0	39.8	38.1	31.7	32.9	34.9
	2019	27.3	28.1	26.6	23.2	24.0	26.7	31.8	32.0	32.5	21.9	25.8	33.4
	2020	23.3	25.8	21.7	19.9	20.9	21.0	31.7	35.3	36.6	15.4	15.8	16.8

T1 − intensive nutrition; T2 − semi-intensive nutrition; T3 − untreated control; * − the crop was not mowed down in the establishment year, data displayed under the column of the first cut in 2017 were recorded at the end of September 2017; the end of the main vegetation period.

associated with the nutrition intensity increasing positively, but at the same time negatively due to increased consumption, by increased yield. The positive change of Nt may indicate that the green yield potential of the crop was probably met or approximated at least. However, this statement can be valid only regarding Site 1 with a lower crop yield. At Site 2, with a higher yield, the change of Nt was negative, which indicates the limited green yield, pointing to some reserves in the crop yield's potential despite the more productive site. As already mentioned, the change status of C-ox content was 0.227% on average, which equals an increase of 1.023 t/ha C-ox during a 4-year period 4 years (0.2258 t/ha C-ox per year), while the change ranged from −1.733 t/ha to 2.975 t/ha. The polynomial course of that dependence is displayed in Figure 6A, with a reliability index ($R^2=0.5665$) that confirms the high reliability similar to a strong correlation ($r=0.7430$) within an adequate linear course of the dependence.

DISCUSSION

DM Yield, Agronomy, and Conditions in the Establishment Year

In the experiment, cv. Gale and sowing rate of 17.5 kg/ha were applied; a slightly lower sowing rate of 15 kg/ha was used by Meripold *et al.* (2017) in a small-plot trial, and by Dubis *et al.* (2020) in a large-scale experiment, when testing cv. Gale and/or cv. Risa respectively. A markedly higher seeding

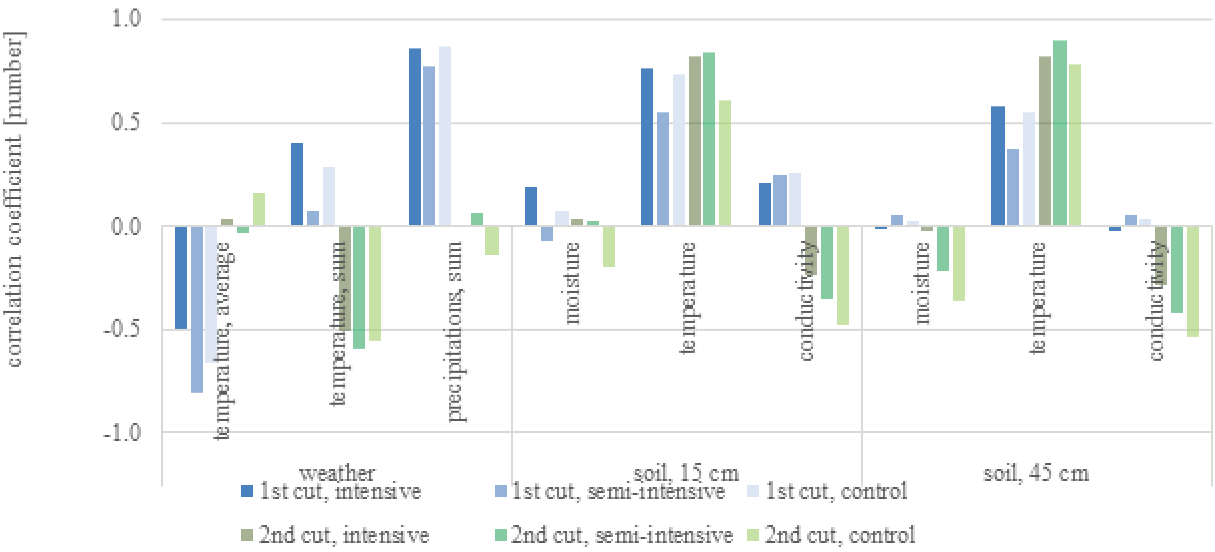

Figure 5. The correlation coefficients of yield and weather and soil–climate relations.

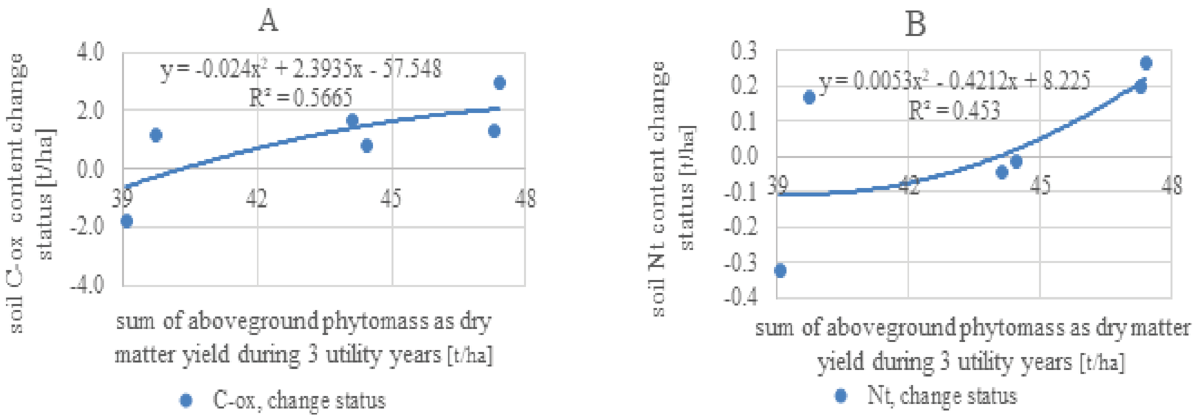

Figure 6. The polynomic course of dependence of soil's organic carbon C-ox (A) and total nitrogen Nt (B) change status on the crop's total dry matter yield during the three utility years (2018–2020).

Table 6

Data on weather and soil conditions according to the crop cuts, during the main vegetation period (April – September of 2017 – 2020)

Site / year	Weather condition			Soil condition, depth 15 cm			Soil condition, depth 45 cm		
Parameter	AT [°C]	SAT [°C]	SP [mm]	M % VWC	T [°C]	EC [mS/cm]	M % VWC	T [°C]	EC [mS/cm]
2017*									
Site 1	18.4	3,312	288	24.3	17.4	0.119	31.7	16.2	0.299
Site 2	16.6	2,988	363	41.4	17.2	0.623	46.9	15.5	1.074
2018									
Site 1, 1st cut	17.0	986	97	27.5	13.2	0.124	36.1	12.1	0.327
Site 1, 2nd cut	20.9	2,445	148	21.9	19.3	0.113	28.3	18.3	0.279
Site 2, 1st cut	15.7	911	123	46.0	12.1	0.688	50.9	10.5	1.249
Site 2, 2nd cut	19.3	2,258	186	38.1	19.5	0.569	43.3	18.2	0.937
Site 1	20.0	3,600	221	20.7	19.9	0.067	28.7	17.4	0.274
Site 2	18.6	3,348	259	34.7	18.8	0.395	43.7	16.5	0.802
2019									
Site 1, 1st cut	16.5	1,172	298	32.0	15.2	0.155	28.1	13.6	0.269
Site 1, 2nd cut	19.7	1,872	167	31.4	19.8	0.165	27.8	18.9	0.269
Site 2, 1st cut	14.8	1,051	279	45.0	15.1	0.662	46.5	12.8	0.890
Site 2, 2nd cut	17.9	1,701	301	36.9	20.2	0.385	30.4	19.0	0.560
Site 1	18.4	3,312	445	32.3	17.5	0.165	28.3	16.1	0.273
Site 2	16.8	3,024	516	41.6	17.9	0.555	39.5	15.9	0.750
2020									
Site 1, 1st cut	14.8	992	246	25.6	13.4	0.137	33.2	12.2	0.247
Site 1, 2nd cut	19.7	1,635	202	30.4	21.2	0.161	32.2	19.7	0.258
Site 2, 1st cut	13.4	898	211	30.8	14.0	0.716	48.4	12.0	1.107
Site 2, 2nd cut	18.6	1,544	310	31.8	20.7	0.669	44.6	19.1	1.042
Site 1	17.3	3,114	388	28.2	17.4	0.150	32.8	16.0	0.255
Site 2	16.0	2,880	468	31.6	17.3	0.702	46.9	15.5	1.086
Average (2018 – 2020)									
Site 1, 1st cut	16.1	1,050	214	28.4	13.9	0.139	32.5	12.7	0.281
Site 1, 2nd cut	20.1	1,984	172	27.9	20.1	0.146	29.5	19.0	0.269
Site 2, 1st cut	14.6	953	204	40.6	13.7	0.689	48.6	11.8	1.082
Site 2, 2nd cut	18.6	1,834	266	35.6	20.1	0.541	39.4	18.8	0.846
Site 1	18.6	3,342	351	27.1	18.2	0.127	29.9	16.5	0.267
Site 2	17.1	3,084	414	36.0	18.0	0.551	43.4	16.0	0.879

2017* − the establishment year without cuts. AT − average day air temperature; EC − electrical conductivity; M − moisture; SAT − sum of average temperature; SP − sum of precipitation; T − temperature; VWC − volumetric water content.

rate of 5 MGS/ha was applied by Burtseva *et al.* (2020) for cultivars of Gale, Krivich and Magistr. To achieve a/or the satisfactory density of the crop canopy, it is recommended by Zarcinski *et al.* (2021) to sow 20 − 30 kg of seeds per hectare or 300 − 500 seeds per m^2. According to Kschnikatkin *et al.* (2022), the reduction of sowing rate of eastern galega to 2.0 million seeds per hectare should be done after pre-sowing treatment by scarification and seed inoculation, because the sowing material of the crop usually contains 50 − 95% of seeds with a hard shell. However, some negative effects on seedlings' biometric parameters can be noted, if the scarification of seeds is too effective (Zubarev & Zabolatnova 2021). According to the conclusions of Zubarev and Zabolatnova (2021), the swelling rate of eastern galega increased from 0.14 L/h up to 1.09 L/h, which is seven times more than the swelling rate of non-scarified seeds, and the negative effects were noted when seeds were soaked up to 100% of the water level. In the trial, no malformation of the seedlings was noted, even when different soil moisture levels occurred on both sites in the spring of 2017 after the sowing; therefore, the scarification had to be done to an accurate level.

The initial growth of the eastern galega was slow on both trial sites; therefore, the crop stand was mowed down not in the year of establishment. However, the eastern galega development was followed carefully, and the plant samples were taken due to DM yield determination and DM content quantification (Table 6). All over the sites and treatments, the crop reached an average height of 27 cm (range 21 − 34 cm), while it reached a DM yield of 0.52 t/ha on average (range 0.43 − 0.64 t/ha). The research of Nakamura *et al.* (2023) aimed to determine the latest date for sowing, as there is a limit concerning the crop in a Northern Japan region with severe growing conditions. The DM yield of eastern galega in the year after sowing was higher under

Table 7

Soil´s main chemical properties and content of nutrients in the topsoil layer (Depth of 0 − 30 cm); the initial (2016), final (2020) and change status (2020 vs. 2016)

Site	Status	Treatment	Nt [ppm]	P [ppm]	K [ppm]	Ca [ppm]	Mg [ppm]	pH/KCl	C-ox [%]	Humus [%]	C/N, no.
Site 1	Initial	Average*	1,665	39.3	221.1	3,069.9	453.9	5.02	1.614	2.78	9.74
			–	low	middle	middle	high	acidic	–	middle	middle
	Final	Intesive	1,404	116.9	316.8	2,890.0	249.7	4.73	1.732	2.984	12.34
	Change		−28	33.6	95.4	130.9	−37.4	−0.18	0.187	0.322	1.55
	Final	Semi-intensive	1,406	150.4	189.5	3,517.2	255.6	5.41	1.716	2.957	12.20
	Change		−107	124.5	0.0	−173.1	−111.9	−0.16	0.364	0.628	3.27
	Final	Control	1,328	22.7	205.8	3,619.3	338.6	5.46	1.552	2.674	11.69
	Change		−723	14.1	−46.5	−761.0	−368.5	0.89	−0.394	−0.680	2.20
Site 2	Initial	Average*	1,567	77.2	418.7	4,438.8	632.8	5.54	1.569	2.70	9.98
			–	suitable	high	high	very high	weakly acidic	–	middle	middle
	Final	Intensive	2,165	92.9	582.0	4,360.8	698.7	5.72	2.119	3.652	9.79
	Change		443	−8.1	100.6	−458.0	−16.3	−0.21	0.290	0.500	−0.83
	Final	Semi-intensive	2,142	112.9	593.7	4,763.7	654.0	5.58	2.097	3.613	9.79
	Change		596	32.5	141.0	−536.3	−114.0	0.23	0.661	1.139	0.51
	Final	Control	1,801	99.5	466.1	5,287.1	683.5	5.44	1.697	2.924	9.42
	Change		367	49.3	144.1	2,089.6	268.0	0.10	0.256	0.441	−0.62

Average* − initial status displayed as average of Intensive, Semi-intensive and Control treatment; however the Change status is calculated as difference of final and initial status used direct values by the treatments.

conditions that safeguarded pre-overwintering plant length growth of 30 cm or more, as compared with growth of less than 30 cm. As for the rhizomes, prior to overwintering, a length growth of 28 cm or more is favorable, especially to avoid low DM yields observed in cases when the soil freezing depth was deeper than usual. According to their calculation, the effective cumulative temperature (ECT) required for pre-overwintering eastern galega to reach 30 cm in plant length is 1,079°C, for which the sowing date falls on July 10 or June 29, with 80% or 90% probability in their severe region to ensure the safe growth because of the effects of soil freezing on overwintering performance.

During the main vegetation period of the establishment year (April−September 2017), the sum of average daily temperature achieved 3,312°C and 2,988°C (Table 3), so the adequate values of ECT were 2,412°C and 2,088°C, on Site1 and Site2, respectively. Even though these values of ECT doubled approximately those of Nakamura´s *et al.* (2023) data, the height of the aboveground parts of the crop exceeded 30 cm only on Site 1, where the shoots' length of 31 cm was achieved on average, but the length of rhizomes was not monitored. The shoots reached 23 cm in height on average on Site2, which is markedly less than 30 cm, concluded to be critical for severe conditions. With regard to the issue of plant height, an agronomic study of Gonzales-Andres *et al.* (2004) can also be mentioned; however, it aimed only at a closely related species, *G. officinalis,* and recommended a cutting height between 6 and 10 cm above ground level to avoid causing lowest survival that leads to significantly lower yield in the next year. Regarding these closures, for the crop stand, it can be a better choice to be mowed not in the year of establishment.

Mowing down the small plants can only result in a small volume of green phytomass; therefore, the cut is not important and becomes economically questionable. In addition, according to the conclusions of Nakamura *et al.* (2023), the cut may also be counterproductive as the mowing down can lead to renewal of growth after the cut, hence causing the consumption of storage substances necessary for wintering, which will surely weaken the rhizomes. Continental climate of Central Europe is known for the occurrence of strong frosts and bare frosts without snow cover during winter, while the soil regularly freezes over the entire topsoil and deeper; and sudden temperature changes with above-zero temperatures during the day and freezing temperatures at night. Considering all these specifics, mainly the crop's slow initial growth and the climate, the mowing down of eastern galega green phytomass can be recognized as unnecessary, even unsuitable, in the year of establishment. Eastern galega is of Caucasian origin (Nõmmsalu *et al.* 1996) and is characterized by tube-shaped stems. Both facts should be considered when introducing the crop, especially during the preparation of stands for the first wintering. The climate zone of the Caucasus represents a significant climatic divide between the temperate humid climate zone in the north and the subtropical humid region in the south, which are different compared with the continental European climate or the Nordic one, where the crop is introduced and needs to be adapted. Although the crop was found to be very resistant to frost, based on long-term cultivation in conditions of Mecklenburg-Western Pomerania, drought induces reduced growth; however, no danger of dead loss was observed by Bull *et al.* (2011). There is no similar study concerning the continental European mild climate, where semi-arid and semi-humid areas with a harsher winter are the most typical. Although the effect of the sites seems to be certain, non-significant when evaluating the cuts together (Table 6AB), it was significant with regard to the individual cuts (Table 6B). It may be notable too that the study includes no site with arid or semi-arid subclimate, where the eastern galega development and productivity may be entirely different. Due to the slow initial growth, the arid or semi -arid conditions can be a key limiting factor for the success of the stand's establishment, especially if the soil is light and a drying water regime is already present, and irrigation is absent. Due to the number of cultivars of the crop, which are characterized by different genotypic variability and morphological properties, including a vigorous adaptability (Tkacheva *et al.* 2011; Bushuyeva 2015), their regionalization would also be desirable for the specific conditions of the continental European climate. Regarding the tube-shaped stems of the crop, it can be mentioned that better overwintering is required to remain on the stems in general, so it should not be mowed before winter, to avoid water seepage through the cut stems, which could lead to serious damage to the roots during winter.

In the year of establishment, the average DM yield of 0.5 t/ha was reached, which is markedly less than the range of 3.8 − 3.9 t/ha stated concerning the crop productivity under a similar milder climate of Poland (Symanowicz *et al.* 2019; Dubis *et al.* 2020). The yield range of 7.6 − 8.0 t/ha DM reported for the crop productivity in the cold climate of Latvia, Lithuania and Estonia (Adamovics *et al.* 2008; Povilaitis *et al.* 2016; Meripold *et al.* 2017) was achieved in the first productive year, which can be incorrectly stated occasionally as the year of establishment when cited, although the original papers clearly refer to the second year of the crop life when the biomass was started to be harvested and measured.

When sowing 135 germinating seeds per m^2, the crop stand reached 25.0% coverage on average in the year of establishment (2017), while a difference between locations (28.3% on Site 1 and 21.7% on Site 2) was more marked than those among the treatments (24.0 − 26.0 − 25.0%, in the order of treatments T1, T2 and T3). When Burtseva *et al.* (2020) sowed 500 germinating seeds per m^2, and with supplementary irrigation, they maintained an irrigation mode of 80% minimum water capacity (MWC), the empty places in the stand fluctuated within 32 − 45% and the crop coverage formed 55 − 78% at a density of 85 − 120 plants per m^2 in the year of establishment. The herbage density was 5 − 18% less under the variant with 70% MWC. Despite the two irrigation regimes (80 and 70% MWC) conducted within their 7-year experiment, the completeness of the seedlings depended on the weather condition during spring, while from the second year to the fourth year, the herbage density increased up to 258 − 350 plants per m^2 due to the offspring development of the fodder galega roots, and after the fifth year, they recorded a slight decrease in the herbage density.

Productive Years

In papers evaluating eastern galega performance under North European condition, the crop DM yields ranged from 7.6 − 8.0 t/ha in the first productive year to 9.3 − 13.5 t/ha in the further productive years under the cold climate conditions of Latvia, Lithuania, and Estonia (Adamovics *et al.* 2008; Povilaitis *et al.* 2016; Meripold *et al.* 2017), whereas the crop DM yield ranged 9.4 − 16.3 t/ha in productive years under a milder climate in Central and North East Poland (Symanowicz *et al.* 2019; Dubis *et al.* 2020), and the average annual DM yield was about 10 t/ha in Mecklenburg-Western Pomerania in North Germany (Bull *et al.* 2011). In a paper evaluating the performance of a similar perennial leguminous crop under South European conditions based on a small-plot trial, the maximum phytomass yield of the related crop, *G. officinalis* L., was 13 t/ha DM in the first year and 10 t/ha in the second year at five cutting systems per year, while the last cutting was delayed to avoid regrowth in late autumn and leaving the remnant phytomass for the green manure. That experiment in the mountainous Mediterranean conditions of Spain was established in late October (Gonzales-Andres *et al.* 2004). In the study of Fairey *et al.* (2000) conducted across Canada to compare the yield productivity of eastern galega with traditional fodder legumes; to estimate its agricultural potential, the trials were carried out for a maximum of 3 production years. The cumulative DM yields of 5.55 t/ha indicated that cv. Gale is at least as well adapted across Canada as the other legumes. In tests it was found considerable potential of crop, which makes it suitable for many regions of Canada, except of the semi-arid continental climate of the Central Prairies, where the growth could be limited by high air temperature and/or insufficient soil moisture. In the paper of Dubis *et al.* (2020), the results of 11-year field experiments conducted in Northeast Poland are presented, which concluded that the yield of eastern galega green phytomass was conditioned mainly by the age of the crop. The crop DM yield peaked in year 4 in the low-input technology when it reached 14.7 t/ha, and in year 5 in the high-input technology when it achieved 15.3 t/ha. The yield decreased rapidly at a rate of 2.3 − 3.5 t/ha per year between the fourth (fifth) and seventh year of the experiment in both technologies. In years 7 and 8, the yield was stabilized at 7.79 − 8.16 t/ha in the low-input and at 8.21–8.29 t/ha in the high-input cultivation. Beginning from the ninth year, the yield decreased by 0.6 t/ha per year in the high inputhigh-input and by 0.9 t/ha per year in the low-input system. In the long-term experiment, the high inputhigh-input technology yield was 0.62 t/ha per year higher, while the maximum yield was achieved 1 year later, and the rate of decrease in phytomass yield in the last three years of the experiment was 30% lower in comparison with the low-input technology.

Also based on long-term research of Symanowicz *et al.* (2019) conducted on Central Poland, the phytomass of eastern galega peaked in the fourth and fifth year of cultivation, when the crop reached a DM yield of 16.8 – 16.9 t/ha. Based on this long-term research, the DM yield of the crop increased in response to NP, NK, PK, and NPKCa fertilisation from 7.81 t/ha (non-fertilised treatment) to 12.8 and 14.1 t/ha (NP, NK or PK), and 16.3 t/ha (NPKCa). In the study, they stated that the climatic condition during the experimental period of 1994 – 1998 was not suitable due to very low precipitation which significantly decreased the crop yield with the highest DM yield of 10.8 t/ha harvested at the treatment where the seeds was inoculated by *R. galegae.* In their study, Meripold *et al.* (2017) found out the crop yield ratios of the first and second cuts were 1:0.51 and 1:0.47, as the first one for the stand was treated with an N dose of 50 kg/ha and the second one without N applied, respectively. Testing cv. Gale under the cold Estonian condition, they achieved an average DM yield of 10.4 and 9.4 t/ha in the order of treatments, and with increasing yields by utility year approaching under both their nutrition treatments (7.8 – 13.5 – 9.9 t/ha and 7.6 – 10.0 – 10.5 t/ha, respectively) in the first three productive years. According to their results, the maximum phytomass yield of 13.5 t/ha DM was achieved in the second productive year of the crop, and the yield increased by 11% (1.0 t/ha) when the rate of N fertilisation was increased by 50 kg/ha. In an experiment conducted by Slepetys (2010), the crop phytomass was highest (11.9 t/ha) in years 10 and 11.

Inoculation and Plant Nutrients

In the present time, due to an often-discussed global environmental nexus, it is necessary to regulate the doses of N fertilisers, and it is considerable to pay attention to other ways of N input into the agricultural system. Such an option is primarily the fixing of air nitrogen by the symbiotic microorganisms by legume crops, various strains of nodule-forming *Rhizobium galegae* or *Neorhizobium galegae* used to inoculate the seeds of the eastern galega (Österman *et al.* 2015; Karasev *et al.* 2019; Symanowicz *et al.* 2019). In general, with the use of effective inoculants, adjustment of symbiotic relationships and conditions of the habitat for plants and legumes achieve a capture of 70 – 140 kg of atmospheric N per hectare during 1 year, while the average and highest values measured for eastern galega are at a higher level. According to the results of Adamovics *et al.* (2008), successful treatment of galega seeds with nodule-forming symbiotic bacteria resulted in fixation of air N from 200 to 453 kg/ha, so the need for commercial N fertilisers can be decreased. Based on Stepanov *et al.*'s study (2021), the crop can fix up to 233 – 379 kg/ha of air N during the growing season in various agro-ecological conditions of Western Siberia, so the nitrogen-fixation coefficient is 1.1 – 1.4 times less in the northern steppe in solonetz than in southern meadow chernozem soil. According to Karbivska (2020), the crop proved to have significantly less root mass accumulation compared with *Lotus corniculatus* within an experiment conducted on Southern Ukrainian steppe zone, which included *M. sativa* and *Trifolium pratense.* Those results showed the formation of symbiotic apparatus and the N accumulation in legume crops were highly dependent on fertilisation application, biological features of plant growth and development over the years. It can be noted too, that the activity of the nitrogenases, key enzymes in root nodules, is highest at an air temperature of 20 – 30°C with an optimum of 20 – 24°C and a soil pH of 6.5 – 7.5, in general. Thus, the effectiveness of seed inoculation depends on the mutual interaction of applied rhizobia and the influence of the environmental factors, especially humidity and temperature of the soil, which was manifested by the dispersion of the growth of the phytomass yield in individual years (Figure 2). That impact on the phytomass quality would be a subject of a possible further work dedicated to the crop. Due to some reasons connected primarily with the pilot and large-scale characteristics of the experiment, the yield benefit of seed inoculation is significant from the relevant literature sources comparing more than what is evident from the trial itself. The results of a rare field experiment with the crop cv. Gale where, due to the absence of an inoculant, seed treatment with rhizobia microbial preparation was not used before sowing, are described by Knotova *et al.* (2018). In their trial, *G. oriental*is achieved a DM yield of (1) 0.45 t/ha and 2.10 t/ha within a single cut per year in the second and third year of crop life, respectively, at the site located in a warm and dry region with an altitude of 270 m, annual precipitation of 512 mm and average annual temperature of 9.4°C; and 2) 7.90 t/ha together within three cuts per year (4.10 − 2.70 − 1.20 t/ha, respectively) in the second year of crop life (without data about the third crop life), at the site located in a cold and humid region with an altitude of 560 m, annual precipitation of 617 mm and average annual temperature of 6.9°C. Their soil–climate conditions and the yield results of their experiment are just complementary to the results and conditions presented in the paper, thus allowing for extending the conclusions. So, the inoculation should become a routine part of growing this crop, because the general advantage of inoculated plants is the binding of atmospheric N, which leads to a longer period of use of the assimilation area of the leaves, and the formation of a larger number of pods and seeds on the plant, thus having a higher green yield. A low rate of N fertiliser dose may correspond with the N supply to overcome the starvation period until nodules are formed on the roots after sowing, while the most suitable is ammonium sulfate incorporated during pre-sowing preparation (Symanowicz *et al.* 2019). As for the pilot nature of the experiment, the best option to determine the yield potential of the crop was to establish the trial in suitable but contrasting conditions, as well as include an overdimensioned nutrition to surely approximate the green yield potential. The eastern galega is a newly introduced crop in Slovakia with symbiotic strains of *R. galegae* or *N. galegae,* which did not occur naturally in the soils of the country.

An experiment done by Sienkiewicz *et al.* (2017) showed that the way set-aside and fallow land is maintained significantly modified both Nt and C-ox concentration in soil, and the test favored the impact of *G. orientalis* cropping among the other treatments, including bare fallow and natural fallow. Vasbieva and Zavyalova (2021) studied total P content in soil, a quantity of its organic, mineral, and plant available forms. Based on long-term cultivation of crops during five cycles of the eight-field crop rotation, they found a significant decrease in the content of organic P in the soil. Under the cropped eastern galega stands, the quantitative and qualitative indicators of the phosphate regime of the soil did not differ from the adequate natural agro-phytocenosis of the crop. These findings are complementary to the results in the paper, mainly regarding the soil change status of the monitored nutrients. However, especially in the case of Ca, the change status may be distorted due to the large-scale nature of the experiment, which is usually accompanied by some inhomogeneity of the plot on a trial site.

CONCLUSIONS

The study verifies the yield potential of eastern galega under moderate Central European climate. Since the crop was newly introduced into Slovakia, it was cultivated on two sites with marginal heavy soil and semi-humid to humid conditions during four crop years. The impact of nutrition intensity was tested as well, including the contrast treatments of intensive, semi-intensive, and untreated control. Dry matter yield of 14.56 t/ha was achieved in total average, with 10.92 t/ha in the first cut and 3.65 t/ha in the second cut. In general, eastern galega productivity increases as the utility year approaches and the nutrition intensity increases. As the yields varied from 4.61 t/ha to 24.65 t/ha, counting the two cuts per year together, the full production potential has been reached, or at least approximated. However, the study is based on the experiment conducted at the sites with suitable soil–climate conditions, including no site with arid or semi-arid subclimate. Therefore, it can be conclude as well, that due to the slow initial growth the crop productivity may be completely different under semi-arid to arid conditions, especially on light soil, where already a drying water regime could be present, what can be assumed as main limiting factor. Despite the suitability of the crop for extensive, semi-intensive to intensive cultivation, the yield decline is present as nutrition decreases (13.14, 15.26 and 15.29 t/ha, respectively), moreover this decline is more evident in time development. So, the appropriate mineral nutrition needs to be applied, and the state of nutrient content in the soil must be monitored to allow the longer lifespan of the crop. Due to the biological specifics of this legume crop, the issue of nutrition needs to be studied in more detail, especially the task of how to achieve symbiotic microbial strain synergies and increase the efficiency of the inoculation of seeds. The effective symbiotic strains of *R. galegae* and *N. galegae* are not present naturally in Slovakia's soils, moreover, the crop for energy purposes can be cultivated preferably on marginal soils, which may be characterized by unfavorable properties for rhizobial bacteria. This study recognized the crop to be an appropriate perennial legume for cultivation in Slovakia, therefore, further agronomical follow-up studies are needed to be performed.

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