ABS ACTA BIOLOGICA SIBIRICA
A journal on the biodiversity of Siberia and the adjacent lands

Acta Biologica Sibirica 10: 601–610 (2024)
doi: 10.5281/zenodo.12198537
http://journal.asu.ru

RESEARCH ARTICLE

Features of the development of *Galega orientalis* Lam. in the conditions of the middle taiga of Western Siberia

Ekaterina A. Moiseeva[1, 3], Ludmila F. Shepeleva[2], Rimma Kh. Bordey[3]

1 *Surgut State Pedagogical University, 50 Let VLKSM St., 10/2, Surgut, 628417, Russian Federation*
2 *Tomsk State University, Lenina Pr., 36, Tomsk, 634050, Russian Federation*
3 *Surgut State University, Energetikov St., 22, Surgut, 628400, Russian Federation*

Corresponding author: Ludmila F. Shepeleva (shepelevalf@mail.ru)

Academic editor: R. Yakovlev | Received 1 February 2024 | Accepted 25 May 2024 | Published 23 June 2024

http://zoobank.org/28ED54F8-22EC-4127-8973-2175C474E717

Citation: Moiseeva EA, Shepeleva LF, Bordey RKh (2024) Features of the development of *Galega orientalis* Lam. in the conditions of the middle taiga of Western Siberia. Acta Biologica Sibirica 10: 601–610. https://doi.org/10.5281/zenodo.12198537

Abstract

This paper presents the results of an introductory assessment of the *Galega orientalis* Lam. culture (Eastern Galega) to introduce it as a food crop in extreme Northern environmental conditions. To reach the study aim, we conducted a small plot experiment based on the methodology of B. A. Dospekhov with randomized repetitions. We sowed the eastern Galega uninoculated seeds (the control experiment) in sandy podzolic soil; the seeds inoculated with microbiological fertilizer; binary sowing with legumes (pea). We observed the experiment and accounted for the research parameters in agreement with the standard research methods. The results of this study demonstrate ontogenetic and seasonal development characteristics of the species under review growing in the vicinity of Surgut, its biologic productivity, and the advantages of its use as a feeding crop. We analyzed the efficiency of the inoculation of the seeds with microbiological fertilizer Baikal-EM1 and binary sowing. These measures aimed to enhance the productivity and adaptive properties in the eastern Galega grown in the middle boreal subzone of Western Siberia. This research proves the introduction of the eastern Galega into the regional forage production to be of high potential. The introductory assessment of the eastern Galega in environmental conditions of the middle boreal forest of Western Siberia was carried out for the first time. We validate the use of the Baikal EM1 fertilizer for presowing seeds preparation. The identified species-specific characteristics in growth, productivity, chemical composition, and nutritional value are equal to those of the same culture grown in more favorable conditions. Therefore, *Galega orientalis* can be recommended as a promising feeding crop for the region in question.

Keywords

Introductory research, *Galega orientalis* Lam., forage production, extreme environmental condition

Introduction

The focus on agricultural adaptation to local conditions in Russia requires the intensive development of the forage production sector. Extreme environmental conditions of the West Siberian middle boreal forest, lack of sowing areas, their low productivity rate, and high cost limit the development of the local nutrient supply. Native hays mainly consist of sedge flood plains presenting an unsatisfactory food material. The introduction of a new perennial legume crop with a high yield rate (eastern Galega) can form the forage reserve and boost forage production in the region. At present, eastern Galega cultivation in the Northern conditions is one of the top priority goals in the sphere of forage production as this species demonstrates wide ecological valency and high nutritious efficiency (Boyko 2011; Ingiri et al. 2011; Karakchieva 2015; Anatolyan 2017).

The scientific publications on the topic provide numerous insights into the efficiency of seeds inoculation with bacterial and fungal preparations and growth regulators positively affecting adaptive and nutritional properties of the Eastern Galega (Nalyukhin 2008; Raig et al. 2008; Kozhemyakin 2010). However, despite their high effectiveness, these substances pose a need for specialized methods and substantial financial investments. This study presents the first attempt to assess the efficiency of the microbiological Baikal EM1 fertilizer in the Northern environmental conditions. The main criteria for selecting this inoculation preparation were its low cost, availability, and simplicity of use.

Therefore, the research of the Eastern Galega, its potential, and the possibility of successful introduction in the Western Siberia middle boreal forest conditions is highly relevant. This research will contribute to the development of crop adaptive technologies, the creation of a sustainable nutrition supply, and the boost of forage production in the region.

Materials and methods

The study object is a perennial legume species *Galega orientalis* Lam. (Eastern Galega), the Gale variety.

This study aims to assess the possibility of the successful introduction of the eastern Galega into the Western Siberia middle boreal forest, study the effect of the microbiological fertilizer Baikal-EM1 on the species in question, and the possibility of its binary sowing with the pea. The study objectives are as follows: to study the phenological features of the Eastern Galega and its development features; to determine the effective temperature sum required to ensure the successful development of plants, valuable biomass, and seeds; to determine photosynthetic efficiency of the Eastern Galega; to evaluate forage properties of the crop under review.

We conducted the introductory experiment at the Surgut State University experimental ground. The experiment had been running from 2013 to 2015 following the methodology basis (Dospekhov 1985) in acidic (5.21) (the Central Agricultural Chemical Research Institute [CACR] method) sandy podzolic soil with a humus content of 5.6% (the Turin's method). The ammonium and nitrate nitrogen content in the tillage horizon was 3.9 mg/kg of soil (the CARC method) and 129 mg/kg of soil (ionometry method). The exchangeable potassium and mobile phosphorus content amounted to 67 mg/kg of soil and 396 mg/kg of soil, respectively (Kirsanov's method). The research design was validated (Moiseeva et al. 2016) through randomized organized repetitions taken four times. The total experimental area covered 18 m^2, the area of a single plot was 1.5 m^2.

We sowed the Eastern Galega seeds inoculated with the Baikal EM1 fertilizer and the pea seeds as a cover crop. The uninoculated seeds sowed alone were accepted as the control experiment.

The seed material meets the standards of the PC1 category (1 reproduction). The Baikal-EM1 fertilizer is manufactured in the LLC Scientific Production Association [SPA] "EM-Center," Ulan-Ude, the Republic of Buryatia. We conducted the seed inoculation of the Eastern Galega concerning the recommendations of the manufacturer.

We carried out phenological monitoring, the assessment of plant population per 1 m^2 and assimilative surface, and the assessment of forage properties according to the established methodology (Nichiporovich 1966). The yield evaluation and samples harvest were conducted manually at the end of the vegetative season with the daily average air temperature lower than 5 °C within five days.

Result

The ontogeny of the Eastern Galega is noted for the pregenerative period prolongation up to two years in extreme environmental conditions of the introduction point. The researched crop reached its generative phase and entered buddying, flowering, and fruiting stages only during the third year of the experiment.

We found a correlation between the introduction species' age and an extension of its vegetating period. This could be attributed to earlier growth and stem elongation. On average, the vegetative period of the plants during the first year was 110 days, whereas during the second and third years, it grew to 124 and 126 days, respectively.

The monitoring results revealed that the use of the Baikal-EM1 fertilizer during the introductory experiment boosted the main phenological development stages by 2–5 days in the first year, by 4 days in the second year, and by 14 days in the third year compared to the control experiment. These results were achieved with the lower effective temperature sum (≥5 ˚C and ≥10 ˚C). We noticed the extension of the vegetative period in the third year due to early and fast completion of the main phenological stages and a prolonged period between budding and fruiting compared to the control experiment.

The sowing of the pea positively affected the main phenological phases completion timeframe only in the first year. The following years were characterized by a decline in the vegetative period of 17 days compared to the control plants group. We observed a three-day delay in the grass formation and a five-day delay in stem formation during the second year. During the third year, these figures grew to be 25 and 7 days respectively. In doing so, the plants required higher temperatures to complete the main phenological stages. It is noteworthy that the Eastern Galega plants included in this experiment variation did not reach their generative state.

Under the conditions of the introductory experiment, the effective temperature sum required by Eastern Galega is limited to 266–299 °C for sprouting and 1400 °C for forming seeds.

The experiment variation involving the Baikal-EM1 inoculation showed a reliable ($p \leq 0.05$) decline in the grass density per area unit by 30% compared to the first-year control samples and a twofold increase in the sprouting amount in the following years (Table 1).

Table 1. The productivity dynamics of the Easter Galega, arranged by the experiment variations and cultivation years

Indicator	Grass life year	Experiment variation		
		Non-inoculated seeds (Control experiment)	Baikal-EM1 inoculated seeds	Inoculated seeds binary sowing with peas
Grass density, unit/m^2	1	215	151	163
	2	216	356	124
	3	204	420	109
Sprout heights above ground, cm	1	18	25	17
	2	43	65	28
	3	92	133	42
Leaf area, thousands m^2/ha	1	8	9	5
	2	83	121	20
	3	95	125	51
Photosynthetic potential, million m^2 daily/ha	1	0.9	0.9	0.5
	2	1.1	1.6	0.2
	3	1.3	1.7	0.6
Net photosynthetic rate, g/m^2 daily	1	2.5	2.9	3.3
	2	4.8	3.9	15.2
	3	6.7	5.9	11.2

Indicator	Grass life year	Experiment variation		
		Non-inoculated seeds (Control experiment)	Baikal-EM1 inoculated seeds	Inoculated seeds binary sowing with peas
Dry mass, t/ha	1	7.4	9.9	6.3
	2	18.3	20.8	12.2
	3	32.1	35.7	23.1
Absolute dry mass, t/ha	1	2.2	2.7	1.8
	2	5.2	6.1	3.5
	3	8.7	10.2	6.8

Source: Compiled by the authors.

We established that the binary sowing of peas negatively affected the grass density of the Eastern Galega in the second and third vegetative years. In the sowing year, this figure was lower than that of the control group by 24%. This percentage grew to 43% in the second year and 47% in the third year.

The research has shown that the use of the Baikal-EM1 fertilizer ensured the highest stem growth in the studied plants. It amounted to 24–133 cm, whereas the binary sowing of peas resulted in stem growth of only 17–42.3 cm (the lowest result).

The binary pea sowing influenced the leaf area index [LAI] of the Eastern Galega in the first year. In this experiment variation, the plants demonstrated the smallest assimilative surface that decreased by 40% (4,86 thousand m^2/ha) compared to the control group results. During the second year, the highest LAI increase can be seen in the experiment variation involving the use of the Baikal-EM1 fertilizer (by 14 times, 121,04 thousand m^2/ha). The variation involving binary pea sowing demonstrated the lowest LAI increase rate (by four times).

We noticed a 3.2% decline in the control group's LAI gain at the end of the third-year vegetative period. The second experience variation subjects also showed the LAI decline of 12% compared to the results of the second year. The plants inoculated with the Baikal-EM1 fertilizer demonstrated the largest leaf area of 125,07 thousand m^2/ha that exceeded the control group results by 24%. The LAI demonstrated by the binary sowing variation was the lowest (51,378 thousand m^2/ha). However, this figure exceeded the LAI during the second year by 2.6 times.

We established that the age of the Eastern Galega plants had a major influence on the LAI dynamics and the photosynthetic potential [PSP], though to a less extent. The plants inoculated with the Baikal EM1 fertilizer demonstrate the highest PSP rate of all the test years. The pea binary sowing resulted in an average PSP decrease of 57% during all three years (Table 1).

The second-year plants sowed with the pea were characterized by the highest pure photosynthesis productivity [PPD] rate (15.21 g/m^2 a day). At the end of the third year vegetative period, the PPD fell to 11.15 g/m^2 a day. However, it still exceeded the control group results almost twice.

The seeds inoculation with the fertilizer resulted in the highest productivity rate. The total pure mass gain to the control results amounted to 2.5–3.6 ton/ha. It increased by 25.3% in the sowing year, then proceeded to grow by 12% during the second year and by 10% during the third year of the introduced species cultivation. The maximum amount of absolute dry mass increased by an average of 16% during the three test years. The binary sowing negatively affected the Eastern Galega productivity: the dry mass yield fell by 1.1 ton/ha (14.8%) at the first year vegetative period end, by 6.1 t/ha (33%) during the second year, and by 9 t/ha (14.8%) during the third year compared to the control experiment results.

During this research, we established that there is a direct correlation between the Eastern Galega productivity rate, its PSP ($r = 0.68$), and an LAI of a single plant ($r = 0.71$). The above-ground biomass of the Eastern Galega is determined more by the assimilative area of the plants ($r = 0.71$) than by the average daily photosynthesis productivity ($r = 0.20$).

We determined that the Eastern Galega grown in the environmental conditions of the Surgut vicinity demonstrates a high forage value (Table 2).

The Baikal-EM1 application contributed to the increase in food units content in the absolute dry mass. The food units grew by 0.5, the crude protein increased by 11%, the digestible protein content grew by 10%, and the crude fiber content fell by 14%. We also noticed an increase in the potassium and phosphorus content by 9% and 32%, respectively (Table 2).

Table 2. The forage properties assessment of the Eastern Galega mass by the grass age and cultivation method

Experiment variation	**Control variation**			**Baikal-EM1 inoculation**			**Binary pea sowing**		
Indicator				**Life year**					
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Crude protein, dry mass [DM] %	9.6	12.4	14.8	10.3	14.7	16.2	9.1	13.0	14.0
Crude fiber, DM %	23.9	28.1	26.1	19.1	25.0	23.4	24.3	27.9	24.0
Crude ash, DM %	5.4	7.6	7.8	5.8	7.6	8.1	5.3	7.0	7.5
Crude fat, DM %	2.0	2.4	2.7	2.1	2.7	2.9	1.9	2.4	2.7
Nitrogen-free extractives [NFE], DM %	59.2	49.6	48.8	62.7	50.0	49.5	59.5	49.7	51.5
Metabolized energy [ME], MJ/kg	7.6	9.2	9.6	7.9	9.7	10.0	7.6	9.3	9.9
Food units, f.u.	0.9	1.4	1.5	1.1	1.5	1.6	0.9	1.4	1.6
Digestible protein, g/kg DM	119.3	205.5	246.0	120.7	245.0	272.0	116.7	217.5	233.0

Source: Compiled by the authors.

The increase in the age of the Eastern Galega corresponded with the growth of nutrient supply in the collected biomass (Table 3).

The crude protein collection varied from 0.3 t/ha to 1.7 t/ha during the Baikal-EM1 experiment variation. These figures exceeded the control group results by 0.1 t/ha, 0.3 t/ha, and 0.4 ha each year. The metabolizable energy rate also exceeded the control figures by 20%.

The binary sowing experiment variation showed a steady underproduction of raw mass and dry mass during all years of monitoring. The plants participating in this variation also demonstrated lower results in crude protein and metabolizable energy rates compared to the control group results.

Table 3. Nutrient supply amount in the Eastern Galega yield collected, ha

Experiment variation	**Control variation**			**Baikal-EM1 inoculation**			**Binary pea sowing**		
Indicator				**Life year**					
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Dry mass, t	2.2	5.2	8.7	2.7	6.1	10.2	1.8	3.5	6.8
Crude protein, t	0.2	0.6	1.3	0.3	0.9	1.7	0.2	0.3	1.0
Metabolized energy, GJ	16.72	47.84	83.52	21.33	59.17	102.0	13.68	23.25	67.32

Source: Compiled by the authors.

Discussion

The ontogenesis of the Eastern Galega is characterized by its prolonged pregenerative period. It took two years for the studied crop to form as it demonstrated the generative phase and completed the budding, flowering, and fruiting stages only in the third year. It is established (Laskin 2006; Gasanov et al. 2010) that the harsh climatic conditions of the North do not enhance the one-year ontogenesis in perennial legume plants. It causes the disruption in the development pace that manifests in reduced, shifted, or even fully reduced generative phases. This fact is reflected in our study. We find it necessary to inoculate the seed material with microbiological fertilizer Baikal-EM1 as it contributes to the prolongation of the vegetative period through earlier and faster completion of all the phenological stages.

The inoculation of seed material with the microbiological fertilizer Baikal-EM1 did not positively influence the Eastern Galega grass density in the sowing year. T. M. Struzhkina and N. N. Ivashchenko (2012) conducted similar research with the same result that they attributed to the cold temperature.

The Eastern Galega plants competed with the pea plants from the sowing year. This badly affected the introduced species caused the grass amount to lower, and led to an overall decrease in productivity. The same conclusion can be found in the studies of M. L. Puzyreva (2000), V. I. Filatov (2006), V. N. Melnikov (2008), C. A. Bekuzarova (2013).

By analyzing the obtained data, we concluded that the Eastern Galega show low photosynthetic activity and biological productivity during the sowing year. This conclusion closely aligns with the results obtained by several researchers (Sagirova 2010; Aleksandrovaм 2014). They established that the Eastern Galega actively forms underground parts during the first stages of development, therefore ensuring successful wintering and the consequent high yield. The increase in the productivity of the plant in question is caused by it developing a strong leaf apparatus.

Conclusion

Field experiments taken on the Eastern Galega in the region of Western Siberia middle boreal forest proved the strong prospects of introducing this species into the marrow forage production.

The seasonal development of the species in question is characterized by shortened phases duration within a virginal state and prolonged stages of budding and flowering. The latter is compensated by the faster completion of the fruiting and seeding stages. When introduced to the new environment, this species demonstrates a pregenerative period prolonged up to two years. The generative organs formation required an effective temperature sum higher than 1400°C.

We analyzed the efficiency of the Baikal-EM1 fertilizer and established that inoculating the Eastern Galega seeds with it prompted the extension of the vegetative period through earlier completion of the main phenological stages in a colder environment. The use of the fertilizer positively affected the leaf area by prompting its growth by 24%. In turn, the PSP rate increased by 24 million m^2 a day/ha, the productivity rate grew by 17%–18%, the crude protein collection gained 7%, and metabolized energy rate increased by 20%. Therefore, the biomass showed favorable feeding properties and met all the zootechnics requirements. We advise cultivating the Eastern Galega independently as the binary sowing with the pea limits its growth and development.

During the research on ecological, biological, and physiological features demonstrated by the species under the environmental conditions of the North, we determined that the introduced species showed high adaptive properties and ecological plasticity. The obtained results will enhance the existing knowledge of the Eastern Galega species, its biological properties, adaptive mechanisms, food value, and a place in the organic farming system. The conducted study on the adaptation process of the Eastern

Galega in harsh conditions of the Western Siberia middle boreal forest will contribute to the development of evidence-based cultivation practices ensuring the target productivity and high food value of the crop. This will serve as a precondition for enhanced production of high-quality forage at the northern limit of agriculture.

Acknowledgement

The research was conducted with the financial support of the Department of Education and Youth Policy in the Khanty-Mansi Autonomous Okrug-Yugra (Order No. 10-P-1534 of 20.06.2023 – Conceptualization, field and laboratory work, statistical processing of materials, writing – original draft preparation). The study was funded by the state task by the Ministry of Science and Higher Education of the Russian Federation № 0721-2020-0019 and RSF № 23-16-00218 (L.F.Sh – methodology, analysis, writing – review and editing).

References

Aleksandrova AS (2014) Features of using fodder Galega for forage in the subtaiga zone of Western Siberia. Thesis for the degree of Candidate of the Agricultural Sciences. State Agrarian University of Northern Trans-Urals. Tumen, 277 pp. [In Russian]

Anatolyan AA (2017) Technologies for creating two-species agrophytocenoses with the participation of new perennial forage crops and awnless brome in the conditions of Cis-baikalia. Thesis for the degree of Candidate of the Agricultural Sciences. Buryat State Agricultural Academy named after V. R. Filippov. Irkutsk, 137 pp. [In Russian]

Bekuzarova SA, Gasiev VI, Sokolova LB, Tsugkieva VB (2013) Binary mixtures of fodder galega. Proceedings of Gorsky State Agrarian University 50(3): 21–26. [In Russian]

Boyko VS (2011) Intensification of field fodder production and reproduction of fertility of irrigated meadow-chernozem soils in the forest-steppe of Western Siberia. Thesis for the degree of Doctor of the Agricultural Sciences. Altai State Agricultural University. Barnaul, 479 pp. [In Russian]

Dospekhov BA (1985) Field Experiment Methodology (With the Basics of Statistical Processing of Research Results). Agropromizdat, Moscow, 351 pp. [In Russian]

Filatov VI, Sagirova RA (2006) Eastern Galega (*Galega orientalis* Lam.) in Eastern Siberia. Moscow Timiryazev Agricultural Academy, Moscow, 83 pp. [In Russian]

Gasanov RG, Zhirov VK (2010) Influence of low temperatures on the phenorhythms of plants of various life forms in the anthropogenic conditions of the Far North. Bulletin of Murmansk State Technical University 13(4/2): 980–993. [In Russian]

Ingiri AA, Laskin PV, Khaitbaev AKh (2011) Effect of applying bacterial fertilizers in the north bounds of crop farming. News of the Orenburg State Agrarian University 2(30): 25–28. [In Russian]

Karakchieva EF (2015) Promising legume-cereal grass mixtures for field forage production in the north. Fodder Production 9: 3–6. [In Russian]

Kozhemyakin AP (2001) Efficiency and main functions of symbiotic and associative inoculant bacteria of agricultural crops. In: Tikhonovich IA (Ed.) Agricultural Microbiology in the 19th and 21st centuries. All-Russia Research Institute for Agricultural Microbiology, Saint Petersburg, 25–26 p. [In Russian]

Laskin PV (2006) Introduction of *Galega orientalis* (Fabacae) in the Arctic (on the example of the Murmansk region). Rastitelnye Resursy 3: 43–47. [In Russian]

Melnikov VN (2008) Fodder galega in the Non-Chernozem zone. Agro XXI 7(9): 46–47. [In Russian]

Moiseeva EA, Shepeleva LF, Kravchenko IV (2016) Dynamics of the content of photosynthetic pigments in the leaves of fodder galega (*Galega orientalis* Lam.) in the middle taiga of Western Siberia. Bulletin of the Kamchatka State Technical University 37: 70–76. [In Russian]

Nalyukhin AN (2008) Influence of micronutrient fertilizer and risotrafin on symbiotic nitrogen fixation and productivity of the fodder galega grown on sod-podzolic medium loamy soil. Thesis for the degree of Candidate of the Agricultural Sciences. All-Russian Scientific Research Institute of Agrochemistry named after D. N. Pryanishnikov. Moscow, 148 pp. [In Russian]

Nichiporovich AA (1966) High Productivity Photosynthetic Systems. Nauka, Moscow, 222 pp. [In Russian]

Puzyreva ML (2000) Main methods of cultivation of fodder galega for fodder and seeds in the subtaiga zone of Western Siberia. Thesis for the degree of Candidate of the Agricultural Sciences. Siberian Research Institute of Feed of the Siberian Branch of the Russian Academy of Agricultural Sciences. Novosibirsk, 192 pp. [In Russian]

Raig H, Metlitskaya J (2001) Breeding of fodder galega. In: Raig H, Nommsalu H, Meripold H, Metlitskaja J (Eds) Fodder galega. Estonian Research Institute of Agriculture, Saku, Estonia, 39–53 p.

Sagirova RA (2010) Features of the growth, development, and productivity of fodder galega in different soil and climatic zones of Cisbaikalia and Transbaikalia. Siberian Herald of Agricultural Science 5: 33–39. [In Russian]

Struzhkina TM, Ivashchenko NN (2012) Effectiveness of using preparations of nitrogen-fixing microorganisms on fodder galega. Fodder Production 12: 16–17. [In Russian]