Impact of planting timing on seed yields and productive longevity of eastern goat rue (Galega orientales Lam)

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Abstract. Eastern goat's rue (Galega orientales Lam.) has a complex of economically useful features, which makes it a priority introduced fodder crop in different soil and climatic zones. The initial stages of ontogenesis determine the development of plants and the amount of seed yield of goat's rue for the next year. In the first year, goat's rue plants develop slowly, which requires its early sowing. It was found that the highest fullness of sprouts in the range of 50-61% was noted when goat's rue was sown in the period from May 25 to June 5. Moisture conditions of vegetation seasons have a decisive influence on growth and development of plants in the year of sowing and their preservation during the overwintering period. The highest yield of seeds in the 1st year of using was when sowing goat's rue from the beginning of May to the middle of the first decade of June which provided accumulation of the sum of effective air temperatures 1409,5-1125,00 С and amount of precipitation within the range 373,9-335,7 mm from shoots to the end of vegetation in the year of sowing and 1208,30 С with 274,9 mm of precipitation in the second year before harvesting. The highest seed yields in the range of 466-560 kg/ha yield were obtained from goat's rue crops of May and June sowing dates. The influence of sowing dates on seed yields was evident during the first two years. In subsequent years, the value of seed yield is leveled.

Keywords: eastern goat's rue, yield, seeds, sowing dates, the structure of the seed herbage.

1. Introduction

At present, the problem of providing voluminous feeds with crude protein, the content of which in dry matter does not exceed 10–12% at a rate of 14–15%, remains unresolved in fodder production [1, 2]. To solve this problem, the priority direction of the development of forage production and agriculture is to increase the share of leguminous crops. Among perennial leguminous grasses, the eastern goat's rue, or eastern galega (Galega orientalis Lam.), Is distinguished by a complex of morphobiological features, first of all, the ability for vegetative reproduction, which ensures the longevity of agrocenoses of this culture [3]. The eastern goat's rue has high forage productivity, biological and ecological plasticity, adaptability, stability and unpretentiousness, high competitive ability in grass mixtures and endurance, frost and winter hardness, drought resistance, increased nitrogen-fixing ability and can be cultivated in a wide range of soil and climatic conditions [4-6]. As a fodder plant, it is characterized by a high content of crude protein, neutral detergent fiber (NDF) and acid detergent fiber (ADF) [7]. The crude protein content is 20.56% dry matter during the budding period, gradually decreasing to 15.13% during the flowering period. The content of crude fat in dry matter varies from 3.51% during the budding period to 3.01% during the flowering phase [8]. In order to assess the potential of galega in Canada, a study was...
conducted comparing the productivity of this crop with traditional forage legumes. The average annual yield of dry matter of forage galega, without taking into account the quality of raw materials, ranked third among seven legumes after alfalfa and clover [9].

The accumulated experimental material and the experience of production use of goat's rue shows that this crop is one of the highest priority among the non-traditional species and the areas of its cultivation in the regions of the country have a tendency to steady growth. The area of natural growth of goat's rue covers the forest-steppe and forest belt of foothill regions and the middle subalpine zone of the Caucasus. In this connection, it is necessary to study the peculiarities of the development of goat's rue in the reproductive sphere and to develop the agricultural technique of seed cultivation for new areas during introduction in atypical for this species conditions of the Non-Black Earth zone.

In connection with the southern origin of goat grass one of the important techniques influencing the formation and productivity of its seed herbage in the regions of the Non-Chernozem zone with less provision of the growing seasons with thermal resources is the sowing period. Analysis of the results of research on the study of sowing dates of goat's rue in different regions revealed a great influence of this agricultural technique on the formation of seed yields. Thus, in the conditions of sharply continental climate of the Urals the sowing date significantly influenced the seed yield of goat's rue during the first three years of use. The best was the early sowing at the onset of physical ripeness of the soil. Seed yield consistently decreased from the optimal date to the last (after 21 days): in the second year of use - by 40%, in the third - by 27% and in the fourth - by 34% [10].

The initial stages of ontogenesis are an important basis for further development of plants and the formation of a high yield of seeds for the next year [11]. This is due to the fact that the formation of rhizomatous shoots and wintering buds, due to which the renewal of plants is provided, is important in ensuring good preservation in winter and productivity of goat's rue in the first year [12]. It was found that for the subsequent normal growth and development of plants in the first year of life is required from 114 to 135 days, with a sum of positive temperatures of the growing season from 2105.3 to 2780.6 oC [13]. According to other data, the main factor determining the value of Eastern goat's rue productivity is the moisture supply of the herbage in the period of growth and development of plants.

The correlation coefficient of dependence of goat's rue yield on average air temperature during the vegetation period is only 0.223, and from the amount of precipitation during the vegetation period - 0.99 [14].

**Purpose of work.** To study the influence of the sowing dates of the eastern goat's rue on the seed yield in subsequent years in the conditions of the Central Non-Black Earth Region of Russia.

2. **Material and methods**
The studies were carried out in the experimental field of V.R. Williams VIC. Soil is sod-podzolic with weakly acidic reaction of soil solution (pHc5.4); the provision of mobile forms of phosphorus and potassium is medium. Agrotechnique of soil preparation is generally accepted in the zone. Goat's rue cultivar Hale was sown in coverless form from May 5 to July 15 (the last recommended date for sowing perennial grasses) at intervals of 10 days. Seeds were scarified before sowing (24-63% hard seededness) and treated with a specific strain of nodule bacteria. Sowing depth 1.5-2 cm, seeding rate - 1 million germinated seeds per 1 ha. Direct harvesting was carried out by Sampo 130 combine with predesication of herbage by Reglon Super.

3. **Results and discussion**
It was found that the highest completeness of galega sprouts in the range of 50-61% was noted when sowing in the period from May 25 to June 5. Taking into account the need of goat's rue in hydrothermal resources, the most favorable combination of air temperature (on average from 11,3 to 17,90 C for a decade) and moisture regime (from 10,2 to 35,6 mm for a decade) was formed at this time. The importance of combination of heat supply and sufficient precipitation level is underlined by indicators of seedling completeness in the second decade of May and in July 2003 - 76-85%, when abundant
precipitation and high daytime air temperatures resulted in the most comfortable conditions for seed germination (Table 1).

| Sowing date | Completeness of sprouting, % | Overwintering, % |
|-------------|-----------------------------|-----------------|
|             | 2000 | 2001 | 2003 | 2000-2001 | 2001-2002 | 2003-2004 |
| 5.05        | 41   | 61   | 37   | 98        | 96        | 95        |
| 15.05       | 42   | 51   | 45   | 99        | 96        | 96        |
| 25.05       | 41   | 55   | 85   | 97        | 86        | 90        |
| 5.06        | 33   | 51   | 65   | 96        | 55        | 92        |
| 15.06       | 35   | 48   | 49   | 96        | 35        | 97        |
| 25.06       | 35   | 33   | 35   | 94        | 28        | 87        |
| 5.07        | 33   | 22   | 76   | 92        | 8         | 79        |
| 15.07       | 29   | 20   | 78   | 91        | 8         | 70        |

The conditions of moisture supply during the growing seasons had a decisive influence on the growth and development of galega plants in the year of sowing and their preservation during the overwintering period [15]. Thus, in 2001, characterized by a late but warm spring, hot and dry summer, when average ten-day air temperatures exceeded the mean annual values by 5-23% and precipitation was less than half of the norm, goat’s rue sprouts developed slowly. As a result, more than half of plants of June sowing dates and 92% of plants of July sowing dates died during the overwintering period. Under the conditions of the summer drought in 2002, starting from the third decade of May when, against the background of low relative air humidity and lack of precipitation, the moisture content of the sowing layer of soil (0-6 cm) reached critical values, complete death of goat’s rue plants of summer sowing dates was recorded. In typical for the Non-Black Soil Zone vegetation seasons, goat’s rue plants sown in May and June managed to accumulate sufficient reserves of plastic substances for overwintering. At sowing in July, there was an increase of plant death to 21-30% in the winter period compared with 5-10% of the May sowing dates (Table 1). Plant height by sowing dates by the end of the growing season consistently decreased from 41.5 to 15.0 cm.

Yield value in the second year strongly depended on the sowing date and weather conditions, both in the year of sowing and in the year of seed production. The highest yield of seeds in the 1st year in the range of 431-511 kg/ha was when sowing goat’s rue from early May to the middle of the first decade of June, which provided accumulation of the sum of effective air temperatures 1409.5-1125.0°C and rainfall in the range 373.9-335.7 mm from shoots to the end of vegetation in the year of sowing and 1208.3°C with 274.9 mm of rainfall in the second year before harvesting ripeness (Table 2). At higher heat availability both in the year of sowing and in the year of harvesting with less precipitation in the post-sowing period and moisture deficit in the year of harvesting, the herbage with low seed yields was formed.

| Sowing date | Sum of effective temperatures >5°C from sprouts to the end of vegetation, °C | Amount of precipitation from sprouts to the end of vegetation, mm | Seed yield from the herbage of the 1st g.p., kg/ha |
|-------------|---------------------------------|-----------------------------|-----------------------------|
|             | 2000 | 2001 | 2003 | 2000 | 2001 | 2003 | 2001 | 2002 | 2004 |
| 5 may       | 1409.5 | 1542.5 | 1168.1 | 373.9 | 335.4 | 417.3 | 511 | 68 | 93 |
| 15 May      | 1377.3 | 1531.6 | 1128.9 | 369.6 | 333.1 | 387.9 | 491 | 69 | 66 |
| 25 may      | 1238.0 | 1467.8 | 1054.4 | 351.1 | 288.1 | 375.9 | 504 | 64 | 42 |
| 5 June      | 1125.0 | 1347.1 | 1002.7 | 335.7 | 253.6 | 356.4 | 431 | 41 | 49 |
In the year of sowing during formation of parturiparous individuals in conditions of limited time before the end of the growing season, determining the deficit of hydrothermal resources for complete development of goat's rue, plants do not have time to form rudimentary generative organs. As a result, the next year shoots develop in the vegetative phase. With the total number of shoots from 141 to 268 pcs/m² in the grass of the second year of life, the proportion of generative organs was only 17-35% (Table 3). As a result, seed yield was low, especially at the summer sowing dates (Table 4).

### Table 3. Influence of sowing date on the formation of densities of eastern galega.

| Sowing date | Number of stems: total / generative, pcs./m² (average for 2001-2007) |
|-------------|-----------------------------------------------------------------------|
| 5 may       | 268 / 95 | 185 / 108 | 132 / 90 | 145 / 93 | 148 / 90 | 144 / 83 |
| 15 may      | 262 / 74 | 180 / 115 | 128 / 94 | 143 / 96 | 140 / 86 | 154 / 85 |
| 25 may      | 239 / 71 | 184 / 120 | 135 / 98 | 158 / 68 | 162 / 98 | 148 / 64 |
| 5 june      | 200 / 62 | 179 / 108 | 134 / 95 | 148 / 96 | 152 / 91 | 136 / 79 |
| 15 june     | 161 / 67 | 178 / 113 | 129 / 97 | 160 / 108 | 158 / 96 | 176 / 119 |
| 25 june     | 146 / 34 | 159 / 100 | 135 / 90 | 152 / 92 | 152 / 97 | 150 / 104 |
| 5 july      | 155 / 31 | 154 / 89 | 127 / 99 | 158 / 103 | 148 / 95 | 151 / 88 |
| 15 july     | 141 / 24 | 148 / 83 | 126 / 93 | 153 / 100 | 148 / 90 | 134 / 84 |
| HCP<sub>05</sub> | 27 / 9 | 19 / 14 | 15 / 11 | 16 / 14 | 16 / 11 | 16 / 14 |

In the third year of life, the share of generative shoots in the total structure of herbage was already 56-65%. As a consequence, the seed yield increased by 2.5-7.9 times compared with the previous year (Table 4). The highest seed yields in the range of 466-560 kg/ha were obtained from goat's rue crops of May and June sowing dates. In the fourth and subsequent years, seed yields leveled off and did not depend on the sowing dates.

### Table 4. Influence of sowing dates of eastern galega on seed yields depending on year of herbage use (average of three experiments for 2000-2007)

| Sowing date | Seed yield, kg / ha |
|-------------|---------------------|
| 2nd        | 3rd    | 4th    | 5th    | 6th    | 7th    |
| 5 may      | 225    | 628    | 764    | 455    | 687    | 723    |
| 15 may     | 209    | 586    | 720    | 471    | 656    | 702    |
| 25 may     | 203    | 649    | 703    | 444    | 713    | 686    |
| 5 june     | 174    | 515    | 709    | 433    | 665    | 663    |
| 15 june    | 95     | 509    | 696    | 431    | 651    | 736    |
| 25 june    | 67     | 445    | 788    | 485    | 706    | 755    |
| 5 july     | 52     | 310    | 698    | 442    | 697    | 714    |
| 15 july    | 51     | 229    | 755    | 454    | 696    | 653    |
| HCP<sub>05</sub> | 22    | 52     | 79     | 42     | 70     | 76     |
4. Conclusions
Thus, the seed productivity of Eastern goat's rue in the second year of life is determined by the sowing period and agrometeorological conditions both in the year of sowing and in the year of seed production. Under the conditions of the Central Non-Black Soil Region of Russia, formation of the highest seed productivity is provided when sowing goat's rue in the period from early May to the middle of the first decade of June and accumulation of the sum of effective temperatures from shoots to the end of vegetation in the first year of 11250 C and more, provided a fairly high number of evenly falling rainfall (335 mm or more) and increased heat availability in the next year (12080 C), combined with sufficient moisture availability. The sowing period has a significant impact on seed productivity of goat's rue for two years.

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