Technological impact on environment in biotechnological system of perennial legumes cultivation

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Abstract. Perennial legumes are key ones in creating a solid forage base. A number of reasons limit the gross collection of forage. Specifically, they are as follows: material and technical resources, a low specific weight of perennial legumes, a sown areas structure, and a cultivation technology. Analysis of various technologies for cultivating perennial legumes for fodder and seeds has showed that one of the main rules for ensuring favorable conditions for the crops cultivation is the use of a targeted effect on the soil cover as well as the even distribution of plants over the feeding area. The research aimed to study the influence of different tillage options and sowing methods on the production process (of seeds) during the cultivation of perennial legumes in Western Siberia. The proposed model of the production process has showed that the energy of plant growth is proportional to the dry mass and resource of the nutrient medium. The energy of growth depends on the respiratory activity of the plant and the rate of trimmed root system regeneration, which can be achieved by the appropriate action of the machines’ operating parts in the process of legumes cultivation. The research found that the rate of the Eastern galega developmental phases varied depending on the type of soil cultivation, processing and seed condition, sowing quality. In addition, the agrophysical conditions of soil cultivation and sowing affect the growth of the stem mass of the Eastern galega.

1. Introduction
The fodder base is of great importance for the successful animal husbandry in the subtaiga zone of Western Siberia. An increase in the area of high-protein crops contributes to the creation of high yields of green mass, the elimination of the protein substances deficiency in the early periods of the growing season.

Perennial legumes are key in creating a solid forage base. The limiting material and technical resources, the low proportion of perennial legumes and the imperfect structure of the sown areas of forage crops significantly reduce the gross feed yield. Therefore, in the current conditions, it is of great importance to find and introduce such fodder crops that are able to provide farms not only with fodder but also with seeds [1].

It is known that the development of technologies for the cultivation of perennial legumes for feed and seeds, as a rule, aims to create favorable conditions for cultivated crops growth. One of the main rules for fulfilling these conditions is the use of a targeted effect on the soil cover as well as the even distribution of plants over the feeding area. As the practice of agricultural production shows, to ensure
favorable conditions for crops cultivation, it is vital to optimize water-air and nutritional modes of the soil. Optimization of the production process of perennial legumes, the establishment of factors, including technogenic ones and affecting the growth, development, productivity and quality of the crop, are the most important tasks of modern agricultural science [2].

To describe the plants functioning, it is reasonable to apply the analytical relationships with biologically interpreted parameters that characterize the development of plants in a wide range of external conditions and are available in the scientific literature. Such an approach was used in a number of works to develop the theoretical foundations of anthropogenic impact on the environment in the biotechnological system of some agricultural crops cultivation.

Along with traditional forage crops in Western Siberia, much attention is focused on less widespread crops (Eastern galega, French grass, etc.), whose increase in the cultivated area does not occur due to a lack of seed, insufficiently perfect soil cultivation technology and sowing methods. The above reasons make studies devoted to the technological impact on the environment in the biological system of cultivation of perennial legumes including the Eastern galega especially relevant. The development of the basic cultivation techniques of the Eastern galega, as well as machines for soil cultivation and sowing [3] will create the biological and ecological foundations of highly productive environmentally sustainable agrocenoses of perennial legumes [4].

The purpose of the research is to study the effect of tillage options and sowing methods on the production process (seeds) during the cultivation of perennial legumes in Western Siberia.

2. Materials and methods

To eliminate the problem of rapid weed infestation of fields caused by the slow development of the Eastern galega in the year of sowing, it is necessary to weed the crops. This is achieved by cultivating wide-row crops of Eastern galega from 2 to 3 times during the growing season in the course of overgrowing weed infestation. Herewith, it is important to prevent the root system of cultivated plants from cutting.

The main essence of the work on perennial legumes cultivation is to control the parameters and the rate of plant growth by influencing the working organs of the machines of the technological complex on the soil-root system of plants [5]. At the same time, a holistic biotechnological system, in which the mechanization issues are solved in unity with the course of biotechnological processes, is being studied [6].

One of the major tasks at each timepoint is to determine the states of the system’s production processes. To achieve this task, it is necessary to have dependencies that characterize the system behavior. Based on the research findings [7], a model of the production process (in the particular case of the growth of the plants’ stem part) of the following type has been obtained:

\[ Y(t) = ISP(t = 0) + \int_0^t RO(t) - UO(t) + \Sigma FS(t) \, dt. \]  

where: ISP (t=0) is the volume of legumes harvest at the beginning of observations; RO(t) is the rate of increase in the volume of the crop with regards to the factors contributing to the plants growth of; UO(t) is the rate of decrease in volume due to the influence of factors hindering the growth; IFS(t) is current changes in the yield over time t from disturbing environmental influences on plants (agrophytocenosis). From the model’s equation it follows that:

- when the integrand is > 0, the yield grows;
- when the integrand is <0, the yield decreases;
- when the integrand is equal to zero, there is lack of the necessary conditions for the yield increase.

When analyzing the equation, it is necessary to regard that the plant growth energy is proportional to the dry mass and the resource of the nutrient medium. As well, the fact that the energy of growth depends on the plant respiratory activity and the rate of the pruned root system regeneration is significant. Both conditions are provided by the corresponding influence of the operating parts of the
machines belonging to the functional-technological complex in the process of cultivating legumes, and can be controlled at any given time.

The influence of soil cultivation options and sowing methods on the production process (seeds) during the perennial legumes cultivation was studied in experiments conducted in the fields of the Northern Agriculture Department of the Omsk Agrarian Scientific Center, with the equipment of the Additive Technologies and Materials Processing Center of the Omsk State Agrarian University.

The research aimed to assess the production process (according to the indicator of average daily growth) of the Eastern galega with various types of mechanical soil cultivation:

• rototilling + subsoil-broadcast sowing;
• rototilling + wide-row sowing;
• ploughing + subsoil-broadcast sowing;
• ploughing + wide-row sowing.

The soils on the experimental plots were gray forest soils. The humus content in the soil layer was 3.5-4.0%, the bulk soil mass in the 0.5 m layer was 1.55-1.70 g/cm$^3$, the groundwater level was 3.5-3.8 m. The Gorno-Altai 87 variety of the Eastern galega was used. The seeding rate was taken as 1 million grains per hectare.

3. Results and discussion

An analysis of the integral assessment of the influence of the technological impact options (method of tillage + method of sowing) starkly illustrated the production process of the Eastern galega depending on the technogenesis factors (Fig. 1).

Figure 1. Growth dynamics of Eastern galega under various types of technogenic impact: 1. rototilling + subsoil-broadcast sowing; 2. rototilling + wide-row sowing; 3. ploughing + subsoil-broadcast sowing; 4. ploughing + wide-row sowing

Scarification of the seed material of the Eastern galega helped to achieve seedlings already on the $12^{th}$-$16^{th}$ day. The dynamics of the plant development showed that in the initial period there was a slow plants development. Thus, at the end of July the average daily increments were 0.3-0.5 cm and in the first decade of August – up to 1.2-1.6 cm. However, they decreased to 0.1-0.4 cm in September. At the end of the growing season, most of the plants formed one main vegetative shoot being 20-44 cm high.

As well, the rate of the Eastern galega’s developmental phases changed. The rate of development varied depending on the type of soil cultivation, processing and seed condition, sowing quality [8, 9].
Thus, the best result in terms of the average daily growth of the stem mass in height was obtained with rototilling and subsoil-broadcast sowing.

The deviation in the stem mass growth is explained by non-identical agrophysical conditions after implementing various options for tillage and sowing. With a smaller fractional composition of the soil, i.e. with its best grinding, aeration and moisture supply, the growth of plants in height was maximum. With the subsoil-broadcast sowing of plants over the feeding area, the seeds were placed with greater uniformity [10], and as a result, this influenced the average daily growth of stems in height.

4. Conclusion

Scientific research was conducted using the equipment of the collective use center “Additive technologies and materials processing” of the Omsk State Agrarian University. The research found that the rate of passage of the developmental phases in the Eastern galega varied depending on the type of soil cultivation, seed processing and condition, and sowing quality. In addition, the agrophysical conditions of soil cultivation and sowing affected the growth of the stem mass of the Eastern galega.

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