Methods for pre-sowing treatment of legume grass seeds to improve their sowing properties

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Abstract. In recent years, more and more areas of agricultural land have been cultivated with the valuable non-traditional fodder crop galega, which perfectly combines high productivity with excellent fodder values and sustainable seed production, rationally uses agro-climatic conditions of the zone and increases soil fertility, and is valuable as a forecrop and a honey-bearing plant. The sowing material of the Eastern galega contains 50...95% of seeds with a hard shell. Seed hardness is explained by impermeability of seed shells to water and air. To increase the germinating capacity of seeds and reduce the norm of galega seeds sowing to 2.0 million/ha the sowing material of perennial leguminous fodder crop - Eastern galega should undergo pre-sowing treatment - scarification and seed inoculation. The construction and working principle of the developed technical means are presented: a scarifier SS-0,5 and an inoculator IS-1,0. The developed scarifier and inoculator of seeds of leguminous crops qualitatively perform the technological process of pre-sowing treatment of Eastern galega seeds. At optimum feed of 0.5 t/h and 1.0 t/h, the quality indicator of Eastern galega seed scarifying reaches 98.8 %, the completeness of inoculator treatment reaches 99.8 %, without seed damage that meets the agrotechnical requirements.

1. Introduction
It is known that the flora of the globe includes up to 300 thousand flowering plants. However, the number of plants used for practical purposes is not large enough - only about 30 thousand, and used systematically - 12 thousand, of which about 5 thousand are ornamental plants. Approximately 80% of the world's cultivated area is occupied by only 250 species. According to FAO, worldwide biodiversity of cultivated plants is steadily decreasing: in the XX century about 75% of the gene pool was lost. This has serious consequences: worsening phytosanitary conditions over large areas; increasing dependence of crop production on weather fluctuations; unsustainable provision of livestock fodder. Therefore, strengthening the fodder base is a strategically important task [1, 2].

Despite the richness of the natural flora, the number of adaptive and productive forage legumes in the field is still extremely low. Currently, no more than 25 species of plants are cultivated for fodder purposes, including perennial leguminous grasses - Eastern galega, red clover, Pannonian clover, alfalfa, melilot and others. An urgent problem of modern crop production is the search for the most effective growth regulators and optimal ways of their use. The production of non-traditional fodder crops is one of the foundations for the creation of a fodder base for livestock production, because an increase in the diet of high-quality forage produced on the basis of non-traditional perennial leguminous grasses allows to provide animals with protein and necessary mineral components, and this, in turn, will solve the issue of supplying environmentally safe livestock products to the
population. This category of nontraditional crops includes Eastern galega (Galega orientalis Lam.) - a crop with great potential: productive longevity - 10...15 years and more, plasticity, high winter hardiness, cold hardiness, unique biological ability - creeping-rooted system, highly productive (in two mowing periods - up to 60-70 tons/ha of green mass, 10...15 tons/ha of hay), high nutritive value, stable seed production. In addition, the cultivation of perennial grasses, especially legumes, which enrich the soil not only with organic matter, but also with environmentally safe biological nitrogen, is one of the sources of humus reserves in the soil [3, 4].

2. Materials and methods

The methodology of design of scarifier and inoculator of Eastern galega seeds and other legume grass seeds, developed on the basis of analysis of existing methods and technical means for scarifying legume grass seeds, physical and mechanical properties of legume grass seeds, taking into account the generally accepted methods of quality assessment of technological process performance to sowing material GOST 28636-90 "Seeds of low-spreading fodder crops. Sort and sowing qualities. Technical conditions", GOST R 53235-2005 "Seeds of agricultural plants. Variety and sowing qualities. General technical conditions". GOST R 54783-2011 "Testing of Agricultural Machinery. General provisions". GOST 12038-84 "Seeds of agricultural crops. Methods of determination of germinating capacity" [4].

3. Results

Phenological observations have shown that sowing methods and seeding rates did not significantly affect the phases of development of galega plants. The density of plants, which is determined by seeding rate and sowing method, has a significant influence on the optimization of the galega agrocenosis structure. The research established that the field germination of unscarified galega seeds leads to an increase in the seeding rate, as with continuous row sowing, and the inter-row method of sowing. On the average for three years at sowing of 2 mln/ha of germinated seeds it was 77.1 - 78.4%, with increasing to 5 mln/ha - 76.2-77.5%. With both methods of sowing, an increase in the percentage of surviving galega plants for harvesting with decreasing seeding rate is observed (Table 1) [5, 6].

| Sowing method | SR, mln pcs/ha | Completeness of sprouting | Survivability | Number of stalks |
|---------------|----------------|--------------------------|---------------|-----------------|
|               |                | pcs/m² | %        | pcs/m² | %        | pcs/m² | per 1 plant, pcs. |
| Row (15 cm)   | 2              | 156.7   | 77.1     | 118.2   | 75.4     | 359.6   | 3.04               |
|               | 3              | 235.9   | 76.9     | 175.0   | 74.2     | 398.5   | 2.28               |
|               | 4              | 311.8   | 76.7     | 230.4   | 73.9     | 445.3   | 1.93               |
|               | 5              | 387.5   | 76.2     | 286.4   | 72.6     | 467.2   | 1.63               |
|               | 2              | 154.2   | 78.4     | 118.4   | 76.8     | 320.3   | 2.71               |
| Inter-row (30 cm) | 3          | 230.7   | 78.6     | 171.2   | 75.4     | 365.6   | 2.14               |
|               | 4              | 306.9   | 78.0     | 229.9   | 74.9     | 396.7   | 1.73               |
|               | 5              | 381.3   | 77.5     | 281.3   | 73.8     | 409.5   | 1.46               |

As the row spacing increases, there is a gradual reduction in the number of stalks per plant, which is probably due to increased competition between the plants for essential life factors. The plants are more evenly distributed over the area with the row method of sowing, which allows a better use of nutrients, moisture and light. The formation of the grass stand of galega in the first year of life depends to a certain extent on the seeding rate. The increase of seeding rate from 2.0 to 5.0 mln/ha of germinated seeds at both studied methods of sowing caused the increase of density of grass stand, but at the same time the number of stems per one plant decreases. The main reasons for the increased consumption of seeds of high-protein legume crops are their hardness and high strength of the surface shell, which hinders the penetration of air and water, resulting in seeds not swelling and the germ not developing. This leads to long germination time and irrecoverable loss of a part of the sown seeds,
besides, uneven germination sharply reduces both the seed yield and the general productivity of biological mass [6,7].

In order to increase seed germination, reduce the seed rate of galega to 2.0 mln/ha and preserve herbage density, the sowing material of a perennial legume fodder crop - Eastern galega should undergo pre-sowing treatment - scarification and seed inoculation. The seed of Eastern galega contains 50...95% hard-seeded seeds. The solid seed is due to the impermeability of the seed shells to water and air. Seed hardness as a biological trait is useful, since it provides stability of legume component species in herbage, leads to the emergence of new young plants in subsequent years as the hard-seeded seeds germinate, but this situation does not satisfy the conditions of intensive agriculture in the production of forage crops. The solution of the problem of satisfying the requirements of the branch of plant-growing by conditioned seed material of Eastern galega is largely determined by the effectiveness of technological and technical support of the processes of pre-sowing treatment of seeds. The used methods and technical means of pre-sowing treatment of Eastern galega seeds in most cases are not effective, and the physical wear of equipment for pre-sowing treatment reaches 80...90%.

Currently, seed scarification can be carried out using domestic scarifiers SK-300, SS-0,5, SKS-1, STS-2, SKS-30, SK-300, clover-grinder-scarifier KS-0,2, but these technical means are lacking in farms and seed stations. Therefore galega seeds are passed 2-3 times through clover-grinder KS-1.0 or K-0.3 with a capacity of 0.3-1.0 t/h. The peculiarity of clover-grinder is that it must be very accurately adjusted to the treatment of galega seeds to avoid damage to the seeds [8]. In the absence of the above mentioned tools, the scarifying is carried out manually, on a table with a surface made of sandpaper (on a fibrous basis). In small batches (up to 300 g), galega seeds are placed on the table surface, and then the bar, wrapped in sandpaper, is moved several times over the seeds. Productivity with this method of scarification is 0.05 ... 0.06 t/h. The number of scarified seeds in this case reaches 65...70%, which does not meet the agrotechnical requirements.

The absence of special machines for seed pre-sowing treatment (scarifiers) leads to an increase in the rate of seeding, which is extremely inefficient at the current market cost of legume grass seeds. Moreover, there are losses of part of the seed during pre-sowing treatment associated with injury, and as a consequence, deterioration or complete loss of germination of seeds [4].

To increase the germination of seeds for sowing, they must be scarified on a special machine (scarifier). Scarifying creates scratches and micro-cracks in the dense seed coat, allowing the seed to pass through water and air, swell quickly and germinate. Scarifying the seeds of Eastern galega increases their germination rate to 99%. But the scarification should be carried out not earlier than 8...10 days before sowing, as otherwise scarified seeds lose their germinating capacity [7, 8].

The SS-0,5 seed scarifier is designed for pre-sowing treatment (scarification) of legume grass seeds (Eastern galega, red clover, Pannonian clover, alfalfa, melilot, etc.). The scarifier consists of disc-type working tools interconnected with each other. Each working unit performs a specific function, and the arrangement of the working units is chosen so as to ensure a compact installation. The technological scheme of the scarifier SS-0,5 is based on the following technical solutions: for transportation from the feed hopper uses a helical pipe with a transition to a four-section distributive rotating working body; for seed treatment (cracks and scratches) there is a scarifying surface in the form of a stationary disc with an abrasive surface in the working chamber.

The SS-0,5 seed scarifier operates as follows. Eastern galega seeds are fed manually or by a feeding device into the feeding hopper. After the electric motor is switched on by means of the control panel, the seeds to be treated are conveyed from the seed hopper through a spiral pipe to a four-section distributor rotating tool, which is positioned over the surface of a stationary abrasive disc. When the four-section distributor rotates, the seeds are rotated around their own axis and are driven by centrifugal force over the surface of the abrasive surface disc. As a result of contact with the abrasive surface (when the seeds move), the seeds are scratched and micro-cracked on their hard shell. In addition, there is an abrasive surface inside the entire circumference of the drum, in contact with which the seeds are additionally scratched and micro-cracked. The treated seeds are ejected by inertia.
into the gap between the abrasive disc and the drum into the discharge pipes and further into the bags secured by bag holders.

Of the variety of methods of biostimulants application, namely, application to soil, pre-sowing treatment of seeds and spraying of crops, pre-sowing treatment of seeds is the most acceptable for production, as it is well technological, not requiring additional costs, while consuming small doses of biostimulants. Pre-sowing treatment of seeds with biostimulants activates the initial growth processes.

Preparation of perennial legume grass seeds for sowing involves inoculation. Inoculation involves treating the seeds of legume grasses with biostimulants containing rhizotorfin, a preparation containing a culture of nodule bacteria. It is mandatory to inoculate all seeds of perennial legumes, as there are no nodule bacteria in the soil that can enter into symbiosis with the plants. Pre-sowing treatment of seeds with biostimulants activates the initial growth processes, it contributes to a more intensive transition of seedlings from heterotrophic nutrition to autotrophic nutrition. There is an increase of germination energy by 1.2-5.3%, laboratory germination - 1.6-4.2%, sprout length - by 0.2-0.7 cm, germinal root length - by 0.4-0.8 cm. In addition, growth regulators have a multifunctional effect, since seeds at the time of germination have a high plasticity and susceptibility to changes in environmental conditions. There are four main forms of biostimulants: powder, granular, dry and liquid. Powder and dry biostimulants are not always effective because they have low adhesion and uneven distribution on the seed surface, which affects the qualitative indicator of inoculation - the completeness of treatment (at least 95%). To make the particles better adhere to the surface of treated seeds, adhesive agents are added to the aqueous suspension of the preparation (liquid or solid hard concentrate, molasses, flour paste, latex, and slurry), which is not quite technological. Granular biostimulants are mainly introduced into the seed furrow. With this method, bacteria can die due to high temperatures of the surface layer of soil, lack of moisture on the soil surface and increased concentration of chemicals. The best way to treat the seeds, in terms of application to the surface, are liquid biostimulants, which are mixed with water and simply applied to the seeds.

At present, innovative compositions of biostimulants for seed pre-sowing preparation of perennial legume grasses have been developed: binary seed treatment with bacterial preparations Humariz (rhizotorfin (1 g contains 10-15 bln. rhizobia) enriched with micronutrients), Epin-Extra, Baikal EM-1, Albite, Agrika with microelements together with growth regulators and microelement fertilizers in chelated form Siliplant, Zircon, Poly-Feed, Aquamix, Megamix-Seeds, etc.

Inoculation of perennial legume grass seeds with biological preparations of nodule bacteria is currently carried out by seed treatment machines PSSH-5, PS-10, Mobitoks. The process of preparing seed dressing machines to work with biostimulants is very time-consuming and washing them is not always carried out qualitatively. Besides, legume-rhizobium symbiosis is very sensitive to pesticides. All dressing agents more or less inhibit the formation of nodules and reduce their nitrogen-fixing activity. Seed treatment with biostimulants can be carried out in rotating drums or concrete mixers. This method of seed treatment is ineffective because of uneven application of the biostimulant to the surface of the seed. Special applicators are used abroad and in Russia, which allow the use of conventional seed loaders with auger and belt conveyors. Sometimes, in practice, ordinary garden watering cans or other simple devices, the accuracy of which does not meet the modern requirements, are used for dosing the preparation into the grain loaders.

Small quantities of seed are handled manually. A batch of 100-200 kg of seeds is poured onto a tarpaulin 3x4 m in size, moistened with a suspension of biopreparation, diluted with adhesive in water in an amount of 2-2.5% of the seeds' weight and mixed, alternately raising opposite ends of the tarpaulin, until bacteria are evenly distributed on the seeds' surface. After 20-30 minutes, the seeds absorb moisture and regain their friability. The treated seeds are bagged and sown within a day. This method of treatment leads to caking of seeds and formation of vaults during sowing. We offer a new environmentally friendly biotechnology for pre-sowing treatment of perennial legume grass seeds with biostimulants by using a high-pressure fog inoculator. Ecologically safe biotechnology, construction and technological scheme and design of inoculator with high pressure fog system for pre-sowing treatment of perennial legume grass seeds with growth biostimulants are substantiated. The system of
A high pressure fog with the help of nozzles allows for biological active substances, a part of growth biostimulants, to get directly to the seed germ during treatment of seeds. The promising use of installation-inoculator with a high pressure fog system based on the continuous effect of fog on the seeds during the continuous transportation of the seed material was proved.

The treatment of perennial legume grass seeds by the inoculator with the high pressure fog system with the seeds treatment completeness up to 100% and without their damage, will allow increasing the germinating ability of seeds up to 98%. The high-pressure fog system (70 to 100 bar) allows a droplet diameter of 5 to 10 microns to be produced. Such a droplet stays in the working chamber for a long time, hits the surface of the seed and easily penetrates to the germ, thus provoking germination of the seed. This biotechnology allows any type of seed of perennial legumes and any type of growth biostimulant in liquid form to be used for treatment, as there is a system for preparing biostimulants before they are fed into the working chamber. Nozzle humidification with control and management of moisture level will allow to avoid excessive overwatering of seeds during treatment with inoculant before sowing and to sow them immediately into the soil.

The technological scheme of the inoculator is based on the following technical solutions: a non-axial screw auger is used for seed transportation inside the working chamber in the form of a pipe; a high pressure fog system with nozzles is used for seed treatment with growth biostimulants in the working chamber. The technological process of environmentally friendly biotechnology of seed inoculation of perennial legume grasses includes two devices: high pressure system; seed inoculator.

The high-pressure fogging system consists of: a high-pressure unit generating pressure of 70-100 bar; a biopreparation tank (50-100 l). A pump is located inside the tank to create primary pressure (1-2 bar) when the biopreparation is fed into the high-pressure unit. The fog system contains filters. The high-pressure unit is designed to feed the biopreparation through a high-pressure pipeline to nozzles located on the surface of the working chamber of the inoculator by the diameter of the working chamber with a certain pitch. The nozzles produce a droplet with a diameter of 5-10 µm. The inoculator consists of a working chamber in the form of a tube with a diameter of 130 mm and a length of 1500 mm. Inside the working chamber, there is a stainless steel axle-less screw with a diameter of 100 mm and a step of 65 mm that transports seeds. At the beginning of the working chamber, there is a feeding device and at the end - a discharging device. The auger screw is driven by a gearmotor W=1.5 kW. The screw auger has a rotation speed of 410 min⁻¹. On a surface of working chamber on diameter nozzles (8-10 pieces) are established for creation of the processed grass seeds medium in the form of a fog. The nozzle humidification system allows the moisture level to be adjusted depending on the type of grass seed (timer on the high-pressure unit).

The technological process. Legume grass seeds are fed into the inoculator loading chamber, then it enters the working chamber, where they are treated with biostimulants coming from nozzles in the form of a mist with a drop diameter of 5 to 10 microns. These growth stimulant droplets are retained in the working chamber for a long time, hit the surface of the seed and easily penetrate to the germ, thereby provoking germination of the treated seeds. It is known that before inoculation the seeds of perennial leguminous grasses are scarified, i.e. scratches and microcracks are applied to the hard shell of the seed surface for better penetration of water and air to the seed germ, including biostimulants for growth. The grass seed inside the working chamber is transported by a non-axial screw auger. Due to the absence of an internal shaft, the maximum amount of seed treatment with biostimulants in the form of a mist is increased to 70%. There is no pressure inside the working chamber, as the nozzles only serve to create a droplet with a diameter of 5-10 µm. The humidity level in the working chamber rises to 100% in 5 to 10 seconds. The nozzle humidification system allows adjustment of the moisture level inside the working chamber depending on the type of legume seeds. The fog system for pre-sowing seed treatment with growth regulators consumes 8-10 watts per litre of biopreparation sprayed. This is the lowest figure compared to other seed inoculation methods. Adiabatic nozzle humidification used in the inoculator with high-pressure fog system also allows to solve problems with control and management of moisture level in seed pre-sowing treatment, because excessive seed moisture leads to difficulties when sowing seeds into the soil by various seeding devices. The required quality of seed
treatment for perennial legume grasses meets the requirements for inoculators (seed quantity after treatment must be at least 95 %, no seed damage allowed). After seed treatment in the inoculator, the legume seeds will be dispatched to their destination. The moisture level of the treated seeds is increased by 3-4 % and the treated legume seeds can be immediately sown with seeders of different types. The use of this inoculator with a high-pressure fog system can increase the germination rate of perennial legume seeds up to 98 %.

To determine the quality of the scarifier and inoculator during the study we used seeds of galega that meet the requirements of GOST R 52325-2005 for seeds of Eastern galega of RS category, which corresponds to agricultural requirements. Seed purity was 99.8% and moisture content was 9.5%. At the same time, the content of solid seeds in the initial material was 48%. It should be noted that according to State Standard GOST 12038-84, solid seeds are classified as germinating seeds of forage legume grasses. The research was carried out at seed rates of 0.05 to 0.6 t/h for scarification and 0.5 to 1.1 t/h for inoculation.

The trials of the scarifier SS-0,5 were carried out in the period from 15.04.2021 to 25.10.2021 at Agrofirma "Biokor-S", Mokshan district, Penza region.

The quality of the technological process of seed scarification of Eastern galega was evaluated according to the following indicators: seed scarification quality C; seed germination after scarification B; number of damaged seeds П.

From analysis of dependencies (Figure 1) it follows that increasing the flow Q from 0.05 to 0.6 t/h has an insignificant influence on quality of scarification C and has high values of 97.9 ... 99.3%, which correspond to agricultural requirements (not less than 95.0 %). In this case, germination indices B with increasing flow Q decreases slightly from 98.8 to 97% (according to GOST P52325-2005 germination should be at least 80% for the category of seeds OS and ES) and the number of damaged seeds П increases as well slightly - to 0.85%, which also meets agricultural requirements (not more than 1.5%) at flow Q = 0.05 ... 0.6 t/h. From the analysis of the three dependencies, it can be assumed that the optimum flow value is in the range of Q=0.5...0.6 t/h. At the maximum flow of 0.5 t/h, the quality indicator of Eastern galega seed scarification reaches 98.8 %, seed damage is 0.6 %, which meets the agricultural requirements. Reducing the value of the flow leads to a decrease in the performance of the scarifier SS-0.5. Increasing the flow more than 0.5 t/h leads to a slight decrease in the quality of scarification and an insignificant increase in seed damage.

The quality of the technological process of seed inoculation of Eastern galega was evaluated by the following indicators: seed inoculation quality U; seed germination after inoculation B; seed moisture B.c. From the analysis of relationships (Figure 2) it follows that increasing the flow Q from 0.5 to 1.1 t/h has an insignificant impact on the quality of seed inoculation (completeness of treatment) U and has high values 99.7 ... 99.8 %, which corresponds to agricultural requirements (not less than 95.0 %). In this case the indices of germinating capacity B with increasing of flow Q decreases insignificantly from 99.8 to 99 % (according to GOST R 52325-2005 the germinating capacity should be not less than 80% for the category of seeds OS and ES).
80 % for the category of seeds OS and ES) and the humidity of seeds B.c. after treatment with the inoculator with increasing of flow to 1.1 t/h decreases to 11.2 %, which also meets the agronomic requirements.

From the analysis of the three dependencies it can be concluded that the optimum value of feed is within Q=1.0...1.1 t/h. At the maximum feed of 1.1 t/h, the quality indicator of seed inoculation of Eastern galega reaches 99.8 %, there is no seed damage, which meets the agronomic requirements. An increase of more than 0.8 t/h leads to a slight reduction in seed moisture after treatment.

4. Conclusion
The developed technical means for presowing treatment of forage legume seeds with the use of a legume seed scarifier SS-0.5 and a seed inoculator IS-1.0 qualitatively perform the technological process of seed scarification of Eastern galega and meet the basic technical requirements according to reliability and construction safety indicators. The SS-0,5 scarifier and the IS-1,0 seed inoculator easily fit into the technology of pre-sowing preparation of forage legume seeds and are recommended to be used in agricultural production.

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