Agrobiological methods of increase in germinating capacity of seeds of perennial legume grasses in the Middle Preduralie

Y N Zubarev and M V Zabolotnova*

Perm State Agro-Technological University named after Academician D.N. Pryanishnikov, 23 Petropavlovskaya St., Perm 614000, Russia

E-mail: m.zabolotnova@list.ru

Abstract. The article presents the results of laboratory research of swelling rate of non-traditional for the region perennial crops: Galega orientalis, Poterium polygamum in comparison with traditional Medicago varia Mart. Investigation of watering and swelling process was carried out by gravimetric method. Positive effect of scarification on the rate of water consumption of Galega orientalis and Medicago varia Mart is confirmed; swelling rate of Galega orientalis increased from 0.14 l/h up to 1.09 l/h, Medicago varia Mart – from 0.24 l/h up to 1.85 l/h, which is seven times more than the swelling rate of non-scarified seeds. The swelling rate of scarified seeds of Poterium polygamum conversely decreased from 1.69 l/h to 0.74 l/h. Laboratory seed germination of Galega orientalis and Medicago varia Mart with seed scarification and soaking up to 60% of water level increased threefold relative to the control variant without scarification and twofold to the control variant with scarification. Negative effect on biometric parameters of Galega orientalis and Medicago varia Mart seedlings was noted when seeds were soaked up to 100% of water level. Laboratory germination of Poterium polygamum in all experimental variants was equal to 96%. However, parameters of seedlings were different regarding experimental factors, thus biometric parameters of seedlings increased with the raise of water level in non-scarified seeds of Poterium polygamum and decreased in scarified ones.

1. Introduction

Extensive introduction and application of various range of non-traditional crops in combination with traditional fodder perennial legume and cereal grasses cultivated in every soil-climatic zone define the multi-variability and diversity of field systems. Only three decades ago, Galega orientalis was considered as a non-traditional crop for the Middle Preduralie but due to its active study and introduction, skepticism was replaced by high-priority inclusion of Galega orientalis into field and fodder economies.

At present, Galega orientalis has the second highest planted area after Trifolium pratense (60 thousand ha) among legume perennial crops in the Perm Krai driving Medicago sativa to the fodder outsiders [1]. In search of further diversity and multi-variability development of modern agriculture and fodder production, development of low-cost and ecologically adaptive plants of multi-purpose agricultural use, we were interested in Poterium polygamum as a very promising perennial crop successfully cultivated in a number of central regions in the Russian Federation.

Adaptation is a stressful process for new crops cultivated in the region due to environmental impact. Therefore, crop potential is developed only after the study of physiological aspects of seeds.
and selection of appropriate technological methods. Galega orientalis and Medicago varia Mart are legume crops, their seeds have specific hard shell, which is the reason for low germination. Poterium polygonum is a perennial plant of the Cruciferae family, scientific literature does not consist information on pre-sowing treatment of seeds to increase field germination rate. The fruit of Poterium polygonum is a two-seeded nut [2, 3, 4]. Therefore, for regions with changing weather conditions in spring such as the Perm Krai, an experiment on the effect of scarification and soaking of seeds of non-traditional for the region perennial grasses on laboratory seed germination was carried out in order to forecast the optimal technological methods for new crop cultivation.

2. Materials and methods

The research was carried out in the laboratory of the Department of General Agriculture and Plant Protection of the Perm State Agro-Technological University according to conventional procedures and the GOSTs (State Standards) [5, 6, 7]. Seeds of Galega orientalis of the Gale variety, Medicago varia Mart of the Sarga variety, and Poterium polygonum of the Stimul variety were used as a seeding material of perennial grasses. Investigation of watering and swelling process was carried out by gravimetric method. 50 pcs of seeds were soaked in water at room temperature and neutral environment ($\text{pH} = 6.8-7.0$), the seeds were taken out every 30 minutes, dried on filter paper and weighed until the water content reached 30%. 60%. 100%, then put in germinating cabin. The experiment was repeated three times, an average value of swollen seeds mass was calculated as an average of three values. Obtained results were statistically processed by the analysis of variance. Experiment design: Factor A – crop; A1 – Galega orientalis; A2 – Medicago varia Mart; A3 – Poterium polygonum. Factor B – mechanical impact on a seed coat (scarification); B1 – without scarification; B2 – with scarification. Factor C – water level of seeds: C1 – 0% air-dried seeds (the control); C2 – 30%; C3 – 60%; C4 – 100%. Assessment criteria were the following: kinetic equation of seed swelling rate, laboratory germination, biometric parameters of seedlings. Laboratory germination of Medicago varia Mart and Galega orientalis was defined on the 7th and 14th day, respectively, according to the GOST 12038-84 requirements «Seeds of Agricultural Crops. Germination Assessment Methods», Poterium polygonum – on the 7th day according to the GOST P 55294-2012 «Seeds of Minor Fodder Crops. Sowing Qualities. Technical Specifications».

3. Results Discussion

Stress tends to temporarily delay seed germination. However, short and optimal impact on seeds during rest period can speed up germination. In the course of research, we studied the effect and interaction of two stress factors – water and mechanical impact. One of the main elements in seed germination is water consumption which triggers the mechanism of structural (swelling) and metabolic processes. In most plants, water enters the seed through the micropyle and scar tissue, except for the hard-seed forms – through the strophyolar gap. In order to germinate, seed must reach a critical moisture level [8]. To assess the rate of water consumption of scarified and non-scarified seeds of Galega orientalis, Medicago varia Mart, and Poterium polygonum, the constants of kinetic equation in swelling process were calculated as presented in Table 1.

| Factor A (crop)          | Factor B (mechanical impact on a seed coat) | B1 – without scarification | B2 – with scarification |
|-------------------------|---------------------------------------------|---------------------------|------------------------|
|                         | B1 – without scarification | Cs 1/h | $\alpha$ | Cs 1/h | $\alpha$ |
| A1 – Galega orientalis  | 0.14                                        | 1.45          | 1.09        | 1.45          |
| A2 – Medicago varia Mart| 0.24                                        | 1.38          | 1.85        | 1.38          |
| A3 – Poterium polygonum | 1.69                                        | 1.10          | 0.74        | 1.10          |

Table 1. Value of the constants of kinetic equation in swelling process of perennial grass seeds.
In physical and colloid chemistry, the swelling process is explained by mutual diffusion of solvent and polymer accompanied by an increase in volume of the last one [9]. A quantitative measure of swelling is swelling degree \( \alpha \) calculated as a difference in sample mass before and after swelling. Swelling rate is found on the graph as the angle of tangent slope to the positive direction of time axis. Kinetics of swelling process was carried out according to the first-order reaction mechanism. Therefore, swelling rate (\( \frac{d\alpha}{dt} \)) can be represented as the equation:

\[
\frac{d\alpha}{dt} = Cs * (\alpha_{\infty} - \alpha_t)
\]

Constant of swelling rate (Cs) and swelling degree (\( \alpha_t \)) describe the kinetics of process, ultimate swelling degree \( (\alpha_{\infty}) \) – its final result. Thus, the mechanical impact on a seed coat had a positive effect on swelling rate of Galega orientalis and Medicago varia Mart: swelling rate of scarified seeds of Galega orientalis increased from 0.14 1/h to 1.09 1/h, Medicago varia Mart – from 0.24 1/h to 1.85 1/h, seven times more than the swelling rate of non-scarified seeds. Situation with the seeds of Poterium polygamum was the opposite: swelling rate of scarified seeds decreased from 1.69 1/h to 0.74 1/h as it resulted in a type of fruit. As mentioned earlier, the fruit of Poterium polygamum is a nutt, we assume that the seed shell has a function of sponge for accumulation and distribution of moisture, physical impact negatively affects water consumption due to a violation of the structure. The difference in swelling rate of non-scarified seeds of Galega orientalis (0.14 1/h) and Medicago varia Mart (0.24 1/h) when HCP05=0.16 is mathematically insignificant, but the difference in swelling rate of scarified seeds is significant and the highest value is observed in Medicago varia Mart – 1.85 1/h. The highest value of ultimate swelling degree of seeds is recorded in Galega orientalis – 1.45, the lowest one in Poterium polygamum – 1.10. Scientists P.A. Vlasov, S.A. Mokeeva, S.I. Kokonov, T.N. Ryabova, I.M. Morozova, E.A. Grafutko, E.D. Osminin, A.V. Tagirov and S.V. Yanushko also confirm the practical importance of scarification on productivity of perennial legume grasses [10,11,12,13,14].

Recently, a number of publications were presented concerning technologies for sowing legume grasses with pre-soaking of seeds as well as optimization of parameters of sowing device for these seeds. N.P. Kryuchin. O.A. Artamonova. D.N. Kotov and E.I. Artamonov recommend a torsion-pin sowing device for sowing hard-flowing seeds [15,16,17,18,19]. Pre-sowing technology for preparation of Melilotus albus and Onobrychis seeds including scarification and soaking was developed on the basis of the Samara State Agricultural Academy [20]. Our research also confirms the positive effect of seed soaking on laboratory germination of seeds of perennial grasses. Experimental data are presented in table 2.

Analysis of variance of experimental data determined the mathematical significance of pre-soaking on biometric parameters of seedlings, but denied the impact of scarification on the length of root and shoot. All studied factors (crop, mechanical impact on a seed coat, and water level of seeds) are characterized as statistically significant for the laboratory seed germination rate. Thus, the maximum value of laboratory germination in legume crops was noted in the variant with seed scarification and water level of 60%: in Galega orientalis – 54% and Medicago varia Mart – 80%, which is three times more than the absolute control (without scarification and soaking) and two times more than the control variant with scarification. Upon reaching the water level of 100% and scarification, the death of seeds of Galega orientalis was noted due to excessive leakage of substances and destruction of cell structures during the swelling period, since the mechanical impact on a seed coat “uncorked” the stropyolar gap and the rate of water absorption increased. In experimental variants without scarification, laboratory germination of Galega orientalis and Medicago varia Mart seeds increased relative to water level of seeds. Without pre-soaking of seeds, laboratory germination corresponded to 18-24%, when the water level reached 30% – 24-46%, and 52-64% (HCP05=3) with the water level of 100%. The value of laboratory germination of Poterium polygamum regarding studied factors does not change and corresponds to 96%.
Table 2. Impact of scarification and water level of perennial grass seeds on laboratory germination

| Factor A (crop) | Factor B (mechanical impact on a seed coat) | B<sub>1</sub> - without scarification | B<sub>2</sub> - with scarification |
|----------------|------------------------------------------|---------------------------------|---------------------------------|
|                | Length of root, cm | Length of shoot, cm | Laboratory germination, % | Length of root, cm | Length of shoot, cm | Laboratory germination, % |
| A<sub>1</sub> – Galega orientalis | 1.6 | 2.1 | 18 | 1.8 | 2.8 | 26 |
| A<sub>2</sub> – Medicago varia Mart | 1.8 | 4.3 | 24 | 0.9 | 4.9 | 60 |
| A<sub>3</sub> – Poterium polygamum | 3.3 | 5.8 | 98 | 3.8 | 7.2 | 92 |
| C<sub>1</sub> – control (2021) 012032 |                |                |                                |                |                |                                |
| A<sub>1</sub> – Galega orientalis | 1.7 | 2.5 | 24 | 2.0 | 3.0 | 39 |
| A<sub>2</sub> – Medicago varia Mart | 2.0 | 4.2 | 46 | 2.5 | 4.5 | 78 |
| A<sub>3</sub> – Poterium polygamum | 3.8 | 6.0 | 96 | 3.3 | 4.9 | 98 |
| C<sub>2</sub> – when the water level reaches 30% |                |                |                                |                |                |                                |
| A<sub>1</sub> – Galega orientalis | 2.0 | 2.6 | 40 | 2.4 | 3.2 | 54 |
| A<sub>2</sub> – Medicago varia Mart | 2.1 | 4.7 | 58 | 2.5 | 4.8 | 80 |
| A<sub>3</sub> – Poterium polygamum | 3.6 | 6.0 | 94 | 3.1 | 5.1 | 96 |
| C<sub>3</sub> – when the water level reaches 60% |                |                |                                |                |                |                                |
| A<sub>1</sub> – Galega orientalis | 1.4 | 1.9 | 52 |                       | death |                                |
| A<sub>2</sub> – Medicago varia Mart | 2.0 | 4.3 | 64 | 2.2 | 4.3 | 78 |
| A<sub>3</sub> – Poterium polygamum | 4.2 | 6.2 | 94 | 3.0 | 5.8 | 98 |
| C<sub>4</sub> – when the water level reaches 100% |                |                |                                |                |                |                                |
| HCP<sub>05</sub> of particular differences | 0.2 | 0.2 | 6 |                |                |                                |

Biometric parameters of seedlings are determined at the time of counting laboratory germination that is on the 7<sup>th</sup> day in Medicago varia Mart and Poterium polygamum, and on the 14<sup>th</sup> day in Galega orientalis. Pattern of increase in the length of both roots and shoot of Galega orientalis and Medicago varia Mart was founded regarding the water level of seeds. Thus, the length of radicle of Medicago varia Mart increased from 1.8 cm during sprouting of air-dry seeds to 2.1 cm when seeds reached the water level of 60% (HCP<sub>05</sub>=0.1). However, upon presoaking of Medicago varia Mart seeds until the water level of 100%, a decrease in the length of seedling roots is observed. Similarly, the root length increases by 25% in Galega orientalis when the water level reaches 60%. Analyzing the shoot length of Galega orientalis and Medicago varia Mart, a similar tendency of increase in seedlings parameters relative to the duration of seed soaking is mentioned regardless of the type of previous mechanical treatment of seeds (HCP<sub>05</sub> of the main effects of the Factor B = F<sub>F</sub>&lt;<sub>F</sub>l). However, it should be pointed out that the length of roots and shoots decrease when the water level reaches 100% relative to the previous experimental variants, which can be explained as the negative effect of excess water.
between the cotyledons during seed swelling that impeded germination. The opposite tendency is observed during germination of Poterium polygamum. Biometric parameters of seedlings of non-scarified seeds of Poterium polygamum increased with the raise of water level, while those of scarified seeds decreased. The length of root and shoot of non-scarified seeds in the control variant is equal to 3.3 cm and 5.8 cm and in the variant with soaking – 4.2 cm and 6.2 cm, respectively. The length of root and shoot of scarified seeds in the control variant is equal to 3.8 cm and 7.2 cm and in the variant with soaking – 3.0 cm and 5.8 cm, respectively, which confirms our hypothesis about the significance of seed coat of Poterium polygamum in water absorption and moisture distribution.

4. Conclusion

The positive effect of scarification on water consumption rate of Galega orientalis and Medicago varia Mart is confirmed: the swelling rate of scarified seeds of Galega orientalis increased from 0.14 l/h to 1.09 l/h and Medicago varia Mart – from 0.24 l/h to 1.85 l/h, which is seven times more than the swelling rate of non-scarified seeds. The negative effect of scarification on the rate of water consumption of Poterium polygamum is approved: the swelling rate of scarified seeds decreased from 1.69 l/h to 0.74 l/h. It is established that the use of pre-sowing treatment (scarification and soaking) of Galega orientalis and Medicago varia Mart seeds contributes to an increase in laboratory germination. The maximum value of laboratory germination in legume crops is noted in the variant with seed scarification and water level of 60%: in Galega orientalis – 54% and Medicago varia Mart – 80%, which is three times more than the absolute control (without scarification and soaking) and two times more than the control variant with scarification.

References

[1] Zubarev Yu N 2003 Issues of field grass sowing in the Preduralie (M.: MSKHA) p 392
[2] Kaplan M, Tutar H, Kardes Y M, Das A and Kokten K 2019 Progress in nutrition 21 pp 868– 870
[3] Karkanis A C, Fernandes A, Vaz J, Petropoulos S, Georgiou E, Ciric A, Sokovic M, Oludemi T Barros L and Ferreira ICFR 2019 Food & function 10 pp 1340-51
[4] Ceccanti C, Landi M, Rocchetti G, Moreno MBM, Lucini L, Incrocci L, Pardossi A and Guidi L 2019 Hydroponically Grown Sanguisorba minor Scop.: Effects of Cut and Storage on Fresh-Cut Produce Antioxidants 12 p 631
[5] Seeds of agricultural crops 1984 Germination assessment methods: GOST 12038-84 (M.: Pub Standartov) p 30
[6] Seeds of minor fodder crops 2020 Sowing qualities Technical specifications (Reedition): GOST R 55294-2012 (M.: Standartinform) p 10
[7] Dospekho B A 2012 Method of field experiment (with the fundamentals of statistical processing of research results) (M.: Alyans) p 352
[8] Timani K V, Dzhenn R K, Amen R D, Askochenskaya N A and et al 1982 Physiology and biochemistry of seed rest and germination Translation from English (M.: Kolos) p 495
[9] Quick reference book of physical and chemical values 2003 (M SPb.: Ivan Fedorov) p 240
[10] Vlasov P A 2006 Achievements of science and technical equipment of Agro-Industry 2 pp 38-39
[11] Mokeeva S A, Kokonov S I and Ryabova T N 2020 Newsletter of Ulyanovsk State Agricultural Academy 2 pp 47-53
[12] Morozova I M and Grafutko E A 2010 Influence of certain scarification methods on germination of solid seeds of Galega orientalis and Trifolium hybridum Newsletter of Vitebsk State University 58 pp 63-67
[13] Osminin E D and Tagirov A V 2018 Methods of scarification under seed inoculation of legume grasses Innovative ideas of young scientists for Agro-Industry of Russia (Penza: RIO PGAU) pp 231-233
[14] Yanushko S V Methods to increase sowing qualities of legume grass seeds 2010 Melioration 1 pp 181-189
[15] Vdovkin S V and Lavrova O A 2019 Analysis of sowing devices for soaking seeds Innovative achievements of science and technical equipment of Agro-Industry (Kinel: RIO Samarskiy GAU) pp 372-375
[16] Kryuchin N P, Vdovkin S V and Kryuchin A N 2019 Optimization of parameters of sowing device for hard-flowing seeds New technologies and technical means for effective development of Agro-Industry pp 239-244
[17] Kryuchin N P and Artamonova O A 2020 Theoretical study of soaking seed carrying process by operating parts of torsion-pin sowing device News of Orenburg State Agrarian University 2 (82) pp 148-152
[18] Kryuchin N P, Artamonova A O, Kotov D N and Artomonov E I bulletin 1 p 2
[19] Petrov A M 1994 Substantiation of sowing technology and parameters of pin sowing device of pneumatic seeder for sowing soaking seeds of Galega orientalis Dis Cand Tech Sci: (Saratov) p 214
[20] Kryuchin N P, Petrov A M and Artamonova O A 2018 Development of technology for pre-sowing seed treatment of legume grasses News of Orenburg State Agrarian University 5 pp 99–102