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CORRELATIONS BETWEEN GERMINATION CAPACITY AND SELECTED PHYSICAL PROPERTIES OF PERENNIAL RYEGRASS CV. MAJA SEEDS

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Abstract

Perennial ryegrass is one of the most valuable pasture grasses. The species is recommended for sodding various types of land in Poland due to its fast growth and the ability to produce large numbers of vegetative shoots. Seedling emergence and biomass yield are largely determined by seed quality. This study analyzes the correlations between the basic physical properties of seeds of perennial ryegrass cv. Maja and their germination capacity. The basic dimensions (length, width and thickness) and mass of each of the 150 seeds were determined, and their arithmetic mean diameter, geometric mean diameter, aspect ratio, sphericity index and density were calculated. The seeds were germinated for 14 days, and the results were recorded daily, which enabled to determine germination time for each seed. The relationships between the evaluated parameters were determined by the Student's *t*-test for independent samples and correlation analysis. The analyzed physical properties of seeds had no significant effect on the germination rate index. Germinated and non-germinated seeds differed significantly in width, length and arithmetic mean diameter, but they should not be sorted based on their plumpness to improve the quality of seed material because it could lead to a high loss of viable seeds.

Symbols:

C_g – germination capacity, %,
D_a – arithmetic mean diameter, mm,
D_g – geometric mean diameter, mm,
m – seed mass, mg

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R – aspect ratio, %,
T, W, L – seed thickness, width and length, mm,
T_n – time required to produce a healthy germ, days,
T_o – duration of germination test, days,
W_g – germination rate index,
V_g – germinative energy, %,
ρ – seed density, g·cm^{-3},
Φ – sphericity index, %.

Introduction

Grasses belong to the group of wind-pollinated flowering plants. They are highly valued for their environmental significance, and they are an important economic commodity. Grasses are ubiquitous plants that shape the natural landscape. Grasses and forests are abundant sources of biomass which accumulates solar energy and lowers carbon dioxide levels in ambient air. Grasses constitute cheap and nutritious fodder material, in particular for ruminants, and they are indispensable in the production of milk and meat (BARYŁA, KULIK 2005, PROŃCZUK 2005, MOORBY et al. 2006, HOEKSTRA et al. 2007, SURMEN et al. 2013).

Perennial ryegrass (*Lolium perenne* L.), also known as English ryegrass, is one of the most valuable species of pasture grasses. It is a common wildlife species in Poland which is also used in pastures and meadows. Perennial ryegrass is a highly competitive species that dominates over other plants and leads to their elimination under supportive conditions (BARYŁA, KULIK 2005, 2006, 2013, GILLILAND et al. 2011). It thrives in localities with full sun exposure and fertile mineral soils. The species is sensitive to environmental stressors, and its growth is stilted in response to summer droughts and freezing temperatures in winter, but it is capable of resilient regrowth when unfavorable conditions subside. Perennial ryegrass initiates growth in early spring and grows back easily after harvest or grazing. The species is resistant to trampling and nibbling by animals, and it is capable of utilizing manure nitrogen, which is why it is highly recommended for pastures (KULIK et al. 2004, BUMANE, ADAMOVICS 2006, MOORBY et al. 2006, HOEKSTRA et al. 2007, BARYŁA, KULIK 2013, SURMEN et al. 2013).

Perennial ryegrass is widely used to seed lawns that play various roles, including ecological, sanitary, recreational and esthetic (PROŃCZUK 2005, PROŃCZUK, PROŃCZUK 2008, JANKOWSKI et al. 2010, 2012). The key features that determine the suitability of perennial ryegrass for sodding are fast growth and the ability to produce large numbers of vegetative shoots (HARKOT, POWROŹNIK 2010, STARCZEWSKI, AFFEK-STARCZEWSKA 2011, CARVALHO et al. 2013).

Perennial ryegrass is also widely grown for seeds. Seed yield ranges from 225 to 2500 kg ha^{-1}, depending on variety, soil type, soil fertility, fertilization and crop protection regimes, and, most importantly, climate (SZCZEPANEK 2005, BUMANE, ADAMOVICS 2006, NIZAM 2009, ROLSTON et al. 2009, POP et al. 2010, DIMITROVA, KATOVA 2011, CHYNOWETH et al. 2012). Ryegrass seeds are husked kernels, 5–7 mm in length. In Poland, the species ripens in early July when its seeds turn brown-grey and have to be harvested before they fall to the ground (ELGERSMA et al. 1988). Seeds are usually harvested in two stages: the first-cut is left in the field to dry, after which it is threshed in a combine harvested equipped with a pick-up attachment.

There is a general scarcity of published data about the range of changes in the physical properties of grass seeds and the relationships between those parameters. Such information is required for designing and modeling seed sowing, harvesting, transport, cleaning, sorting and storage processes (HEBDA, MICEK 2007, BOAC et al. 2010, KALKAN, KARA 2011, MARKOWSKI et al. 2010, 2013, SOLOGUBIK et al. 2013). The results of laboratory and field experiments performed on other plant species (MUT, AKAY 2010, HOJJAT 2011, NIK et al. 2011, SADEGHI et al. 2011, AHIRWAR 2012, AMIN, BRINIS 2013) indicate that germinative energy and germination capacity are influenced by seed dimensions and seed mass because larger and heavier seeds produce more abundant and denser stands, which contributes to a higher yield. Therefore, an attempt was made in the present experiment to investigate the influence of the mass and geometric properties of grass seeds on germination efficiency.

The aim of this study was to determine the correlations between the basic physical properties of perennial ryegrass seeds and their germination capacity, which are vital parameters for planning and developing seed separation processes.

Materials and Methods

The experimental material comprised seeds of tetraploid perennial ryegrass cv. Maja. The seeds were grown on soils of 4a, 4b and 5 complex in an organic plantation covering an area of 3.75 ha in the Region of Podlasie. The plantation was started in the first 10 days of April 2013 by sowing 38 kg ha^{-1} seeds in soil subjected to various cultivation measures after fall tillage. Manure fertilizer was applied at 40 t ha^{-1} immediately before fall tillage. In October 2013, the field was fertilized with slurry at 10 000 l ha^{-1} after harvest. In spring 2014, the turf was harrowed to stimulate grass tillering and to eliminate weeds. Seeds were harvested in two stages in the first 10 days of September 2014: cut grass was left to dry in the field, after which it was threshed in

a combine harvester equipped with a pick-up attachment. Seed yield was determined at 660 kg ha^{-1}. Seed samples of approximately 1 kg were collected, and their physical properties and germination capacity were determined in the Agricultural Analytical Laboratory of the Faculty of Technical Sciences at the University of Warmia and Mazury in Olsztyn. The relative moisture content of seeds was determined at 12.7% with the use of the MAX 5-/WH halogen moisture analyzer (Radwag Radom, Poland).

Batches of 150 seeds each were separated from seed samples by the survey sampling method (GREŃ 1984). The length and width of each seed were determined with the use of the MWM 2325 laboratory microscope (PZO Warszawa, Poland) to the nearest 0.02 mm (one measurement covered two micrometer readings with 0.01 mm resolution), and seed thickness was measured with a dial thickness gauge with 0.01 mm resolution. The measurements were performed in accordance with the methodology described by KALINIEWICZ et al. (2011). Seed weight was determined on the WAA 100/C/2 weighing scales (Radwag Radom, Poland) with 0.1 mg resolution.

Based on the number of seeds in each batch, standard error for the evaluated physical parameters did not exceed: 0.2 mm for seed length, 0.1 mm for seed width and thickness, and 0.2 mg for seed mass.

In the second stage of the experiment, measured data were used to calculate the following parameters for every seed:

– arithmetic and geometric mean diameters, aspect ratio and sphericity index (MOHSENIN 1986):

$$D_a = \frac{T + W + L}{3} \tag{1}$$

$$D_g = (T \cdot W \cdot L)^{\frac{1}{3}} \tag{2}$$

$$R = \frac{W}{L} \times 100 \tag{3}$$

$$\Phi = \frac{(T \cdot W \cdot L)^{\frac{1}{3}}}{L} \times 100 \tag{4}$$

– density (on the assumption that seeds had an ellipsoid shape):

$$\rho = \frac{6 \times m}{\pi \times T \times W \times L} \tag{5}$$

– germination rate index (KALINIEWICZ et al. 2015):

$$W_g = \frac{T_o + 1 - T_n}{T_o + 1} \tag{6}$$

In the germination test, perennial ryegrass seeds were placed in a container lined with moistened filter paper and covered with a glass lid. Evaporated water was supplemented daily with a sprinkler, and filter paper was kept moist throughout the experiment. The test was carried out at a temperature of approximately 25°C under exposure to natural light. Germination progress was monitored daily between 8 a.m. and 9 a.m. Seeds that produced a sprout with a minimum length of 75% seed length were classified as germinated. Observations were continued for 14 days (from 23 May to 6 June). Germinative energy V_g and germination capacity C_g were determined based on the ratio of the number of seeds that had germinated in 7 and 14 days (*International Rules for Seed Testing* 2004) to the number of seeds in the analyzed sample.

The results were processed with the use of Statistica PL v. 12.5 application at a significance level of α=0.05. Differences in the physical properties of germinated and non-germinated seeds were determined by the Student's t-test for independent samples, and the relationships between those parameters were evaluated by linear correlation analysis (RABIEJ 2012).

Results and Discussion

The physical properties of perennial ryegrass seeds are presented in Table 1. The coefficient of variation ranged from approximately 9% (arithmetic mean diameter) to 94% (germination rate index). Relatively high variation was observed for seed thickness (23%), seed mass (37%) and seed density (25%). Seed thickness was determined in the range of 0.25 to 1.05 mm, seed width – 1.11 to 2.02 mm, and seed length – 4.87 to 8.95 mm. Mean length and mass data indicate that the analyzed seeds were longer (by around 20%) and lighter (by around 10%) than the seeds of perennial ryegrass cv. Bastion grown in Switzerland and examined by WAGNER et al. (2001). The seeds analyzed in this study were similar to seeds of tetraploid varieties in terms of average mass and were significantly heavier than the seeds of diploid varieties examined by Pop et al. (2010). They were also 29% heavier than the seeds of perennial ryegrass cv. Veja from Lithuania (ŠLEPETYS 2001), 24% and 30% heavier than the seeds of perennial ryegrass cv. Grasslands Nui and cv. Grasslands Samson, respectively, from New Zealand (ROLSTON et al. 2005). The above findings indicate that the seeds of perennial ryegrass cv. Maja are similar to seeds of other

tetraploid varieties in terms of plumpness. The seeds of the analyzed species were similar in length to the seeds of yellow lupine cv. Mister (SADOWSKA, ŻABIŃSKI 2011), and were similar in thickness to psyllium (AHMADI et al. 2012) and parsnip seeds (KALINIEWICZ et al. 2014). The aspect ratio of perennial ryegrass seeds was determined in the range of 16.42% to 28.43%.

Table 1
Statistical distribution of the physical properties and calculated parameters of perennial ryegrass seeds

Physical property/ parameter	Value			Standard deviation
	minimum	maximum	mean	
T [mm]	0.25	1.05	0.69	0.158
W [mm]	1.11	2.02	1.46	0.182
L [mm]	4.87	8.95	6.90	0.717
m [mg]	0.8	5.9	3.02	1.117
D_a [mm]	2.21	3.68	3.02	0.276
D_g [mm]	1.27	2.33	1.89	0.195
R [%]	16.42	28.43	21.33	2.661
Φ [%]	20.78	36.58	27.59	2.862
ρ [g cm^{-3}]	0.273	1.410	0.827	0.206
W_g [–]	0	0.733	0.209	0.176

The germination test revealed that perennial ryegrass seeds were characterized by very low germinative energy (V_g=11.33%), but relatively high germination capacity (C_g=93.33%). The germination capacity of the analyzed perennial ryegrass seeds exceeded 80% (acceptable germination level), and it was comparable with the values reported by WAGNER et al. (2001) and GRYGIERZEC et al. (2015) for other perennial ryegrass cultivars. However, their germinative energy was approximately 55 percentage points lower than that noted by JODEŁKA et al. (2003) in cv. Ovation. An analysis of seed germination rates (Fig. 1) demonstrated that the first seeds began to germinate already on day 4 of the germination test, but more than 45% of seeds germinated only at the end of the trial on day 13. The above could be attributed to the fact that the husk has a high percentage of total seed mass (ELGERSMA et al. 1988), and it forms an insulation layer that prevents water from reaching the interior of the seed.

The results of the Student's t-test for independent samples (Fig. 2) suggest that germinated and non-germinated seeds differed significantly only in width, length and, consequently, arithmetic mean diameter. In view of those parameters, germinated seeds were somewhat smaller than non-germinated seeds. However, a detailed analysis revealed that perennial ryegrass seeds should not be sorted based on the above attributes. All seed fractions had a high percentage of germinated seeds, therefore, the separation process would lead to a high loss of viable seeds without eliminating non-germinated seeds

from the sorted product. Despite an absence of statistically significant differences, germinated seeds were characterized by higher thickness, mass, sphericity index and density, and by lower geometric mean diameter and aspect ratio in comparison with non-germinated seeds.

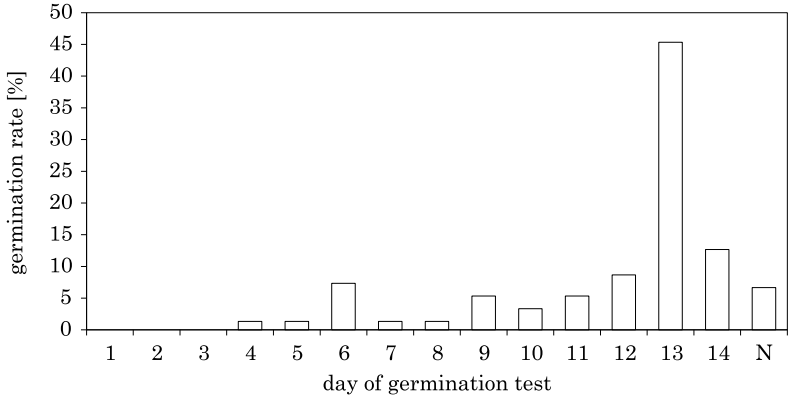

Fig. 1. Germination percentage of perennial ryegrass seeds: N – non-germinated seeds

The strength of linear relationships between selected physical properties of perennial ryegrass seeds is presented in Table 2. Statistically significant correlations between the analyzed parameters were noted in the majority of cases (28 out of 45). The most highly correlated parameters were seed length and arithmetic mean diameter, and in the group of attributes that can be potentially used in separation processes – seed thickness and seed mass. Those results indicate that perennial ryegrass seeds would be most effectively separated with the use of mesh screens with longitudinal openings. The germination rate index was not significantly correlated with any of the evaluated physical properties, which suggests that the analyzed attributes cannot be used to improve the emergence time of perennial ryegrass seedlings. This observation is confirmed by the values of the germination rate index before and after seed samples were divided into three thickness groups of nearly identical size (Fig. 3). The use of mesh screens with longitudinal openings would effectively separate seeds that differ in average mass, but it would not contribute to their germination uniformity. For this reason, the germination efficiency of perennial ryegrass seeds can be improved with the use of chemical, physical and physiological methods, such as seed dressing, soaking in selected chemical solutions, conditioning, irradiation and electromagnetic field stimulation (DANNEBERGER et al. 1992, SCHOPFER et al. 2001, PODLEŚNY 2004, LYNIKIENE et al. 2006, MUSZYŃSKI, GŁADYSZEWSKA 2008, GRZESIK et al. 2012).

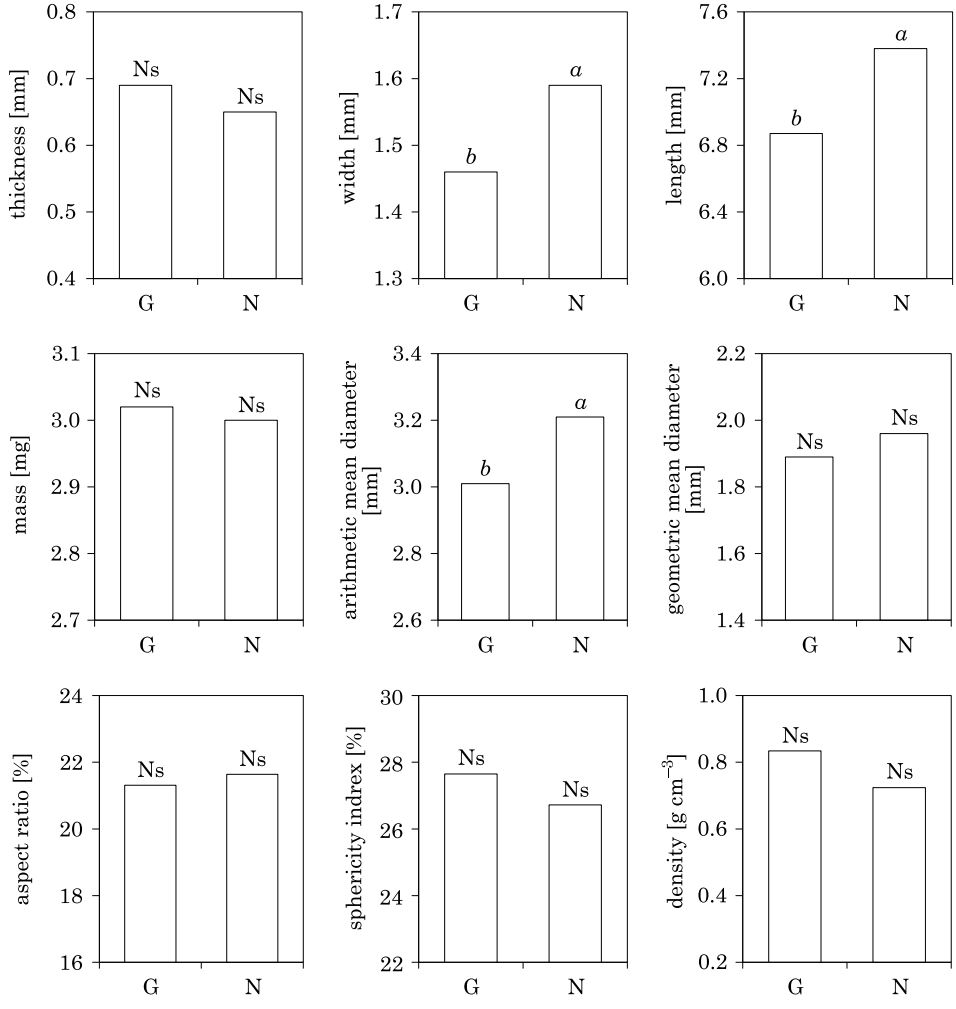

Fig. 2. Significance of differences between the physical properties and calculated parameters of perennial ryegrass seeds: G – germinated seeds, N – non-germinated seeds; *a* and *b* – statistically significant differences, Ns – not significant

Table 2

Coefficients of linear correlation between the physical properties and calculated parameters of perennial ryegrass seeds

Physical property/ parameter	T	W	L	m	D_a	D_g	R	Φ	ρ
W	-0.056	1							
Lc	0.021	**0.422**	1						
m	**0.778**	**0.168**	**0.204**	1					
D_a	**0.197**	**0.575**	**0.964**	**0.363**	1				
D_g	**0.785**	**0.472**	**0.528**	**0.761**	**0.711**	1			
R	-0.060	**0.627**	**-0.431**	0.001	**-0.248**	0.027	1		
Φ	**0.772**	0.041	**-0.502**	**0.548**	**-0.278**	**0.462**	**0.486**	1	
ρ	**0.235**	**-0.381**	**-0.335**	**0.562**	**-0.329**	-0.090	-0.090	**0.273**	1
W_g	0.106	-0.092	-0.071	0.102	-0.062	-0.041	-0.041	0.092	0.159

The bold font indicates that the value of the correlation coefficient is higher than the critical value of 0.166.

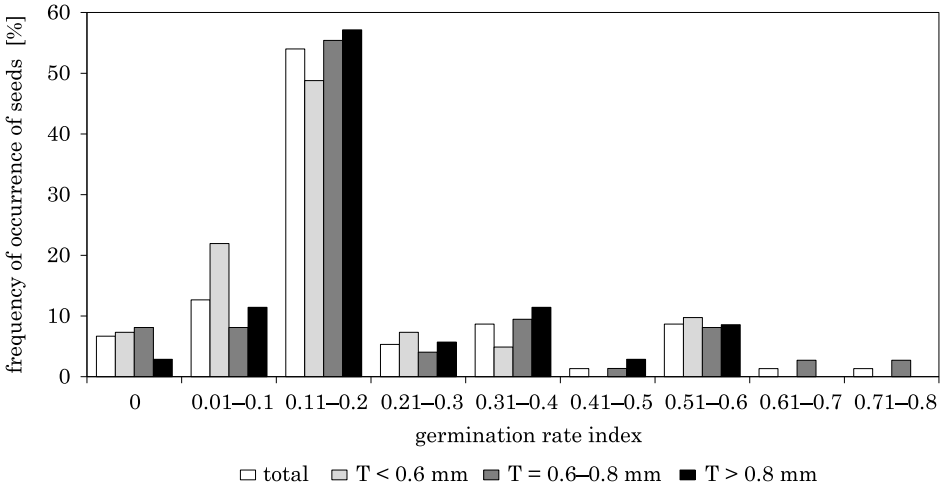

Fig. 3. Germination rate index calculated based on the thickness of perennial ryegrass seeds

Conclusions

1. The analyzed seeds of perennial ryegrass cv. Maja are characterized by very low germinative energy of 11.33%, but relatively high germination capacity of 93.33%. The majority of seeds germinate on day 13 of the germination test.

2. The examined physical properties of seeds, including length, width, thickness, arithmetic mean diameter, geometric mean diameter, aspect ratio, sphericity index and seed density, do not exert a significant influence of the germination rate index. Therefore, seeds should not be separated based on their plumpness as it would not improve the uniformity of seedling emergence.

3. In comparison with non-germinated seeds, germinated seeds are characterized by higher thickness, mass, sphericity index and density, and by lower width, length, arithmetic mean diameter, geometric mean diameter and aspect ratio. Despite those differences, there is no need to eliminate non-germinated seeds from the seed material because it could lead to a significant loss of high-quality seeds.

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