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ASSESSMENT OF SOWING VALUE AND VIGOUR OF SOYBEAN SEEDS (*Glycine max* L.) DEPENDING ON SEEDS INOCULATION

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Abstract. The aim of study was to evaluate the sowing value and vigour of soybean (cv. Merlin) seeds depending on inoculation. The experiment was carried out in 2021 at the Seed Laboratory in the Department of Agronomy, at the University of Life Sciences in Poznań, on the seeds of soybean harvested in the fields of the Złotniki branch of the ZDD Gorzyń Experimental Station in 2020. The research factor included: A – seeds of soybean controlled (seeds without inoculation), B – seeds inoculated with *Bradyrhizobium japonicum* + *Bradyrhizobium diazoefficiens* (Nitraza), C – seeds inoculated with *Bacillus amyloliquefaciens* (BA-Agro 1) and D – seeds inoculated with *Bradyrhizobium japonicum* + *Bradyrhizobium diazoefficiens* and *Bacillus amyloliquefaciens* (BA-Agro 1). The results confirm the high dependence of the sowing quality of the obtained seeds on weather conditions during harvest. The experiment showed that the lowest germination capacity of soybean seeds cv. Merlin was found in the object without inoculation (52%). A significant increase in the germination capacity of soybean compared to the object without inoculation was observed after inoculation with *Bacillus amyloliquefaciens* (BA-Agro 1) or *Bradyrhizobium japonicum + Bradyrhizobium diazoefficiens and Bacillus amyloliquefaciens* (by 11% points).

Słowa kluczowe: soybean, inoculation, germination capacity, vigour

INTRODUCTION

Soybean (*Glycine max* L.) serves as one of the world's most valuable crops, not only as an oilseed crop and feed for livestock and aquaculture but also as a good source of protein for human consumption [Masuda and Goldsmith 2009]. The crop can be grown in tropical, subtropical, and temperate climates. It is also a significant source of vegetable oil and protein concentrates. Soybeans are high in protein and fat, with roughly 40% of dry matter being protein and 20% fat [Lakshmeesha et al. 2013]. In 2009–2010, global soybean output was expected to reach 250.39 million metric tons [USDA 2009]. One way to increase the production potential of soybean and thus the production of quality soybean oil is to prepare the biologically active seed before it is sowing [Procházka et al. 2015]. Seed purification is a biological, chemical and physical (mechanical) procedure used to mitigate the negative effects of different external or internal influences. It improves its germination and vigour and thus boosts the formation of a healthy plant with increased production potential [Egli et al. 2005, Khandwa et al. 2002]. The process of seed treatment can be combined with inoculation. It can be therefore said that seed enhancement is one of the very inexpensive and most productive methods of plant protection and stimulation

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of growth (Procházka et al. 2016). It is necessary and useful to inoculate plants with symbiont microorganisms like mycorrhiza and N-fixing bacteria and free-living bacteria that stimulate growth [Makkawi et al. 1999]. According to Murtaza et al. [2014], the seed inoculation is an effective strategy to boost legume productivity. *Pseudomonas* is among the bacteria stimulating the growth of the plant. *Bradyrhizobium* is among the N-fixing bacteria living in symbiosis with legumes including soybean. The main parameters of seed value are germination energy and germination capacity. Unfortunately, results from the laboratory test do not cover with results of field germination obtained in the field. That is why it is needed to predict e.g. weather or soil conditions, already during the laboratory assessment. Hence, seed vigour assessments are increasingly being carried out. Crop steadiness has been associated with seed vigour [Cantarelli et al. 2015]. Seed vigour is one of the factors that influence plant growth across a wide range of conditions [ISTA 2015]. As a result, the physiological condition of the seed determines germination and longevity, as well as reserve degradation and vigour [Krzyzanowski et al. 2008.] Plant survival in the field is harmed by poor seed physiological quality and increases plant unevenness [Cantarelli et al. 2015, Finch-Savage and Bessel 2016].

Thus, for seed production, seed vigour plays a key role, as it allows the rapid and uniform establishment of young plants and a suitable population in the field [Krzyzanowski and Franca-Neto 2001, Panasiewicz 2020a, 2020b]. The objective of this research is to evaluate the sowing value and seed vigour of soybean (cv. Merlin) seeds using differentiated vaccination.

MATERIAL AND METHODS

The laboratory experiment on soybean seeds of the Merlin variety was carried out in 2021 at the Seed Laboratory in the Department of Agronomy, at the University of Life Sciences in Poznan, with seeds from the 2020 harvest in the fields of the Zlotniki Branch of the ZDD Gorzyń Experimental Station. The field experiment was carried out as a one-way experiment with four replications. Experimental factor was inoculation: A (seeds without inoculation*),* B (seeds inoculated with *Bradyrhizobium japonicum + Bradyrhizobium diazoefficiens* (Nitraza)*,* C (seeds inoculated with *Bacillus amyloliquefaciens* and D (seeds inoculated with *Bradyrhizobium japonicum + Bradyrhizobium diazoefficiens* and *Bacillus amyloliquefaciens*. After harvesting, the seeds were stored for 6 months in a cold store at a temperature of 5 °C, protected from light. The research was carried out in the laboratory based on the evaluation of the sowing value (germination energy, germination capacity, share of abnormally germinating seeds, share of rotting seeds) according to International Seed Testing Association [2020] methods and seed vigour included: seedling growth test, seedling growth rate test, conductivity test [Dąbrowska et al. 2000] was determined. Vigour Index – was calculated as average sprout length (cm) x average germination capacity (%) [Dąbrowska et al. 2000]. Additionally the number of infested seeds by *Fusarium* was counted and the long of 10 roots from each replication were measured.

The meteorological data in 2020 were obtained from the Experimental Station in Złotniki. In addition, the weather conditions were determined using the Sielianinow hydrothermal coefficient (K) calculated using the formula [Molga 1986]:

$$K = \frac{P\ x\ 10}{\Sigma_t\ x\ 10}$$

Where:
P – the sum of atmospheric precipitation in the analyzed period,
$\sum_t$ – the sum of the average daily temperature in the analyzed period.
Interpretation of the Sielianinov hydrothermal coefficient:
$K > 1.5$ – excessive humidity for most plants;
$1.0 < K < 1.5$ – humidity sufficient for most plants;
$0.5 < K < 1.0$ – insufficient humidity for most plants;
$K < 0.5$ – drought.

Significant less water were recorded from the second decade of March to the beginning of May. The driest month was April, with no rainfall in the 1st and 3rd decades. In May and in the first decade of June and in the first and second decade of July, the coefficient of Sielianinow showed humidity sufficient for most plants. Low rainfall in the third decade of July contributed to the weaker development of plants. Moreover high precipitation in the last decade of August influenced on the postpone the term of harvest to the second decade of September.

All analyses were done in four replications. All data were processed using one-way analysis of variance (ANOVA) with the SAS package. The means of treatments were compared using Tukey's Multiple Range test and the least significant difference (LSD) was declared at the $p < 0.05$.

RESULTS AND DISCUSSION

One of the most essential aspects of plant production is the quality of the seeds used for sowing. They are also one of the most cost-effective aspects of plant production, and using certified material allows you to benefit from varietal progress. Biological protection strategies, such as biological inoculation, are becoming increasingly popular as a result of environmental concerns and the excellent quality of plant output of many species. The quality of seed used to plant the following season may be affected by weather conditions during soybean reproductive growth as high soybean seed quality has been linked to the presence of optimum conditions during seed maturity. The result of the experiment showed that the quality of of soybean seeds harvested in 2020 was low, germination energy was 48 – 62% and germination capacity was between 52 – 63% (tab. 1). According to Dz. U. 2013, poz. 517 the harvested seeds did not obtain the criterion of certified seed, for which the minimum germination capacity may not be lower than 80%. Inoculation of the seeds significantly influenced on the sowing quality of the soybean seeds cv. Merlin. In the study, in comparison to seeds without inoculation, seeds inoculated with *Bacillus amyloliquefaciens* (C) and *Bradyrhizobium japonicum + Bradyrhizobium diazoefficiens* and *Bacillus amyloliquefaciens* (D), have the highest germination capacity (63%). Several crop studies have shown that so-called plant-growth-promoting bacteria can boost seed germination [Lucy et al. 2004, Wu et al. 2016].

The lowest germination capacity was found in the control, where the seeds were without vaccination (52%). This could be because microorganisms improve root growth by producing amino acids, indole acetic acid (IAA), gibberellins, and other polyamines, which act as plant growth promoters. As a result, when plants absorb more water and nutrients, rhizobia-soybean interaction sites emerge [Schmidt et al. 2015, Yadav et al. 2017]. According to Shaukat et al. [2006] faster germination after seeds of sunflower inoculation with PGPB was connected with a greater activity of the phosphatase enzyme. Similar results were also found in wheat seeds Shaukat et al. [2006]. The lowest share of abnormally germinating seeds was observed on the object

Table 1. Sowing value of soybean seeds depending on inoculation

Inoculation	Germination energy (%)	Germination Capacity (%)	Share of abnormally germinating seeds (%)	Share of rotting seeds (%)
A	48	52	14	38
B	57	59	12	31
C	59	63	15	26
D	62	63	9	29
Average	56	59	12.5	31
$LSD_{0.05}$	5	10	n.s.	6

n.s. – no significante differences

with *Bradyrhizobium japonicum* + *Bradyrhizobium diazoefficiens* and *Bacillus amyloliquefaciens* (D), but there were no significant difference between the combinations. Moreover the highest share of rotting soybean seeds was noticed on the check object with no inoculation. According to many authors [Glick et al. 1995, Glick et al. 2007, Bashan and de-Bashan 2010], bacteria fix atmospheric nitrogen and supply it to plants. Though this is usually a minor component of the benefit, the bacterium provides plant synthesis siderophores, which sequester iron from the soil and provide it to plant cells. Siderophore complex that can be taken up; synthesize phytohormones like auxins, cytokinins and gibberellins which can act to enhance or regulate various stages of plant growth; solubilize minerals such as phosphorus, making them more readily available for plant growth. This is following Gholami et al. [2009], who observed that plant growth-promoting bacteria contributed significantly to the germination and vigour of maize seeds. In our study the analysis of variance showed that the applied inoculation of seeds of soybean did not significantly modify the seedling growth test, vigour index and the seedling growth rate test (tab. 2), but the longest seedlings were observed on the combination with *Bradyrhizobium japonicum* + *Bradyrhizobium diazoefficiens* (B) (2.01 cm), while the heaviest seedlings were on the object with seeds without inoculation.

Table 2. Seed vigour, number of seeds with *Fusarium* and length of radicle of soybean depending on inoculation

Inoculation	Seedling growth test (cm)	Seedling growth test rate (mg·seedling)	Conductivity test ($\mu s \cdot cm^{-1} \cdot g^{-1}$)	Vigour ndex	Number of seeds with *Fusarium* (pcs./100 seeds)	Root Length (cm)
A	1.42	1.99	54	69.2	7.0	2.9
B	2.01	1.58	50	111.9	3.5	3.5
C	1.60	1.50	39	89.0	7.8	3.5
D	1.73	1.79	47	106.0	9.5	3.5
Average	1.69	1.72	48	94.0	7.0	3.4
$LSD_{0.05}$	n.s.	n.s.	6	n.s.	4.3	n.s.

n.s. – no significante differences

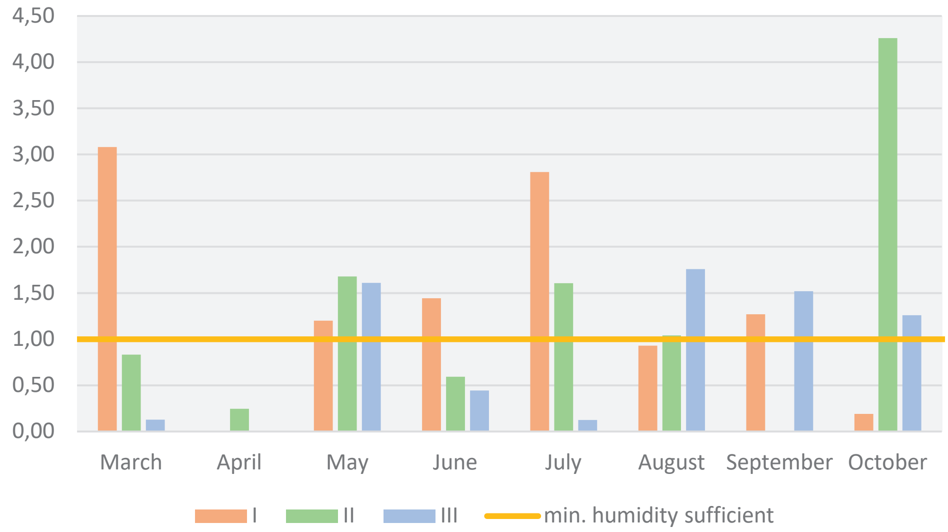

Fig. 1. Characteristics of weather conditions during the growing season 2020 in Złotniki based on the Sielianów index.

The conductivity test is a useful instrument for detecting seed vigour since it indirectly analyzes the degree of cell membrane breakdown by measuring the number of electrolytes produced in the seed soaking solution. The conductivity test is a useful instrument for detecting seed vigour since it indirectly analyzes the degree of cell membrane breakdown by measuring the number of electrolytes produced in the seed soaking solution. In our study the highest result for the test was observed on the combination without seed inoculation (A), what suggest that the seed had the lowest vigour, while the better vigour had the seeds inoculated with *Bacillus amyloliquefaciens* (C). Weak seeds have a weaker membrane structure, which leads to more electrolyte leakage and higher conductivity readings [Pandey 1992].

The longest roots were observed on the object with *Bradyrhizobium japonicum* + *Bradyrhizobium diazoefficiens* (B), while the seeds with object A (without inoculation) had the shortest roots. Mand et al. (1991) and Weaver et al. (1990) observed that inoculation with *Bradyrhizobium japonicum* significantly increased the number of nodules, nodule fresh weight, plant dry weight, nitrogen fixation, total nitrogen content and seed yield.

CONCLUSIONS

The results confirm the high dependence of the quality of the obtained seeds on the weather conditions during harvesting. The experiment showed that the lowest germination capacity of soybean cv. Merlin was found in the object without vaccination (52%). After inoculation with *Bacillus amyloliquefaciens* and *Bradyrhizobium japonicum* + *Bradyrhizobium diazoefficiens* and *Bacillus amyloliquefaciens*, a significant increase in soybean germination capacity was observed compared to the object without inoculation by 11% points.

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OCENA JAKOŚCI SIEWNEJ NASION SOI (*GLYCINE MAX* L.) W ZALEŻNOŚCI OD SZCZEPIENIA NASION

Summary

Synopsis. Celem badań była ocena wartości siewnej i wigoru nasion soi (odmiana Merlin) w zależności od inokulacji. Doświadczenie przeprowadzono w 2021 roku w Laboratorium Nasiennym Katedry Agronomii, Uniwersytet Przyrodniczy w Poznaniu na nasionach soi zebranych na polach Zakładu Doświadczalno-Dydaktycznego Uprawy Roli i Roślin Gorzyń, filia Złotniki w 2020 roku. Czynnik badawczy stanowiło szczepienie nasion, badania uwzględniały: A – nasiona soi bez inokulacji, B – nasiona inokulowane *Bradyrhizobium japonicum* + *Bradyrhizobium diazoefficiens* (Nitraza), C – nasiona inokulowane *Bacillus amyloliquefaciens* (BA-Agro 1) oraz D – nasiona inokulowane *Bradyrhizobium japonicum* + *Bradyrhizobium diazoefficiens* i *Bacillus amyloliquefaciens* (BA-Agro 1). Uzyskane wyniki potwierdzają dużą zależność jakości uzyskanych nasion od warunków pogodowych podczas zbioru. Doświadczenie wykazało, że najniższą zdolność kiełkowania nasion soi odmiany Merlin stwierdzono na obiekcie bez szczepień (52%). Po szczepieniu *Bacillus amyloliquefaciens* (BA-Agro 1) oraz *Bradyrhizobium japonicum* + *Bradyrhizobium diazoefficiens i Bacillus amyloliquefaciens* zaobserwowano istotny wzrost zdolności kiełkowania soi w porównaniu z obiektem bez szczepienia o 11 pkt%.

Key words: soja, szczepienie, zdolność kiełkowania, wigor

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