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SEED VITALITY OF SUNFLOWER INBRED LINES INFLUENCED BY METEOROLOGICAL FACTORS AND SEED SIZE

UTICAJ METEOROLOŠKIH FAKTORA I VELIČINE SEMENA NA VITALNOST SEMENA INBRED LINIJA SUNCOKRETA

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ABSTRACT

Climate changes inevitably affect plant production, but it is difficult to predict their direct impact on a vitality (germination) of a produced seed. Germination is the most important indicator of seed vitality and a key stage in the life cycle of plants. Seed germination is significantly affected by environmental factors during the growing season, as well as the method of processing (according to seed size). The aim of this work was to determine the impact of three factors on seed germination of four sunflower inbred lines: i) genotype, ii) environment conditions in a production year, and iii) seed size obtained during processing. The germination was examined in a standard laboratory test by ISTA Ruls, six months after the processing and natural breaking of dormancy. Larger and smaller sizes seeds, obtained in two consecutive years, which were characterized by different environmental conditions (sum of precipitation, mean monthly temperatures and air humidity during flowering), were used. Collected data was analyzed using a three-way analysis of variance, and correlation analysis. The coefficient of variation was 8.19%. Significantly higher average seed germination was obtained during 2020 (92%,) compared to 2021 (85%). The effect of seed size was not statistically significant, regardless of the tested inbred line. It can be concluded that the increase in the seed germination of sunflower inbred lines is mainly influenced by genotype, but also the increase in precipitation, minimum and maximum air humidity during flowering and the decrease in mean monthly temperatures, which was confirmed by the correlation coefficients between the above agroecological conditions and the germination rate of the produced seeds.

Keywords: *meteorological factors, germination, inbred lines, seed size, sunflower.*

REZIME

Klimatske promene neizbežno utiču na biljnu proizvodnju, ali je teško predvideti direktan uticaj na vitalnost (klijavost) proizvedenog semena. Klijanje je najznačajniji pokazatelj vitalnosti semena i ključna faza u životnom ciklusu biljaka. Klijavost semena je pod uticajem faktora spoljašnje sredine tokom vegetacije, ali i načina dorade (prema krupnoći semena). Cilj rada je bio da se ispita uticaj tri faktora na klijavost proizvedenog semena inbred linija suncokreta i to: i) genotip, ii) klimatski uslovi u proizvodnoj godini, i iii) krupnoća semena dobijena tokom separacije semena prilikom dorade. Klijavost semena četiri inbred linije suncokreta je ispitana standardnim laboratoriskim testovima po ISTA pravilima, šest meseci nakon dorade i prolaska dormantnosti prirodnim putem. Korišćena su semena krupnije i sitnije veličine, dobijena u dve uzastopne godine, koje su karakterisali različit klimatski uslovi (suma padavina, srednje mesečne temperature i vlažnost vazduha tokom oplodnje). Podaci su analizirani trofaktorijalnom analizom varijanse, kao i koficijentom korelacije. Koeficijent varijacije iznosio je 8,19%. Prosečna klijavost semena je bila značajno viša u 2020. godini (92%) u odnosu na 2021. godinu (85%). Efekat veličine semena nije bio statistički značajan, bez obzira na testiranu inbred liniju. Može se zaključiti da na povećanje klijavosti semena inbred linija suncokreta najviše utiču genotip, ali i povećanje padavina, minimalna i maksimalna vlažnost vazduha tokom cvetanja i smanjenje srednjih mesečnih temperatura, što je potvrđeno i koeficijenti korelacije između navedenih agroekoloških uslova i klijavosti proizvedenog semena.

Ključne reči: *klimatski faktori, klijavost, inbred linije, veličina semena, suncokret.*

INTRODUCTION

Sunflower kernels represent a rich source of high-quality edible oil. There is an increasing demand for sunflower oil in the world, which therefore leads to an increase in seed production (*Pilorgé, 2020*). In Serbia, sunflower is the main oil crop, with more than 80% of the total amount of all vegetable oils produced (*Ćuk et al., 2020*). Global agriculture is passing through a phase of agroecological transition caused by climate change. Climate change is already affecting food security through increasing temperatures, changing precipitation patterns, and greater frequency of extreme weather events (temperatures, droughts, floods, storms, etc.). Agricultural production, especially seed production, is substantially important because seed-producing plants provide 95% of food supplies. Seed is the main factor of successful seed production, but it is a complex biological system (*Miklič et al., 2000*). The main task of sunflower seed production is to produce seeds with high germination potential in order to use their genetic potential for obtaining high and stable yields (*Krstić et al., 2021*). Unfortunately, very little is known about the consequences of climate change on seed production and seed vitality. Will seed germination, as the main indicator of seed vitality, be affected by those changes (*Lamichhane et al., 2018*), is a question that needs an answer. Seed germination is a crucial stage in the life cycle of plants (*Luan et al., 2014*), and in crop production, seed germination testing is usually performed to determine the optimal sowing rate. As seed germination decreases, the number of plants per unit area also decreases, which negatively affects the yield (*TeKrony and Egli, 1991*). Seed size plays an important role in germination (*Semerci, 2013*) as well as the formation of a stronger seedling, which is necessary to achieve optimal plant number per area unit, and has a direct impact on the yield (*Nik et al., 2011*). Seed germination depends on many endogenous factors (genetic constitution, primary and secondary seed dormancy, etc.), but also exogenous factors such as environmental conditions (temperature, insolation, air humidity during fertilization, etc.) and edaphic (soil humidity) conditions (*Toscano et al., 2017*; *Varga et al., 2020*; *Vicente et al., 2020*). Sunflower is a plant species that requires an appropriate amount of water and heat in all stages of development in order to achieve optimal productivity and seed quality, but also to provide high-vitality seeds for the following years. Compared to other environmental conditions, precipitation and temperature have the greatest influence on yield. High daily air temperatures, low air humidity and frequent rainfall during the period of flowering and seed filling have a great influence on fertilization, and therefore on the yield and seed quality. The germination also depends on the applied agricultural technique, as well as the seed processing method (*Miklič et al., 2012*; *Fattahi et al., 2017*). According to *Nenadić et al. (2011)*, the following have a great impact on germination: performance of a combine, manipulation of harvested seed - from the combine to a processing center, storage conditions of natural and processed seeds, as well as time and method of seed processing. *Mrdja et al. (2012)* concluded that a large number of parameters influenced seed germination and that it was not possible to declare with certainty, which were the most important and influential. The most important task is to maintain the vitality i.e. germination of sunflower seed at a high level during storage for the next three to four years. However, examples from the practice show that the germination of sunflower seeds decreases suddenly after two to three years after the seed production (*Miladinov et al., 2014*).

Having all above mentioned in mind, the aim of this work was to determine the impact of three factors on seed germination of four sunflower inbred lines: i) genotype, ii) environment conditions in a production year, and iii) seed size obtained during processing (larger and smaller seeds).

MATERIAL AND METHOD

The seed material for this research was produced in 2020 and 2021 at Bosnia and Herzegovina (Republic of Srpska - Bijeljina site). Four sunflower inbred lines were included in tests (BG N 2, HA-267 SU, IMI-AB-14 PR, HA-267). The chosen genotypes originate from the genetic pool of the Institute of Field and Vegetable Crops, National institute of the Republic of Serbia, Novi Sad. All cultural practices required by a common practice in the production of basic sunflower seeds were applied. After harvesting and primary seed processing (removal of impurities - harvest residues), larger and smaller seeds were separated on a processing line starting from a fine precleaner, indented cylinder, and cleaner to a gravity table. On the fractionators, the seeds were separated into larger and smaller sizes by means of slotted sieves of different sizes. The upper sieve for the larger fraction was 3.75 mm, while the lower sieve for the smaller fraction was 3.00 mm. The seed purity of all inbred lines was 99.9%.

Seed germination was determined under laboratory conditions according to the standardized laboratory method by ISTA (International Seed Testing Association) Rules, six months after the processing and natural breaking of the seed dormancy (ISTA, 2018). The test was performed in sand in four replications/100 seeds each, at the temperature of 25°C (ISTA, 2018). The germination was determined after ten days of testing.

The data were statistically processed using SPSS 21 statistical program (trial version). The methods of basic statistics, three-way analysis of variance (ANOVA), Duncan's multiple interval tests and Pearson's correlation were used. In addition, the percentage share of each individual factor and their interactions on seed germination was assessed based on the sum of squared ratio in the total sum of squares.

Metrological conditions

The analysis of precipitation, temperature and air humidity for the two experimental years (*Figure 1*) showed that the years differed in the sum of precipitation, average monthly temperatures and air humidity during the flower fertilization period. During 2020, the sum of precipitation in the period from the beginning of April to the end of September was 181 l/m^2 higher than in 2021. The sum of mean monthly temperatures was 1.3 °C higher in 2021. Compared to 2020, the mean monthly temperature in June, when the sunflower inbred lines were in the bud stage, was 2.5 °C higher, while in July, during the flowering and seed-filling phase, it was even 2.7 °C higher.

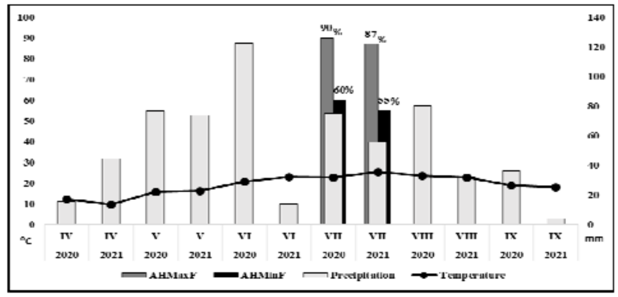
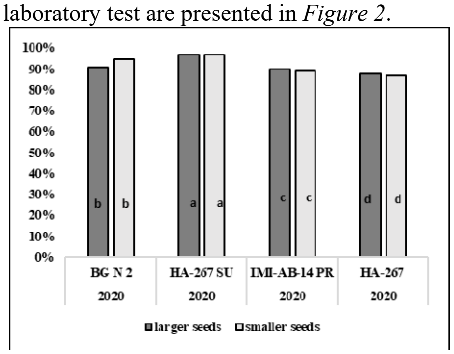


Fig. 1. Meteorological conditions for production years (Source: https://rhmzrs.com/meteorologija/agrometeorologija) AHMaxF- maximum air humidity during flowering; AHMinF- minimum air humidity during flowering

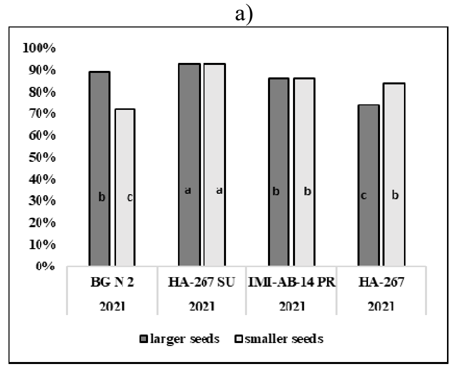
The conditions in 2020 can be characterized as favorable for the production of inbred sunflower lines at the Bijeljina site, while the vegetation period of 2021 (April-September) was warmer and drier compared to the multi-year average, which implies that 2021 was a less favorable year for the production of inbred lines of sunflower.

RESULTS AND DISCUSSION

The results of sunflower inbred lines seed germination in a standard laboratory test are presented in *Figure 2*.



a)



b)

Fig. 2. Germination of the smaller and larger seed of sunflower inbred lines during a) 2020 and b)2021 year

The coefficient of variation was 8.19%, and significantly the higher germination, on average, was in 2020 (92%) compared to 2021 (85%). Significantly the highest germination rate was achieved by the inbred line HA-267 SU (97 %) in 2020 and in

2021 (93%), while the lowest was achieved by the inbred line HA-267 in 2020 (88 %) and in 2021 (79%).

Three-way ANOVA confirmed that the genotype (39%) and the production year (27%) had a statistically significant influence on seed germination, while the seed size with partitioning in the total sum of squares of 0.1% had no significant influence on this variable. The interactions between all the mentioned factors had a statistically highly significant or significant influence on the inbred line seed germination (*Fig. 3*).

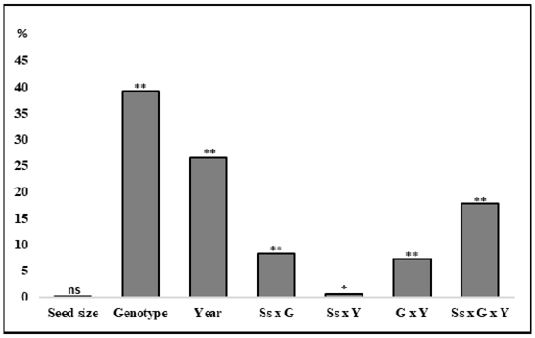


Fig. 3. ANOVA and partitioning of all factors on the influence of seed germination
*** - statistically highly significant (p <0.01); * - statistically significant (p <0.05); ns - no significance Ss-seed size; G-genotype; Y-year*

The seed germination for both seed sizes and for all inbred lines was, on average, 92% in 2020 (the same for both seed sizes), while in 2021 it was 86% for larger seeds and 84% for smaller seeds. Statistical analysis showed that the differences in germination were not significant, i.e. the seed size had no statistically significant effect on the seed germination. Some authors pointed out that larger sunflower seeds achieved higher germination than smaller seeds (*Ahmed et al., 2019*; *Mrdja., 2015*), which is partially in agreement with this study, while the statements of *Nasreen et al. (2015)* contradict the results of this work, pointing out that seed size had high influence on the sunflower seed germination. The fact that the genetic constitution of the genotype causes variability in seed size between genotypes should be also considered.

The genotype with a partition in sum of squares of 39% had the greatest influence on statistically highly significant differences in seed germination. These results are in agreement with the statements of *Krstić et* al. (2022), implying that genotype had a statistically high influence on seed germination of sunflower inbred lines. Large fluctuations in the yield and seed quality between localities, as well as between the years are present at investigated production conditions, most often due to the lack of water during a seed formation and filling. The production year, as a factor, had a great influence on statistically highly significant differences in the seed germination of inbred lines, with a partition in the sum of squares of 27%. The air temperature and a large amount of precipitation during June, July and August (277.4 l/m^2) in 2020, which was 175.4 l/m^2 higher compared to the same period in 2021, when inbred lines were in the stage of bud, fertilization and seed filling, had a positive effect on the seed germination of inbred sunflower lines. According to *Vrebalov (1989),* the sunflower has the greatest need for water in the phase of intensive growth (from the bud stage to flowering), which amounts to 43% of the total required. As stated by *Liović et al. (2017),* wet years can have an unfavorable impact on sunflower production, due to the development of diseases that can significantly reduce the yield, physical and technological quality of seeds, which was not a problem in 2020. The results of the work are in agreement with *Pacheco et al. (2005),* who stated that the environmental conditions largely influenced the germination of sunflower seeds, which most often results in a high variability, among different years in the same locality. *Lachabrouilli et al. (2021)* also confirmed that the influence of agroecological factors during the growing season on seed germination was much greater than the influence of the genotype itself. Our results are in agreement with the reports of *Čanak et al. (2020),* implying that the sum of effective temperatures had a significant influence on sunflower seed germination. The authors stated that the germination of the produced seeds increased with the increase of the sum of effective temperatures from the end of flowering to technological maturity. Predictions are that global climate change will significantly affect seed dormancy, and thus seed germination in most plant species *(Huang et al., 2017).*

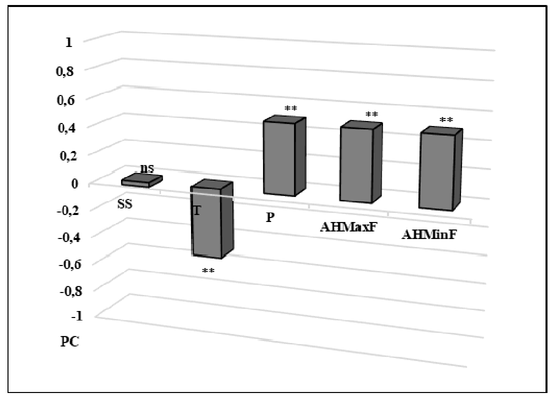


Fig. 4. Correlation between germination and environmental factors
*** - significance of correlation at level 0.01; * - significance of correlation at level 0.05; ns - no significance; PC - Pearson's coefficient of correlation; SS-seed size; T-temperature; P-precipitation; AHMaxF- maximum air humidity during flowering; AHMinF- minimum air humidity during flowering*

In the research, the correlations between germination and seed size, precipitation, mean monthly temperatures, minimum and maximum air humidity during sunflower flowering were examined as well (*Figure 4*). The strongest positive and highly statistically significant correlation was found between the precipitation, minimum and maximum air humidity during flowering and seed germination of sunflower inbred lines (r= 0.500). Also, the strongest negative statistically highly significant correlation was established between mean monthly temperatures and the seed germination of inbred lines (r= -0.497), which was the only correlation in this regard. It was noticed that with an increase in precipitation, minimum and maximum air humidity during flowering and a decrease in mean monthly temperatures in the production year, the germination of the inbred line-produced seeds increased. *Nenadić et al. (2011)* stated that the conditions of air humidity and temperature had a significant effect on the quality of soybean seeds, and in this paper, the same was also proven on the quality of sunflower seeds. *Krstić et al. (2021)* stated that on Bijeljina site, with a total rainfall of 355 l/m^2 and mean monthly temperature of 20.1 °C, the germination rate of the produced sunflower inbred line seed was 92% during the growing season in 2018. In 2019, with a total precipitation of 511 l/m^2 (with a worse distribution of precipitation) and a mean monthly temperature of 19.2 °C, the germination was 84%. In this research, in a year with a lower mean monthly temperature and with a higher amount of precipitation (better distribution of precipitation), the sunflower inbred line achieved better germination of the produced seed, which is in agreement with the previous statement.

In addition to the direct influence of the environmental conditions on the quality of sunflower seeds, the indirect influence manifested through the activity of pollinators should not be neglected either. The sunflower is an entomophilous plant and the presence of insects is necessary for the transfer of pollen. The activity of bees, which is under the direct influence of environmental conditions, has a great impact on fertilization, which later affects the yield and seed quality. Varying environmental conditions, especially wind, precipitation, temperature and relative humidity, greatly influenced the visits and behavior of bees. *Jančić et al. (1980)* pointed out that the best fertilization, yield and yield quality were achieved when the mean daily temperature during the flowering period is 20 °C, the ratio of minimum and maximum daily temperatures was 10 °C / 30 °C, relative air humidity was 95% /55% and fewer rainy days.

CONCLUSION

In this research, the influence of meteorological conditions in the production year, and the genotype, as well as the method of seed processing – seed size, on the germination of the produced seed of sunflower inbred lines was examined. The genotype had the greatest influence on the investigated variable, followed by the environmental conditions during the production season. The seed size as a factor, created in the seed processing by selecting processing machines, had no effect on the seed germination. In our production conditions, there are large fluctuations of yield and quality of seeds between localities, as well as between years (referring to the environmental conditions during vegetation), most often due to lack of water during seed formation and filling. It can be concluded that the increase in the seed germination of sunflower inbred lines is mainly influenced by genotype and the increase in precipitation, minimum and maximum air humidity during flowering and the decrease in mean monthly temperatures, which was confirmed by the correlation coefficients between the above agroecological conditions and the germination rate of the produced seeds.

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