The Effect of Irrigation on the Yield and Soybean (Glycine max L. Merr.) seed Germination in the Three Climatically Varying Years

Galić Subašić, Daria; Rapčan, Irena; Jurišić, Malden; Petrović, Davor; Radočaj, Dorijan

The Effect of Irrigation on the Yield and Soybean (*Glycine max* L. Merr.) seed Germination in the Three Climatically Varying Years

Utjecaj navodnjavanja na prinos i klijavost sjemena soje (*Glycine max* L. Merr.) u tri klimatski različite godine

Galić Subašić, D., Rapčan, I., Jurišić, M., Petrović, D., Radočaj, D.

Poljoprivreda / Agriculture

ISSN: 1848-8080 (Online)
ISSN: 1330-7142 (Print)

https://doi.org/10.18047/poljo.30.2.3

Fakultet agrobiotehničkih znanosti Osijek, Poljoprivredni institut Osijek

Faculty of Agrobiotechnical Sciences Osijek, Agricultural Institute Osijek

ISSN 1330-7142
UDK=633.34+631.53.01:631.67"4"
https://doi.org/10.18047/poljo.30.2.3

THE EFFECT OF IRRIGATION ON THE YIELD AND SOYBEAN (*Glycine max* L. MERR.) SEED GERMINATION IN THE THREE CLIMATICALLY VARYING YEARS

Galić Subašić, D., Rapčan, I., Jurišić, M., Petrović, D., Radočaj, D.

Original scientific paper
Izvorni znanstveni rad

SUMMARY

The paper presents the results of a three-year investigation of the effect of irrigation on the germination and yield of soybeans in three climatically different years in the conditions of eastern Croatia. The experiment was conducted with four soybean varieties (Lucija, Tena, Ika, and Vita) of different maturity groups and in different irrigation treatments (control: natural conditions, rational: 60–100% soil-water retention capacity (SWRC), and abundant irrigation: 80–100% SWRC). An analysis of variance revealed a statistically significant effect of irrigation on the yield throughout all three study years. The variety selection affected the yield in 2013 and 2014, while it did not manifest a statistical significance in 2015. The effect of irrigation on seed germination was exerted only in 2015, and an interaction between the irrigation and soybean variety was not observed in any of the study years. According to the results of the $LSD_{0.05}$ test, statistically significant differences were observed between the irrigation methods, whereby the t largest statistical difference in. seed germination was achieved with abundant irrigation ($LSD_{0.05}$ = 1.2039). A correlation analysis between the yield and germination produced a statistically significant positive correlation, which was weaker in 2013 and 2014, it was more pronounced in 2015 (r = 0.427*).

Keywords: soybean, irrigation, germination, yield, weather conditions

INTRODUCTION

The grain legumes are a rich source of dietary protein for millions of people around the world and therefore present a key driver for the insurance of global food security (Jha et al., 2022), while soybean (*Glycine max* L. Merr.) is an important legume that provides a primary source of high-quality protein and oil. It has become increasingly popular in the cultivation of arable crops due to its role in livestock diet, as well as in human nutrition. The high nutritional value of soybean grain, which contains about 40% of protein with a favorable amino acid composition, as well as 20% of fat with a high proportion of essential unsaturated fatty acids and other valuable components, are the primary reasons of an increased soybean cultivation (Gaweda, 2020). Soybean in globally cultivated on about 125 million ha, and a global annual yield is estimated at 340 million t (FAO, 2022). In 2022, soybean in the Republic of Croatia was cultivated on 90,699 ha, and 194,771 t of grain were produced, with an average yield of 2.1 t ha^{-1} (Ministry of Agriculture of the Republic of Croatia, 2023). Climate-change predictions emphasize that the serious water shortages will occur in the near future. A water deficit negatively affects soybean production, and the magnitude is not determined by the intensity of the deficit only but is also related to the growth stage in which the deficit occurs. A soybean yield varies

Daria Galić Subašić, PhD., Prof. Dr. Irena Rapčan, Prof. Dr. Mladen Jurišić, Davor Petrović, PhD, Dorijan Radočaj, PhD (dradocaj@fazos.hr) – Josip Juraj Strossmayer University of Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia

considerably in relation to an abiotic stress, primarily drought (Basal and Szabo, 2020; Popović et al., 2020). A temperate climate is characterized by a great variability in weather conditions, and on most locations, agriculture depends on precipitation. Their quantity and distribution vary from year to year and during the growing season, which causes a production instability. Production sustainability is seriously hampered by the dry periods, with the yield reductions of up to 40% (Cotrim et al., 2020). Soybean is a short-day thermophilic plant whose yield potential is strongly affected by water scarcity, with a reproductive phase, more precisely with a phase extending from the pod enlargement to the seed filling, being the main critical period (Schoving et al., 2022). Many studies demonstrated the inhibition of morphological traits, disease resistance, protein and oil content, and seed yield when soybean is subjected to drought stress during the initial growth stages (Basal and Szabó, 2020), which constitutes a high danger to the global food security (Xiong et al., 2020). Seed germination is the most important indicator of seed quality, and it refers to the determined number of normal seedlings in relation to the total number of seeds placed for germination, expressed as a percentage. Germination and dormancy are the plant seeds' complex processes that are influenced by the genes, plant hormones, and environmental factors. Germination is a basic characteristic of every healthy seed, and it begins when certain conditions, such as water, temperature, oxygen and light, are met (Saraf, 2017). In the grain legumes, in which the dormancy has been lost through breeding, germination is mainly controlled by the availability of water and soil temperature, but the influence of environmental factors is strongly related to a taxonomic affiliation and a climatic area of legume's origin (Kigel et al., 2015). It is well-known that the quality of seed, and thus the establishment of a sustainable and profitable crop (Finch-Savage and Bassel, 2015), affect germination. For this purpose, in this study the field and laboratory experiments were performed to more comprehensively describe seed germination and seedling growth in relation to the air temperature and water content.

MATERIALS AND METHODS

The field study was performed on the experimental parcels of the Agricultural Institute in Osijek (45°32` N, 18°44` E, 88 m H) during 2013, 2014, and 2015. Irrigation was carried out in three treatments, including a control (natural conditions with a non-irrigated treatment), rational (60–100% of the soil's water-retention capacity [SWRC]), and abundant irrigation (80–100% of the SWRC), according to the variants from sowing up to the seed-filling growth stage, having calculated the irrigation rate on the basis of the soil's water properties. The soil's water content was determined every three days in two layers (at 10–15 cm and 20–25 cm soil layer, respectively) using a watermark device. The amount of water added in the second treatment was a total of 105 mm in three rations in mid-June and in mid- and late July. The third irrigation treatment of 210 mm was distributed from mid-June to the end of July in the ten-day intervals. These treatments were carried out in the soybean growth stages, in which the plant is sensitive to a water shortage. The varieties used were created by the Agricultural Institute in Osijek: *Lucija* (00), *Vita* (0), *Ika* (0-I), and *Tena* (0-I). The amount and distribution of precipitation in the soybean vegetation period (from April to September) in the three study years differed significantly and had varying effects on the dynamics of the soil's water content. Accordingly, the number of irrigation rations and their schedule differed on a year-to-year basis. Germination was determined on the processed seeds according to the legal regulations, applying a usual method of deploying a rolled filter paper in the laboratory of the Department of Seed Production of the Agricultural Institute in Osijek. One hundred seeds per soybean variant were placed on a moistened filter paper applying the "scheme for germination and quality testing of seeds," wrapped in plastic (PVC) films, and placed in the Binder chambers at 25°C temperature for germination. After five days, the number of germinated seeds was determined, and a germination energy value was obtained for each variant in three repetitions. Other ungerminated grains were returned to the chambers, and the number of germinated grains was determined again after three days. Thus, the obtained germination rate for each variant was expressed as a percentage.

Climatic conditions significantly affect agricultural production, so monthly precipitation and the monthly mean air temperatures during a soybean-growing season were analyzed in the study years to obtain a long-term average (1981–2010) for the Osijek area (Table 1).

Table 1. Monthly precipitation (mm) and average monthly air temperature (°C) in the study years and a long-term average of the Osijek area (Osijek Airport) (DHMZ, 2015)

Tablica 1. Mjesečne oborine (mm) i srednje mjesečne temperature zraka (°C) u istraživanim godinama i višegodišnji prosjek za područje Osijeka (Zračna luka Osijek) (DHMZ, 2015)

Month *Mjesec*	2013	2014	2015	1981–2010
Precipitation (mm) /*Oborine (mm)*				
IV	44.9	81.3	12.9	52.4
V	119.0	161.4	113.4	63.9
VI	63.6	91.0	17.1	87.1
VII	36.5	66.4	25.6	56.0
VIII	32.9	54.3	105.8	68.3
IX	123.7	68.9	41.1	62.9
Total IV–IX *Ukupno IV–IX*	420.6	523.3	315.9	390.6
Average monthly air temperature (°C) / *Prosječna mjesečna temperatura zraka (°C)*				
IV	13.1	13.2	12.1	11.8
V	16.7	16.1	17.8	17.1
VI	20.0	20.5	20.8	20.1
VII	22.9	21.9	24.6	22.0
VIII	22.9	20.8	23.7	21.3
IX	15.9	17.0	17.9	16.7
Average IV–IX *Prosjek IV–IX*	18.58	18.25	19.48	18.17

A statistical analysis was conducted using SAS and *Microsoft Excel*. An analysis of variance was used to examine the effect of a treatment on the investigated properties. Statistically significant differences between the mean values of the examined treatments were determined by the least significant difference (LSD) test ($p < 0.05$), calculated for all observed variables, and the strength and direction of a connection between them were tested by a correlation coefficient (r) according to the Roemer-Orphal scale (Vasilj, 2000).

RESULTS AND DISCUSSION

Man and Modra (2008) concluded that, in addition to the contamination, drought is the second major problem facing the world and that it is the main risk factor in the reduction of food-production potential due to its impact on agricultural production. Some of the negative impacts of climate change on crops, as stated by Raza et al. (2019), are the damages inflicted due to extreme heat, increased drought, increased soil erosion, increased crop diseases, a longer growing season, an increased weed growth, and a thaw stress. In the last few decades, there is a trend of incremental average daily temperatures (Carlowicz, 2010). In an analysis of climate change in Croatia, Šestak et al. (2022) found that, for the Osijek area, a period with a temperature threshold exceeding 20°C in the successive 28 years was extended by as many as 25 days if compared to a period from 1961 to 1990. High air temperatures are almost always accompanied by a lack of precipitation, which leads to large losses in crop yields (Milunović et al., 2022; Svečnjak, 2023; Vasileva et al., 2023). The eastern part of Croatia also features higher average air temperatures in addition to a more pronounced lack of precipitation (330 mm from May to September), so water stress is further increased when compared to the west of the country (425 mm in the same months). The same author stated that the effect of irrigation on agronomic and economic properties primarily depends on the weather conditions, so a yield increase will be larger in the drier years if compared to the years with the normal amounts of precipitation.

A result analysis showed a statistically significant influence of irrigation on the soybean yield in all three study years and on the seed germination in the last year (Table 2). A variety had a significant effect only on the yield during 2013 and 2014. An interaction of irrigation and variety had a statistically significant impact on the yield in 2013 and 2015.

Table 2. An analysis of variance of the soybean yield and seed germination

Tablica 2. Analiza varijance za prinos i klijavost zrna soje

Parameter / *Parametar*	Irrigation / *Navodnjavanje*	Variety / *Sorta*	Irrigation x Variety / *Navodnjavanje x sorta*
Yield (2013) / *Prinos (2013)*			
F	286.62*	22.7*	4.15*
p	<.0001	<.0001	0.0053
Seed germination (2013) / *Klijavost sjemena (2013)*			
F	1.632	0.72	1.26
p	0.2181	0.5500	0.3144
Yield (2014) /*Prinos (2014)*			
F	25.78*	40.08*	1.59
p	<.0001	<.0001	0.1928
Seed germination (2014) / *Klijavost sjemena (2014)*			
F	2.04	3.75	0.69
p	0.1523	0.0243	0.6616
Yield (2015) / *Prinos (2015)*			
F	135.92*	9.24	3.11*
p	<.0001	0.0003	0.0214
Seed germination (2015) / *Klijavost sjemena (2015)*			
F	8.44*	1.23	1.58
p	0.0017	0.3197	0.1972

Table 3. $LSD_{0,05}$ for soybean yield and seed germination

Tablica 3. $LSD_{0,05}$ prinosa i klijavosti zrna soje

Properties /*Čimbenici*		Yield (t ha^{-1}) / *Prinos (t ha^{-1})*		Germination (%) / *Klijavost (%)*	
		$LSD_{0.05}$		$LSD_{0.05}$	
Irrigation / *Navodnjavanje*	Control / *Kontrola*	2.9896^{A}	0.1887*	96.50^{B}	1.2039*
	Rational / *Racionalno*	3.8459^{B}		96.39^{B}	
	Abundant / *Obilno*	4.0359^{C}		98.72^{A}	
Year / *Godina*	2013	3.7807^{A}	0.2756*	97.28^{A}	1.3042 n.s.
	2014	3.6958^{A}		97.39^{A}	
	2015	3.3949^{B}		96.94^{A}	
Variety /*Sorta*	Lucija	3.7353^{B}	0.3226*	97.81^{A}	1.4831 n.s.
	Vita	3.3752^{A}		97.03^{A}	
	Ika	3.6583^{A}		96.33^{A}	
	Tena	3.7265^{B}		97.81^{A}	

Control: non-irrigated treatment, rational irrigation: 60–100% SWRC, abundant irrigation: 80–100% SWRC.

As figured in Table 3, the highest average yield was achieved in the abundant irrigation treatment in 2013 with the variety *Lucija*. The *Vita* variety achieved the lowest average yield, which was also obtained in 2015 in the control treatment. Regarding the seed germination, an abundant irrigation achieved the highest germination, whereas a rational irrigation achieved the lowest one. Seed germination was very uniform concerning a year and a variety. According to the $LSD_{0,05}$ test, statistically significant differences were observed with regard to the irrigation treatments, yield ($LSD_{0,05} = 0.1887$), and seed germination ($LSD_{0,05} = 1.039$). A year ($LSD_{0,05} = 0.2756$) and a variety ($LSD_{0,05} = 0.3226$) had a statistically significant effect on the yield but not on the seed germination.

Full bloom, an initial pod, and a full pod occurred during June and July, when a pronounced lack of precipitation but also a slightly higher air temperature if compared to the long-term average were recorded in 2015, Egli et al. (2005a) concluded that an evaluation of long-term temperature records suggests that a temperature, in some soybean production areas, will routinely reduce the grain vigor of some soybean varieties. Heat stress accelerates seed filling but reduces the duration of this growth stage (Boote et al., 2005) and causes a smaller and wrinkled grain (Egli et al., 2005b). In a drier year, for instance in 2003 if compared to 2005, an increase in the soybean yield from 1.85 to 2.68 t ha^{-1} (44.9%) if compared to an increase of 0.42 t ha^{-1} (16.1%) in 2005 was recorded in a research by **Šimunić** et al. (2008). Kovačević et al. (2010) noted that an average soybean yield in the study area during three consecutive years amounted to 2.29 t ha^{-1}, 2.98 t ha^{-1} and 1.92 t ha^{-1}, respectively. These yield values were significantly lower than an average yield (3.62 t ha^{-1}) in this study. The lowest yield of 3.39 t ha^{-1} was achieved in 2015, which was significantly drier (only 315.9 mm) than the first (420.6 mm) and the second (523.3 mm) study years and a long-term average for this area (390.6 mm) during the soybean-cultivation season. Svečnjak (2023) pointed out that the effect of irrigation on the agronomic and economic properties of soybeans primarily depend on the weather conditions during the growing season, so the yield increase will be significantly higher in the drier growing seasons if compared to the years with the normal amounts of precipitation. An abundant irrigation in this study achieved the highest average yield of 4.06 t ha^{-1}, which is an increase of 35% if compared to the control. Heatherly (1993) also reported an increase in the yield in the irrigation experiments at different stages of 1.54–2.98 t ha^{-1} if compared to the control (0.74–1.28 t ha^{-1}). In a four-year research project, Josipović et al. (2011) obtained the soybean yields from 2.98 (control) to 4.02 t ha^{-1} (60–100% SRWC) with the different irrigation variants, which is very similar to the yield obtained in this study. By irrigating the soybeans at different growth stages, Candoğan and Yazgan (2016) achieved yields of 2.93 to 4.00 t ha^{-1}, with a control treatment in which they recorded 1.97 t ha^{-1}, and the average yield in this study (3.62 t ha^{-1}) is within this range, while Jaybhay et al. (2019) recorded a yield of 2.92 to 3.22 t ha^{-1}. In the two-year experiments with six soybean varieties and three irrigation treatments, Shirazi et al. (2024) recorded a yield of 0.45 to 3.75 t ha^{-1}. The lowest yield in these studies was achieved with the smallest amount of irrigation water and the highest yield with the largest amount of irrigation water. The different soybean varieties also react differently to the weather conditions and agrotechnical measures. Thus, Sudarić and Vratarić (2008) stated that the average yields of tested varieties in the eastern part of Croatia were 3.99–5.00 t ha^{-1} (Lucija), 3.80–4.70 t ha^{-1} (Vita), 4.10–4.60 t ha^{-1} (Tena), and 4.06–5.10 t ha^{-1} (Ika). Vianna et al. (2019) examined 20 soybean genotypes and recorded yields from 1.90 to 4.79 t ha^{-1}, and Jukić et al. (2021) recorded an average yield of 2.65 t ha^{-1} (less than in this research), analyzed the differences between the varieties in an experiment with the 12 domestic and 10 foreign varieties, and detected that the influence of a variety on the yield was statistically significant, as was the case in this study. In the two-year experiments with two soybean varieties, Veas et al. (2022) noted the average yields of 6.40 and 7.64 t ha^{-1} in the control treatment. However, when the varieties were exposed to heat and water stress, the yield decreased, and the greatest decrease was in the combination of these two stresses (2.81 to even 5.25 t ha^{-1}).

Seed germination is one of the biological properties of grain that is influenced by the environment, so Vieira et al. (1992) detected reduced germination under drought stress during two study years. Svečnjak (2023) also stated that the soybeans produced in dry conditions had a lower germination. In the irrigation experiments at different soybean growth stages, Heatherly (1993) observed a seed germination of 72–92%, if compared to the control of 56–78%. From the results of the four-year experiments with four soybean varieties at three locations, Duvnjak et al. (2008) concluded that the environment had a stronger influence on seed germination than the variety. Miladinović et al. (2009; 2024) stated that the high temperatures in the last decade of July and throughout August, accompanied by a lack of precipitation, had a negative effect on the soybean seed germination, while Kovač et al. (2009) determined that the insufficient amounts of water and a high air temperature at the time of seed pouring significantly affected the seed germination. This was also confirmed by this research, because a lower soybean seed germination (96.94%) was observed in a year characterized by a dry and warm weather during the soybean growing season. In the experiments with several soybean populations, Pereira et al. (2017) found the statistically insignificant and significant correlations of yield and seed germination. A statistical analysis of a relationship between the yield and seed germination in all three years of monitoring shows a positive correlation. In 2013 and 2015, the correlation was weak (r = 0.303 and r = 0.219), while it was of medium strength (r = 0.427) in 2014, as displayed in Figure 1.

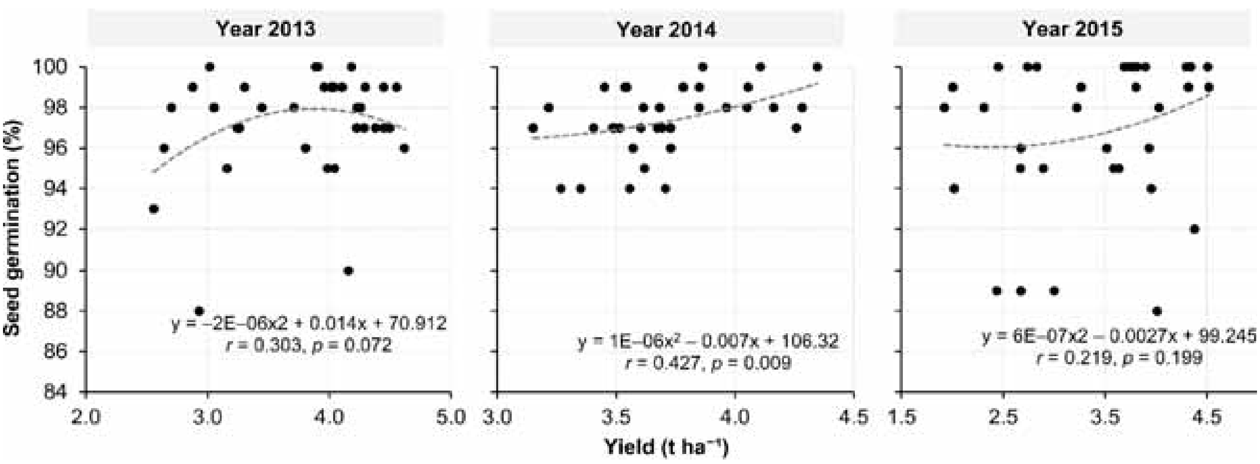

Figure 1. A correlation between the soybean yield and seed germination in the study period (2013–15)

Grafikon 1. Korelacija između prinosa zrna i klijavosti zrna u periodu istraživanja (2013. – 2015.)

CONCLUSIONS

This study confirmed the findings of the several previous studies that water is the main limiting factor in the achievement of high-quality soybean yields. These research results concerning the yield, quality, and soybean-seed germination can be of importance to the breeders and soybean growers for the sake of a development of varieties in specific agroecological conditions. A basic indicator of seed viability is germination, be it for two reasons. The first one is that this physiological indicator also reflects other qualities, such as the state of health and the state of seed moisture, while the second one is a possibility that the high-quality seeds will produce the seedlings and subsequently the plants that will achieve a good set in the field. Due to a high economic value of soybean as a crop, it is important to initially ensure the most favorable productional conditions for growth and development. To this end, a high seed quality, according to the germination and germination energy, is of primary importance, since such seeds ensure a faster and stronger germination and thus better initial conditions for growth and development. A better understanding of the key biotic and abiotic factors that influence a crop's establishment remains critical and is the first step to the obtainment of this goal.

REFERENCES

1. Basal, O., Szabo, A. (2020). Physiology, yield and quality of soybean as affected by drought stress. *Asian Journal of Agriculutre and Biology*, *8*(3), 247-252, doi:10.35495/ajab.2019.11.505
2. Boote, K.J., Allen, L.H. Jr., Prsada, P.V.V., Baker, J.T., Gesch, R.W., Synder, A.M., Pan, D., Thomas, J.M.G. (2005). Elevated temperature and CO_2 impacts on pollination, reproductive growth and yield of several globally important crops. *Journal of Agricultural Meteorology*, *60*, 469-474. doi: 10.1002/pmic.200700903
3. Candoğan, B.N., Yazgan, S. (2016). Yield and quality response of soybean to full and deficit irrigation at different growth stages under sub-humid climatic conditions. *Tarim Bilimleri Dergisi – Journal of Agricultural Sciences*, 22, 129-144.
4. Carlowicz, M. (2010) Ecosystem, vegetation affect intensity of urban heat island effect. *The Earth Observer*, 22, 36-37.
5. Jha, U.C., Nayyar, H., Agrawal, S.K., Siddique, H.M. (2022). *Developing Climate Resilient Grain and Forage Legumes*, Springer Nature.
6. Cotrim, M.F., Gava, R., Campos, C.N.S., de David, C.H.O., de Assis Reis, I., Teodoro, L.P. R. (2020). Physiological performance of soybean genotypes grown under irrigated and rainfed conditions, *Journal of Agronomy and Crop Sciences*, 207, 34-43. doi: 10.1111/jac.12448
7. Duvnjak, T., Popović, R., Liović, I., Vratarić, M., Sudarić, A. (2008). Genotype by environment interaction of germination in soybean cultivars. *Cereal Research Communications*, 36, Supplement: Proceedings of the V. Alps-Adria Scientific Workshop, 28.4.– 2.5.2008. Stara Lesna, Slovakia, 83-86.
8. Egli, D.B., TeKrony, D.M., Heitholt, J.J., Rupe, J. (2005a). Air temperature during seed filling and soybean seed germination and vigor. *Crop Science*, 45, 1329-1335.
9. Egli, D.B., TeKrony, D.M., Spears, J.F. (2005b). Effect of high temperature stress during different stages of seed development in soybean (*Glycine max* L. Merrill) *Seed Technology*, *27*, 177-189.
10. FAO (2022). FAOSTAT Database. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor
11. Finch-Savage, W. E., Bassel, G. W. (2015). Seed vigour and crop establishment: extending performance beyond adaptation. *Journal of Experimental Botany*, *67*(3), 567-591. doi: 10.1093/jxb/erv490
12. Gawęda, D., Nowak, A., Haliniarz, M., Woźniak, A. (2020). Yield and economic effectiveness of soybean grown under different cropping systems. *International journal of plant production*, *14*(3), 475-485. doi: 10.1007/s42106-020-00098-1
13. Heatherly, L.G. (1993). Drought stress and irrigation effects on germination of harvested soybean seed. *Crop Science*, 33, 777-781.
14. Jaybhay, S.A., Varghese, Ph., Taware, S.P., Idhol, B.D., Waghmare, B.N., Salunkhe, D.H. (2019) .Response of soybean [*Glycine max* (L) Merrill] to irrigation at different growth stages. *Agricultural Science Digest*, 39(2), 132-135. doi: 10.18805/ag.D-4932.
15. Josipović, M., Sudarić, A., Kovačević, V., Marković, M., Plavšić, H., Liović, I. (2011). Irrigation and nitrogen fertilization influences on properties of soybean (*Glycine max* (L.) Merr.) varieties. *Poljoprivreda*, *17*(1), 9-15.
16. Jukić, G., Šunjič, K., Varnica, I., Cegur, Ž., Delić, I., Beraković, I. (2021). Prinos i kakvoća sjemena soje na lokaciji Osijek. *56. hrvatski i 16. međunarodni simpozij agronoma*, 5.-10.9.2021., Vodice, Hrvatska, 353-357.
17. Kigel, J., Rosental, L., Fait, A. (2015). Seed physiology and germination of grain legumes. *Grain legumes*, 327-363.
18. Kovačević, V., Josipović, M., Kaučić, D., Iljkić, D. (2010) Weather impacts on yields of maize, sugar beet, soybeans and sunflower. *45. hrvatski i 5. međunarodni simpozij agronoma*, 15.-19.02.2010., Opatija, Hrvatska, 796-800.
19. Kovač, D., Milošević, M., Dokić, V., Vujaković, M., Balešević-Tubić, S., Petrović, D., Taški Ajduković, K. (2009). Uticaj agrometeoroloških uslova na kvalitet semena soje. *Zbornik radova instituta za ratarstvo i povrtarstvo 46*(1), 121-127.
20. Man, T.E., Modra, C. (2008). Drought impact of environment and agricultural products. *Journal of Environmental Protection and Ecology*, *9*(1), 70-76.
21. Miladinović, J., Hrustić, M., Vidić, M., Balešević, T. S., Đorđević, V., Đukić, V. (2009). Soybeans production in Serbia in 2008. *Zbornik radova Instituta za ratarstvo i povrtarstvo*, *46*(2), 271-276.
22. Ministry of Agriculture of the Republic of Croatia (2023) Annual report on the state of agriculture in 2022.
23. Miladinović, V., Popović, V. M., Delić, D., Stevanović, Z. D., Kiprovski, B., Kolašinac, S., Mikulić-Petkovsek, M., Ugrenović, V. (2024). Effectiveness of Bradyrhizobium japonicum inoculation on nodulation dynamics in *Glycine max* (L.) roots. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *52*(2), 13627-13627. doi: 10.15835/nbha52213627

24. Milunović, I., Popović, V., Rakaščan, N., Ikanović, J., Trkulja, V., Radojević, V., Dražić, G. (2022). Genotype×year interaction on rye productivity parameters cultivated on sandy chernozem soil. Genetika, Belgrade, *54*(2), 887-905. doi: 10.2298/GENSR2202887M
25. Pereira, E.M., Silva, F.M., Val, B.H.P. Pizolato Neto, A., Mauro, A.O., Martins, C.C., Unêda-Trevisoli, S.H. (2017). Canonical correlations between agronomic traits and seed physiological quality in segregating soybean populations. *Genetics and Molecular Research*, *16*(2), gmr16029547. doi:10.4238/gmr16029547
26. Popović, V., Vučković, S., Jovović, Z., Rakaščan, N., Kostić, M., Ljubičić, N., Mladenović-Glamočlija, M., Ikanović, J. (2020). Genotype by year interaction effects on soybean morpho-productive traits and biogas production. *Genetika*, *52*(3), 1055-1073. doi: 10.2298/GENSR2003055P
27. Raza, A., Razzaq, A., Mehmood, S.S., Zou, X., Zhang, X., Lv, Y., Xu, J. (2019). Impact of Climate Change on Crops Adaptation and Strategies to Tackle Its Outcome: A Review. *Plants* (Basel) *8*(2), 34. doi: 10.3390/plants8020034
28. Saraf, D., Vidak, M., Grdiša, M., Carović-Stanko, K. (2017). Klijanje i dormantnost kod mahunarki. *Agronomski glasnik,* 79 (1-2), 41-60. doi: 10.33128/ag.79.1-2.4
29. Schoving, C., Champolivier, L., Maury, P., Debaeke, P. (2022). Combining multi-environmental trials and crop simulation to understand soybean response to early sowings under contrasting water conditions. *European Journal of Agronomy*, *133*, 126439. doi: 10.1016/j.eja.2021.126439
30. Shirazi, R.M., Shirzadi, M.H., Aien, A., Afshamanesh, G.H.R. (2004). Effects of different irrigation regimes on the yield and qualitative characteristics of different cultivars of soybean (*Glycine max* L) in Jiroft. *Legume Research – An International Journal*, *47*(1), 59-63. doi: 10.18805/LRF-761.
31. Sudarić, A., Vratarić, M. (2008). Značenje, dostignuća i trendovi u oplemenjivanju soje u Poljoprivrednom institutu Osijek. *Sjemenarstvo*, *25*(3-4), 2007-216.
32. Svečnjak, Z. (2023). Štete od ljetnih suša u proizvodnji kukuruza i soje. *Glasnik zaštite bilja*, *46*(6), 26-33. doi: 10.31727/gzb.46.6.3
33. Šestak, I., Vitezica, L., Hrelja, I. (2022). Analysis of Climate Change in Croatia Based on Calculation of Temperature Thresholds. *Agriculturae Conspectus Scientificus*, 87 (4), 295-302.
34. Šimunić, I., Husnjak, S., Senta, A., Tomoć, F. (2008). Utjecaj suše na visinu priroda poljoprivrednih kultura. *43. hrvatski i 3. međunarodni simpozij agronoma*, 18.-21.2.2008., Opatija, Hrvatska, 51-55.
35. Vasilj, Đ. (2000) *Biometrika i eksperimentiranje u bilinogojstvu*. Zagreb: Hrvatsko agronomsko društvo.
36. Veas, R.E.A., Ergo, V.V., Vega, C.R.C., Lascano, R.H., Randanini, D.P., Carrera, C.S. (2022). Soybean seed growth dynamics exposed to heat and water stress during the filling period under field conditions. *Journal of Agronomy and Crop Science*, 208, 472-485. doi: 10.1111/jac.12523
37. Vianna, M.S., Nogueira, A.P.O., Hamawaki, O.T., de Sousa, L.B., Gomes, G.F., Glasenapp, J.S., Hamawaki, R.L., da Silva, C.O. (2019). Selection of lineages, genetic parameters, and correlations between soybean characters. *Bioscience Journal*, *35*(5), 1300-1314. doi: 10.14393/BJ-v35n5a2019-42656.
38. Vasileva, V., Georgiev, G., Popović, V. (2023). Genotypic specificity of soybean [*Glycine max* (L.) Merr.] plastid pigments content under sowing date and interrow spacing. *Genetika-Belgrade*, *55*(2), 455-471. doi: 10.2298/GENSR2302455V
39. Vieira, R.D., TeKrony, D.M., Egli, D.B. (1992) Effects of drought and defoliation stress in the field on soybean seed germination and vigor. *Crop Science*, *32*, 471-475.
40. Xiong, R., Liu, S., Considine, M.J., Siddique, K.H.M., Lam, H.-M., Chen, Y. (2020). Root system architecture, physiological and transcriptional traits of soybean (*Glycine max* L.) in response to water deficit: A review. *Physiologia Plantarum, 172*(2), 405–418. doi: 10.1111/ppl.13201

UTJECAJ NAVODNJAVANJA NA PRINOS I KLIJAVOST SJEMENA SOJE (*Glycine max* L. MERR) U TRI KLIMATSKI RAZLIČITE GODINE

SAŽETAK

U radu su predstavljeni rezultati trogodišnjih istraživanja učinka navodnjavanja na klijavost i prinos zrna soje u tri klimatski različite godine u uvjetima istočne Hrvatske. Pokus je proveden s četiri sorte soje (Lucija, Tena, Ika i Vita) različitih grupa zriobe i u različitim tretmanima navodnjavanja (kontrola: prirodni uvjeti, racionalno: 60 - 100 % retencijskoga kapaciteta tla za vodu (RKV) i obilno navodnjavanje: 80 - 100 % RKV-a). Analizom varijance utvrđen je statistički značajan učinak navodnjavanja na prinos tijekom svih triju godina istraživanja. Sorta je utjecala na prinos u 2013. i 2014. godini, dok u 2015. nije pokazala statističku značajnost. Učinak navodnjavanja na klijavost zrna ostvaren je samo tijekom 2015., a interakcija navodnjavanje – sorta ni u jednoj godini istraživanja. Prema rezultatima $LSD_{0,05}$ testa uočavaju se statistički značajne razlike između načina navodnjavanja, pri čemu je najveća statistička razlika s obzirom na klijavost zrna ostvarena obilnim navodnjavanjem ($LSD_{0,05}$ = 1.2039). Tijekom istraživanja utvrđena je analiza jednostruke korelacija između prinosa i klijavosti, koja pokazuje statističku značajnost pozitivnoga smjera, a slabiju 2013. i 2014. godine, dok je u 2015. godini korelacija bila jače izražena (r = 0.427*).

Ključne riječi: soja, navodnjavanje, klijavost, prinos, vremenske prilike

(**Received on June 10, 2024; accepted on October 15, 2024** – *Primljeno 10. lipnja 2024.; prihvaćeno 15. listopada 2024*.)