# The Effects of Different Sowing Dates on Winter Wheat

Utjecaj različitih rokova sjetve na ozimu pšenicu

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# THE EFFECTS OF DIFFERENT SOWING DATES ON WINTER WHEAT

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Preliminary communication
*Prethodno priopćenje*

**SUMMARY**

***Three separate field experiments, with different sowing dates, were conducted to determine a suitable sowing date for the highest agromorphological traits and technological quality parameters. The results in growing season 2022–23 demonstrated the following: with a sowing date delay (i.e., with the second sowing date occurring on November 4, 2022), the grain yield was significantly advanced when compared to the first sowing date (occurring on October 13, 2022), while the grain yield was significantly increased in eight genotypes (out of a total of twelve of them) on the third sowing date (i.e., on November 14, 2022) when compared to the first. The reason for disproportions of grain yield on the first two sowing dates was the attack of barley yellow dwarf virus in autumn that seriously damaged more developed plants pertaining to the first sowing date, whereafter they were also more prone to other wheat diseases. The relative differences concerning the second sowing date with regard to the first one were as follow: an increase by 59.1% concerning the grain yield, by 6.3% concerning the test weight, and by 22.5% concerning a 1000 kernel weight, a decrease by 23.3% concerning the heading date, by 1.2% concerning the protein content, by 2.1% concerning the wet gluten content, and by 2.5% concerning the sedimentation value. The difference in grain yield between the second and the third sowing date amounted to 34.2% due to a premature senescence of plants in later sowing, as a result of increased June temperatures.***

***Keywords: genotypes, grain yield, quality, sowing dates, wheat***

## INTRODUCTION

Nowdays, climate change affects wheat productivity, causing food security problems with massive economic losses (Kirby et al., 2016). The most sustainable approach to ensure global food demands is to increase the grain yield of main crops (Skendžić et al., 2021). In a climate change context, the frequency and intensity of some disasters, such as droughts, floods, and storms, could be increased, exerting a significant impact on the food sector (Field et al., 2012). In Croatia, in less than 32 years, the temperature has increased by approximately 1.3°C (*WorldData*). Also, a pronounced winter and spring warming is recorded (Šestak et al., 2022). Temperature is a very important parameter in winter wheat growth cycle, as it controls the wheat phenology and, simultaneously, the length of the required growing period.

Besides heat and drought stress, wheat grain production can be deteriorated by pest and disease occurrences and shortened growth cycles (Wang et al., 2021). Essentially, all manifestations of a climate change exert an impact on disease pressure. For example, increased temperatures have reduced the overwintering mortality of aphids, enabling earlier dispersion (Zhou et al., 1995). Theoretically, climate change may alleviate disease pressure by changing a pathogen's development, host–pathogen interactions, and pathogen-transmitting vector physiology, altogether with the emergence of the new strains of pathogens (Velasquez et al., 2018).

The choice of sowing date was determined under the consideration of avoidance of high temperatures and drought conditions during the anthesis stage or of the mitigation of effects caused by biotic stresses (Gao

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et al., 2022). Thus, as the anthesis stage is critical in wheat because of drought and some diseases, it is very important to regulate the flowering time.

The late sowing of wheat has already become a widely used measure to cope with climate changes and improve the grain yield (Xiao and Tao, 2014). On the other hand, a delayed sowing increases the exposure of wheat to the heat stress, which has an immense impact on leaf photosynthesis, grain filling, and grain yield formation (Garg et al., 2013). In the present one-year study, three separated experiments were conducted to test the effects of sowing date on the grain yield, grain-related traits, and technological quality traits. The overall study objectives were (i) to examine the effects of sowing dates on agromorphological traits and technological quality traits and (ii) to determine suitable sowing dates for the highest wheat yield for different wheat genotypes.

## MATERIAL AND METHODS

### Experimental design and crop management

Twelve winter wheat genotypes were grown in field experiments of the Agricultural Institute Osijek (45°32′ N, 18°44′ E), Croatia, during the growing season of 2022/23. An average temperature during the growing season amounted to 10.2°C, and annual precipitation amounted to 539.4 mm (Fig. 1). At this site, the soil is a eutric cambisol with the chemical properties of humus, 2.00–2.20% and pH(KCl) = 6.25. Soybean was a precrop. The seeds were sown by broadcasting at a rate of 330 seeds per $m^2$ on October 22, 2022 (1st sowing date), November 4, 2022 (2nd sowing date), and November 10, 2022 (3rd sowing date), respectively, using the Hege 80 sowing machine, which is conventionally applied on small trial plots. The plots (7.56 $m^2$) were arranged in a completely random design with two replicates. Standard agrotechnical measures were applied without fungicide use.

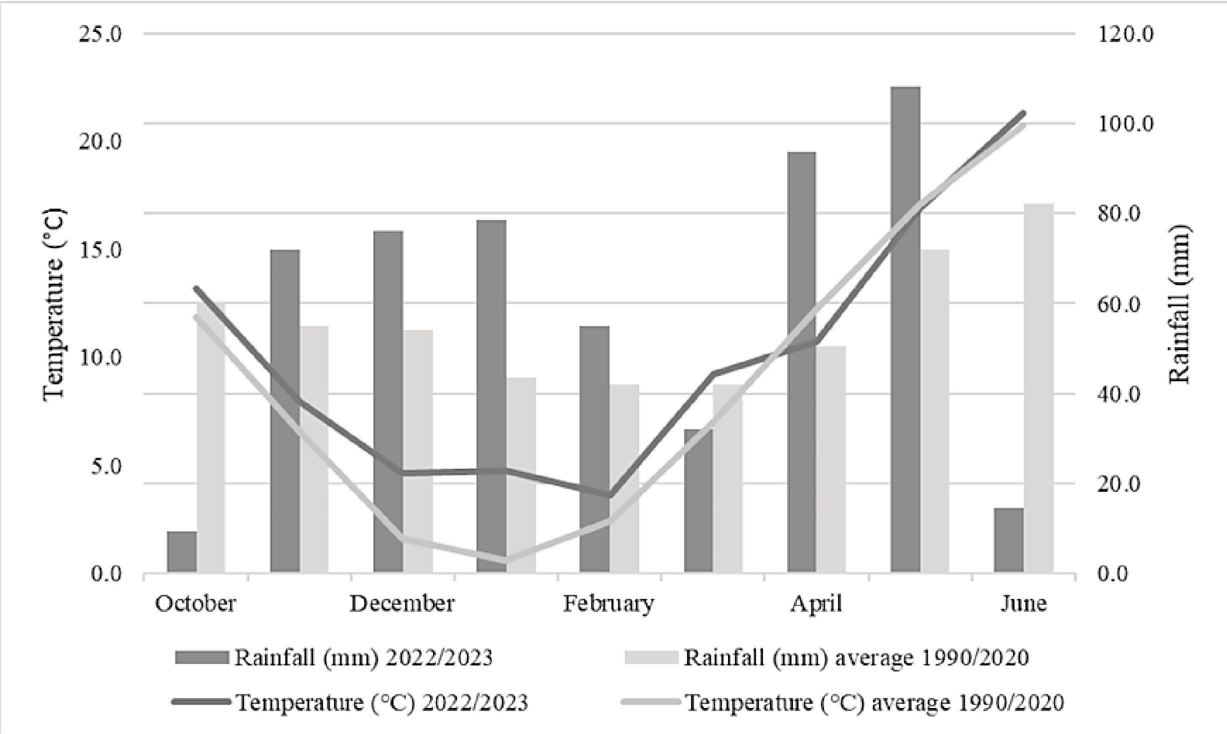


**Figure 1. The amount of rainfall (mm) and average monthly temperatures (°C) during the growing season (October–June for the period 1990–2020 and for the growing season 2022–23 on the Osijek location.**

*Grafikon 1. Količine oborina (mm) i srednje mjesečne temperature zraka* (°C) *tijekom vegetacijske sezone (listopad – lipanj) u razdoblju 1990. – 2020. te za vegetacijsku sezonu 2022./23. za područje Osijeka.*

### Agronomical, morphological, and technological quality traits

A mature grain was harvested from the whole plot by a plot combine (Wintersteiger) at the beginning of July. The grains were collected and weighed. The *GAC 2100* (DICKEY-john) analyzer was used to measure the test weight (kg $hl^{-1}$), and MARVIN grain analyzer calculated the 1000 kernel weight (g). The heading date of each genotype was recorded when more than 50% of wheat plants at field plots had full head emergence. Plant height (cm) was measured at maturity by measuring a rod from the base of the plant to the tip of a spike. All technological quality traits (i.e., protein content, starch content, wet gluten content, and sedimentation value) were measured by grain analysis device (*Infratec™ 1241 Foss Tecator*), based on a near infrared reflectance.

**Statistical analysis**

Data preparation was performed with *Microsoft Excel 2010*. The means were tested based on Fisher's Least Significant Difference (LSD) test ($\alpha = 0.05$) using the *Statistica* software, version 12.0 (Statsoft Inc., Tulsa, USA). The same software was used for principal component analysis (PCA). The agromorphological traits were expressed as an average value of two replications ± standard deviation. Relative differences (%) were determined for the second and for the third sowing dates relative to the first sowing date, and the third sowing date relative to the second.

## RESULTS AND DISCUSSION

The duration of winter wheat growing season could be shortened due to global warming (Tian et al., 2014). As a consequence, wheat grain yield is also influenced by climate changes (Asseng et al., 2012). Winter wheat in Croatia is usually sown between October 10 and October 25, a period that was decleared as an optimal sowing time in previous 30 years. Wheat genotypes planted on November 4, 2022, produced significantly higher average grain yield, followed by a grain yield obtained from wheat plants sown on November 10, 2022 (Table 1).

**Agro-morphological traits under influence of three sowing dates**

The significantly lowest grain yield was recorded when sowing on October 13, 2022, on average for all genotypes. In their research, Liu et al. (2021) demonstrated that grain yield declined by 0.97 ± 0.22% with each one-day (i.e., either early or delayed) change in sowing beyond the normal sowing date.

**Table 1. Agromorphological traits in three sowing dates for twelve genotypes, on average.**

*Tablica 1. Agromorfološka svojstva u tri sjetvena roka u prosjeku za dvanaest genotipova.*

| Sowing date / *Datum sjetve* | GY ($dt\ ha^{-1}$) | TW ($kg\ hl^{-1}$) | 1000KW (g) | HD | PH (cm) |
|---|---|---|---|---|---|
| 1st (October 13, 2022) / *(13. listopada 2022.)* | 45.93c | 74.63b | 32.10c | 5.75c | 90.75a |
| 2nd (November 4, 2022) / *(4. studenoga 2022.)* | 112.23a | 79.67a | 41.43a | 7.50b | 89.92a |
| 3rd (November 10, 2022) / *(10. studenoga 2022.)* | 73.88b | 78.81a | 39.81b | 8.75a | 89.92a |

*Different letters mean significant difference, GY - grain yield / *urod zrna*, TW - test weight / *hektolitarska masa*, 1000KW-1000 kernel weight / *masa 1000 zrna*, HD - heading date (the value was presented as a date in May) / *datum klasanja (vrijednost je uzeta kao datum u svibnju)*, PH - plant height / *visina biljke*

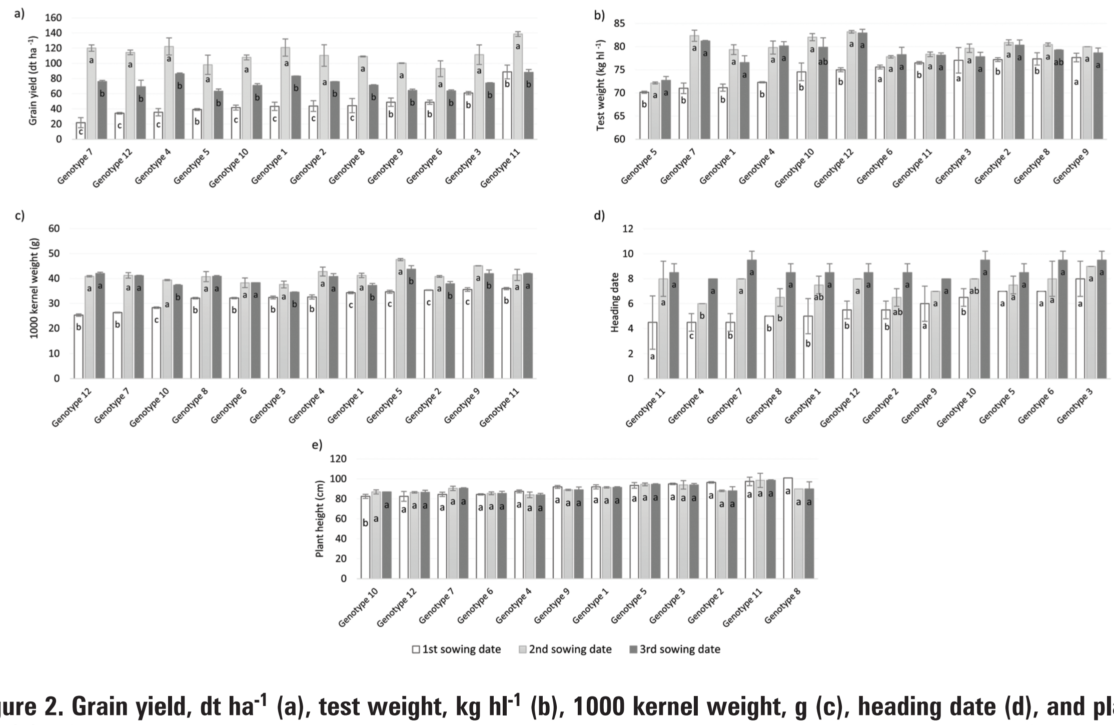


**Figure 2. Grain yield, dt ha$^{-1}$ (a), test weight, kg hl$^{-1}$ (b), 1000 kernel weight, g (c), heading date (d), and plant height, cm (e), of twelve wheat genotypes on three sowing dates. The bars represent the mean values of two replicates ± SD. The different letters indicate significant difference between the sowing dates in each genotype separately ($p < 0.05$). The genotypes are ordered ascendently according to values on the first sowing date.**

*Grafikon 2. Urod zrna, dt ha$^{-1}$ (a), hektolitarska masa, kg hl$^{-1}$ (b), masa 1000 zrna, g (c), datum klasanja (d) i visina biljke, cm (e), dvanaest genotipova pšenice u tri sjetvena roka. Stupci predstavljaju srednje vrijednosti dvaju ponavljanja ± SD. Različita slova označuju značajnu razliku u rokovima sjetve kod svakoga od genotipa zasebno (p < 0,05). Genotipovi su uzlazno poredani prema vrijednostima u prvome sjetvenom roku.*

Qasim et al. (2008) concluded that the crop planted on optimal sowing date produced a higher grain yield, if compared to the late and early planting. Furthermore, it was reported previously that the plant height, 1000 kernel weight, grain, and biological yield were at a maximum value in those plots which were sown on an optimal sowing date if compared to the other sowing dates (Shahzad et al., 2002). For example, planting on the onset of November resulted in the highest grain yield, stalk yield, and harvest index (Yassin and Kittani, 2009). In the current research, grain yield and test weight were the highest on the second sowing date concerning all genotypes (Figs. 2a and b). Oweis et al. (2000) reported that a delay in sowing stage has been proven to exert a negative impact on water use efficiency in west Asia and North Africa under rainfed conditions. For example, there is a tendency for very early (i.e., mid-summer) sowings of winter canola in Western Europe to escape pest damage during the fall (Nelson et al., 2022), which was opposite to our research in 2022–23, where the plants were under an aphid attack in the fall, as a vector of barley yellow dwarf virus on an early sowing date. All genotypes except the G3 one had a significantly lower 1000 kernel weight on the first sowing date when compared to the second and and to the third sowing date (Fig. 2c). Genotype 3 had a 1000 kernel weight at the same significant level for the first and third sowing date. Thus, a delayed sowing on November 10, 2022, resulted in a lower 1000 kernel weight and was mainly the result of a reduction in the growth period and shriveling of grain due to a high temperature that prevailed during the milk and grain filling stage. On an optimal sowing date, wheat plants had longer crop duration and could therefore accumulate more biomass if compared to the late sowing, having thus resulted in a higher grain yield (Gupta et al., 2017). Also, on the third sowing date on November 10, 2022, that is, during the reproductive establishment, the plants were exposed to the higher temperatures that could have forced maturity. Moreover, the heading date was significantly different between the three sowing dates, whereas the genotypes on the first sowing date were, on average, two and three days earlier if compared to the second and to the third sowing date (Table 1, Fig. 2d). According to Qiao et al. (2023), by the end of the 21st century, the predicted optimal sowing dates in almost all areas will be delayed to some extent, by around 20 days. This is in line with the current research, where a sowing date occurring 22 days later with regard to the optimal one has produced a significantly increased grain yield in the growing season researched. In the current research, there were no significant differences, on average, for a plant height of twelve genotypes between the three sowing dates (Fig. 2e). In a research by Alam et al. (2013), wheat genotypes did not show significant difference concerning the plant height and the days to maturity between the two different sowing dates.

**The influence of sowing dates on the technological quality traits**

In the context of end-use products, achieving the highest possible grain and flour quality is one of the goals of wheat production. According to Motzo et al. (2007), the environmental conditions prior or subsequent to the grain filling greatly affect the wheat quality and can be modified by manipulation of a sowing date and varietal selection. Due to the significant average differences for all genotypes, it was observed that the third sowing date had an increased protein content, wet gluten content, and sedimentation value, followed by the first sowing date. The lowest content of technological quality traits was observed on the second sowing date (Table 2). This was expected, as the protein content and grain yield are in a negative correlation (Geyer et al., 2022). These differences between the quality parameters on different sowing dates were small and thus the influence of sowing dates on the technological quality traits does not exert such a major impact as the grain yield. Due to a low number of replications, it was not possible to significantly distinguish the values of technological quality within one genotype (Figs. 3a, b, c, and d). Similar to our results, the research by Yadava and Singh (2003) reported that the protein content was increased with a delayed sowing. Also, Kaur et al. (2010) reported that the protein content of wheat grain was higher in the late sowing than on the occasion of timely sowing. However, there were the opposite results obtained in a research conducted by Mikos-Szymańska and Podolska (2015), who revealed that neither a sowing date nor a seeding rate affected wet gluten, gluten index, or the sedimentation value. On average, the starch content of all genotypes has not been significantly affected by sowing dates (Fig. 3b). As the formation of starch occurs mainly during the wheat's grain filling stage, we believe that there was no problem with temperatures, and starch was developed to the same extent on each sowing date in that stage. In an opposition to our research results, Pan et al. (2005) reported that the sowing date had a highly significant effect on the grain yield and starch content on four experimental sites.

**Table 2. Technological quality traits in three sowing dates for twelve genotypes, on average.**
*Tablica 2. Svojstva tehnološke kvalitete u tri sjetvena roka u prosjeku za dvanaest genotipova.*

| Sowing date / *Datum sjetve* | PC (%) | SC (%) | WGC (%) | SV |
|---|---|---|---|---|
| 1st (October 13, 2022) / *(13. listopada 2022)* | 13.27b | 66.67a | 32.25b | 45.58b |
| 2nd (November 4, 2022) / *(4. studenoga 2022.)* | 13.10c | 65.88a | 31.83c | 44.46c |
| 3rd (November 10, 2022) / *(10. studenoga 2022.)* | 13.49a | 66.18a | 32.84a | 46.95a |

*Different letters mean significant difference, PC - protein content / *sadržaj proteina*, SC - starch content / *sadržaj* škroba, WGC - wet gluten content / *sadržaj vlažnoga ljepka*, SV – sedimentation value / *sedimentacijska vrijednost.*

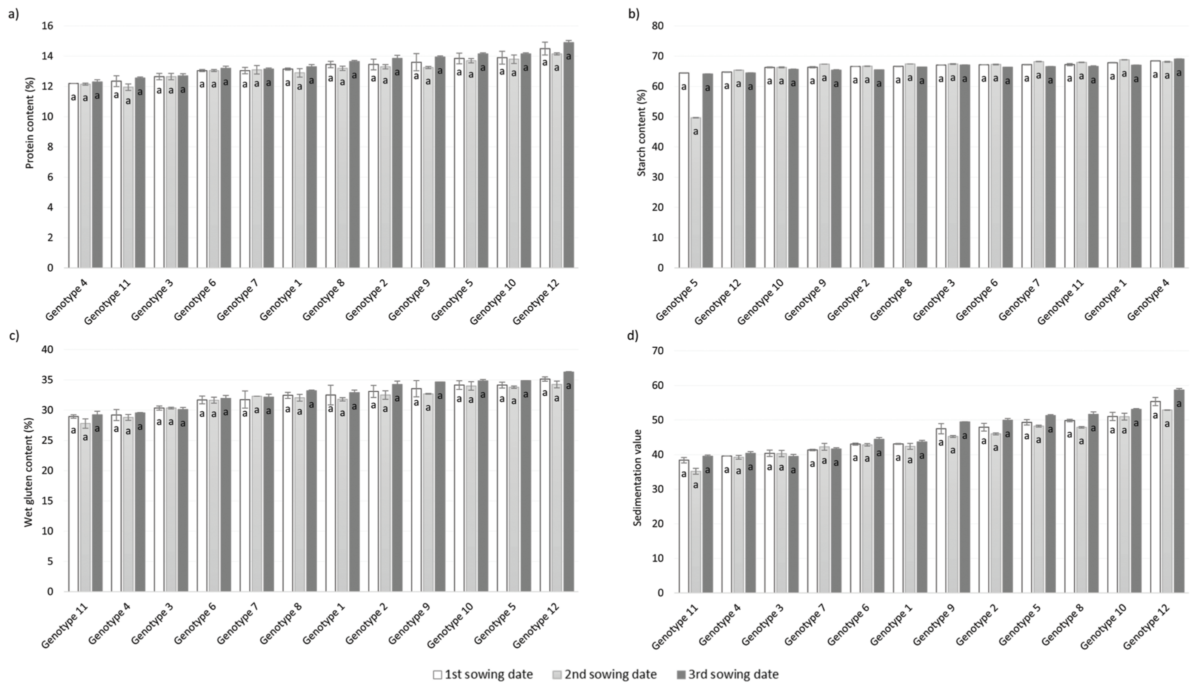


**Figure 3. Protein content, % (a), starch content, % (b), wet gluten content, % (c), and sedimentation value (d) of twelve wheat genotypes on the three sowing dates. The bars represent the mean values of two replicates ± SD. The different letters indicate a significant difference between the sowing dates in each genotype separately ($p < 0.05$). The genotypes are ordered ascendently, according to the values on the first sowing date.**

*Grafikon 3. Sadržaj proteina, % (a), sadržaj škroba, % (b), sadržaj vlažnoga ljepka, % (c) i sedimentacijske vrijednosti (d) dvanaest genotipova pšenice u tri sjetvena roka. Stupci predstavljaju srednje vrijednosti dvaju ponavljanja ± SD. Različita slova označuju značajnu razliku u rokovima sjetve kod svakoga od genotipu zasebno (p < 0,05). Genotipovi su uzlazno poredani prema vrijednostima u prvome sjetvenom roku.*

## A relation between the researched traits on three sowing dates

According to the obtained results concerning the PCA, grain yield, test weight, 1000 kernel weight and heading date were in a strong positive correlation with the sowing date, and it was therefore expected that the sowing date would have the highest influence on those traits (Fig. 4). In a previous research conducted by Spanic et al. (2021), the traits that contributed positively to the PCA2 were the sedimentation value, protein content, and wet gluten content, thus reflecting a quality potential. This is in line with the current research, in which those three traits showed a highly positive correlation with the PCA. However, the relative differences of technological quality traits were very small between the sowing dates if compared to the grain yield and 1000 kernel weight (Table 3). It is assumed that the protein content and related quality traits were not influenced by the sowing dates to a high extent, as those traits were formed in the early stage of grain development.

The highest relative differences were observed in relation to the grain yield and 1000 kernel weight, where it could be seen that those traits were increased on the second and on the third sowing date in relation to the first sowing date. The sowing on November 4, 2022, significantly influenced the entire attributing characters (i.e., the grain yield, test weight, 1000 kernel weight, and heading date), so the average for twelve genotypes was significantly superior than the traits measured during the early sowing occurring on October 13, 2022, and during a delayed sowing on November 10, 2022 (except the test weight). According to Alam et al. (2013), a delayed sowing decreased the number of grains per spike, the number of spikes per square meter, and the 1000 kernel weight. Relative differences concerning the test weight between the sowing dates were lower than those concerning the grain yield and the 1000 kernel weight.

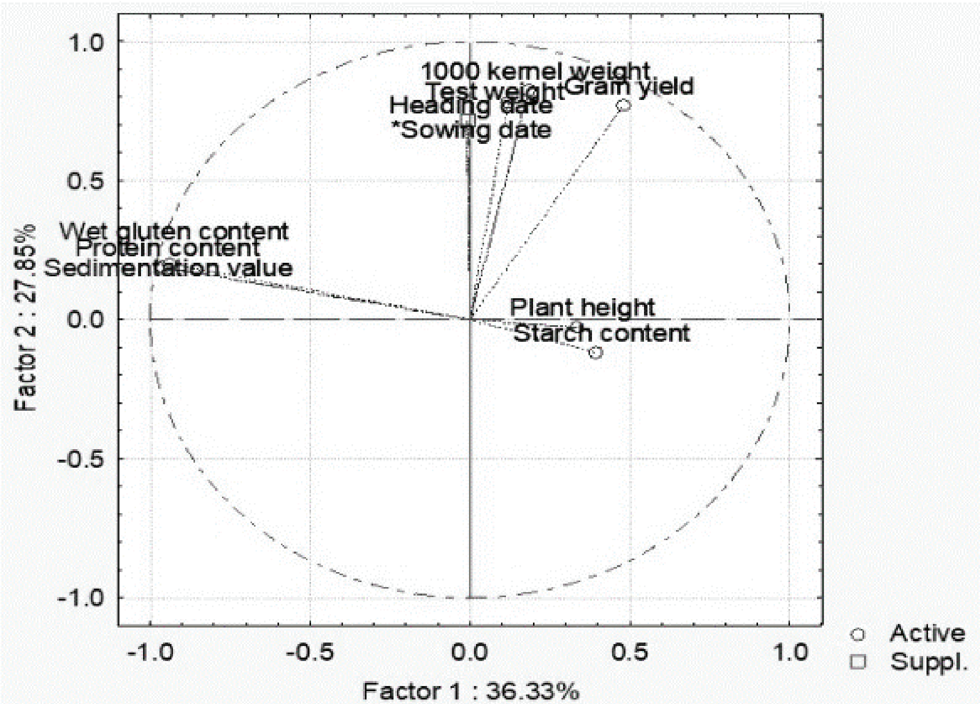


**Figure 4. Principal component analysis (PCA) showing a relationship between the agronomical, morphological, and technological quality traits and the sowing date.**

*Grafikon 4. Analiza glavnih komponenata koja pokazuje odnos između agronomskih I morfoloških svojstava, svojstava tehnološke kvalitete i sjetvenoga roka.*

**Table 3. Relative differences in % of researched traits on the second and on the third sowing dates in relation to the first sowing date and on the third sowing date in the relation to the second sowing date.**

*Tablica 3. Relativne razlike istraživanih svojstava u % u drugom i trećem sjetvenom roku u odnosu na prvi te u trećem sjetvenom roku u odnosu na drugi.*

| | Relative differences in % in relation to first sowing date / *Relativne razlike u % u odnosu na prvi sjetveni rok* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | GY | TW | 1000KW | HD | PH | PC | SC | WGC | SV |
| 2nd SD* | 59.1 | 6.30 | 22.50 | 23.30 | -0.9 | -1.2 | -1.2 | -2.1 | -2.5 |
| 3rd SD | 37.8 | 5.30 | 19.40 | 34.30 | -0.9 | 1.70 | -0.7 | 1.00 | 2.90 |
| | Relative differences in % in relation to the third sowing date / *Relativne razlike u % u odnosu na treći sjetveni rok* | | | | | | | | |
| 2nd SD | 34.2 | 1.10 | 3.90 | -16.70 | 0.00 | -3.00 | -0,50 | -3.20 | -5.60 |

*SD–- sowing date / *datum sjetve*, GY–- grain yield / *urod zrna*, TW–- test weight / *hektolitarska masa*, 1000KW-1,000-kernel weight / *masa 1000 zrna*, HD - heading date / *datum klasanja*, PH - plant height / *visina biljke*, PC - protein content / *sadržaj proteina*, SC - starch content / *sadržaj* škroba, WGC-wet gluten content / *sadržaj vlažnog ljepka*, SV-sedimentation value / *sedimentacijska vrijednost*

## CONCLUSION

On average, the grain yield attributes (i.e., the grain yield and 1000 kernel weight) concerning twelve genotypes were significantly affected by three sowing dates. Less pronounced relative changes were obtained concerning the test weight and technological quality parameters. On the first sowing date, pathogen dispersion occurred as a consequence of the vulnerable plant hosts being weakened by a virus in the fall. A delayed third sowing date decreased both the grain yield and the 1000 kernel weight if compared to the second sowing date. A disproportion between the second and third sowing date was mostly reflected in the grain yield and might be due to a premature maturity on the third sowing date. Thus, further studies on the sowing dates within a smaller interval, such as that amounting to five days in a few years, are necessary to obtain an optimal sowing date.

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## REFERENCES

1. Alam, M.P., Kumar, S., Ali, N., Manjhi, R.P., Kumari, N., Lakra, R.K., & Izhar, T. (2013). Performance of wheat varieties under different sowing dates in Jharkhand. *Journal of wheat research*, *5*(2), 61–64. https://epubs.icar.org.in/index.php/JWR/article/view/36764
2. Asseng, S., Ewert, F., Martre, P., Rotter, R.P., Lobell, D.B., Cammarano, D,... & Zhu, Y. (2015). Rising temperatures reduce global wheat production. *Nature Climate Change*, *5*(2), 143–147. https://doi.org/10.1038/nclimate2470
3. Field, C., Barros, V., Stocker, T., & Dahe, Q. (2012). Managing the risks of extreme events and disasters to advance climate change adaptation: Special report of the intergovernmental panel on climate change; Cambridge University Press: Cambridge, UK.
4. Gao, F. C., Yan, H. D., Gao, Y., Huang, Y., Li, M., Song, G. L., ... & Li, G. Y. (2022). Interpretation of genotype-environment-sowing date/plant density interaction in sorghum [*Sorghum bicolor* (L.) Moench] in early mature regions of China. *Frontiers in Plant Science*, *13*, 1008198. https://doi.org/10.3389/fpls.2022.1008198
5. Garg, D., Sareen, S., Dalal, S., Tiwari, R., & Singh, R. (2013). Grain filling duration and temperature pattern influence on the performance of wheat genotypes under late planting. *Cereal Research Communications, 41*(3), 500–507. https://doi.org/10.1556/CRC.2013.0019
6. Geyer, M., Mohler, V., & Hartl L. (2022). Genetics of the inverse relationship between grain yield and grain protein content in common wheat. *Plants (Basel), 18, 11*(16), 2146. https://doi.org/10.3390/plants11162146.
7. Gupta, S., Singh, R.K., Sinha, N.K., Singh, A., & Shahi, U.P. (2017). Effect of different sowing dates on growth and yield attributes of wheat in Udham Singh Nagar district of Uttarakhand, India. *Plant Archives, 17*(1), 232–236.
8. Kaur, A., Pannu, R.K., & Buttar, G.S. (2010). Quality of wheat (*Triticum aestivum* L.) as influenced by sowing dates and nitrogen scheduling. *Indian Journal of Agriculture Science, 80*(9), 781–785. Retrieved June 5, 2023 from: https://epubs.icar.org.in/index.php/IJAgS/article/view/913
9. Kirby J.M., Mainuddin M., Mpelasoka F., Ahmad M.D., Palash W., Quadir M.E., Shah-Newaz S.M., & Hossain M.M. (2016). The impact of climate change on regional water balances in Bangladesh. *Climate Change, 135*, 481–491. https://doi.org/10.1007/s10584-016-1597-1
10. Liu, K., Zhang, C., Guan, B., Yang, R., Liu, K., Wang, Z., … & Wang, X. (2021). The effect of different sowing dates on dry matter and nitrogen dynamics for winter wheat: an experimental simulation study. *PeerJ, 9*, e11700. https://doi.org/10.7717/peerj.11700
11. Mikos-Szymańska, M., & Podolska, G. (2015). The effects of sowing date and seeding rate on spelt and common wheat protein composition and characteristics. *Quality Assurance and Safety of Crops & Foods, 8*(2), 289–300. https://doi.org/10.3920/QAS2014.0574
12. Motzo, R., Fois, S., & Giunta, F. (2007). Protein content and gluten quality of durum wheat (*Triticum turgidum* subsp. *durum*) as affected by sowing date. *Journal of the Science of Food and Agriculture, 87*(8), 1480–1488.
13. Oweis, T., Zhang, H.P., & Pala, M. (2000). Water use efficiency of rainfed and irrigated bread wheat in a Mediterranean environment. *Agronomy Journal, 92*(2), 231–238.
14. Pan, J., Jiang, D., Dai, T.-B., Lan, T., & Cao, W.-X. (2005). Variation in wheat grain quality grown under different climatic conditions with different sowing dates. *Chinese Journal of Plant Ecology, 29*(3), 467–473. https://doi.org/10.17521/cjpe.2005.0062
15. Qasim, M., M. Qamer, Faridullah, & Alam, M. (2008). Sowing dates effect on yield and yield components of different wheat varieties. *Journal of Agricultural Research, 46*(2), 135–140.
16. Qiao, S., Harrison, S.P., Prentice, I.C., & Wang, H. (2023). Optimality-based modelling of wheat sowing dates globally. *Agricultural Systems, 206*, 103608. https://doi.org/10.1016/j.agsy.2023.103608
17. Shahzad, K., Bakht, J., Shah, W.A., Shafi, M., & Jabeen, N. (2002). Yield and yield components of various wheat cultivars as affected by different sowing dates. *Asian Journal of Plant Sciences, 1*, 522–525. https://doi.org/10.3923/ajps.2002.522.525
18. Skendžić, S., Zovko, M., Živković, I.P., Lešić, V., & Lemić, D. (2021). The impact of climate change on agricultural insect pests. *Insects, 12*(5), 440. https://doi.org/10.3390/insects12050440
19. Spanic, V., Cosic, J., Zdunic, Z., & Drezner, G. (2021). Characterization of agronomical and quality traits of winter wheat (*Triticum aestivum* L.) for Fusarium head blight pressure in different environments. *Agronomy, 11*(2), 213. https://doi.org/10.3390/agronomy11020213
20. 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.
21. Tian, Y.L., Zheng, C.Y., Chen, J., Chen, C.Q., Deng, A.X., Song, Z.W., Zhang, B.M., & Zhang, W.J. (2014). Climatic warming increases winter wheat yield but reduces grain nitrogen concentration in East China. *PLoS ONE, 9*, e95108. https://doi.org/10.1371/journal.pone.0095108
22. Velasquez, A. C., Castroverde, C. D. M., & He, S. Y. (2018). Plant–pathogen warfare under changing climate conditions. *Current Biology, 28*(10), R619–R634. https://doi.org/1016/j.cub.2018.03.054

23. Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D.B., Huang, Y.,….& Asseng, S. (2017). Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences of the United States of America, 114*(35), 9326–9331. https://doi.org/10.1073/pnas.1701762114

24. Zhou, X.L., Harrington, R., Woiwod, I.P., Perry, J.N., Bale, J.S., & Clark, S. J. (1995). Effects of temperature on aphid phenology. *Global Change Biology, 1*(4), 303–313. https://doi.org/10.1111/j.1365-2486.1995.tb00029.x

25. Yadava, R., & Singh, T.B. (2003). Stability analysis in wheat for grain protein. *Indian Journal of Genetics and Plant Breeding, 63*(4), 337–338.

26. Yassin, M. I. &. Kittani, H.F. (2009). A multivariate analysis of the effects of planting dates on productivity of some wheat genotypes. *Journal of Science Education and Technology, 10*(2), 46–59.

27. Xiao, D.P., & Tao, F.L. (2014). Contributions of cultivars, management and climate change to winter wheat yield in the North China Plain in the past three decades. *European Journal of Agronomy 52*, 112–122. https://doi.org/10.1016/j.eja.2013.09.020

28. Wang, C.J., Wang, R., Yu, C.M., Dang, X.P., Sun, W.G., Li, Q.F., Wang, X.T., & Wan, J.Z. (2021). Risk assessment of insect pest expansion in alpine ecosystems under climate change. *Pest Management Science 77*(7), 3165–3178. https://doi.org/10.1002/ps.6354

29. WorldData. Retrived May 15, 2023, from: https://www.worlddata.info/europe/croatia/climate.php

# UTJECAJ RAZLIČITIH ROKOVA SJETVE NA OZIMU PŠENICU

## SAŽETAK

***Provedena su tri odvojena poljska pokusa s različitim rokovima sjetve kako bi se odredio pogodan rok sjetve za agromorfološka svojstva i parametre tehnološke kvalitete. Rezultati su u vegetacijskoj sezoni 2022./23. pokazali sljedeće: (1) s odmakom roka sjetve (drugi rok sjetve 4. studenoga 2022.) u odnosu na prvi rok sjetve (13. listopada 2022.), urod zrna bio je značajno povećan, dok je u trećem roku sjetve (14. studenoga 2022.) u odnosu na prvi značajno povećan urod zrna kod osam od dvanaest genotipova. Razlog nesrazmjera uroda zrna u prvim dvama rokovima sjetve bio je jesenski napad virusa patuljastoga žutila ječma, koji je ozbiljno oštetio razvijenije biljke iz prvoga roka sjetve, nakon čega su bile sklonije i drugim bolestima pšenice. Relativne razlike za drugi rok sjetve u odnosu na prvi bile su sljedeće : povećanje za 59,1 % za urod zrna, 6,3 % za hektolitarsku masu, 22,5 % za masu 1000 zrna, smanjenje za 23,3 % za datum klasanja, 1,2 % za sadržaj proteina, 2,1 % za sadržaj vlažnoga glutena i 2,5 % za sedimentacijsku vrijednost. Razlika u urodu zrna između drugoga i trećeg roka sjetve iznosila je 34,2 % zbog uranjene senescence biljaka u kasnijoj sjetvi, kao posljedice povišenih temperatura u lipnju.***

***Ključne riječi: genotipovi, urod zrna, kvaliteta, rokovi sjetve, pšenica***

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