11th INTERNATIONAL SCIENTIFIC CONFERENCE RURAL DEVELOPMENT 2023
BIOECONOMY FOR THE GREEN DEAL
26-28th September, 2023, Vytautas Magnus University Agriculture Academy, Lithuania

VYTAUTAS MAGNUS UNIVERSITY AGRICULTURE ACADEMY

Proceedings of the 11th International Scientific Conference Rural Development 2023

Edited by assoc. prof. dr. Judita Černiauskienė

ISSN 1822-3230 (Print)
ISSN 2345-0916 (Online)

Article DOI: https://doi.org/10.15544/RD.2023.009

THE INFLUENCE OF SOWING DATE AND SEED RATE ON WINTER WHEAT *(TRITICUM AESTIVUM* L.) PRODUCTIVITY

Ilona VAGUSEVIČIENĖ, Department of Agroecosystems and soil science, Faculty of Agronomy, Vytautas Magnus University, address: K. Donelaičio str. 58, LT-44248 Kaunas, Lithuania, ilona.vaguseviciene@vdu.lt (*corresponding author*)
Darija Jodaugienė, Department of Agroecosystems and soil science, Faculty of Agronomy, Vytautas Magnus University, address: K. Donelaičio str. 58, LT-44248 Kaunas, Lithuania, darija.jodaugiene@vdu.lt
Rita ČEPULIENĖ, Department of Agroecosystems and soil science, Faculty of Agronomy, Vytautas Magnus University, address: K. Donelaičio str. 58, LT-44248 Kaunas, Lithuania, rita.cepuliene@vdu.lt
Edita MAŽUOLYTĖ-MIŠKINĖ, Department of Agroecosystems and soil science, Faculty of Agronomy, Vytautas Magnus University, address: K. Donelaičio str. 58, LT-44248 Kaunas, Lithuania, edita.mazuolyte-miskine@vdu.lt

The experiment, in which winter wheat was sown at different dates (7, 14, 21, 28 September, and 5 October) and at different seed rates (5, 4, 3, and 2 million seeds ha^{-1}), was carried out at the Experimental Station of Vytautas Magnus University Agriculture Academy, between 2021 and 2022. The soil of the experimental field was Cal(ca)ri-Epihypogleyic Luvisol. Before the experiment was installed, the topsoil had a neutral reaction (pH-7.0), medium humus content (2.15%), high phosphorus content (226 mg kg^{-1}), and medium potassium content (143 mg kg^{-1}). The results obtained showed that grain yields ranged from 6.5 to 8.1 t ha^{-1}, the 1000-grain weight ranged from 37 to 46 g, the number of grains per ear ranged from 50 to 82, and the percentage of protein and wet gluten in the grains was 12.6–14.6% and 24.3–29.0%, respectively.

Keywords: *winter wheat, yield, yield structure elements, grain quality.*

INTRODUCTION

Wheat has a very great importance in the world. It is one of the most important crops grown in the agricultural sector and, according to Tadesse (2019), accounts for around 19% of human calorie intake worldwide, of which 21% is protein. Farmers choosing to grow wheat face various challenges that directly or indirectly affect the yield of the crop. The optimum sowing date ensures the sum of favorable temperatures for maximum yields. During the autumn growing season, the plants have time to emerge and form enough side stems. However, late sowing does not allow winter wheat to emerge, resulting in lower crop density (Muhammad et al., 2015). Early sowing of wheat increases the risk of overdevelopment, as higher density and development lead to higher autumn pest incidence and disease infestation, as well as leads to a higher incidence of weeds in the crop. However, higher densities increase yields (Wajid et al., 2004). Crop sowing at appropriate dates provides favorable conditions for wheat growth and development (El-Gizawy, 2009). Each week of wheat sowing delay reduces the crop's vegetative length and reproductive stages and causes yield reduction (Akmal et al., 2004). Malik et al. (2009) reported that a high seed rate compensates for the reduction in germination count and tillers. Intra- and interplant competition for light, water, and nutrients were influenced by the seed rates.

Seed rates strongly influence the inter- and intraplant competition for nutrients, space, light, and water. Lower seed rates reduce the interplant competition during vegetative growth but intraplant competition could be increased at the grain formation stage due to a higher number of tillers (Ozturk et al., 2006).

Optimum grain quality is limited by various factors such as insufficient or excessive moisture, poor overwintering, damage from diseases or pests, inadequate sowing timing or rate, and fertilization. The occurrence of these factors at certain critical stages of plant development can cause significant damage to yield and grain quality (Bahar et al., 2011). Ma et al. (2018) found that the sowing date and seed rate had a significant effect on the morphological and physiological characteristics of winter wheat. To produce winter wheat with optimum productivity and better prepared for overwintering, plants need to form 2–4 side shoots. Winter wheat sowing should start 35–45 days before the end of the autumn growing season.

In a 3-year study, Klepeckas et al. (2020) found that the optimum sowing date for winter wheat in Lithuania was 8–15 September, but a warming climate may adjust these dates. Up to 25% of the crop is sown later than 25 September. If the wheat sown in late September or early October has managed to form three leaves and the germination of the side shoots, the plants would have finished tillering in spring. Klepeckas et al. (2020) showed that a delayed sowing date can have a significant impact on the phenology of winter wheat: a one-week delay in sowing can delay flowering and maturity by almost 6 days, reduce the grain's milky ripeness by 1.25 days, and reduce yields by between 6.0 and 7.7%. Delayed sowing significantly reduces winter wheat plant height, number of unproductive stems, leaf area, and root biomass (Fang et al., 2010; Ma et al., 2018; Li et al., 2020).

Due to various factors that reduce productivity, it is important to sow at the optimum date, as this is when the nutrients available to the plants and absorbed by plants are at their highest, and when temperatures are most favorable for germination and the formation of new parts of the plant (Alam et al. 2022).

Timely sowing and the selection of varieties with better genetic characteristics are the main factors that lead to higher productivity (Singh et al. 2021; Alam et al. 2022). Increasing the seed rate leads to a significant increase in plant height, root biomass, the number of unproductive stems, and a reduction in leaf area in winter wheat. Increasing plant density increases competition for resources, especially water (leading to higher water consumption by plants), nutrients, and space, which has a significant impact on final yield (Fang et al., 2010; Ma et al., 2018; Li et al., 2020; Fazily, 2021). Delayed sowing leads to an increase in seed rate due to the risk of poor plant development (Fazily, 2021).

Higher seed rates have a positive effect on wheat grain quality. A higher density of the crop produces more main stems, on which the plants grow and mature larger and heavier grains. Coarse grains have a more favorable protein/starch ratio and a better grain quality. Higher crop density increases the 1000-grain weight (Zecevic et al., 2014). Lower-density crops produce more side stems, which produce smaller, lower-weight, and lower-quality grains. At lower seed rates, smaller grains form on the outgrowing side stems, and coarser grains form on the main stems, which leads to slower maturity and reduced grain uniformity (Geleta et al., 2002; Zecevic et al., 2014). Drought and heat stress reduce starch content but increase grain protein and mineral concentration (Ben et al., 2021). Gaile et al. (2017) concluded that grain quality traits are strongly influenced by the environment and less influenced by seed rate.

The aim of the study was to determine the influence of sowing date and seed rate on the productivity and grain quality of a common wheat crop.

RESEARCH METHODS

Experimental location and conditions. Field experiments were carried out at the Experimental Station of Vytautas Magnus University Agriculture Academy in Lithuania (54° 53' 3.26", 23° 50' 33.25") in 2021–2022. The soil of the experimental field was *Cal(ca)ri-Epihypogleyic Luvisol* (WRB, 2022). Soil tests were performed before the experiment: pH_{KCl} of the topsoil was 7.0, the concentration of available P_2O_5 – 226 mg kg^{-1}, available K_2O – 143 mg kg^{-1}, and the humus content in the soil surface layer was 2.15%.

Experimental design. A two-factor experiment was conducted to investigate the influence of sowing date and seed rate on winter wheat productivity.

Factor A – sowing date (7, 14, 21, 28 September, and 5 October);

Factor B – seed rate (2, 3, 4, and 5 million seeds ha^{-1}).

Winter oilseed rape was used as the precrop. The bruto plot area was 40 (4x10) m^2 and the neto – 20 (2x10) m^2. The winter wheat variety 'Skagen' was cultivated in the experiment.

Background fertilization of winter wheat: ammonium nitrate (N_{51}+N_{68}) was applied in the spring after the regrowth of winter wheat (BBCH 20–26) and at the end of the winter wheat tillering stage (BBCH 27–30). Winter wheat was additionally fertilized through the leaves with urea (N_{10}) during the stem elongation stage (BBCH 31–33). Plant protection measures were applied to prevent suppression of plant growth due to outbreaks of weeds, pests, and diseases.

Experimental and analytical methods. Soil pH_{KCl} was measured by extraction with 1N KCl using the potentiometric method (LST EN ISO 10390:2021), organic carbon (C) – by the Tyurin method (LST EN 13037:2012), available phosphorus (P_2O_5) and potassium (K_2O) were determined according to the Egner-Riehm-Domingo (A-L) method (LST EN ISO 6878:2004; LST EN ISO 9964:3:1998), humus (%) was calculated by multiplying the carbon content by a factor of 1.724. Cereal yield (t ha^{-1}) was calculated using the data of the combine harvester computerized weighing system. By randomly selecting 10 ears of wheat from each plot, the number of grains per ear was determined. The protein content was determined by the Kjeldahl method (LST EN ISO 20483), and wet gluten content by a GLUTOMATIC system (Perten) (according to LST EN ISO 21415-2; LST EN ISO 21415-4).

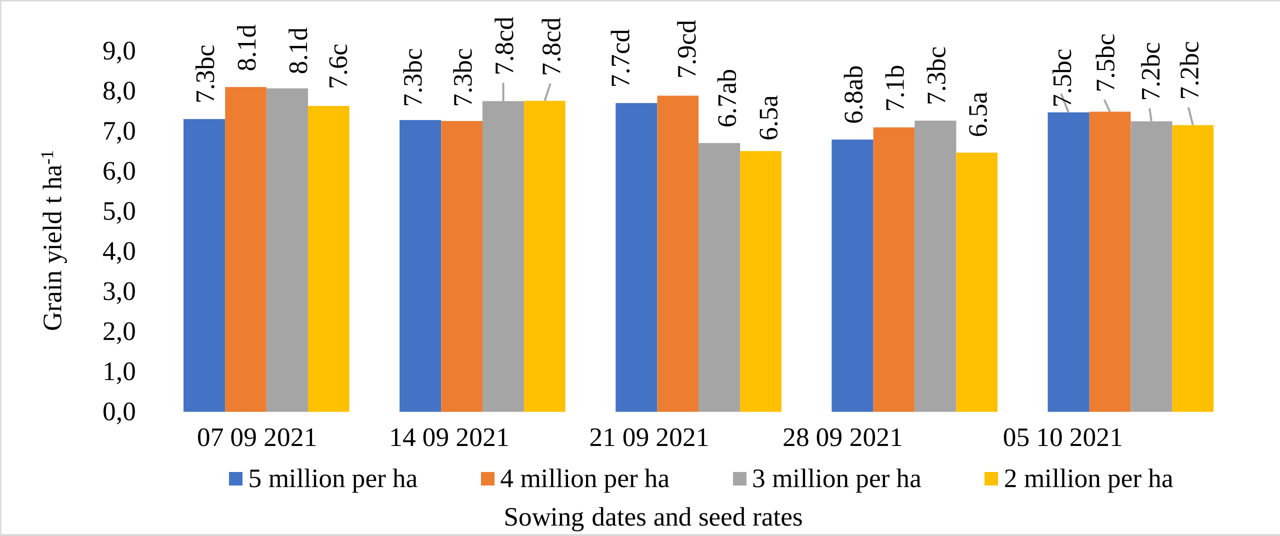
The average 1000-grain weight was determined by counting and weighing two samples of 500 grains and then averaging the values found and multiplying them by two.

Statistical analysis. The statistical reliability of the data was assessed by two-factor analysis of variance (ANOVA), using the software package SELECTION. The statistical reliability of the data was assessed by the lowest absolute limit of a significant difference R_{05} (data reliability: significant differences ($p<0.05$) between the means are indicated by different lowercase letters of the alphabet) (Tarakanovas and Raudonius, 2003).

RESEARCH RESULTS AND DISCUSSION

The sowing date is a fundamental factor in deciding the crop yield. The sowing of crops at an ideal time is essential to achieve higher yield, as the sowing date is temperature-dependent (Shah et al., 2017; Hussain et al., 2021). The experimental data showed that the choice of seed rate, rather than sowing date, had a greater influence on yield (Figure 1). Early sowing (7 September) resulted in significantly higher yields (8.1 t ha^{-1}) in the crops of 4 and 3 million seeds ha^{-1} compared to the crops of 5 and 2 million seeds ha^{-1}. The lowest yield (7.3 t ha^{-1}) was found in the densest crop (5 million seeds ha^{-1}). On 14 September, the highest density crop (5 and 4 million seeds ha^{-1}) had a significantly lower yield of 7.3

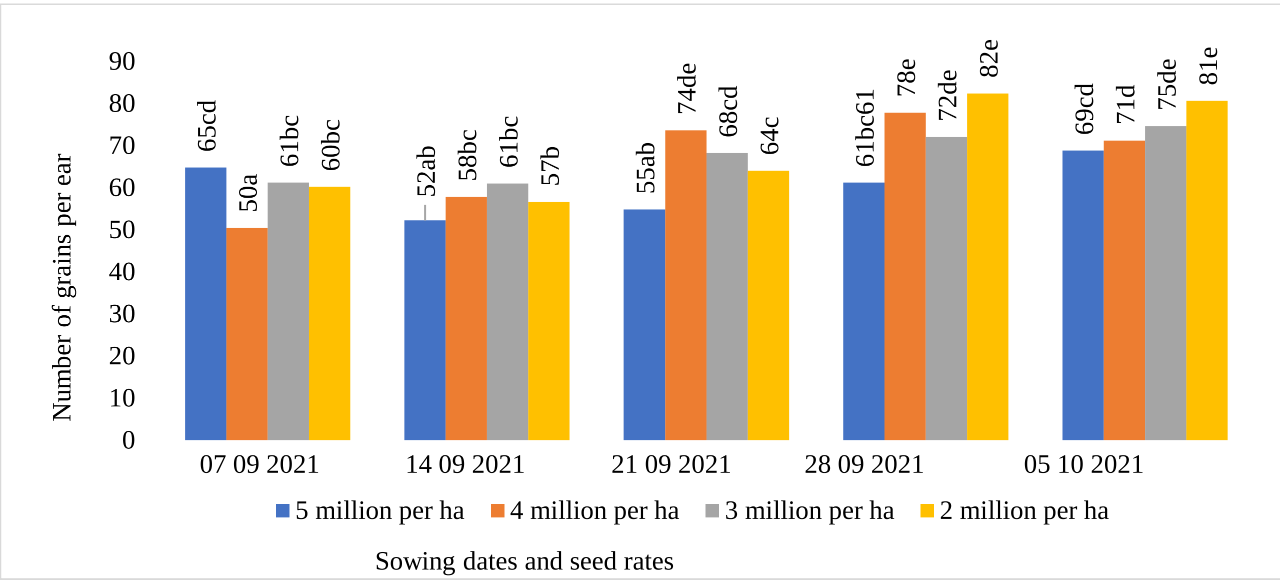
t ha^{-1} compared to the yield (7.8 t ha^{-1}) found in the crops of 3 and 2 million seeds ha^{-1}. For the crop sown on 21 September, the wheat crops sown at rates of 4 and 5 million seeds ha^{-1} had the highest yields (7.9 and 7.7 t ha^{-1}), compared to the less dense crops (3 and 2 million seeds ha^{-1}), which had yields of between 6.5 and 6.7 t ha^{-1}. After sowing on 28 September, the lowest yield of 6.5 t ha^{-1} was found in the crop with a rate of 2 million seeds ha^{-1}, compared to the highest yields (7.1 and 7.3 t ha^{-1}) found in the wheat crops with a rate of 4 and 3 million seeds ha^{-1}. The yield of wheat that was sown late (5 October) did not differ significantly, ranging from 7.5 to 7.2 t ha^{-1}.



Note. The differences between the means of the variants in the columns marked with different letters (a, b, c…) are significant (P≤0.05).

Figure 1. The influence of sowing dates and seed rates on the yield of winter wheat

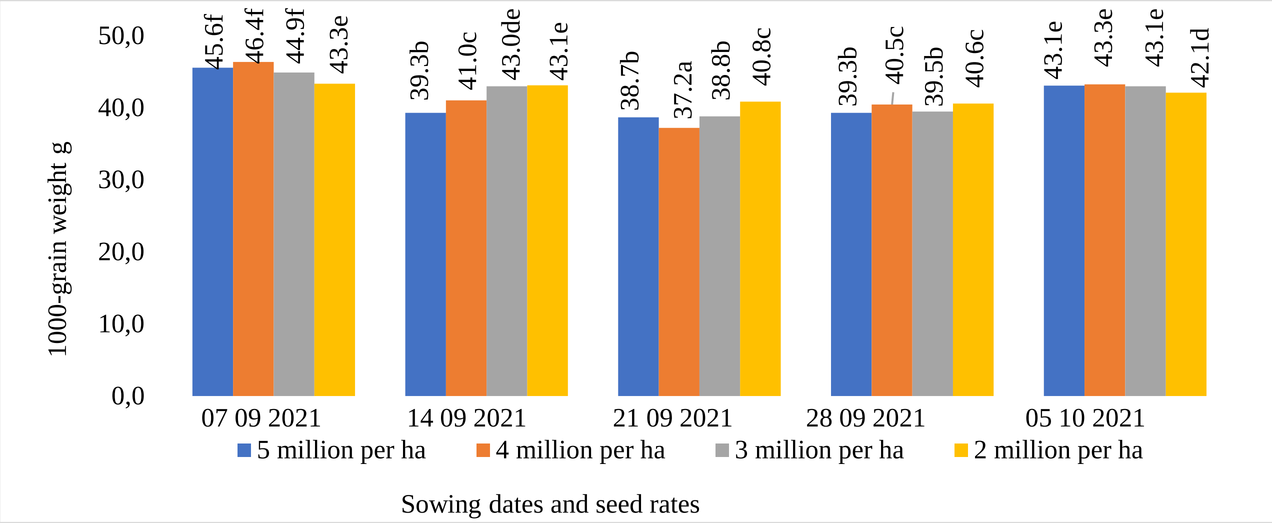
Sowing a higher seed rate produces more productive stems in the crop, but lower 1000-grain weight and the number of grains per ear (Spink et al., 2000). The number of grains per ear is an important parameter that influences the final yield and quality. The number of grains per ear in winter wheat varied from 50 to 82 grains per ear, according to the results of the study (Figure 2). In the early sowing (7 September), the significantly highest number of grains per ear (from 65 to 60 units) was found in the crops with the rate of 5, 3, and 2 million seeds ha^{-1}, compared to the number of wheat grains (50 units) in the crop of 4 million seeds ha^{-1}. The number of wheat grains per ear sown on 14 September was not significantly different. On 21 September, the significantly highest number of grains per ear (74 and 68) was found in the wheat crops sown at 4 and 3 million seeds ha^{-1} compared to the 5 million seeds ha^{-1} crop, where the number of grains per ear was 55. After sowing on 28 September, the lowest number of grains per ear was 61 in the 5 million seeds ha^{-1} crop, compared to the number of grains per ear (between 72 and 82) in the lower seed rate crop. In the late sown crop, the number of grains per ear increased as the seed rate was reduced.



Note. The differences between the means of the variants in the columns marked with different letters (a, b, c…) are significant (P≤0.05).

Figure 2. The influence of sowing dates and seed rates on the number of grains per ear of winter wheat

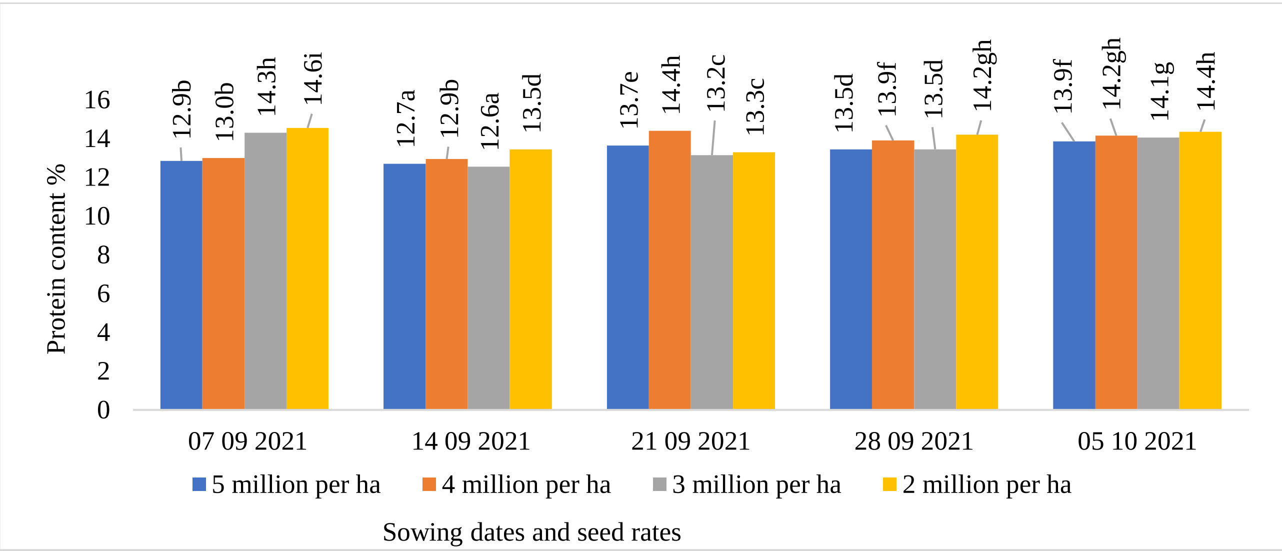
Some studies have shown that higher seed rates result in a lower 1000-grain weight (Spink et al., 2000; Laghari et al., 2011). The study data did not support the claim that the 1000-grain weight is reduced by very late or late sowing dates (Khan, 2000; Akhtar et al., 2006). The highest 1000-grain weight was in the early and late-sown crops (Figure 3). Significantly higher 1000-grain weight was found in the early sown (7 September) crops with 5, 4, and 3 million seeds ha^{-1} seed rate compared to the crop with the rate of 2 million seeds ha^{-1}. For wheat sown on 14 September, the significantly higher 1000-grain weight was found in the less dense crops with the rate of 3 and 2 million seeds ha^{-1}. The wheat crop sown on 21 September had a significantly higher 1000-grain weight (40.8 g) in the 2 million seeds ha^{-1} compared with the higher seed rate crop. The 1000-grain weight of the late sowing (5 October) was not significantly different (from 43.1 g to 43.3 g) but was significantly lower (42.1 g) in the less dense crop (2 million seeds ha^{-1}).



Note. The differences between the means of the variants in the columns marked with different letters (a, b, c…) are significant (P≤0.05).

Figure 3. The influence of sowing dates and seed rates on the 1000-grain weight of winter wheat

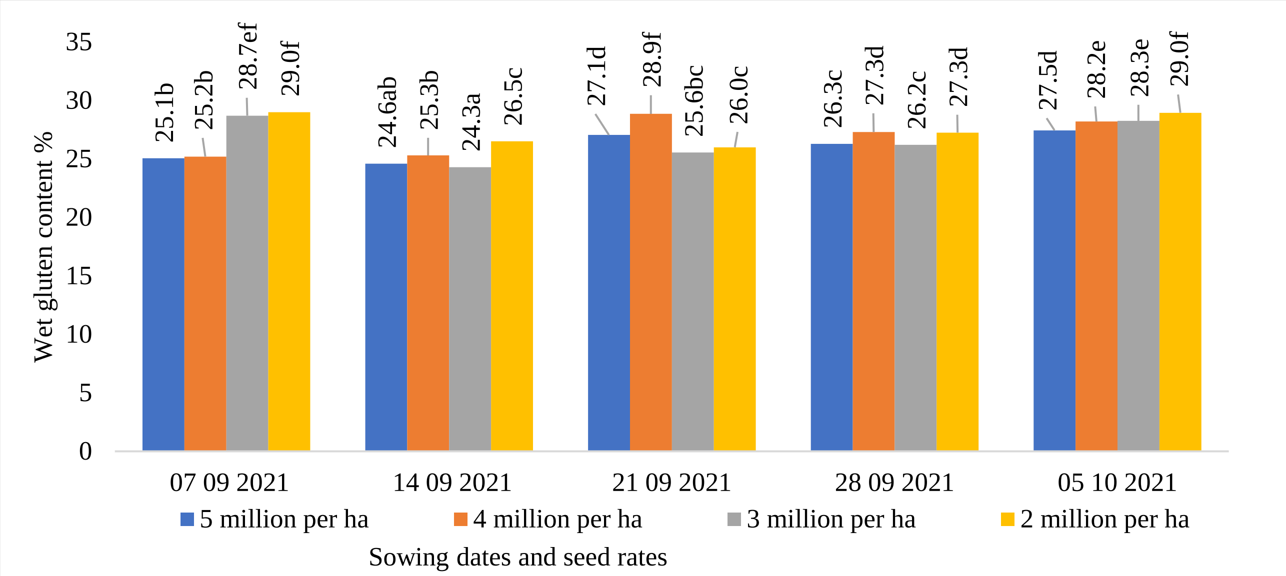
The proper selection of a sowing date can have a considerable positive impact on both the quantity and quality of crop yield (Singh et al., 2021) by regulating the thermal conditions and precipitation, particularly during the kernel filling period as well as avoiding or minimizing the exposure to adverse environmental conditions (Tapley et al., 2013). The experiment showed that wheat grains in the early sowing (7 September) crop with a rate of 2 million seeds ha^{-1} had the highest protein content (14.6%) compared to all subsequent sowings (Figure 4). For wheat sown on 7, 14, 21, 28, September, and 5 October, grain protein content increased with delayed sowing. Significantly, the lowest protein content (12.6 and 12.7%) was found in the grain after sowing on 14 September at the rates of 3 and 5 million seeds ha^{-1}.



Note. The differences between the means of the variants in the columns marked with different letters (a, b, c…) are significant (P≤0.05).

Figure 4. The influence of sowing dates and seed rates on the protein content in winter wheat

Analysis of the experimental data (Figure 5) shows that the wet gluten content varied between 24.3% and 29.0%. In the early sowing (7 September), the gluten content was significantly higher (29.0 and 28.7 %) in the crops with the rates of 2 and 3 million seeds ha^{-1}, compared to the crops of 5 and 4 million seeds ha^{-1}. The wheat grains sown on 21 September had the highest gluten content (28.9%) in wheat grains sown at a rate of 4 million seeds ha^{-1}, compared to the less dense crops (3 and 2 million seeds ha^{-1}), which had wet gluten content ranging from 25.6% to 26.0%. In the late sowing (5 October), the wet gluten content of wheat grains increased with decreasing seed rate. The gluten content was significantly lowest in the grains from the highest seed rate and significantly higher (0.7–1.5 p.p.) in the grains from the wheat sown at lower seed rates.



Note. The differences between the means of the variants in the columns marked with different letters (a, b, c…) are significant (P≤0.05).

Figure 5. The influence of sowing dates and seed rates on the wet gluten content in winter wheat

CONCLUSIONS

Winter wheat yields ranged from 6.5 t ha^{-1} to 8.1 t ha^{-1}. The significantly lowest yield (6.5 t ha^{-1}) was recorded on 21 and 28 September in the crops with the lowest seed rate of 2 million seeds ha^{-1}. The highest yield (8.1 t ha^{-1}) was recorded in the early sown winter wheat fields at 3 and 4 million seeds ha^{-1}. Significantly more grain was formed in the ears of wheat sown later (on 28 September and 5 October) compared to those sown on 7 September and 14 September. The latest winter wheat sown on 5 October produced the best quality grains with a protein content of 13.9–14.4% and a wet gluten content of 27.5–29.9%. The grains of poorer quality matured in the densest (5.0 million ha^{-1} seed rate) crop sown at all sowing dates.

REFERENCES

1. Akhtar, M., Cheema, M. S., Jam, M., Ali, L. 2006. Effect of time of sowing on some important characters of wheat, *Triticum aestivum*, genotypes. *Agricultural Research Journal*, 44(4), 255–259.
2. Akmal, M., Hirasawa T. 2004. Growth response of seminal roots of wheat seedlings to a reduction in the water potential of vermiculite. *Plant Soil*, 267, 319-328. https://doi.org/10.1007/s11104-005-0138-x
3. Alam, M. S., Kumar, R., Patel, J. N. 2022. Effect of sowing dates and varieties on the nutrient uptake and economics of Wheat crop (*Triticum aestivum* L.) under changing climate. *The Pharma Innovation Journal*, 11(2), 533–538.
4. Bahar, B., Yildirim, M.,Yucel, C. 2011 . Heat and drought resistance criteria in spring bread wheat (*Triticum aestivum* L.): Morpho-physiological parameters for heat tolerance. *Scientific Research and Essays*, 6(10), 2212–2220.
5. Ben Mariem S., Soba D., Zhou B., Loladze I., Morales. F, Aranjuelo I. 2021. Climate Change, Crop Yields, and Grain Quality of C3 Cereals: A Meta-Analysis of [CO2], Temperature, and Drought Effects. *Plants*, vol. 10(6),1052. https://doi.org/10.3390/plants10061052
6. El-Gizawy, N. K. B. 2009. Effect of planting date and fertilizer application on yield of wheat under no till system. *World Journal of Agricultural Sciences*, 5 (6), 777–783.
7. Fang, Y., Xu, B. C., Turner, N. C., Li, F. M. 2010. Grain yield, dry matter accumulation and remobilization, and root respiration in winter wheat as affected by seeding rate and root pruning. *European Journal of Agronomy*, 33, 257–266. https://doi.org/10.1016/j.eja.2010.07.001
8. Fazily, T. 2021. Effect of Sowing Dates and Seed Rates on Growth and Yield of Different Wheat Varieties: A Review. *International Journal of Agricultural Science and Technology*, 8, 10–26. https://doi.org/10.47856/ijaast.2021.v08i3.002

9. Gaile, Z., Ruza, A., Kreita, D., Paura, L. 2017. Yield components and quality parameters of winter wheat depending on tillering coefficient. *Agronomy Research*, 15(1), 79–93.
10. Geleta, B., Atak, M., Baenziger, P. S., Nelson, L. A., Baltenesperger, K. M., Eskridge, K. M. 2002. Seeding rate and genotype effect on agronomic performance and end use quality of winter wheat. *Crop Science*, 42, 827–832. https://doi.org/10.2135/cropsci2002.0827
11. Hussain, J., Khaliq, T., Rahman, M. H. U., Ullah, A., Ahmed, I., Srivastava, A. K., Gaiser, T., Ahmad, A. 2021. Effect of Temperature on Sowing Dates of Wheat under Arid and Semi-Arid Climatic Regions and Impact Quantification of Climate Change through Mechanistic Modeling with Evidence from Field. *Atmosphere*, 12, 927. https://doi.org/10.3390/atmos12070927
12. Khan M. A., Hussain I., Baloch M. S. 2000. Wheat Yield Potential-Current Status and Future Strategies. *Pakistan Journal of Biological Sciences*, 3, 82-86. https://doi.org/10.3923/pjbs.2000.82.86
13. Klepeckas, M., Januškaitienė, I., Vagusevičienė, I., Juknys, R. 2020. Effects of different sowing time to phenology and yield of winter wheat. *Agricultural and Food Science*, 29(4), 346–358. https://doi.org/10.23986/afsci.90013
14. Laghari, G.M., F.C. Oad, S. Tunio, Q. Chachar, A.W. Ghandahi, M.H. Siddiqui, S.W. Hassan and A. Ali. 2011. Growth and yield attributes of wheat at different seed rates. *Sarhad Journal of Agriculture*, 27(2), 177-183.
15. Li, D., Zhang, D., Wang, H., Li, H., Fang, Q., Li, H., & Li, R. 2020. Optimized planting density maintains high wheat yield under limiting irrigation in North China Plain. *International Journal of Plant Production*, *14*, 107-117.. https://doi.org/10.1007/s42106-019-00071-7
16. Ma, S. C., Wang, T. C., Guan, W. K., Zhang X. 2018. Effect of sowing time and seeding rate on yield components and water use efficiency of winter wheat by regulating the growth redundancy and physiological traits of root and shoot. *Field Crops Research*, 221, 166–17442. https://doi.org/10.1016/j.fcr.2018.02.028
17. Malik, A. U., Alias M. A., Bukhsh H. A., Hussain I. 2009. Effect of seed rates sown on different dates on wheat under agro-ecological conditions of Dera Ghazi Khan. *Journal of Environment and Earth Science*, 19(3): 126-129.
18. Mumtaz M. Z., Aslam M., A., Nasrullah H. M., Akhtar M., Ali B. 2015. Effect of Various Sowing Dates on Growth, Yield and Yield Components of Different Wheat Genotypes. *American-Eurasian Journal Agriculture & Environmental Science*, 15 (11), 2230–2234.
19. Ozturk, A., Caglar, O., Bulut, S. 2006. Growth and yield response of facultative wheat to winter sowing, freezing sowing and spring sowing at different seeding rates. *Journal Agronomy Crop Sciences*, 192, 10–16. https://doi.org/10.1111/j.1439-037X.2006.00187.x
20. Shah, M.A., Farooq M., Shahzad M., Khan M.B., Hussain M. 2017. Yield and phenological response of BT cotton to different sowing dates in semi-arid climate. *Pakistan Journal of Biological Sciences*, 54, 233–239. https://doi.org/10.21162/PAKJAS/17.4394
21. Singh, N., Singh, S. S., Singh, G., Singh, R., Yadav, S. K. 2021. Effects of interaction (Date of sowing X varieties) on wheat (*Triticum aestivum* L.). *International Journal of Chemical Studies*, 9(2), 201–203. https://doi.org/10.22271/chemi.2021.v9.i2c.11807
22. Spink, J.H., Semere, T., Spares, D.L., Whaley, J.M., Foulkes, J.M., Clare, R.W., Scott, R.K. 2000. Effect of sowing date on the optimum plant density of winter wheat. *Annals of Applied* Biology, 137, 179–188. https://doi.org/10.1111/j.1744-7348.2000.tb00049.x
23. Tadesse, W., Sanchez-Garcia, M., Assefa, S. G., Amri, A., Bishaw, Z., Ogbonnaya, F. C., Baum, M. 2019. Genetic gains in wheat breeding and its role in feeding the world. *Crop Breeding, Genetics and Genomics*, vol. 1. https://doi.org/10.20900/cbgg20190005
24. Tapley M., Ortiz V.B., Santen E., Balckcom K.S. 2013. Location, seeding date, and variety interactions on winter wheat yield in Southeastern United States. *Agronomy Journal*, 105, 509–518. https://doi.org/10.2134/agronj2012.0379
25. Wajid, A., Hussain, A., Ahmad, A., Goheer, A.R., Ibrahim, M., Mussaddique, M. 2004. Effect of Sowing Date and Plant Population on Biomass, Grain Yield and Yield Components of Wheat, *International Journal of Agriculture & Biology*, vol. 6(6), p. 1003–1005.
26. Zecevic, V., Boskovic, J., Knezevic, D., Micanovic, D. 2014. Effect of seeding rate on grain quality of winter wheat. *Chilean journal of agricultural research*, 74(1), 23–28. https://doi.org/10.4067/S0718-58392014000100004