Hungarian University of Agriculture and Life Sciences

Thesis of the PhD Dissertation

Elias El Chami

Gödöllő, Hungary

2023

Hungarian University of Agriculture and Life Sciences

INFLUENCE OF AGROTECHNOLOGY ON *FUSARIUM* INFECTION, MYCOTOXIN PRODUCTION AND TECHNOLOGICAL QUALITY OF Winter Wheat (*Triticum aestivum L.*)

DOI: 10.54598/004080

Thesis of the PhD Dissertation

Elias El Chami

Gödöllő, Hungary

2023

Influence of Agrotechnology on *Fusarium* Infection, Mycotoxin Production and Technological Quality of Winter Wheat (*Triticum aestivum L.*)

Doctoral School Plant Sciences

Discipline Agronomy

Head Prof. Helyes Lajos, DSc

Hungarian University of Agriculture and Life Sciences

Doctoral School of Plant Sciences

Supervisors Prof. emeritus Jolánkai Márton, DSc

Dr. Tarnawa Ákos

Hungarian University of Agriculture and Life Sciences

Doctoral School of Plant Sciences

....	....
Approval of the	Approval of the
Head of Doctoral School	Supervisors

CONTENTS

1. INTRODUCTION

Cereals and cereal by-products constitute a major part of the daily human and animal diet. According to the Food and Agriculture Organization of the United Nations (FAO), rice, maize, and wheat are staple foods for 4 billion people and make up about 60% of the world's food energy intake. Latest estimates for world cereal production in 2021/2022 are 2813.2 million tonnes. In 2021/2022, approximately 478.5 million tonnes of cereal were exported worldwide. Wheat (*Triticum aestivum L.*) is the most widely grown cereal crop in the world. The major exporters of wheat are Argentina, Australia, Canada, the European Union, Kazakhstan, Russian Federation, Ukraine, and the United States. The primary use of bread wheat is for bread manufacture. Wheat flour is also used to produce biscuits, confectionery products, pasta, and vital wheat gluten. Other than its primary use as a human food source, wheat has several alternatives uses around the world. These include, but are not limited to, use in animal feed, conversion of wheat starch to ethanol, brewing of wheat beer, the production of wheat-based cat and pet litter, wheat based raw materials for cosmetics, wheat protein in meat substitutes and to make wheat straw composites. Among the most important risks associated with cereal consumption are mycotoxins, heavy metals, pesticide residues, and alkaloids. Cereal and cereal products can be contaminated with mycotoxins produced by *Fusarium spp.* that colonize crops in the field.

1.1 Objectives

The aim of this research lies in studying the influence of agrotechnology on *Fusarium* infection, mycotoxin production and technological quality of wheat. While taking the following questions into account:

Part one:

Does nitrogen fertilization affect *Fusarium* infection and mycotoxin contamination?

Does wheat variety affect *Fusarium* infection and mycotoxin contamination?

Do environmental conditions affect *Fusarium* infection and mycotoxin contamination?

Part two:

Does nitrogen fertilization affect protein content, gluten content, falling number, Zeleny sedimentation Index, thousand kernel weight and test weight?

What is the highest nitrogen fertilizer rate after which no effect is found on wheat quality parameters?

Are excessively high nitrogen fertilization rates needed for good quality wheat?

2. MATERIALS AND METHODS

2.1 Experimental design

The experiment was conducted during the growing seasons (2020, 2021 and 2022) at the experimental field and laboratories of the Hungarian University of Agriculture and Life Sciences (MATE), Agronomy Institute, Gödöllő, Hungary. The experimental site is in a hilly area with a close to average climatic zone of the country (47°35'40.8"N 19°22'08.4"E, 210 m above sea level). A three-year crop rotation of soybean, wheat, and maize was implemented in the field. Prior to sowing, the field was cleared, ploughed and rotor-tilled, and the seedbed was prepared. The plots were sown in October and harvested in the middle of July with plot machines. The sowing depth was 5 cm. The rate of sowing was 450 to 500 seeds per square meter. Weeds were controlled by herbicides (Mustang Forte™) and wheat pests and diseases beside *Fusarium* were controlled by pesticides. Rainfall (mm) measurements were collected from the World Weather Online® meteorological service during the flowering period (May) when wheat is most susceptible to *Fusarium* infection. Rainfall during the flowering period (May) was 24.6 mm in 2022, 88.39 mm in 2021 and 42.8 mm in 2020. The soil type of the experimental field was sand-based brown forest soil (Chromic Luvisol). The agronomic characteristic of the soil was neutral sandy soil with variable clay content. The soil structure was susceptible to compaction issues.

The trial design was that of a split plot with main plots consisting of different wheat varieties and subplots consisting of different nitrogen doses. Main plots and subplots were 50 cm apart horizontally and 30 cm apart vertically, and the area of each subplot was 5 m^2. Each treatment had three replications.

During the 2020 and 2021 growing seasons the wheat varieties used were Alföld, Mv Kolompos, and Mv Karéj. Nitrogen fertilizer was applied in the form of granular ammonium (NH_4NO_3) with 34% content of the active ingredient either in single dose application or in split dose application. Single dose nitrogen fertilization was done once during the growing season at the heading stage (April) with the following doses: 40, 80, 120, and 160 kg N ha^{-1}. Split dose nitrogen fertilization was done twice during the growing season, the first application was at tillering stage (March) and the second application at heading stage (April). The doses of nitrogen in the first application were: 40, 80, and 120 kg N ha^{-1}. In the second application 40 kg N ha-1 was added only. Plots without nitrogen topdressing were used as control. Wheat was harvested in the middle of July and representative samples were randomly taken from each plot. *Fusarium* percentage was calculated by counting the number of colonies that formed on wheat kernels (100 kernels from each treatment) disinfected for 2 minutes with a solution of pentachloronitrobenzene (PCNB) and chloramphenicol (distilled water 1 L, PCNB 1 g, chloramphenicol 100 ppm) and then incubated for 7 days under laboratory conditions (23 °C ± 0.6 °C and 45% RH ± 5% RH) on Nash and Snider *Fusarium* selective medium (distilled water 1 L, peptone 15 g, KH_2PO_4 1 g, $MgSO_47H_2O$ 0.5 g, agar 20 g, PCNB 1 g, chloramphenicol 100 ppm). Mycotoxin concentrations of deoxynivalenol (DON), zearalenone (ZEA), and fumonisins (FUM) were analyzed using ROSA FAST 5 Quantitative Test by Charm Sciences (DONQ-FAST5 Test, FUMQ-FAST5 Test, ZEARQ-FAST5 Test).

During the 2022 growing season the wheat varieties used were Alföld and Mv Ménrót. Nitrogen fertilizer was applied once at the heading stage (April) in the following doses: 200, 400, 600, 800, and 1000 kg N ha^{-1}. Plots without nitrogen topdressing were used as control. Apart from nitrogen topdressing, all other agronomic treatments as well as sowing and harvesting were identically applied to all plots to study the impact of nitrogen treatments independently. Wheat was harvested in the middle of July and representative samples were randomly taken from each plot. Protein content, gluten content, and Zeleny sedimentation index were measured with Near-infrared (NIR) spectroscopic equipment Mininfra Scan-T Plus 2.02 version. The falling number was measured with Perten 1400 system (ICC method No. 107/1 1995). Test weight was measured with the Chondrometer Hectoliter grain tester (ISO 7971-3:2019). Thousand kernel weight and test weight were measured with the KERN EMS and the Sartorius MA-30 precision scales.

For the statistical evaluation of the results, the analysis of variance (ANOVA) module of the IBM SPSS V.21 software at a 5% significance level with subsequent Tukey’s test was performed.

3. RESULTS

3.1 Effect of nitrogen fertilization, wheat variety and growing season on *Fusarium* infection and mycotoxin production

3.1.1 Effect of nitrogen fertilization

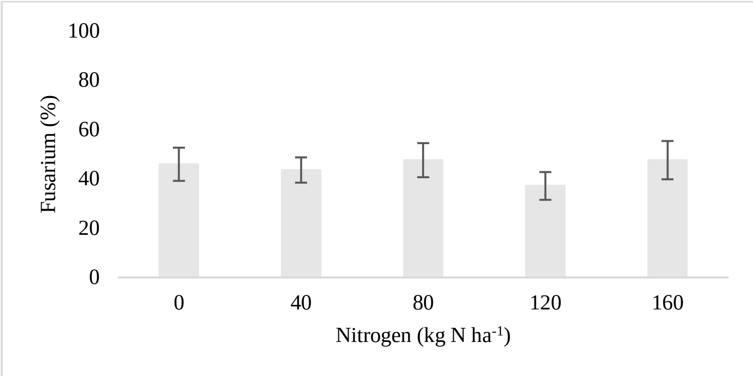

Figure 1. Effect of single dose nitrogen fertilization (kg N ha^{-1}) on *Fusarium* infection (%) in 2020

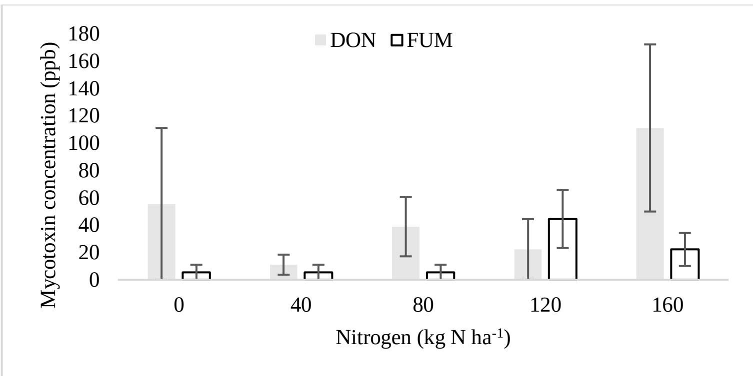

Figure 2. Effect of single dose nitrogen fertilization (kg N ha^{-1}) on mycotoxin concentration (ppb) in 2020

In 2020, the increasing single doses of nitrogen fertilization did not show a statistically significant effect on *Fusarium* infection (F = 0.450, P = 0.772) and mycotoxin production (DON, F = 0. 980, P = 0. 429; FUM, F = 2.135, P = 0.094). There was no statistically significant difference in *Fusarium* infection and mycotoxin contamination between the increasing nitrogen doses. *Fusarium* infection and mycotoxin contamination did not change with the increasing nitrogen doses (Figure 1, 2).

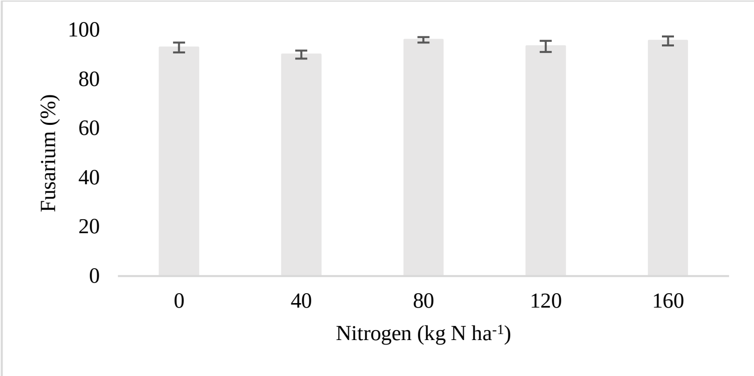

Figure 3. Effect of single dose nitrogen fertilization (kg N ha^{-1}) on *Fusarium* infection (%) in 2021

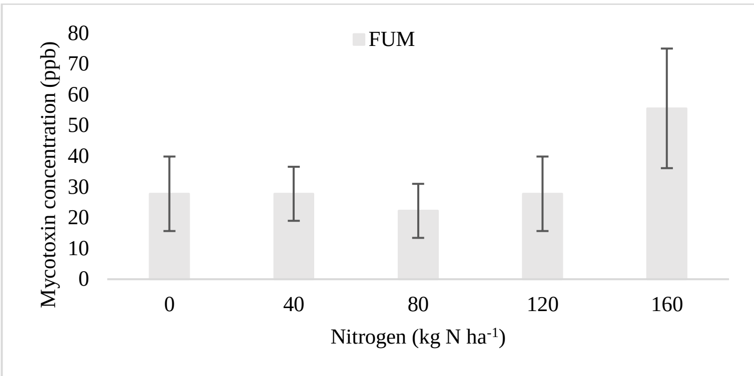

Figure 4. Effect of single dose nitrogen fertilization (kg N ha^{-1}) on mycotoxin concentration (ppb) in 2021

In 2021, the increasing single doses of nitrogen fertilization did not show a statistically significant effect on *Fusarium* infection (F = 1.770, P = 0.154) and mycotoxin production (FUM, F = 1.065, P = 0.386). There was no statistically significant difference in *Fusarium* infection and mycotoxin contamination between the increasing nitrogen doses. *Fusarium* infection and mycotoxin contamination did not change with the increasing nitrogen doses (Figure 3, 4).

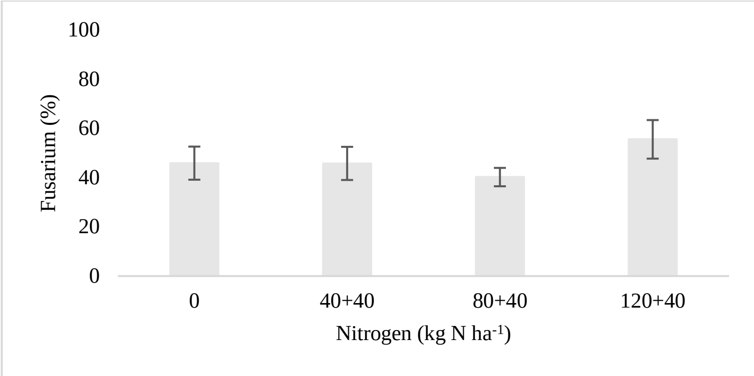

Figure 5. Effect of split dose nitrogen fertilization (kg N ha^{-1}) on *Fusarium* infection (%) in 2020

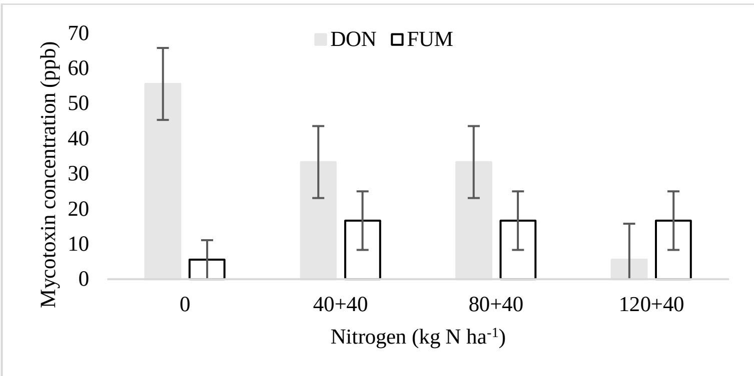

Figure 6. Effect of split dose nitrogen fertilization (kg N ha^{-1}) on mycotoxin concentration (ppb) in 2020

In 2020, the increasing split doses of nitrogen fertilization did not show a statistically significant effect on *Fusarium* infection (F = 0.978, P = 0.415) and mycotoxin production (DON, F = 0.351, P = 0.789; FUM, F = 0.516, P = 0.674). There was no statistically significant difference in *Fusarium* infection and mycotoxin contamination between the increasing nitrogen doses. *Fusarium* infection and mycotoxin contamination did not change with the increasing nitrogen doses (Figure 5, 6).

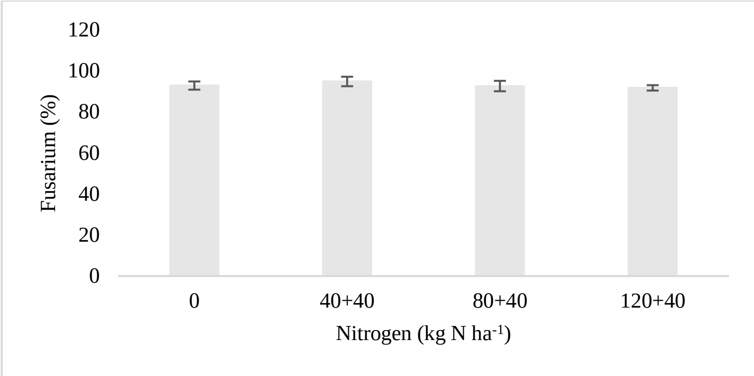

Figure 7. Effect of split dose nitrogen fertilization (kg N ha^{-1}) on *Fusarium* infection (%) in 2021

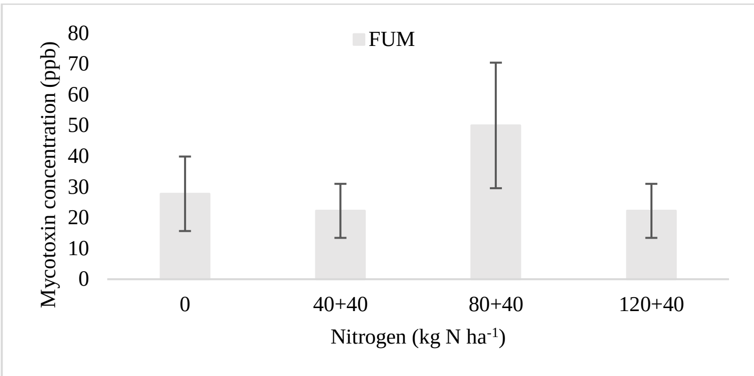

Figure 8. Effect of split dose nitrogen fertilization (kg N ha^{-1}) on mycotoxin concentration (ppb) in 2021

In 2021, the increasing split doses of nitrogen fertilization did not show a statistically significant effect on *Fusarium* infection (F = 0.394, P = 0.758) and mycotoxin production (FUM, F = 0.975, P = 0.417). There was no statistically significant difference in *Fusarium* infection and mycotoxin contamination between the increasing nitrogen doses. *Fusarium* infection and mycotoxin contamination did not change with the increasing nitrogen doses (Figure 7, 8).

3.1.2 Effect of wheat variety

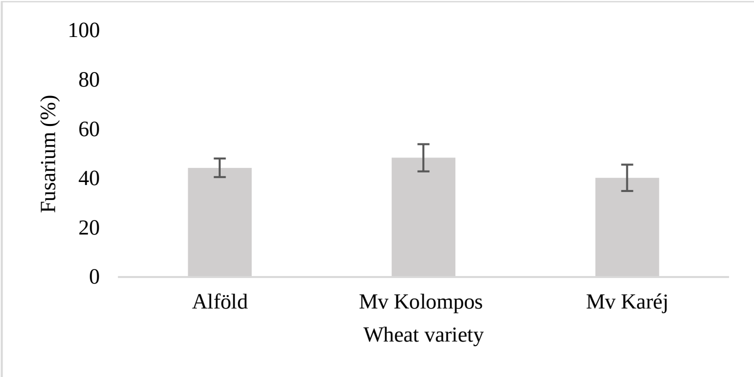

Figure 9. Effect of wheat variety on *Fusarium* infection (%) in single dose nitrogen fertilization in 2020

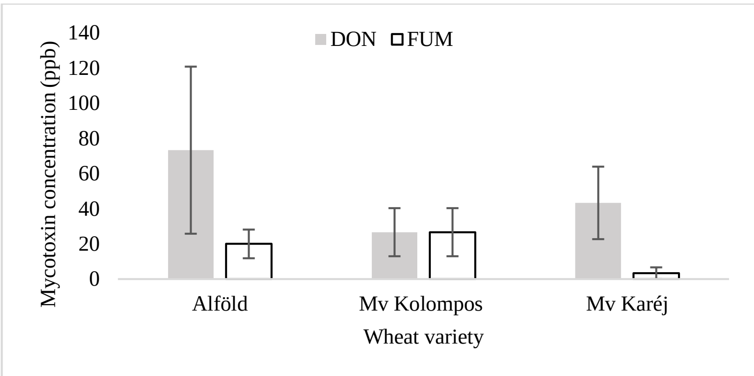

Figure 10. Effect of wheat variety on mycotoxin concentration (ppb) in single dose nitrogen fertilization in 2020

In 2020, wheat variety did not show a statistically significant effect *Fusarium* infection (F = 0.677, P = 0.513) and mycotoxin production (DON, F = 0.584, P = 0.562; FUM, F = 1.635, P = 0.207). There was no statistically significant difference in *Fusarium* infection and mycotoxin contamination between Mv Kolompos, Mv Karéj and Alföld wheat varieties. *Fusarium* infection and mycotoxin contamination did not change between the wheat varieties (Figure 9, 10).

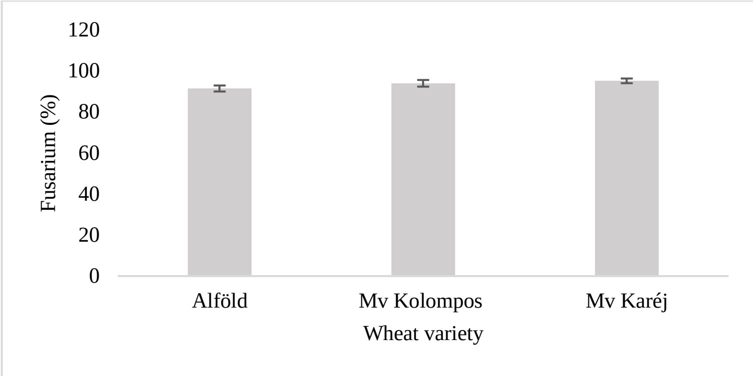

Figure 11. Effect of wheat variety on *Fusarium* infection (%) in single dose nitrogen fertilization in 2021

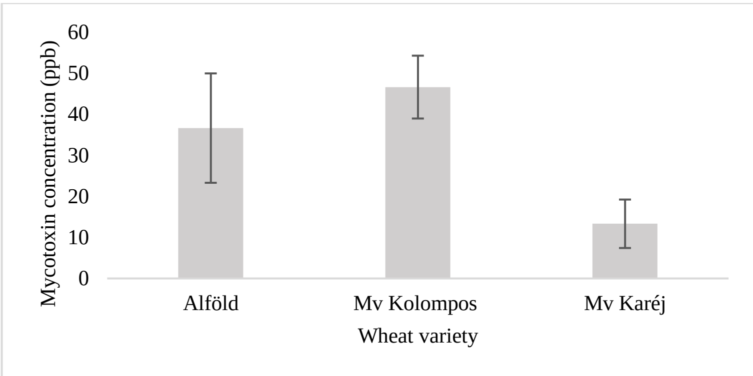

Figure 12. Effect of wheat variety on mycotoxin concentration (ppb) in single dose nitrogen fertilization in 2021

In 2021, wheat variety did not show a statistically significant effect on *Fusarium* infection (F = 1.796, P = 0.178) but it showed a statistically significant effect on fumonisin production (FUM, F = 3.234, P = 0.049). Mv Kolompos had the highest fumonisin concentration (46.67 ppb) followed by Alföld (36.67 ppb) and then Mv Karéj (13.33 ppb) (Figure 11, 12).

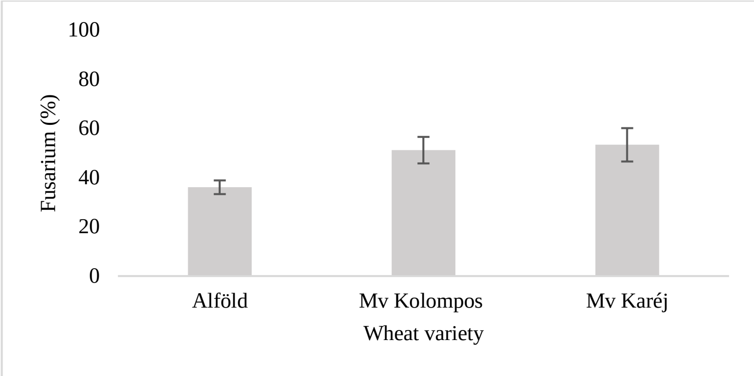

Figure 13. Effect of wheat variety on *Fusarium* infection (%) in split dose nitrogen fertilization in 2020

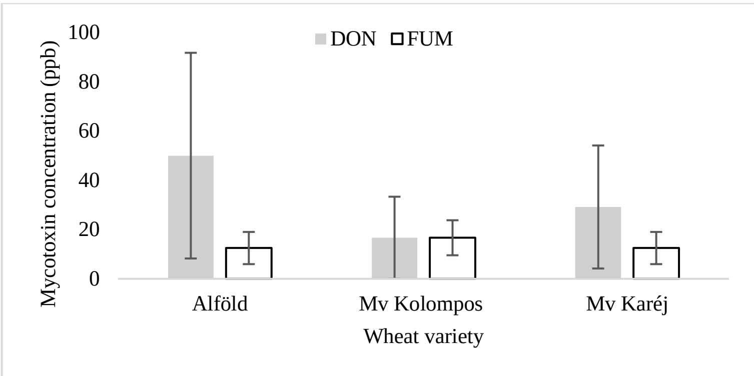

Figure 14. Effect of wheat variety on mycotoxin concentration (ppb) in split dose nitrogen fertilization in 2020

In 2020, wheat variety did not show a statistically significant effect on *Fusarium* infection (F = 3.2, P = 0.054) and mycotoxin production (DON, F = 0.322, P = 0.727; FUM, F = 0.128, P = 0.88). There was no statistically significant difference in *Fusarium* infection and mycotoxin contamination between Mv Kolompos, Mv Karéj and Alföld wheat varieties. *Fusarium* infection and mycotoxin contamination did not change between the wheat varieties (Figure 13, 14).

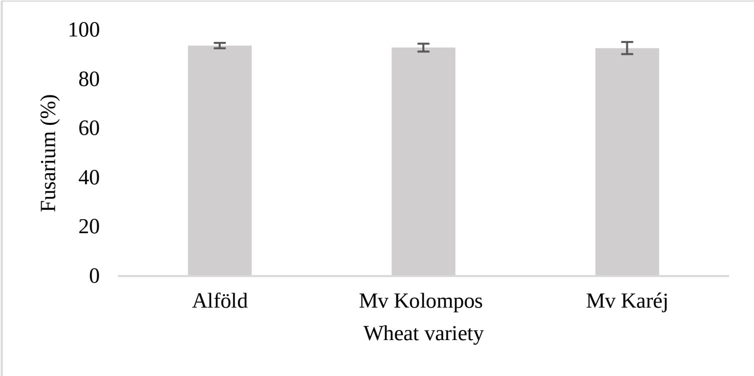

Figure 15. Effect of wheat variety on *Fusarium* infection (%) in split dose nitrogen fertilization in 2021

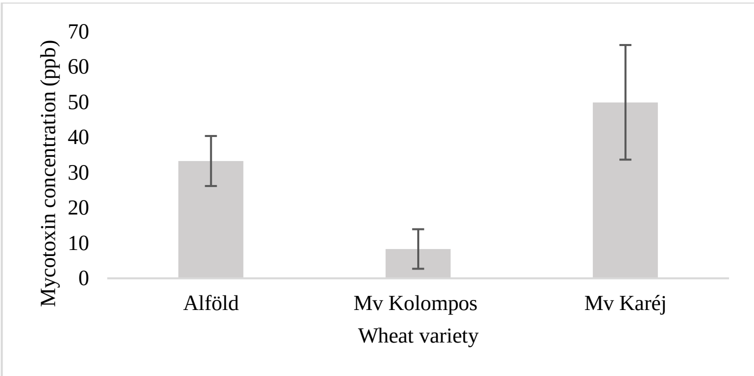

Figure 16. Effect of wheat variety on mycotoxin concentration (ppb) in split dose nitrogen fertilization in 2021

In 2021, wheat variety did not show a statistically significant effect on *Fusarium* infection (F = 0.087, P = 0.917) but it showed a statistically significant effect on fumonisin production (FUM, F = 3.8, P = 0.033). Mv Karéj had the highest fumonisin concentration (50 ppb) followed by Alföld (33.33 ppb) and then Mv Kolompos (8.33 ppb) (Figure 15, 16).

3.1.3 Effect of growing season

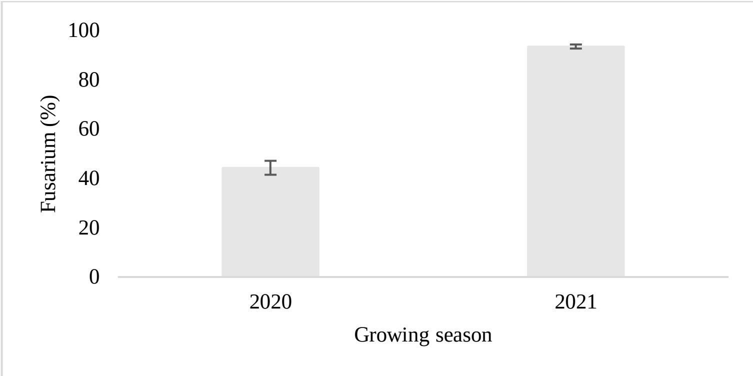

Figure 17. Effect of growing season on *Fusarium* infection (%) in wheat with single dose nitrogen fertilization

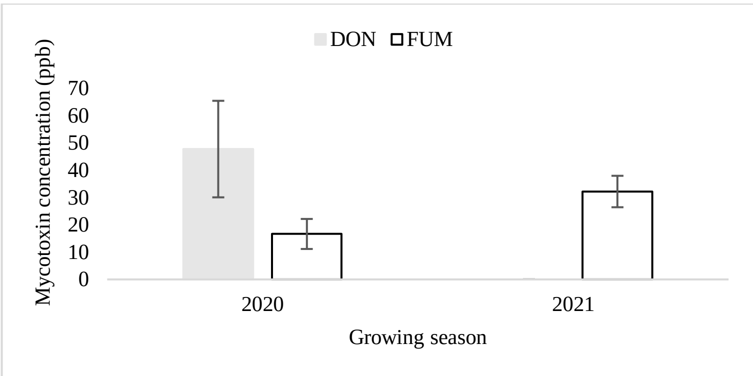

Figure 18. Effect of growing season on mycotoxin concentration (ppb) in wheat with single dose nitrogen fertilization

The growing season in the case of wheat with single dose nitrogen fertilization significantly affected *Fusarium* infection (F = 277.89, P = .000) and mycotoxin production (DON, F = 7.29, P = .008; FUM, F = 3.81, P = 0.05). *Fusarium* infection was higher in 2021 (93.56 %) than in 2020 (44.33 %). Zearalenone was not detected throughout the two growing seasons. Fumonisins concentration (total mean = 24.44 ppb) was higher than that of deoxynivalenol (total mean = 23.89 ppb). Deoxynivalenol was not detected in 2021, its concentration was 47.78 ppb in 2020. Fumonisins concentration was higher in 2021 (32.22 ppb) than in 2020 (16.67 ppb) (Figure 17, 18).

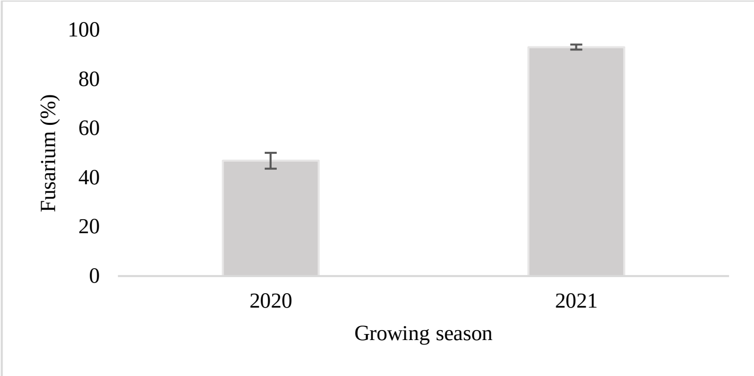

Figure 19. Effect of growing season on *Fusarium* infection (%) in wheat with split dose nitrogen fertilization

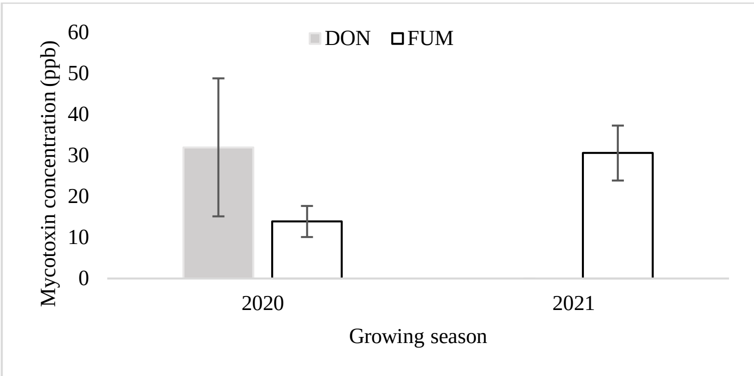

Figure 20. Effect of growing season on mycotoxin concentration (ppb) in wheat with split dose nitrogen fertilization

The growing season in the case of wheat with split dose nitrogen fertilization significantly affected *Fusarium* infection (F = 187.31, P = 0.000) and fumonisins concentration (F = 4.7, P = 0.03) but did not significantly affect deoxynivalenol concentration (F = 3.61, P = 0.06). *Fusarium* infection was higher in 2021 (93.1 %) than in 2020 (46.9 %). Zearalenone was not detected throughout the two growing seasons. Fumonisins concentration (total mean = 22.2 ppb) was higher than that of deoxynivalenol (total mean = 15.97 ppb). Deoxynivalenol was not detected in 2021, its concentration was 31.9 ppb in 2020. Fumonisins concentration was higher in 2021 (30.6 ppb) than in 2020 (13.9 ppb) (Figure 19, 20).

3.2 Effect of nitrogen fertilization on wheat quality parameters

3.2.1 Effect of nitrogen on thousand kernel weight and test weight

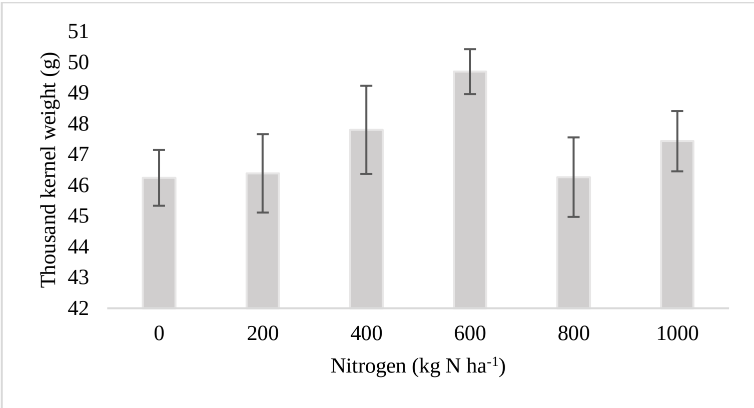

Figure 21. Effect of nitrogen (kg N ha^{-1}) on thousand kernel weight (g) in Mv Ménrót

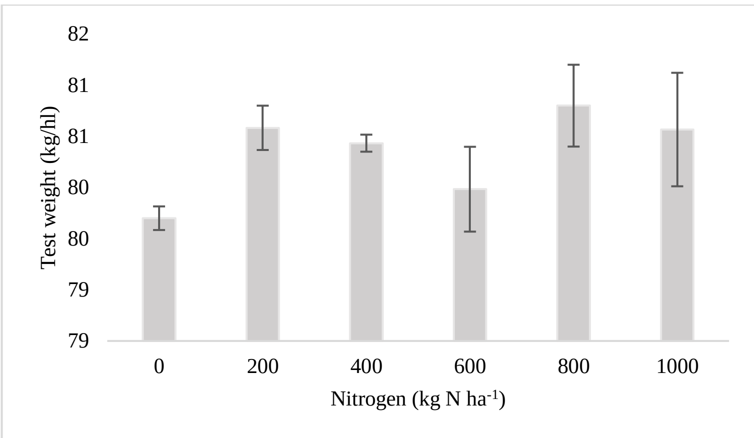

Figure 22. Effect of nitrogen (kg N ha^{-1}) on test weight(kg/hl) in Mv Ménrót

In Mv Ménrót, nitrogen fertilization did not show a significant effect on thousand kernel weight (F = 1.414, P = 0.288) and test weight (F = 1.473, P = 0.269) (Figure 21, 22).

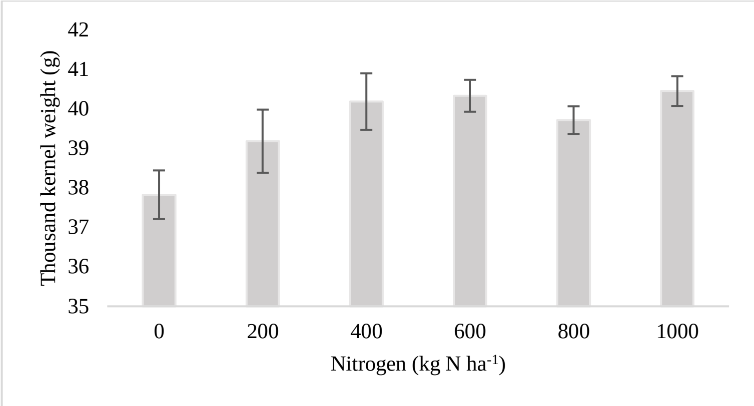

Figure 23. Effect of nitrogen (kg N ha^{-1}) on thousand kernel weight (g) in Alföld

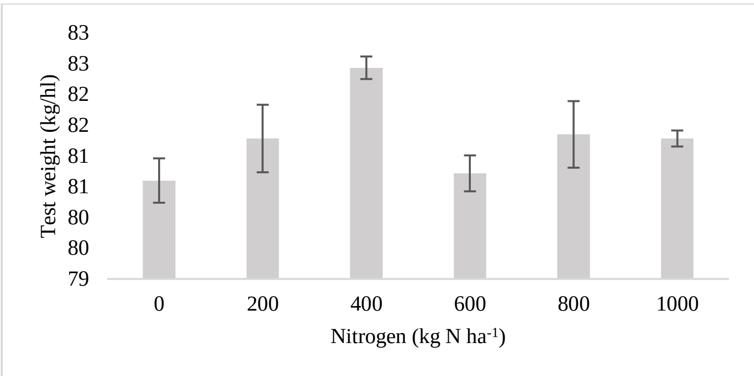

Figure 24. Effect of nitrogen (kg N ha^{-1}) on test weight (kg/hl) in Alföld

In Alföld, nitrogen fertilization did not show a significant effect on thousand kernel weight (F = 3.030, P = 0.054) and test weight (F = 2.953, P = 0.058) (Figure 23, 24).

3.2.2 Effect of nitrogen on gluten content

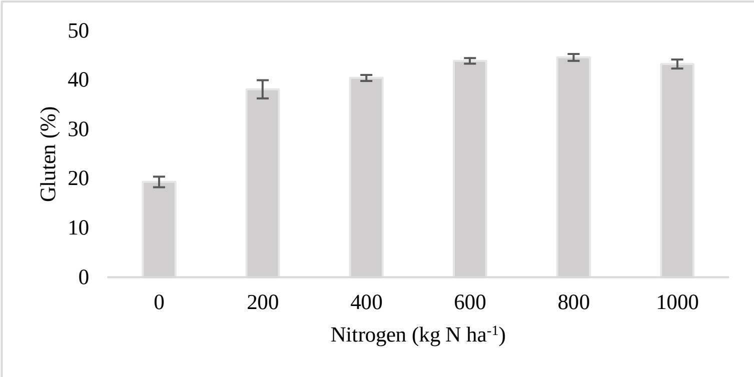

Figure 25. Effect of nitrogen (kg N ha^{-1}) on gluten (%) in Mv Ménrót

In Mv Ménrót, nitrogen fertilization significantly affected gluten content (F = 83.882, P = 0.000). Gluten content was 19.33 % at 0 kg N ha^{-1}, 38.13 % at 200 kg N ha^{-1}, 40.43 % at 400 kg N ha^{-1}, 43.9 % at 600 kg N ha^{-1}, 44.6 % at 800 kg N ha^{-1}, and 43.27 % at 1000 kg N ha^{-1}. Gluten content increased with increasing nitrogen dose. Gluten content was the lowest at 0 kg N ha^{-1} and the highest at 600 kg N ha^{1} (Figure 25).

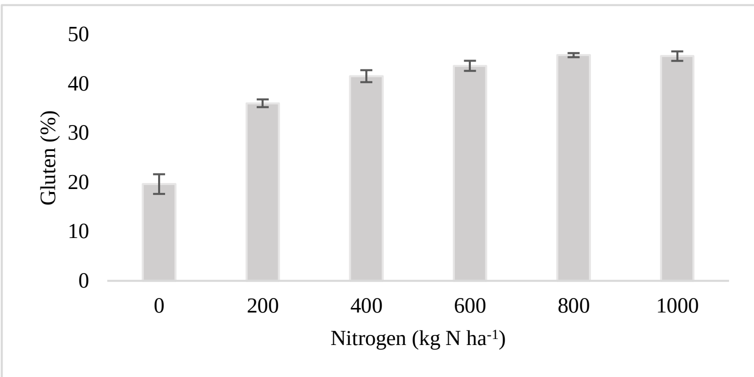

Figure 26. Effect of nitrogen (kg N ha^{-1}) on gluten (%) in Alföld

In Alföld, nitrogen fertilization significantly affected gluten content (F = 72.897, P = 0.000). Gluten content was 19.63 % at 0 kg N ha^{-1}, 36.03 % at 200 kg N ha^{-1}, 41.53 % at 400 kg N ha^{-1}, 43.63 % at 600 kg N ha^{-1}, 45.8 % at 800 kg N ha^{-1}, and 45.6 % at 1000 kg N ha^{-1}. Gluten content increased with increasing nitrogen dose. Gluten content was the lowest at 0 kg N ha^{-1} and the highest at 600 kg N ha^{-1} (Figure 26).

3.2.3 Effect of nitrogen on protein content

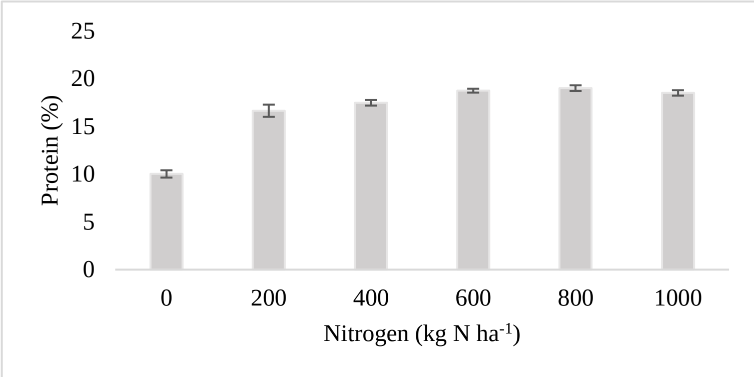

Figure 27. Effect of nitrogen (kg N ha^{-1}) on protein (%) in Mv Ménrót

In Mv Ménrót, nitrogen fertilization significantly affected protein content (F = 80.969, P = 0.000). Protein content was 10.02 % at 0 kg N ha^{-1}, 16.63 % at 200 kg N ha^{-1}, 17.47 % at 400 kg N ha^{-1}, 18.73 % at 600 kg N ha^{-1}, 19 % at 800 kg N ha^{-1}, and 18.5 % at 1000 kg N ha^{-1}. Protein content increased with increasing nitrogen dose. Protein content was the lowest at 0 kg N ha^{-1} and the highest at 600 kg N ha^{-1} (Figure 27).

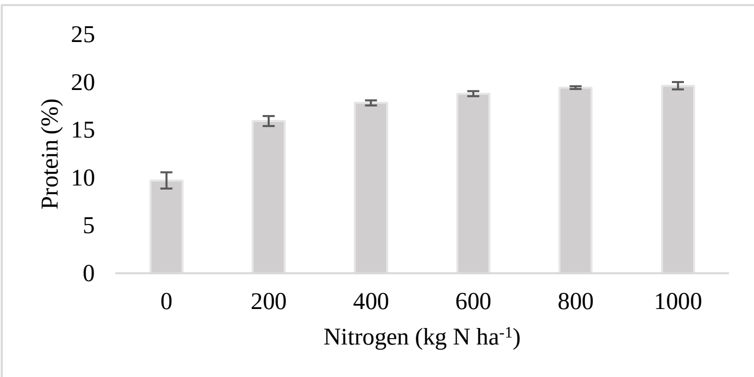

Figure 28. Effect of nitrogen (kg N ha^{-1}) on protein (%) in Alföld

In Alföld, nitrogen fertilization significantly affected protein content (F = 64.941, P = 0.000). Protein content was 9.72 % at 0 kg N ha^{-1}, 15.93 % at 200 kg N ha^{-1}, 17.83 % at 400 kg N ha^{-1}, 18.8 % at 600 kg N ha^{-1}, 19.43 % at 800 kg N ha^{-1}, and 19.63 % at 1000 kg N ha^{-1}. Protein content increased with increasing nitrogen dose. Protein content was the lowest at 0 kg N ha^{-1} and the highest at 600 kg N ha^{-1} (Figure 28).

3.2.4 Effect of nitrogen on Zeleny sedimentation index

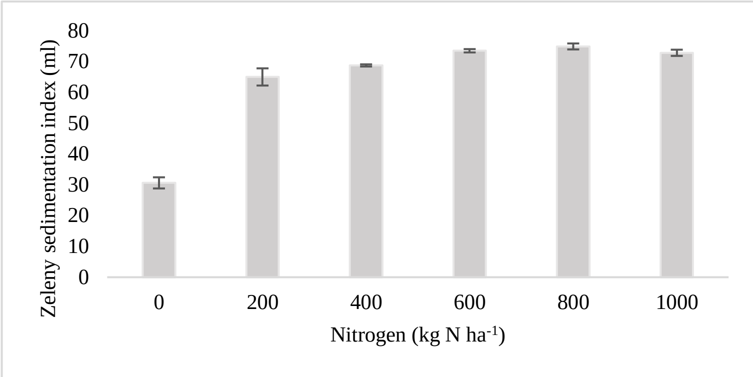

Figure 29. Effect of nitrogen (kg N ha^{-1}) on Zeleny sedimentation index (ml) in Mv Ménrót

In Mv Ménrót, nitrogen fertilization significantly affected Zeleny sedimentation index (F = 127.132, P = 0.000). It was 30.63 ml at 0 kg N ha^{-1}, 65.03 ml at 200 kg N ha^{-1}, 68.76 ml at 400 kg N ha^{-1}, 73.53 ml at 600 kg N ha^{-1}, 74.93 ml at 800 kg N ha^{-1}, and 72.87 ml at 1000 kg N ha^{-1}. Zeleny sedimentation index increased with increasing nitrogen dose. It was the lowest at 0 kg N ha^{-1} and the highest at 600 kg N ha^{-1} (Figure 29).

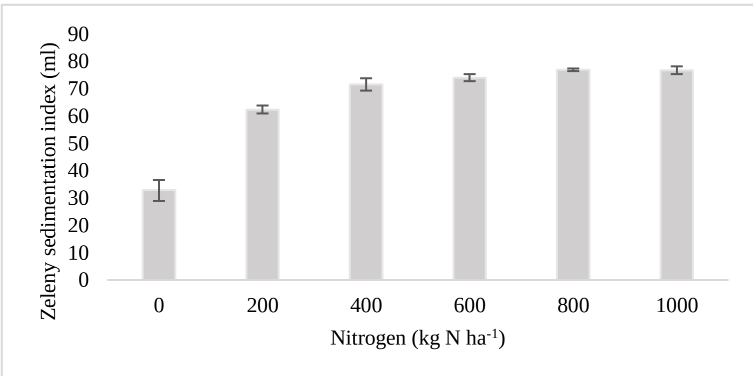

Figure 30. Effect of nitrogen (kg N ha^{-1}) on Zeleny sedimentation index (ml) in Alföld

In Alföld, nitrogen fertilization significantly affected Zeleny sedimentation index (F = 67.123, P = 0.000). It was 32.87 ml at 0 kg N ha^{-1}, 62.40 ml at 200 kg N ha^{-1}, 71.57 ml at 400 kg N ha^{-1}, 74.07 ml at 600 kg N ha^{-1}, 76.93 ml at 800 kg N ha^{-1}, and 76.77 ml at 1000 kg N ha^{-1}. Zeleny sedimentation index increased with increasing nitrogen dose. It was the lowest at 0 kg N ha^{-1} and the highest at 600 kg N ha^{-1} (Figure 30).

3.2.5 Effect of nitrogen on falling number

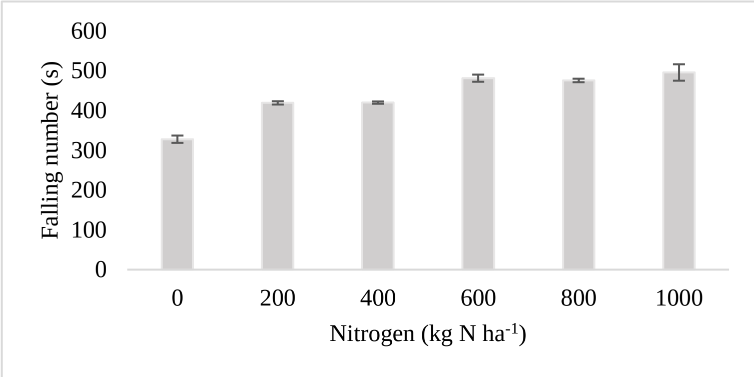

Figure 31. Effect of nitrogen (kg N ha^{-1}) on falling number (s) in Mv Ménrót

In Mv Ménrót, nitrogen fertilization significantly affected the falling number (*F* = 36.357, *P* = 0.000). The falling number was 327.67 s at 0 kg N ha^{-1}, 419 s at 200 kg N ha^{-1}, 419.67 s at 400 kg N ha^{-1}, 481 s at 600 kg N ha^{-1}, 475.33 s at 800 kg N ha^{-1}, and 495.33 s at 1000 kg N ha^{-1}. The falling number increased with increasing nitrogen dose. It was the lowest at 0 kg N ha^{-1} and the highest at 600 kg N ha^{-1} (Figure 31).

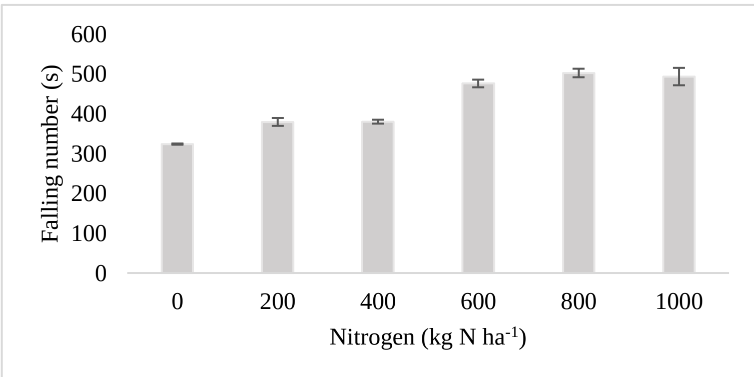

Figure 32. Effect of nitrogen (kg N ha^{-1}) on falling number (s) in Alföld

In Alföld, nitrogen fertilization significantly affected the falling number (*F* = 40.984, *P* = 0.000). The falling number was 324 s at 0 kg N ha^{-1}, 379.67 s at 200 kg N ha^{-1}, 380.33 s at 400 kg N ha^{-1}, 476.33 s at 600 kg N ha^{-1}, 502.67 s at 800 kg N ha^{-1}, 493.67 s at 1000 kg N ha^{-1}. The falling number increased with increasing nitrogen dose. It was the lowest at 0 kg N ha^{-1} and the highest at 600 kg N ha^{-1} (Figure 32).

4. CONCLUSION AND RECOMMENDATIONS

Nitrogen fertilization plays a crucial role in crop growth and development. The used nitrogen fertilization doses and the time of nitrogen application did not influence *Fusarium* infection and mycotoxin production. Breeding programs have made significant progress in developing *Fusarium* tolerant wheat varieties. Wheat varieties exhibit different levels of resistance or tolerance to *Fusarium*. Tolerance reduces the severity of infection and subsequent mycotoxin contamination. The used wheat varieties showed the same level of *Fusarium* infection. Environmental conditions play a critical role in *Fusarium* infection and mycotoxin production. Factors such as rainfall, temperature, and relative humidity contribute to the development and severity of *Fusarium* infection and mycotoxin contamination especially during crucial growth stages. Optimal temperatures within the range of 25-30°C, aw above 0.78, and RH of 88-95% provide favorable environment for *Fusarium* growth and mycotoxin production, while extreme temperatures can inhibit their development. It is important to note that the interaction between nitrogen fertilization, wheat variety, and environmental conditions is complex. Understanding the specific environmental requirements and interactions involved in *Fusarium* infection and mycotoxin production is crucial for implementing effective management strategies. By considering these factors, farmers and agricultural practitioners can make informed decisions to minimize *Fusarium* infection and reduce mycotoxin contamination, safeguarding both crop quality and human and animal health. Optimizing nitrogen fertilization practices and selecting *Fusarium*-resistant wheat varieties are essential strategies for reducing *Fusarium* infection and mycotoxin production in wheat, protecting crop quality, and ensuring food and feed safety. Nitrogen is a crucial nutrient that plays a vital role in wheat growth, development, and grain yield. Nitrogen fertilization significantly affected the quality parameters of wheat crops. Proper nitrogen fertilization can improve wheat quality by enhancing key parameters such as protein content, gluten content, falling number and Zeleny sedimentation index. Adequate nitrogen supply promotes photosynthesis and protein synthesis, leading to higher protein accumulation in wheat grains. This is particularly important for wheat varieties used for bread-making, as higher protein content contributes to better dough strength and bread quality. Furthermore, nitrogen fertilization influences gluten content, which is crucial for determining the baking quality of wheat. Gluten proteins, specifically glutenin and gliadin, contribute to dough elasticity and the ability to retain gas during fermentation. By carefully managing nitrogen fertilization, farmers can enhance wheat quality parameters, ultimately improving the market value and end-use suitability of their wheat crops.

5. NEW SCIENTIFIC RESULTS

Measurements of this experiment proved that:

- The following nitrogen fertilization doses: 0, 40, 80, 120, 160 kg N ha^{-1} did not show a signification effect on *Fusarium* infection and mycotoxin production.

- The following nitrogen fertilization doses: 0, 40+40, 80+40, 120+40 kg N ha^{-1} did not show a signification effect on *Fusarium* infection and mycotoxin production.

- Increasing nitrogen doses and the time of nitrogen application did not affect *Fusarium* infection and mycotoxin production.

- The following wheat varieties: Mv Karéj, Mv Kolompos and Alföld did not show a significant difference in *Fusarium* infection and mycotoxin production. They exhibit the same level of tolerance towards *Fusarium spp.*

- The growing season's environmental conditions during anthesis showed a significant effect on *Fusarium* infection and mycotoxin production.

6. SCIENTIFIC PUBLICATIONS

El Chami, J., El Chami, E., Tarnawa, Á., Kassai, K.M., Kende, Z., Jolánkai, M., (2023). Influence of *Fusarium* head blight on technological quality of wheat. *Acta Phytopathologica et Entomologica Hungarica*. https://doi.org/10.1556/038.2023.00179

El Chami, E., El Chami, J., Tarnawa, Á., Kassai, K.M., Kende, Z., Jolánkai, M., (2023). *Fusarium* head blight in wheat: impact of growing season, wheat variety and nitrogen fertilization under natural infection. *Acta Phytopathologica et Entomologica Hungarica.*

El Chami, E., El Chami, J., Tarnawa, Á., Kassai, K.M., Kende, Z., Jolánkai, M., (2023). Influence of nitrogen fertilization on the technological quality of wheat. *Acta Agraria Debreceniensis.*

El Chami, E., El Chami, J., Tarnawa, Á., Kassai, K.M., Kende, Z., Jolánkai, M., (2022). Influence of growing season, nitrogen fertilization and wheat variety on *Fusarium* infection and mycotoxin production in wheat kernel. *Acta Alimentaria* 51, 282–289. https://doi.org/10.1556/066.2022.00036

El Chami, J., El Chami, E., Tarnawa, Á., Kassai, K. M., Kende, Z., & Jolánkai, M., (2022). Effect of *Fusarium* infection on wheat quality parameters. *Cereal Research Communications 51*(1), 179–187. https://doi.org/10.1007/S42976-022-00295-W

El Chami, E., El Chami, J., Tarnawa, Á., Kassai, K.M., Kende, Z., Jolánkai M, (2022). Agronomic impact on *Fusarium* infection and mycotoxin contamination of wheat grain. *Georgikon for Agriculture* 26, 96-104

Abd Ghani, R., Omar, S., El Chami, E., El Chami, J., Jolánkai, M., (2021). Agri-environmental impacts on yield formation of soybean crop. *Columella: Journal of Agricultural and Environmental Sciences* 8, 5–10. https://doi.org/10.18380/SZIE.COLUM.2021.8.2.5