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AKADÉMIAI KIADÓ

Influence of *Fusarium* head blight on technological quality of wheat

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RESEARCH ARTICLE

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ABSTRACT

Wheat is a cereal of special importance in the world cereal production. *Fusarium* head blight is one of the most important diseases of wheat caused by phytopathogenic *Fusarium* species that significantly reduce wheat production. This disease reduces grain yield and quality and causes the presence of harmful mycotoxins. The purpose of this study is to test the effect of *Fusarium* infection on wheat quality parameters in two wheat varieties Alföld and Mv Karéj. The results showed that *Fusarium* infection was higher in 2021 (91.47% and 95.20%) compared to 2020 (44.33% and 40.27%) in the two wheat varieties used Alföld and Mv Karéj respectively. In Alföld, *Fusarium* infection had a negative effect on protein content, test weight, thousand kernel weight, gluten content and Zeleny sedimentation index, whereas falling number was not affected. In Mv Karéj, *Fusarium* infection had a negative effect on test weight, thousand kernel weight, falling number and Zeleny sedimentation index, whereas protein content and gluten content were not affected. Although *Fusarium* infection reduced wheat quality, Mv Karéj showed a stable protein and gluten content whereas Alföld showed a stable falling number. Thus, Mv Karéj is more tolerant to *Fusarium* infection compared to Alföld.

KEYWORDS

Fusarium, wheat, technological quality

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INTRODUCTION

Wheat is a cereal of special importance in the world cereal production. During crop production, both abiotic and biotic stresses occur, often acting in combinations under field conditions (Mittler, 2002) and potentially increase sensitivity to pathogens. *Fusarium* head blight (FHB) is one of the most devastating fungal diseases of wheat and other small grain cereals and has caused serious epidemics worldwide (Bai et al., 2003) The major fungal pathogen associated with this disease in wheat is *Fusarium graminearum* (Kikot et al., 2011). During the wheat's flowering stage, *Fusarium* infection occurs when weather conditions become favorable. The infection begins in the middle of the wheat spike and then spreads throughout the rest of it, eventually causing the entire ear spike to turn white and the kernels to become light-weight and shrivelled (Kelly et al., 2015). Occurrence of FHB can be a serious problem because of several reasons, such as considerable economic losses caused by lowered yield, deteriorated grain quality (Bottalico and Perrone, 2002; Argyris et al., 2003; Prange et al., 2005), and possible contamination of infested grain with mycotoxins that are known to be harmful for both consumer and livestock health (Dexter and Nowicki, 2003).

In many regions, severe intensity of FHB occurs in cultivated wheat approximately two to three times per decade (Shaner, 2003; Stack, 2003; Champeil et al., 2004). Severe yield losses can occur during the epidemic year which are largely determined by the weather (Mesterházy et al., 2020). Thus, growers use multiple control measures to protect crops against FHB infections and prevent yield loss. The most important ways to control FHB are the use of FHB tolerant wheat varieties, good planting practices, fungicides, biological controls, and crop rotation (Mesterházy et al., 2015; Dendouga et al., 2016; Sakr and Shoaib, 2021).

Fusarium head blight poses a toxicological risk due to the mycotoxin contamination of wheat. In addition, it may influence grain components such as starch and proteins (Siuda et al., 2010) and impair wheat quality essential for baking performance (Lancova et al., 2008). Those biochemical changes in grain composition and subsequent changes in wheat quality traits are caused by the incomplete accumulation of the kernel constituents through the mechanical blocking of vascular bundles by fungal mycelium (Kang and Buchenauer, 2000; Ribichich et al., 2000; Goswami and Kistler, 2004) or through the impaired synthesis of grain components due to the presence of mycotoxins (Eriksen and Pettersson, 2004). Moreover, during the invasion of the kernel, *Fusarium ssp.* secretes enzymes such as carbohydrases and proteases that degrade the cell wall and the kernel components (Pekkarinen and Jones, 2000; Dexter and Nowicki, 2003; Eggert et al., 2011). As a result, FHB infection leads to poor end use quality (Dexter and Nowicki, 2003). The aim of this study is to investigate the effect of *Fusarium* infection on wheat quality parameters: falling number, protein and gluten content, test weight, thousand kernel weight and Zeleny sedimentation index.

MATERIAL AND METHODS

Two winter wheat varieties Alföld and Mv Karéj were examined under identical agronomic conditions in a long-term field trial. The trial was run at the Gödöllő experimental field of the Hungarian University of Agriculture and Life Sciences. The soil type of the experimental field is chernozem (calciustoll). Plots were sown and harvested by plot machines. The rate of sowing

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was 450–500 seeds per square meter. Weeds were controlled by herbicide and wheat pests and diseases beside *Fusarium* were controlled by pesticide. Each variety had a total plot area of 75 m^2. Each plot was then divided into 15 sub-plots of 5 m^2 each to create replications. At the end of the growing season, wheat grain samples were collected from each sub-plot and measured for *Fusarium* infection, protein content, gluten content, test weight, thousand kernel weight, falling number and Zeleny sedimentation index. Wheat kernels (100 kernels from each sample) were sanitized with a solution of PCNB and chloramphenicol and incubated under laboratory conditions on Nash and Snyder *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). After 7 days we counted the number of colonies to determine the level of *Fusarium* infection. The quality parameters were measured from wheat grain samples. Near infrared (NIR) spectroscopic equipment Mininfra Scan-T Plus 2.02 version was used to measure gluten, protein, and Zeleny sedimentation values of whole grains. Falling number was determined with Perten Type:1400 system, which meets the requirements of ICC method No. 107/1 1995. Test weight was measured with OS 1 type equipment which meets the requirements of ISO 7971-3:2019. Test weight and thousand kernel weight were determined with the KERN EMS and the Sartorius MA-30 precision scales. To determine the effect of *Fusarium* infection on wheat quality parameters, the linear regression module at 5% significance level of IBM SPSS V.21 statistical software was used. In addition, analysis of variance (ANOVA) module at 5% significance level was performed to determine the influence of growing season on *Fusarium* infection and quality parameters in Alföld and Mv Karéj varieties.

RESULTS

Fusarium infection level

Growing season significantly affected *Fusarium* infection [$F = 135.813$, $P = 0.000$] and [$F = 100.952$, $P = 0.000$]. *Fusarium* infection was higher in 2021 (91.47% and 95.20%) compared to 2020 (44.33% and 40.27%), in the two wheat varieties Alföld and Mv Karéj used, respectively (Table 1). Simple linear regression is used to test the effect of *Fusarium* infection on the following wheat quality parameters: protein content, test weight, thousand kernel weight, falling number, gluten content, and Zeleny sedimentation index.

Protein content

In Alföld, growing season significantly affected protein content [$F = 20.862$, $P = 0.000$] (Table 1). It was lower in 2021 (13.41%) compared to 2020 (14.75%). *Fusarium* infection had a strong negative effect on protein content in wheat [$R = -0.682$], protein content decreased when the infection increased. The fitted regression model between *Fusarium* infection and protein content is $y = -0.027x + 15.917$. The regression is statistically significant [$R^2 = 0.465$, $F = 24.309$, $P = 0.000$] (Fig. 1, Table 2).

In Mv Karéj, growing season did not affect protein content [$F = 3.443$, $P = 0.074$] (Table 1). *Fusarium* infection had no effect on protein content [$R = -0.310$]. The fitted regression model between *Fusarium* infection and protein content is $y = -0.007x + 15.047$. The regression is not statistically significant [$R^2 = 0.096$, $F = 2.974$, $P = 0.096$] (Fig. 1, Table 2).

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Table 1. Descriptive statistics and ANOVA for the influence of growing season on *Fusarium* infection and quality parameters in Alföld and Mv Karéj varieties

Descriptive statistics			Mean	Std. Deviation	Std. Error	Minimum	Maximum
Fusarium Infection	Alföld	2020	44.33	14.60	3.77	20	66
		2021	91.47	5.68	1.47	80	100
		Total	67.90	26.32	4.81	20	100
	Mv Karéj	2020	40.27	20.71	5.35	12	88
		2021	95.20	4.39	1.13	88	100
		Total	67.73	31.57	5.76	12	100
Protein Content	Alföld	2020	14.75	0.88	0.23	13.10	16.20
		2021	13.41	0.71	0.18	12.70	15.20
		Total	14.08	1.04	0.19	12.70	16.20
	Mv Karéj	2020	14.81	0.62	0.16	13.50	15.80
		2021	14.35	0.73	0.19	13	15.40
		Total	14.58	0.71	0.13	13	15.80
Test Weight	Alföld	2020	75.10	1.22	0.31	72.70	77.30
		2021	72.76	1.32	0.34	70.30	75.20
		Total	73.93	1.72	0.31	70.30	77.30
	Mv Karéj	2020	81.04	0.65	0.17	79.50	82.00
		2021	79.33	0.68	0.18	77.70	80.35
		Total	80.19	1.09	0.20	77.70	82.00
Thousand Kernel Weight	Alföld	2020	45.91	2.19	0.57	42.05	48.95
		2021	39.65	1.15	0.30	37.50	41.30
		Total	42.78	3.62	0.66	37.50	48.95
	Mv Karéj	2020	43.09	1.86	0.48	40.55	45.70
		2021	41.61	2.30	0.59	38.84	45.08
		Total	42.35	2.19	0.40	38.84	45.70
Falling Number	Alföld	2020	430.27	52.96	13.67	360	526
		2021	419.40	33.78	8.72	349.50	467
		Total	424.83	43.99	8.03	349.50	526
	Mv Karéj	2020	415.67	43.59	11.26	348	502
		2021	364.20	20.95	5.41	328	397
		Total	389.93	42.60	7.78	328	502

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Table 1. Continued

Descriptive statistics			Mean	Std. Deviation	Std. Error	Minimum	Maximum
Gluten Content	Alföld	2020	30.00	2.94	0.76	25.70	35.80
		2021	24.79	2.29	0.59	21.40	29.80
		Total	27.39	3.71	0.68	21.40	35.80
	Mv Karéj	2020	29.17	1.96	0.51	25.20	32.60
		2021	28.65	1.86	0.48	25.30	32.70
		Total	28.91	1.89	0.35	25.20	32.70
Zeleny Sedimentation Index	Alföld	2020	53.50	5.63	1.45	45.30	62.30
		2021	38.40	5.79	1.49	28.90	50.30
		Total	45.95	9.51	1.74	28.90	62.30
	Mv Karéj	2020	60.57	8.97	2.32	44.40	71.90
		2021	49.47	4.88	1.26	40.60	56.90
		Total	55.02	9.07	1.66	40.60	71.90

ANOVA			Sum of Squares	*df*	Mean Square	*F*	Sig.
Fusarium Infection	Alföld	Between Groups	16661.633	1	16661.633	135.813	0.000
		Within Groups	3435.067	28	122.681		
		Total	20096.700	29			
	Mv Karéj	Between Groups	22632.533	1	22632.533	100.952	0.000
		Within Groups	6277.333	28	224.190		
		Total	28909.867	29			
Protein Content	Alföld	Between Groups	13.467	1	13.467	20.862	0.000
		Within Groups	18.075	28	0.646		
		Total	31.542	29			
	Mv Karéj	Between Groups	1.587	1	1.587	3.443	0.074
		Within Groups	12.907	28	0.461		
		Total	14.494	29			
Test Weight	Alföld	Between Groups	40.950	1	40.950	25.338	0.000
		Within Groups	45.252	28	1.616		
		Total	86.202	29			
	Mv Karéj	Between Groups	21.845	1	21.845	48.936	0.000
		Within Groups	12.499	28	0.446		
		Total	34.345	29			

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Table 1. Continued

ANOVA			Sum of Squares	*df*	Mean Square	*F*	Sig.
Thousand Kernel Weight	Alföld	Between Groups	294.220	1	294.220	96.249	0.000
		Within Groups	85.592	28	3.057		
		Total	379.812	29			
	Mv Karéj	Between Groups	16.398	1	16.398	3.743	0.063
		Within Groups	122.656	28	4.381		
		Total	139.054	29			
Falling Number	Alföld	Between Groups	885.633	1	885.633	0.449	0.508
		Within Groups	55241.533	28	1972.912		
		Total	56127.167	29			
	Mv Karéj	Between Groups	19866.133	1	19866.133	16.984	0.000
		Within Groups	32751.733	28	1169.705		
		Total	52617.867	29			
Gluten Content	Alföld	Between Groups	203.841	1	203.841	29.351	0.000
		Within Groups	194.457	28	6.945		
		Total	398.299	29			
	Mv Karéj	Between Groups	2.028	1	2.028	0.557	0.462
		Within Groups	101.891	28	3.639		
		Total	103.919	29			
Zeleny Sedimentation Index	Alföld	Between Groups	1710.075	1	1710.075	52.412	0.000
		Within Groups	913.580	28	32.628		
		Total	2623.655	29			
	Mv Karéj	Between Groups	925.185	1	925.185	17.748	0.000
		Within Groups	1459.583	28	52.128		
		Total	2384.768	29			

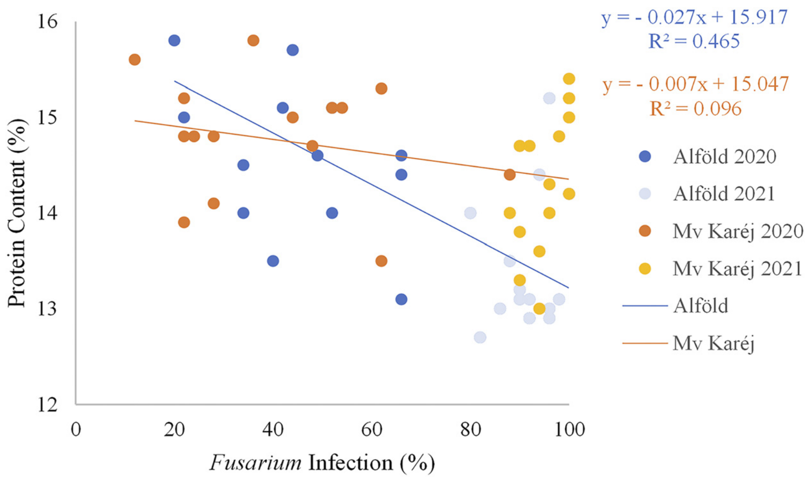

Fig. 1. Influence of *Fusarium* infection (%) on protein content (%)

Test weight

In Alföld, growing season significantly affected test weight [F = 25.338, P = 0.000] (Table 1). It was lower in 2021 (72.76 kg hL^{-1}) compared to 2020 (75.10 kg hL^{-1}). *Fusarium* infection had a strong negative effect on test weight [R = −0.626], test weight decreased when the infection increased. The fitted regression model between *Fusarium* infection and test weight is y = −0.041x + 76.714. The regression is statistically significant [R^2 = 0.391, F = 18.005, P = 0.000] (Fig. 2, Table 2).

In Mv Karéj, growing season significantly affected test weight [F = 48.936, P = 0.000] (Table 1). It was lower in 2021 (79.33 kg hL^{-1}) compared to 2020 (81.04 kg hL^{-1}). *Fusarium* infection had a strong negative effect on test weight in wheat [R = −0.692], test weight decreased when the infection increased. The fitted regression model between *Fusarium* infection and test weight is y = −0.024 + 81.802. The regression is statistically significant [R^2 = 0.479, F = 25.724, P = 0.000] (Fig. 2, Table 2).

Thousand kernel weight

In Alföld, growing season significantly affected thousand kernel weight [F = 96.249, P = 0.000] (Table 1). It was lower in 2021 (39.65 g) compared to 2020 (45.91 g). *Fusarium* infection had a strong negative effect on thousand kernel weight in wheat [R = −0.765], thousand kernel weight decreased when the infection increased. The fitted regression model between *Fusarium* infection and thousand kernel weight is y = −0.105x + 49.920. The regression is statistically significant [R^2 = 0.585, F = 39.441, P = 0.000] (Fig. 3, Table 2).

In Mv Karéj, growing season did not affect thousand kernel weight [F = 3.743, P = 0.063] (Table 1). *Fusarium* infection had a moderate negative effect on thousand kernel weight in wheat [R = −0.454], thousand kernel weight decreased when the infection increased. The fitted regression model between *Fusarium* infection and thousand kernel weight is y = −0.031x + 44.483. The regression is statistically significant [R^2 = 0.206, F = 7.264, P =0.012] (Fig. 3, Table 2).

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Table 2. Model summary, ANOVA and coefficients for the influence of *Fusarium* infection on quality parameters in Alföld and Mv Karéj varieties

Model Summary		*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
Protein Content	Alföld	0.682	0.465	0.446	0.777
	Mv Karéj	0.310	0.096	0.064	0.684
Test Weight	Alföld	0.626	0.391	0.370	1.369
	Mv Karéj	0.692	0.479	0.460	0.800
Thousand Kernel Weight	Alföld	0.765	0.585	0.570	2.373
	Mv Karéj	0.454	0.206	0.178	1.986
Falling Number	Alföld	0.142	0.020	−0.015	44.315
	Mv Karéj	0.428	0.183	0.154	39.176
Gluten Content	Alföld	0.716	0.512	0.495	2.635
	Mv Karéj	0.009	0.000	−0.036	1.926
Zeleny Sedimentation Index	Alföld	0.747	0.557	0.542	6.440
	Mv Karéj	0.613	0.375	0.353	7.294

ANOVA			Sum of Squares	*df*	Mean Square	*F*	Sig.
Protein Content	Alföld	Regression	14.658	1	14.658	24.309	0.000
		Residual	16.884	28	0.603		
		Total	31.542	29			
	Mv Karéj	Regression	1.392	1	1.392	2.974	0.096
		Residual	13.102	28	0.468		
		Total	14.494	29			
Test Weight	Alföld	Regression	33.737	1.000	33.737	18.005	0.000
		Residual	52.466	28.000	1.874		
		Total	86.202	29.000			
	Mv Karéj	Regression	16.445	1.000	16.445	25.724	0.000
		Residual	17.900	28.000	0.639		
		Total	34.345	29.000			
Thousand Kernel Weight	Alföld	Regression	222.123	1.000	222.123	39.441	0.000
		Residual	157.689	28.000	5.632		
		Total	379.812	29.000			
	Mv Karéj	Regression	28.644	1.000	28.644	7.264	0.012
		Residual	110.411	28.000	3.943		
		Total	139.054	29.000			

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Table 2. Continued

ANOVA			Sum of Squares	*df*	Mean Square	*F*	Sig.
Falling Number	Alföld	Regression	1139.541	1.000	1139.541	0.580	0.453
		Residual	54987.626	28.000	1963.844		
		Total	56127.167	29.000			
	Mv Karéj	Regression	9645.185	1.000	9645.185	6.285	0.018
		Residual	42972.682	28.000	1534.739		
		Total	52617.867	29.000			
Gluten Content	Alföld	Regression	203.948	1.000	203.948	29.383	0.000
		Residual	194.351	28.000	6.941		
		Total	398.299	29.000			
	Mv Karéj	Regression	0.009	1.000	0.009	0.002	0.962
		Residual	103.910	28.000	3.711		
		Total	103.919	29.000			
Zeleny Sedimentation Index	Alföld	Regression	1462.319	1.000	1462.319	35.257	0.000
		Residual	1161.336	28.000	41.476		
		Total	2623.655	29.000			
	Mv Karéj	Regression	895.056	1.000	895.056	16.823	0.000
		Residual	1489.712	28.000	53.204		
		Total	2384.768	29.000			

Coefficients			Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
			B	Std. Error	Beta		
Protein Content	Alföld	*Fusarium*	−0.027	0.005	−0.682	−4.930	0.000
		(Constant)	15.917	0.398		39.989	0.000
	Mv Karéj	*Fusarium*	−0.007	0.004	−0.310	−1.725	0.096
		(Constant)	15.047	0.300		50.196	0.000
Test Weight	Alföld	*Fusarium*	−0.041	0.010	−0.626	−4.243	0.000
		(Constant)	76.714	0.702		109.332	0.000
	Mv Karéj	*Fusarium*	−0.024	0.005	−0.692	−5.072	0.000
		(Constant)	81.802	0.350		233.474	0.000

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Table 2. Continued

Coefficients			Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	*t*	Sig.
Thousand Kernel Weight	Alföld	*Fusarium*	−0.105	0.017	−0.765	−6.280	0.000
		(Constant)	49.920	1.216		41.038	0.000
	Mv Karéj	*Fusarium*	−0.031	0.012	−0.454	−2.695	0.012
		(Constant)	44.483	0.870		51.119	0.000
Falling Number	Alföld	*Fusarium*	−0.238	0.313	−0.142	−0.762	0.453
		(Constant)	441.002	22.715		19.414	0.000
	Mv Karéj	*Fusarium*	−0.578	0.230	−0.428	−2.507	0.018
		(Constant)	429.057	17.167		24.993	0.000
Gluten Content	Alföld	*Fusarium*	−0.101	0.019	−0.716	−5.421	0.000
		(Constant)	34.234	1.350		25.350	0.000
	Mv Karéj	*Fusarium*	−0.001	0.011	−0.009	−0.049	0.962
		(Constant)	28.944	0.844		34.287	0.000
Zeleny Sedimentation Index	Alföld	*Fusarium*	−0.270	0.045	−0.747	−5.938	0.000
		(Constant)	64.266	3.301		19.468	0.000
	Mv Karéj	*Fusarium*	−0.176	0.043	−0.613	−4.102	0.000
		(Constant)	66.938	3.196		20.942	0.000

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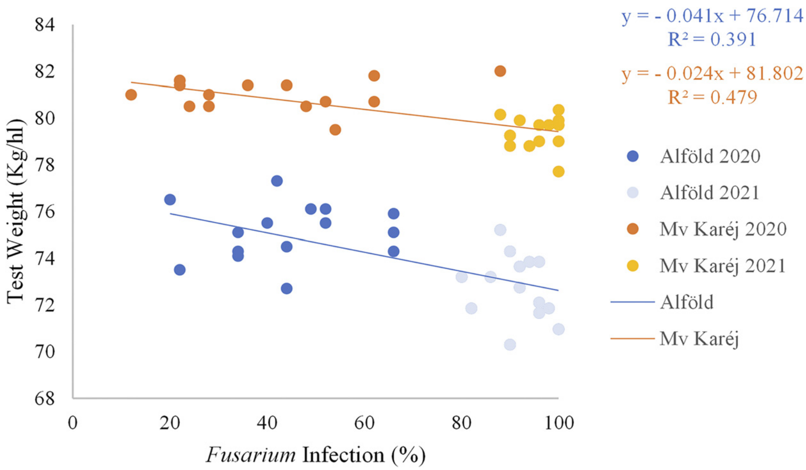

Fig. 2. Influence of *Fusarium* infection (%) on test weight (kg hL^{-1})

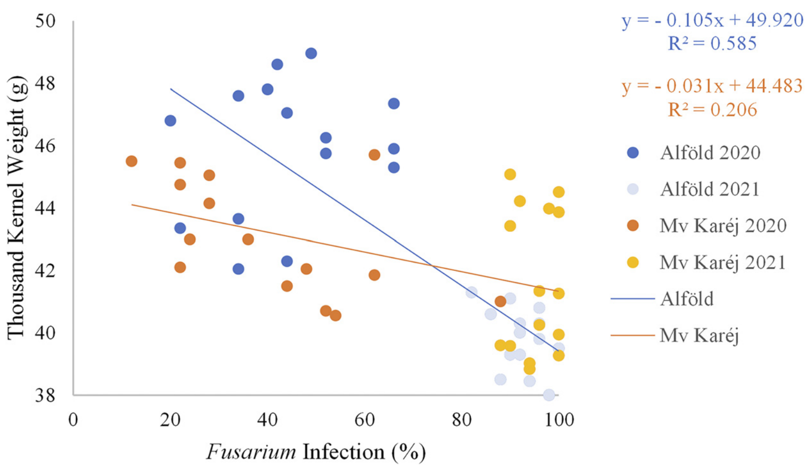

Fig. 3. Influence of *Fusarium* infection (%) on thousand kernel weight (g)

Falling number

In Alföld, growing season did not affect falling number [F = 0.449, P = 0.508] (Table 1). *Fusarium* infection had no effect on falling number in wheat [R = −0.142]. The fitted regression model between *Fusarium* infection and falling number is y = −0.238x + 441.002. The regression is not statistically significant [R^2 = 0.020, F = 0.580, P = 0.453] (Fig. 4, Table 2).

In Mv Karéj, growing season significantly affected falling number [F = 16.984, P = 0.000] (Table 1). It was lower in 2021 (364.30 s) compared to 2020 (415.67 s). *Fusarium* infection had a moderate negative effect on falling number in wheat [R = −0.428], falling number decreased when the infection increased. The fitted regression model between *Fusarium* infection and

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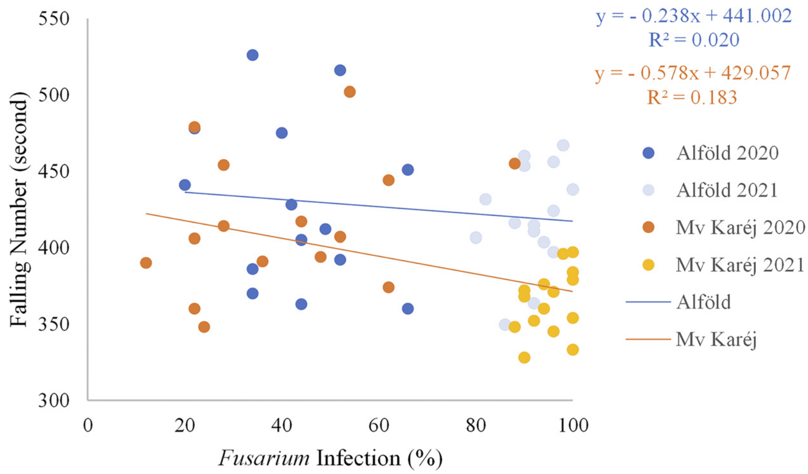

Fig. 4. Influence of *Fusarium* infection (%) on falling number (second)

falling number is y = −0.578x + 429.057. The regression is statistically significant [R^2 = 0.183, F = 6.285, P = 0.018] (Fig. 4, Table 2).

Gluten content

In Alföld, growing season significantly affected gluten content [F = 29.351, P = 0.000] (Table 1). It was lower in 2021 (24.79%) compared to 2020 (30%). *Fusarium* infection had a strong negative effect on gluten content in wheat [R = −0.716], gluten content decreased when the infection increased. The fitted regression model between *Fusarium* infection and gluten content is y = −0.101x + 34.234. The overall regression is statistically significant [R^2 = 0.512, F = 29.383, P = 0.000] (Fig. 5, Table 2).

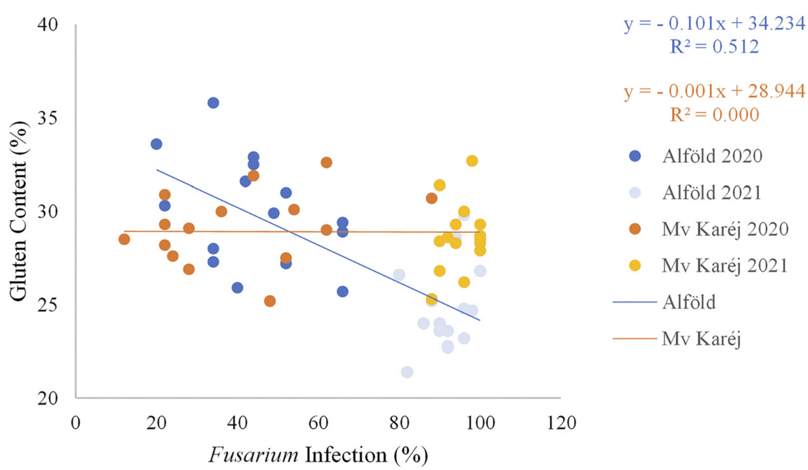

Fig. 5. Influence of *Fusarium* infection (%) on gluten content (%)

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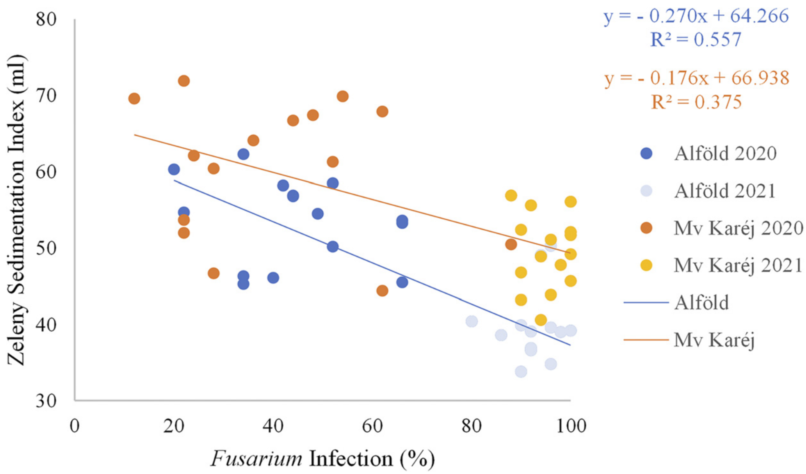

Fig. 6. Influence of *Fusarium* infection (%) on Zeleny sedimentation index (mL)

In Mv Karéj, growing season did not affect gluten content [$F = 0.557$, $P = 0.462$] (Table 1). *Fusarium* infection had no effect on gluten content in wheat [$R = -0.009$] The fitted regression model between *Fusarium* infection and gluten content is y = −0.001x + 28.944. The regression is not statistically significant [$R^2 = 0.000$, $F = 0.002$, $P = 0.962$] (Fig. 5, Table 2).

Zeleny sedimentation index

In Alföld, growing season significantly affected Zeleny sedimentation index [$F = 52.412$, $P = 0.000$] (Table 1). It was lower in 2021 (38.40 mL) compared to 2020 (53.5 mL). *Fusarium* infection had a strong negative effect on Zeleny sedimentation index in wheat [$R = -0.747$], Zeleny sedimentation index decreased when the infection increased. The fitted regression model between *Fusarium* infection and Zeleny sedimentation index is y = −0.270x + 64.266. The overall regression is statistically significant [$R^2 = 0.557$, $F = 35.257$, $P = 0.000$] (Fig. 6, Table 2).

In Mv Karéj, growing season significantly affected Zeleny sedimentation index [$F = 17.748$, $P = 0.000$] (Table 1). It was lower in 2021 (49.47 mL) compared to 2020 (60.57 mL). *Fusarium* infection had a strong negative effect on Zeleny sedimentation index in wheat [$R = -0.613$], Zeleny sedimentation index decreased when the infection increased. The fitted regression model between *Fusarium* infection and Zeleny sedimentation index is y = −0.176x + 66.938. The overall regression is statistically significant [$R^2 = 0.375$, $F = 16.823$, $P = 0.000$] (Fig. 6, Table 2).

DISCUSSION

This study was conducted to determine the impact of *Fusarium* infection on wheat quality during the two growing seasons 2020 and 2021. Differences in climatic conditions prevalent in the 2020 and 2021 growing seasons may be the reason for the increased *Fusarium* infection leading to poor wheat quality. According to El Chami et al. (2022), environmental

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factors play an important role in the determination of fungal development. Thus, fungal activity and the extent of its colonization are strongly determined by climatic conditions. Our study showed that increased *Fusarium* infection adversely affected wheat quality. Prange et al. (2005) and Antes et al. (2001) found that severe *Fusarium* infection had no significant effect on wheat quality parameters. On the contrary, Seitz et al. (1986) and Gärtner et al. (2008) observed in their study that *Fusarium* infection adversely affected wheat quality parameters.

The results showed that *Fusarium* infection decreases protein content in Alföld which is observed by Bechtel et al. (1985), Nightingale et al. (1999), Prange et al. (2005) and Gärtner et al. (2008). However, in Mv Karéj *Fusarium* infection did not have an effect on protein content which is supported by the findings of other studies (Seitz et al., 1986; Dexter et al., 1996; Prange et al., 2005; Wang et al., 2005; Terzi et al., 2007). Other studies found an increase of protein content after severe *Fusarium* infection (Meyer et al., 1986; Boyacioğlu and Hettiarachchy, 1995; Pawelzik et al., 1998; Matthäus et al., 2004; Siuda et al., 2010).

The results showed that *Fusarium* infection decreases gluten contents in Alföld. Dexter et al. (1997) and Gärtner et al. (2008) agrees with the observations of other studies (Meyer et al., 1986; Boyacioğlu and Hettiarachchy, 1995; Pawelzik et al., 1998) who found a slight decrease in gluten content in wheat kernels after *Fusarium* infection. However, in Mv Karéj gluten content was not affected by *Fusarium* infection. Wang et al. (2005) concluded that gluten content in the wheat grain was not affected by *Fusarium* infection. However, Boyacioğlu and Hettiarachchy (1995) concluded that gluten content in wheat kernels increased following their contamination with *Fusarium* species.

The results revealed that *Fusarium* infection decreases falling number in Mv Karéj. Fungal infection of spikes increases degradation of starch due to the presence of enzymes, such as α-amylase, the activity of which is measured using falling number (Wang et al., 2008). After infection with *Fusarium* a reduction of falling number could, therefore, be expected and has been confirmed (Dexter et al., 1996; Siuda et al., 2010). According to Hareland (2003), *Fusarium* species secretes enzymes such as α-amylase which degrade starch in wheat kernels, decreases the quality of wheat flour and lowers the values of the falling number. However, in Alföld falling number was not affected by *Fusarium* infection which was observed by Gärtner et al. (2008), whereby falling number remained unchanged by the infection.

The results revealed that *Fusarium* infection, in the two wheat varieties used Alföld and Mv Karéj, decreases Zeleny sedimentation index. Papousková et al. (2011) observed that Zeleny sedimentation index showed distinctively decreased values in the infected samples. *Fusarium* infection leads to the reduction of Zeleny sedimentation index in wheat kernels according to Meyer et al. (1986) and Gärtner et al. (2008). However, it had no effect on Zeleny sedimentation index in the findings of Kreuzberger et al. (2015).

The results indicated that test weight and thousand kernel weight, in the two wheat varieties used Alföld and Mv Karéj, were significantly decreased by *Fusarium* infection. Wong et al. (1995), McMullen et al. (2012) and Spanic et al. (2017) reported the negative effect that *Fusarium* infection has on test weight. Dexter et al. (1996), Wang et al. (2005) and Dvojkovic et al. (2007) found that *Fusarium* infection decreased thousand kernel weight. *Fusarium* infected kernels are damaged, shriveled, and light weight with low endosperm to bran ratio due to fungal carbohydrate consumption. Results from the mentioned studies indicate that *Fusarium* infection may reduce and deteriorate the quality of the wheat.

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CONCLUSION

In our study, the effect of *Fusarium* infection on wheat quality was analysed in two wheat varieties Alföld and Mv Karéj. The effect of *Fusarium* infection on wheat quality varied between the different wheat varieties as they showed different response patterns against *Fusarium* head blight. In Mv Karéj, *Fusarium* infection had a negative effect on test weight, thousand kernel weight, falling number and Zeleny sedimentation index, whereas protein content and gluten content were not affected. In Alföld, *Fusarium* infection had a negative effect on protein content, test weight, thousand kernel weight, gluten content and Zeleny sedimentation index, whereas falling number was not affected. Although *Fusarium* infection reduced wheat quality, Mv Karéj showed a stable protein and gluten content whereas Alföld showed a stable falling number. Thus, Mv Karéj is more tolerant to *Fusarium* infection compared to Alföld.

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