PhD Dissertation Theses

Agronomic and Phytopathological Evaluation of Precision Tillage Systems

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1. Background and Objectives of the PhD Dissertation

The continuous growth of the global population and the increasing demand for food security place ever-higher expectations on agricultural production. Maize, as one of the most widely cultivated field crops worldwide, plays a key role in food, feed, and industrial raw material supply. However, maize production faces major phytopathological challenges, among which *Fusarium* infection is one of the most severe. *Fusarium* can infect maize at any stage of the growing season, causing significant yield loss and leading to quality and toxicological issues even in isolation.

Advancements in crop production technology over the past decades have provided partial or context-dependent solutions to *Fusarium*-related challenges. However, climate change-induced weather extremes—particularly irregular precipitation and temperature anomalies—pose new and ongoing challenges for both growers and researchers.

The aim of this dissertation is to examine the combined effects of tillage systems, maize hybrids, and year-to-year variability on the occurrence, incidence, and mycotoxin-producing potential of *Fusarium* infection. The study also evaluates the impact of tillage on emergence dynamics, grain yield, and grain compositional parameters. Based on the observations, changes in both physical (e.g., grain mass) and compositional (e.g., protein, starch, and oil content) properties were demonstrated, depending on the investigated factors.

The objective of this dissertation is to contribute to the development of precision crop production and integrated plant protection strategies, with a particular focus on reducing the occurrence of mycotoxin-producing *Fusarium* species and minimizing food safety risks in maize production.

Based on the above challenges and research gaps, the specific objectives of this study were as follows:

1. To evaluate the emergence dynamics of maize under four different tillage systems.
2. To assess how the timing of maize emergence under four different tillage systems affects grain yield and its physical and compositional parameters.

3. To determine the extent of maize stalk base infection under four tillage systems and its impact on yield quantity.

4. To identify the *Fusarium* species (*Fusarium* spp.) present in maize grain under four tillage systems.

5. To determine the contamination levels of deoxynivalenol (DON) and fumonisin toxins (FB1, FB2, FB3, FB4) in maize kernels under different tillage systems.

6. To assess the internal *Fusarium* infection levels of maize kernels under four tillage systems.

7. To detect acetylated fumonisin B1 derivatives in maize samples.

2. Materials and Methods

The experiments were conducted between 2020 and 2023 at the Multifactorial Agrotechnological Experimental Station of KITE Ltd., located near Nádudvar, Hungary. Among the three study years, 2020 and 2023 provided sufficient precipitation for maize cultivation. In both years, rainfall distribution was of key importance: in June and July 2020, precipitation was 1.5 times the multi-year average, while in July and August 2023, it exceeded the usual levels by 10–15%. In contrast, rainfall distribution in 2021 was unfavorable for maize: in March (33%) and April (52%) less than half the average rainfall occurred, and similarly low values were recorded during the critical periods of fertilization and grain filling (June: 14%, July: 69%).

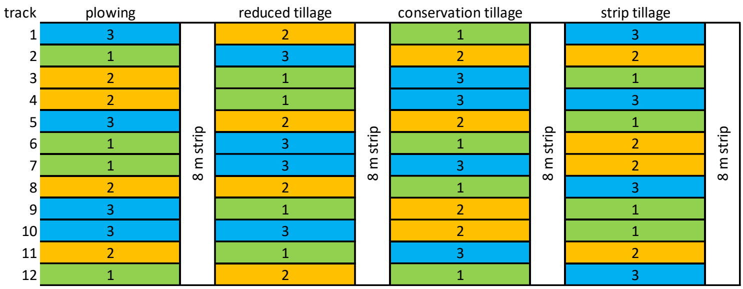

Figure 1: Experimental plots at the Multifactorial Agrotechnological Station of KITE Ltd. in Nádudvar. Legend: blue – Fornad (FAO 420); green – Armagnac (FAO 490); yellow – Loupiac (FAO 380) (Source: author's own editing)

2.1. Agrotechnical Parameters

Over three years, I investigated three forage maize hybrids (Zea mays L.) with different maturity groups (Loupiac – FAO 380, Fornad – FAO 420, Armagnac – FAO 490) across four tillage systems (Figure 1). The first treatment was conventional plowing (Rabe Cormoran), which leaves no residue on the soil surface. The second treatment was reduced tillage using a shallow-angled chisel subsoiler (Gaspardo Artiglio), creating approximately 15% mulch cover with a tillage depth of 30 cm. The third treatment, referred to as conservation tillage, involved the use of a straight chisel subsoiler (Orthman Digger), resulting in approximately 30% residue cover, also to a depth of 30 cm. The fourth treatment was strip tillage using the Orthman ST6 machine, which cultivated only 40% of the soil surface, distinguishing rows and interrows. Residues were pushed into the interrows with a row cleaner, leaving minimal mulch in the rows. In this system, the soil was tilled to a depth of 28 cm.

2.2. Weather Conditions

Throughout the experiment, weather conditions (precipitation and air temperature) were measured using KITE Ltd.'s proprietary meteorological station. For emergence dynamics, soil temperature data were collected from a 5 cm depth below the surface for 30 days post-sowing using soil thermometers. Sensors were installed 3–5 meters from the experimental plots, while soil temperature sensors were placed directly within the tillage plots. As previously noted, 2020 and 2023 had favorable rainfall amounts and distribution for maize, which was reflected in higher yields. Monthly mean air temperatures at the site differed slightly from the 10-year average. April, a critical period for early maize development, had milder temperatures in all three years, contributing to a slower initial development phase.

2.3. Methodology for Yield, Infection, and Toxin Content Assessment

Grain yield physical and compositional parameters (mass, thousand kernel weight, moisture, protein, oil, carbohydrate content) were analyzed using laboratory instruments. Yield data were collected using a precision yield-monitoring combine. Stalk base infection was assessed manually using the stalk-crushing method with random sampling. Endofusariosis was detected using DNA-based ITS sequencing. Mycotoxin analysis was performed using HPLC-MS technology, including the quantification of fumonisins B1–B4, deoxynivalenol (DON), and acetylated fumonisin derivatives. All data were subjected to statistical analysis.

2.4. Statistical Analysis

The effects of the different tillage systems were evaluated by comparing yield and compositional parameters. Given the study was conducted over three years with varying weather conditions, data were analyzed separately for each year to assess year effects in detail.

Hybrid comparisons were also performed annually based on average parameter values. Assumptions for parametric testing were assessed using Levene's test (homogeneity of variances) and Q–Q plots (normal distribution). As most data did not meet these assumptions, comparisons were made using the non-parametric Kruskal–Wallis test. Where significant differences were found among groups, pairwise comparisons were conducted using the Mann–Whitney U test. All statistical analyses were performed using IBM SPSS Statistics 28.0.1.0.

3. Results

3.1. Yield Results

The grain yield results of the different tillage systems showed significant differences over the three-year study period (KW-H = 13.4986; p = 0.0037). The highest average yield was recorded under conventional plowing (13.13 t/ha), which was significantly higher than that of reduced and strip tillage. The lowest yield was observed under conservation tillage (12.52 t/ha), which did not statistically differ from reduced and strip tillage. These findings are consistent with those of Győrffy and Szabó (1968), Drimba and Nagy (1998), Nagy (1995, 1996, 2007), Wilhelm and Wortmann (2004), Rátonyi et al. (2005), Jones et al. (2006), Cociu and Alionte (2011), and Kecskés et al. (2021) (Figure 2).

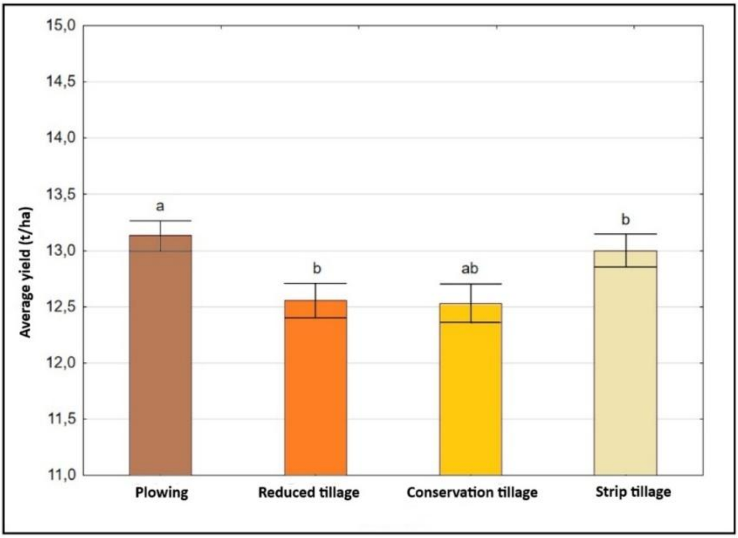

Figure 2: Maize grain yield under different tillage systems (t/ha; ±SE). Lowercase letters indicate significant differences based on Mann–Whitney U tests (p<0.05).

Year-specific yield data also showed significant variation across tillage systems (2020: KW-H = 26.356; p = 0.00001; 2021: KW-H =

552.2854; p = 0.0000; 2023: KW-H = 27.2307; p = 0.00001). In 2020, reduced tillage (15.81 t/ha) did not differ significantly from plowing (15.84 t/ha), whereas conservation (15.68 t/ha) and strip tillage (15.37 t/ha) resulted in significantly lower yields. In the dry year of 2021, the average maize yield declined, with the highest yield still under plowing (5.46 t/ha), significantly exceeding all other systems. In 2023, yield levels were comparable to 2020, with the lowest yield under reduced tillage (15.47 t/ha), which significantly differed from the other systems (Figure 3).

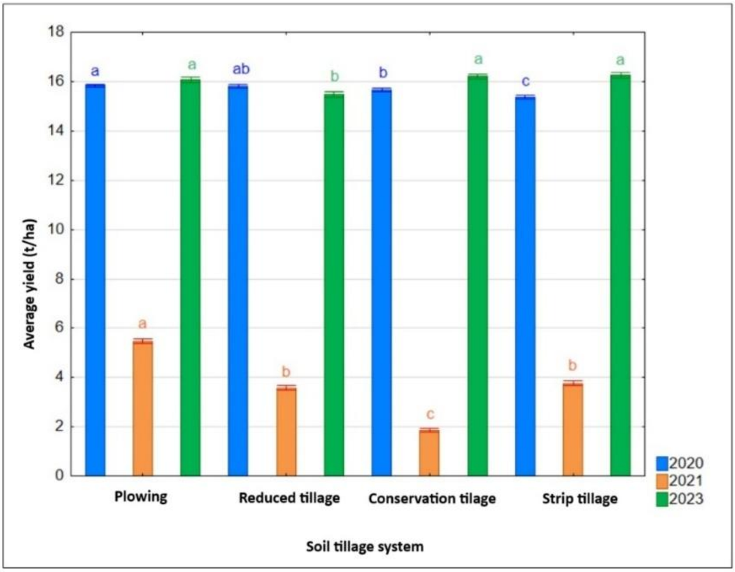

Figure 3: Maize yield per tillage system and year (t/ha; ±SE). Lowercase letters indicate significant differences ($p<0.05$).

Analyzing all three years together, significant differences were found among the hybrids (KW-H = 162.5174; p = 0.0000). All three hybrids differed statistically from each other. Loupiac had the lowest yield (12.37 t/ha), followed by Armagnac (12.46 t/ha), and Fornad yielded the highest (13.55 t/ha) (Figure 4).

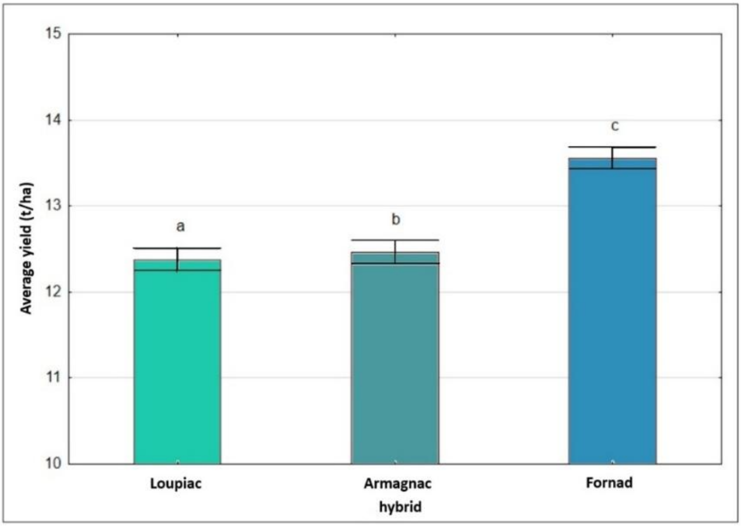

Figure 4: Maize yield by hybrid (t/ha; ±SE). Lowercase letters indicate significant differences ($p<0.05$).

3.2. Emergence Dynamics

Tillage systems had a significant impact on maize emergence dynamics. Based on the combined three-year data, emergence was fastest and most uniform under conventional plowing, significantly outperforming the other tillage treatments. Maize under plowing reached 80% emergence by day 3, while in strip tillage this level was reached only by day 5. From day 5 onwards, differences between tillage systems were not statistically significant (Figure 5).

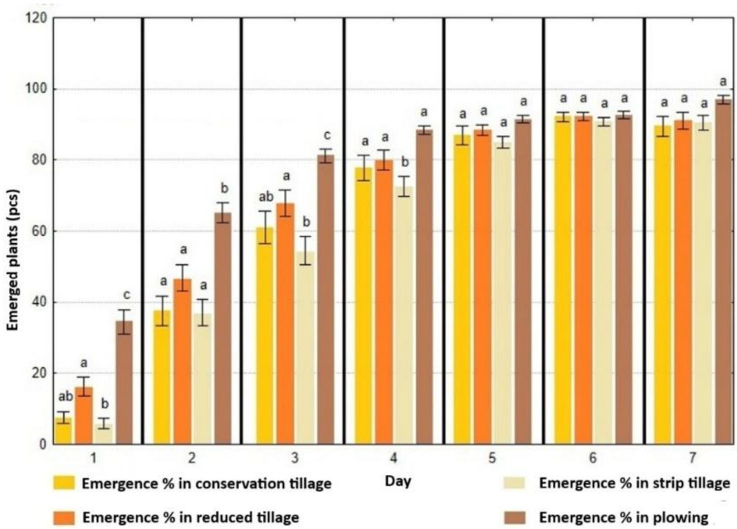

Figure 5: Cumulative emergence of maize under different tillage systems (plants; ±SE). Lowercase letters indicate significant differences (p<0.05).

The time of emergence significantly influenced ear weight (KW-H = 112.2445; p = 0.0000). No statistical difference was observed between ears that emerged on day 1 (217 g/ear) and day 2 (212 g/ear). However, ears emerging from day 3 onwards showed significantly lower weights. The smallest ears were recorded on days 5 (153 g) and 6 (138 g), with no difference between them, yet significantly smaller than earlier-emerging plants. The weight difference between day 1 and day 6 ears was 36% (Figure 6).

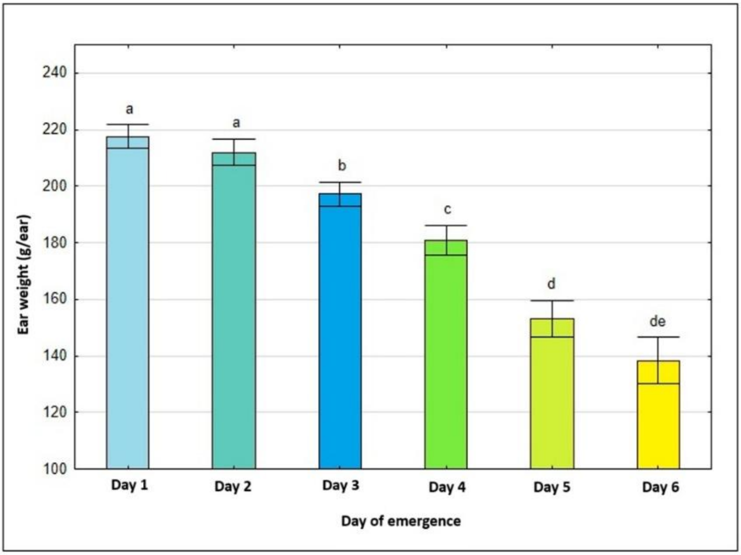

Figure 6: Effect of emergence timing on ear weight (g/ear; ±SE). Lowercase letters indicate significant differences ($p<0.05$).

Protein content in kernels differed significantly by emergence day (KW-H = 24.6707; p = 0.0002). No differences were found among plants that emerged within the first four days (6.84–7.02%). However, plants emerging on day 5 (7.37%) and day 6 (7.36%) had significantly higher protein contents, not differing from each other (Figure 7).

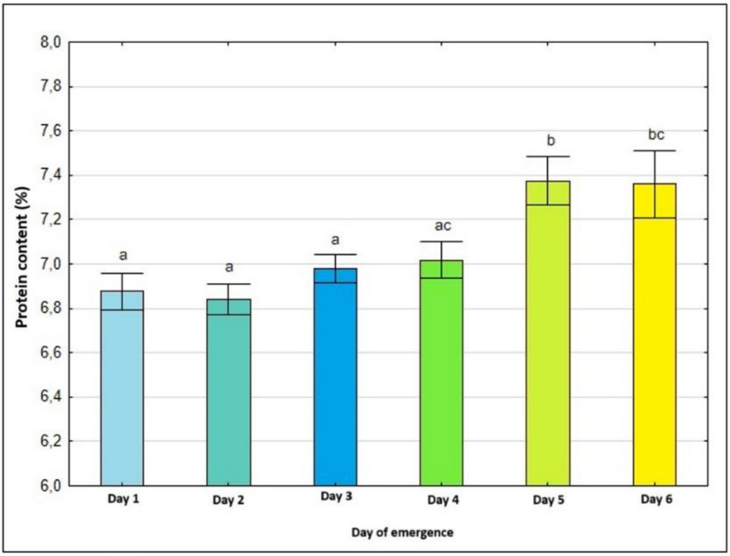

Figure 7: Kernel protein content by emergence day (%; ±SE). Lowercase letters indicate significant differences ($p<0.05$).

Starch content also varied significantly (KW-H = 40.3033; p = 0.00000). A slight decreasing trend was observed among the first four days, though not statistically significant. Day 5 plants had significantly lower starch content (63.59%), and day 6 plants (63.86%) had lower values than early-emerging plants but higher than day 5 (Figure 8).

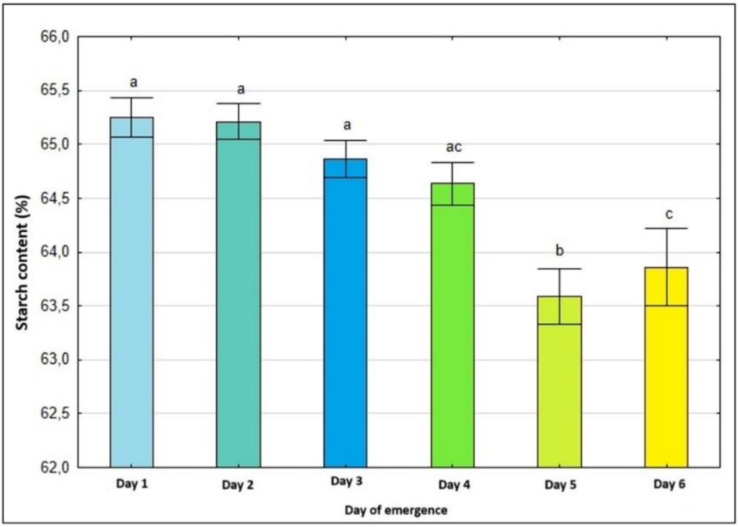

Figure 8: Kernel starch content by emergence day (%; ±SE). Lowercase letters indicate significant differences ($p<0.05$).

3.3. Stalk Base Rot Assessment

Significant differences in stalk base rot incidence were found between tillage systems (KW-H = 19.897; p = 0.0002). The lowest infection rate occurred under reduced tillage (10.12%), significantly lower than in other treatments. Plowing (13.21%) and conservation tillage (15.52%) did not differ significantly. The highest infection rate was under strip tillage (28.28%), significantly higher than all other systems (Figure 9).

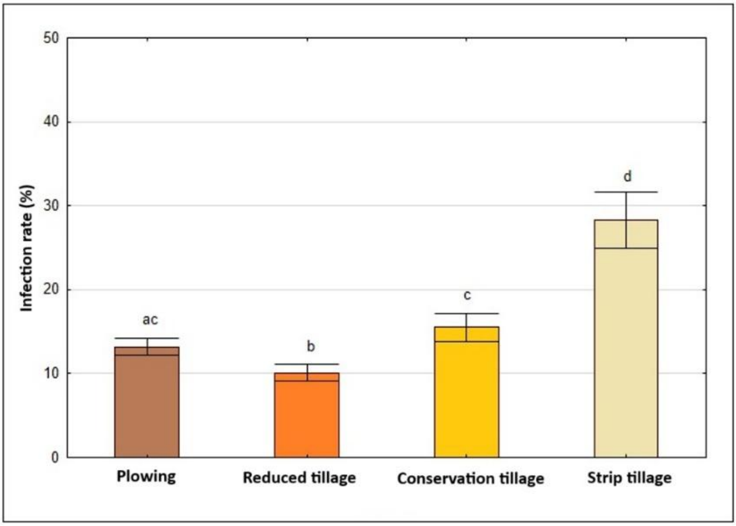

Figure 9: Incidence of stalk base rot under different tillage systems (%; ±SE). Lowercase letters indicate significant differences ($p<0.05$).

Significant differences were observed in the physical characteristics of maize yield depending on the health status of the plant stem base. The ears developed on healthy plants were, on average, 59 grams heavier, which represented a statistically significant difference. The number of kernels per ear was also higher in maize grown on healthy stalks, and this difference was likewise statistically significant. In addition, both the total kernel weight and the thousand kernel weight (TKW) were significantly greater in ears from healthy plants (Table 1). Similar findings regarding the impact of stem base diseases on yield-related physical parameters were reported by Costa et al. (2019).

Table 1: Physical yield parameters by stalk base infection status. Lowercase letters indicate significant differences ($p<0.05$).

Health status	Average ear weight (g) ± SE		Average number of kernels (pcs) ± SE		Average kernel weight (g) ± SE		Average thousand kernel weight (g) ± SE	
Healthy	236 ± 5,71	a	487 ± 7,83	a	207 ± 4,9	a	424 ± 7,75	a
Infected	177 ± 7,34	b	426 ± 14,35	b	158 ± 6,51	b	370 ± 6,95	b

3.4. Internal *Fusarium* Infection and Mycotoxin Results

Based on the measurements of mycotoxin contamination, I found that DON toxin levels varied across the three years. In 2020, the average concentration of DON was 0.2 mg/kg, while in 2021 and 2023, DON production was not detected. The FB1 toxin level differed significantly between all three years. The highest concentration was measured in 2021 (0.4 mg/kg). The concentration of FB2 was lower than that of FB1; the highest FB2 level was recorded in 2021 (0.13 mg/kg), which was significantly higher than the 0.02 mg/kg measured in 2020 but not significantly different from the 0.03 mg/kg observed in 2023.

The concentration of FB3 was 0.01 mg/kg in 2020, which did not differ significantly from the 2021 value (0.12 mg/kg), but was significantly lower than the level measured in 2023. The concentration of FB4 was the lowest among the fumonisins measured. In 2020, it was 0.003 mg/kg, not significantly different from the 2021 value (0.02 mg/kg), but significantly lower than the concentration observed in 2023.

These FB1–FB4 toxin results are consistent with findings reported in the literature, which indicate that most *F. verticillioides* and *F. proliferatum* strains produce B-type fumonisins in the descending order of FB1 > FB2 > FB3 > FB4 (Marín et al., 1995; Musser & Plattner, 1997; Anumudu et al., 2024).

I also evaluated the combined concentration of FB1 and FB2, as regulations define a joint maximum limit for these compounds. In none of the examined years did the fumonisin contamination exceed the legal threshold. The highest total FB1+FB2 concentration was measured in 2021 (0.53 mg/kg), which was significantly higher than the values recorded in the other two years (Table 2).

The ratio of FB1 to FB2 was consistent with the findings of Rheeder et al. (2002) and Chen et al. (2020). Furthermore, the studies of Mesterházy et al. (2022), conducted between 2012 and 2017, also confirmed the dominance of FB1 among total fumonisin content (72.63%), followed by FB2 (20.34%) and FB3 (7.03%).

Year	DON (mean) mg/kg ± SE		FB1 (mean) mg/kg ± SE		FB2 (mean) mg/kg ± SE		FB3 (mean) mg/kg ± SE		FB4 (mean) mg/kg ± SE		FB1+FB2 (mean) mg/kg ± SE	
2020	0,20 ± 0,0218	a	0,07 ± 0,0473	a	0,02 ± 0,0173	a	0,01 ± 0,0050	a	0,003 ± 0,0027	a	0,09 ± 0,0646	a
2021	0 ± 0,0000	b	0,40 ± 0,0925	b	0,13 ± 0,0327	b	0,12 ± 0,0870	ab	0,02 ± 0,0079	ab	0,53 ± 0,1252	b
2023	0 ± 0,0000	b	0,05 ± 0,0113	c	0,03 ± 0,0058	b	0,02 ± 0,0034	b	0,02 ± 0,0034	b	0,08 ± 0,0171	c

Table 2: Year effects on DON and fumonisin (FB1–FB4) levels. Lowercase letters indicate significant differences ($p<0.05$).

The level of internal *Fusarium* infection differed across the three years studied. In 2020 and 2021, the infection rates were 27% and 29%, respectively, with no statistically significant difference between them. In contrast, internal infection increased to 40% in 2023, which was significantly higher compared to the previous two years (Table 3).

Table 3: Internal *Fusarium* infection rates across three years. Lowercase letters indicate significant differences ($p<0.05$).

Year	Internal Fusarium infection (mean) % ± SE	
2020	27 ± 2,51	a
2021	29 ± 2,84	a
2023	40 ± 2,96	b

3.5. Laboratory Identification of Endophytic *Fusarium* Isolates

Fusarium species isolated from maize kernels were identified based on the β-tubulin (β-tub) gene region. The dominant species were *F. verticillioides* and *F. annulatum*, both members of the *Fusarium fujikuroi* species complex (FFSC). Additionally, *F. sporotrichioides* from the *Fusarium sambucinum* species complex (FSAMSC) was found. In five samples, distinction between *F. temperatum* and *F. subglutinans* was not possible, requiring further analysis (Figure 10, Table 4.)

Table 4: *Fusarium* species isolated from maize kernels by tillage system and hybrid.

Year	Tillage	Hybrid	Isolate code	Species	Type strain
2023	Conservation	Armagnac	LA7, LA9		
2023	Conservation	Fornad	LF12		
2023	Conservation	Loupiac	LL19		
2023	Reduced	Armagnac	RA16		
2023	Reduced	Fornad	RF19		
2023	Reduced	Loupiac	RL9, RL10		
2023	Strip	Armagnac	SA35, SA36	*F. annulatum*	CBS258.54
2023	Strip	Fornad	SF20, SF27, SF28		
2023	Strip	Loupiac	SL12		
2023	Plowing	Armagnac	SZA10, SZA11, SZA15		
2023	Plowing	Fornad	SZF23, SZF24		
2023	Plowing	Loupiac	SZL4, SZL8		
2023	Conservation	Loupiac	TL29, TL30		
2023	Reduced	Fornad	RF5	*F. sporotrichioides*	NRRL3299
2023	Reduced	Armagnac	RA14_2		
2023	Strip	Armagnac	SA22		
2023	Strip	Fornad	SF26	*F. subglutinans/ F. temperatum*	CBS747.97 MUCL52463
2023	Strip	Loupiac	SL2		
2023	Plowing	Loupiac	SZL1		
2023	Conservation	Armagnac	LA2, LA8		
2023	Conservation	Loupiac	LL17		
2023	Reduced	Armagnac	RA14, RA15, RA20		
2023	Reduced	Fornad	RF6, RF7, RF20		
2023	Reduced	Loupiac	RL11		
2023	Strip	Fornad	SF5, SF19	*F. verticillioides*	CBS218.76
2023	Strip	Loupiac	SL3, SL10, SL23		
2023	Plowing	Armagnac	SZA14		
2023	Plowing	Loupiac	SZL3, SZL7		
2023	Conservation	Armagnac	TA33, TA34		
2023	Conservation	Fornad	TF32		

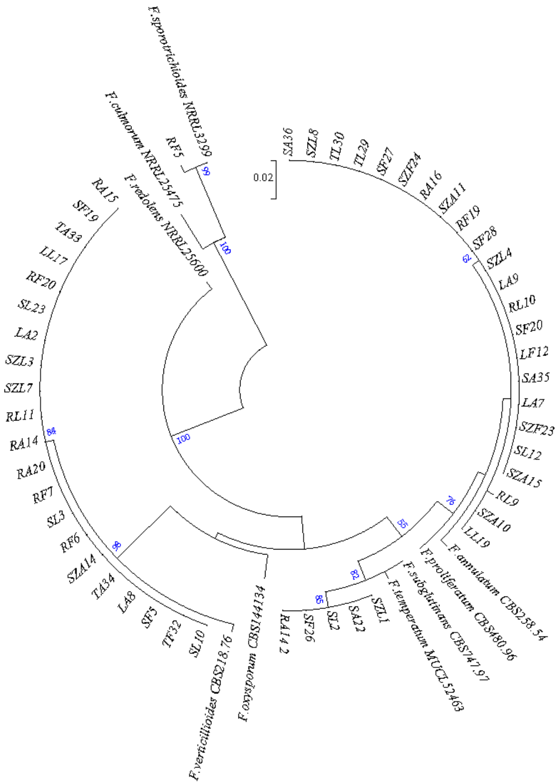

Figure 10: Phylogenetic tree of *Fusarium* isolates based on Maximum Likelihood analysis (MEGA7) with 1000 bootstrap replicates. Only bootstrap values >50% are shown.

During the three cropping years, the level of internal *Fusarium* infection in maize kernels varied. Not only the percentage of *Fusarium* infection differed by year, tillage system, and hybrid, but also the species composition of *Fusarium*. Analyzing the years separately, the highest level of internal *Fusarium* infection was recorded in 2023 (39.7%), with the highest proportion of *F. verticillioides* (19.17%). In 2021, a lower internal infection rate was observed (28.86%) compared to 2023; however, the proportion of *F. verticillioides* was the highest in this year (19.27%). The lowest internal *Fusarium* infection rate was measured in 2020 (26.09%), while the proportion of DON-producing *Fusarium* species was the highest in this year (4.58%), exceeding the values measured in the other two years. The *F. verticillioides* infection rate in 2020 was 8.33%, the lowest among the three examined years (Figure 11). My findings are consistent with those of Tóth et al. (2012), who reported that *F. verticillioides* was the dominant species in Hungary, while *F. sporotrichioides* and *F. subglutinans* were present in lower numbers.

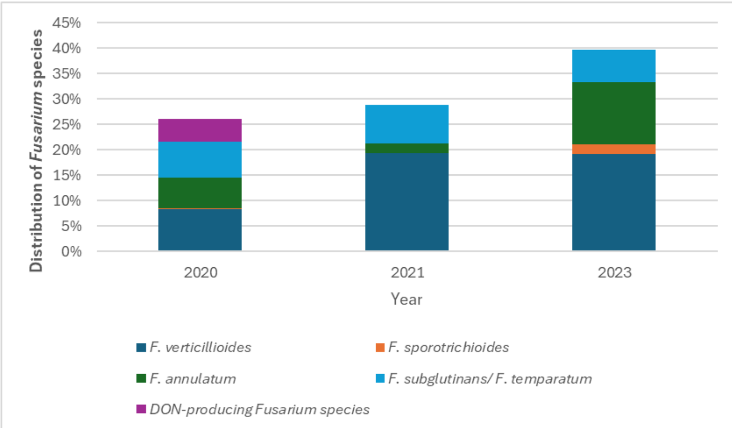

Figure 11: Average *Fusarium* species composition across three years

Tillage systems also influenced internal *Fusarium* infection. Strip tillage had the highest infection rate (38.89%), followed by reduced (36.39%), conservation (28.81%), and plowing (26.8%). *F. verticillioides* was most abundant under reduced tillage (20%), while *F. annulatum* (11.25%), *F. sporotrichioides* (1.67%), *F. subglutinans/temperatum* (8.19%), and DON-producing *Fusarium* species (2.22%) were most prevalent under strip tillage (Figure 12).

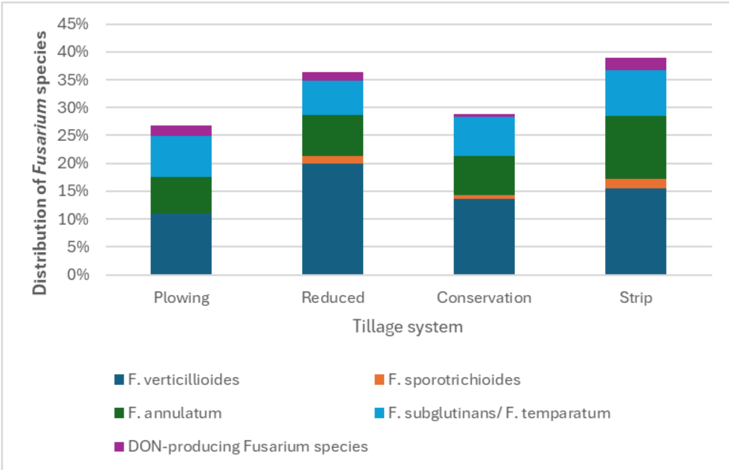

Figure 12: *Fusarium* species composition by tillage system (3-year average)

3.6. Detection of Acetylated Fumonisin B1 Derivatives

Higher fumonisin concentrations were detected in maize samples from 2021, so these were used for acetylated FB1 derivative analysis. Acetylated FB1 compounds were detected across all tillage systems. Similar findings were reported by Flavigna et al. (2013) under field conditions in Italy. Although acetylated FB1 represents only a small fraction of total FB1, it is considered significantly more toxic (Park et al., 2013; Csenki et al., 2023). Since its human toxicity profile is not yet fully known, future risk assessments in food and feed safety should take these derivatives into account (Table 5).

Table 5: Detected acetylated FB1 derivatives in maize samples

Unit / sample	Presumably 10-*O*-linoleoil-FB1	5-*O*-linoleoil-FB1	Presumably 10-*O*-palmitoil-FB1	5-*O*-palmitoil-FB1	Presumably 10-*O*-oleoil-FB1	5-*O*-oleoil-FB1
	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
Plowing 2021	15,4	21,1	2	3,7	6,4	5,4
Reduced 2021	15,2	33,2	32,9	77,1	5,2	8,4
Conservation 2021	11,6	21,6	3,6	8	3,8	6,2
Strip 2021	17,2	18,5	2,7	3,1	6,6	4,6
Conservation 2021	18,7	17,4	3,3	3,9	8,4	5

4. NEW SCIENTIFIC RESULTS OF THE DISSERTATION

1. I established that under field conditions in Nádudvar in 2021, fumonisins produced by *Fusarium verticillioides* included acylated derivatives in maize grain. For the first time worldwide, we identified acylated FB1 toxin derivatives in maize after quantification with authentic calibration standards. This fungus produced fumonisins under warm and dry weather conditions, whereas ears infected with DON-producing *Fusarium* spp. produced DON toxin under warm and humid conditions. In Nádudvar, under natural *Fusarium* spp. infection, different tillage systems resulted in varying levels of mycotoxin contamination.

2. I established that in no-tillage systems the emergence dynamics of maize were delayed by 1–2 days compared to ploughing. Based on three years of experiments conducted in Nádudvar, I found that emergence dynamics differed according to tillage. Soils with less crop residue cover (ploughing, reduced tillage) were 1–2 °C warmer during the first 2–3 weeks after sowing. Significant differences were found between the yield parameters of plants that emerged on day 1 and day 5, with earlier-emerging plants achieving higher yields than later-emerging ones.

3. I established that the highest yields were achieved under ploughing across the three years studied. There were large differences between years: in 2021, due to below-average rainfall, yield under ploughing was 5.46 t/ha, which was significantly higher than in other tillage systems. In both 2020 and 2023, the highest average yields were also recorded under ploughing. Compared to 2021, balanced rainfall resulted in yields 10.38 t/ha higher in 2020 and 10.61 t/ha higher in 2023 under ploughing.

4. I established that in Nádudvar, on meadow chernozem soil, maize yield was primarily determined by rainfall during the middle of the growing season (June–July). In the wet year 2020, the longest-season hybrid Armagnac (FAO 490) achieved the highest yield at 16.13 t/ha, whereas in the drought year 2021, the shorter-season Fornad hybrid (FAO 420) performed best with 4.36 t/ha. In the also wet year 2023, the Fornad hybrid produced 17.14 t/ha, which statistically exceeded the yield of Loupiac (15.6 t/ha) and Armagnac (15.17 t/ha). In June and July 2020, rainfall was 1.5 times the long-term average, while in

the same months of 2021 only 14% and 69% of the long-term average fell. In 2023, compared to the long-term average, June rainfall was 79% and July rainfall 110%.

5. I demonstrated that in Nádudvar, on meadow chernozem soil, maize grain quality parameters (protein, starch, oil content) were influenced by both tillage methods and year effects (2020, 2021, 2023). In 2021 and 2023, protein content differed significantly between tillage methods. Compared to the 2020 value (6%), it was 30% higher (8%) in 2021 and 15% higher in 2023. Oil and starch contents in 2020 showed statistically significant differences between tillage systems. Starch content was 8–9% lower in 2021 and 4–5% lower in 2023 (64%) compared to 2020 (67%). Oil content was 4–9% higher in 2021 compared to 2020 (3.1%), and 16–18% higher in 2023.

6. I demonstrated that stalk rot incidence was also influenced by tillage systems. The lowest infection rates were recorded under reduced tillage (10.12%) and ploughing (13.21%), with no significant difference between them. The highest infection rate was observed under strip tillage (28.28%), which was significantly higher than in other tillage systems. Among yield components, ear weight was 33%, kernel number 14%, kernel mass 31%, and thousand-kernel weight 31% lower in plants affected by stalk rot compared to healthy plants.

5. PRACTICAL IMPLICATIONS OF THE RESULTS

1. Maize emergence dynamics are significantly influenced by the four different tillage systems. Plants that emerge within the first 48–72 hours have the highest yield potential. Therefore, special attention should be paid to the amount of crop residue remaining on the soil surface after primary tillage, as this factor strongly affects soil warming in early spring and, consequently, the pace of emergence.

2. Mycotoxin contamination depends on the year, tillage method, and hybrid. In wetter years (e.g., 2020), DON toxin dominates, while in drier years (2021 and 2023), fumonisins are more prevalent. DON contamination was highest under strip tillage, while fumonisin contamination was high under strip, conservation, and reduced tillage systems. The lowest toxin levels were observed in the Loupiac hybrid. These factors should be carefully considered in mycotoxin risk assessment.

3. Acetylated fumonisins were detected across all tillage systems. To enhance food safety, it is advisable to monitor and evaluate these toxin derivatives in future studies and surveillance systems.

4. The incidence of stalk base rot was highest under strip tillage. When applying strip tillage, attention must be paid to reducing the factors that contribute to infection (e.g., soil-borne *Fusarium* species, entry points created by pests) through integrated plant protection strategies.

5. Maize yield can be improved through integrated crop management practices. Technological interventions that mitigate the effects of extreme weather, the choice of an appropriate tillage method and hybrid, as well as sowing under optimal soil temperature conditions, can help reduce yield fluctuations.

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4. Publications Related to the Topic of the Dissertation

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Candidate: István Kecskés
Doctoral School: Kálmán Kerpely Doctoral School
MTMT ID: 10086927

List of publications related to the dissertation

Hungarian scientific articles in Hungarian journals (5)

1. **Kecskés, I.**, Csótó, A., Nagy, J.: Kukoricaszártő megbetegedés mértékének meghatározása eltérő talajművelési rendszerekben.
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List of other publications

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13. Sojnóczki, I., Nagy, J., **Kecskés, I.**: Impact of tillage systems on maize emergence.
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