

THE EFFECT OF PHYTOSANITARY TREATMENTS ON WHEAT CROP (*Triticum aestivum* L.) AGAINST *Zymoseptoria tritici* (Desmazières) Quaedvlieg & Crous AND *Blumeria graminis* F. sp. *tritici* (Decandolle) Speer

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Abstract

Wheat (*Triticum aestivum* L.) is one of the most important and widely cultivated cereals; however, grain yield can be significantly affected by pathogen attacks, especially *Zymoseptoria tritici* (Desmazières) Quaedvlieg & Crous and *Blumeria graminis* (de Candolle) Speer. These pathogens reduce photosynthesis, affect plant vigor, and cause significant yield losses. To reduce these losses, it is necessary to use specific plant protection products containing active substances with different modes of action. This research was carried out in Iasi County and includes observations on crop phytotoxicity and vigor, the severity and incidence of pathogen attacks, as well as the effectiveness of treatments. The studied variety was FDL Miranda, on which 14 plant protection products were applied. Following the conducted research, it was observed that the wheat plants did not exhibit phytotoxicity to any of the applied products, and the crop vigor was very good. The pathogen *Zymoseptoria tritici* recorded the lowest attack severity of 6.00% when the product Priaxor EC (1.0 L/ha) was applied, while for *Blumeria graminis*, the variant treated with Revyicare (1.5 L/ha) recorded the lowest attack severity of 4.83%.

Key words: diseases management, plant protection product, treatment, winter wheat.

INTRODUCTION

Wheat is the primary crop cultivated globally, spanning diverse geographical regions, environments, and production systems.

It is grown on over 220 million hectares annually, yielding more than 798 million tons with an average productivity of 3,624.99 kg/ha according Food and Agriculture Organization. Despite its importance, wheat productivity is consistently threatened by biotic and abiotic factors, coupled with the slow adoption of advanced agricultural technologies.

Among biotic stressors, *Zymoseptoria tritici* (Desmazières) Quaedvlieg & Crous and *Blumeria graminis* (de Candolle) Speer are two of the most significant pathogens (Ünal et al., 2017).

Annual production losses are estimated at approximately 20.75% (Stukenbrock & Gurr, 2023), a figure that continues to rise due to rapid mutations and the increasing diversity of virulent strains (Singh et al., 2016).

Blumeria graminis is the causative agent of powdery mildew in wheat. As an obligate parasite, it induces yield losses ranging from 5% to 35% (He et al., 2011), with extreme regional impacts recorded in Egypt (22.52%), Russia (33.00%), and Brazil (62.00%) (Kayim et al., 2022). The pathogen affects leaves, stems, and ears throughout the growing season, following a polycyclic epidemic pattern. This cycle is characterized by rapid conidial infections, with new conidia being formed and released within just a few days (Cao et al., 2012). While biological control agents such as *Ampelomyces quisqualis* and *Pseudozyma flocculosa* have been successfully registered for use in viticulture and horticulture (Kiss et al., 2004; Paulitz & Bélanger, 2001), no commercial biological products are currently available for controlling powdery mildew in cereal crops. Similarly, *Zymoseptoria tritici* causes *Septoria tritici* Blotch (STB), a devastating foliar disease that can trigger yield losses of 30% to 50% (Stukenbrock & Gurr, 2023). Particularly

prevalent in temperate climates, the fungus exhibits remarkable evolutionary plasticity, allowing it to bypass modern disease control measures. Under field conditions, *Z. tritici* typically persists for 14 days post-infection, though this period may extend to 28 days in cooler climates (Fones & Gurr, 2015). Even with the use of moderately resistant cultivars and a rigorous three-spray fungicide regime, residual losses of 5% to 10% are often observed. Given that several pathogens pose severe threats to grain quality and yield, effective disease management is vital for European agriculture. This necessity has fostered a robust fungicide market in Europe, valued at over \$4.3 billion as of 2024 (Berraies et al., 2014). Holistic strategies, such as Integrated Pest Management (IPM), combine ecosystem management, crop rotation, and soil health practices to favor beneficial microorganisms and insects (Popescu et al., 2021). However, reducing significant losses still necessitates the use of preventive, systemic, and contact fungicides. These agents primarily function by inhibiting pathogen activity through various modes of action, including the disruption of the cytoskeleton, signal transduction, or membrane sterol biosynthesis (Mueller et al., 2021). Notably, while fungicide use is widespread, Romania reported one of the lowest consumption rates in the EU in 2020, at 0.76 kg/ha (Popescu et al., 2021).

In this context, the present work aims to evaluate the efficacy of systemic fungicides in controlling *B. graminis* and *Z. tritici* in wheat, while further elucidating the active role of these chemical agents in modern crop protection.

MATERIALS AND METHODS

The experiment was conducted under the pedo-climatic conditions of Iasi County, Buhăieni locality (47°29'49.4"N - 27°16'44.5"E), during 2024-2025 growth season. Observations were made on the FDL Miranda variety. It has good resistance to lodging and wintering, drought and heat. It is resistant to powdery mildew and moderately susceptible to brown rust, yellow rust, and septoria leaf spot disease.

The size of the experience, the timing and frequency of the evaluations, and the evaluation scales were established in accordance with OEPP/PP1 1/26(4). The organization of the experiment was done according to the method of randomized blocks. The experimental plot size is 30 m² with 4 replications, representing 120 m² per treatment, for a total experimental area of 1800 m². Timing and frequency of the evaluations were determined according to Tables 1 and 2.

Table 1 Time, Frequency and number of post-application assessment during of trial development

No	Moment	Time
1	A	Application T1 BBCH 31-32
2	A1	7 days after application
3	A2	14-21 days after application
4	A3	28- 35 days after application
5	A4	42-48 days after application

Table 2 Post-application assessment made during of trial development

No	Moment	Assessment description
1	A0	Disease identification
2	A0 to A4	Crop Stage
3	A1 to A4	Phytotoxicity and Vigor
4	A2 to A4	Severity and efficacy of treatments

The assessment notes for phytopathogens at the foliar level were recorded as shown in Figures 1 and 2. The leaves were numbered from top to bottom, with leaf 1 being the flag leaf, followed by leaves 2, 3, 4, and 5.

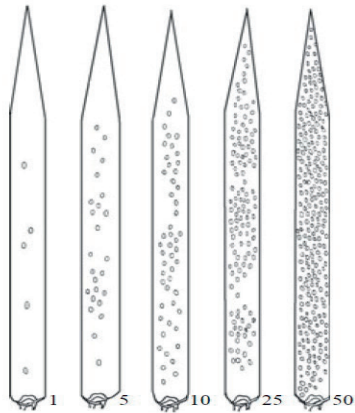


Figure 1. Percentage of leaf affected, *B. graminis* (OEPP/PP 1/26(4)) on wheat



Figure 2. Percentage of leaf affected, *Z. tritici* OEPP/PP 1/26(4) on wheat

Phytotoxicity were assessed according to OEPP/PP 1/135, with observations made on the health status of the plants. These are assigned values from 0-100%, with 100% representing no changes and values from 0-99% indicating discoloration, necrosis, deformation, and anatomical changes. Vigor was defined by assigning scores from 0-100%, with 100% representing no physiological changes and values from 0-99% indicating the presence of changes (e.g., height). The crop's growth stage was described according to the BBCH scale.

A total of 14 treatments were applied to the wheat plants, including 10 single fungicides applied with normal dose and 5 at with reduced dose along with an insecticide.

The experiment variants include: 1. Untreated control - without fungicide applied; 2. Input 460 EC (Protiocanazol 160 g/l + Spiroxamină 300 g/l) at rate of 1.00 l/ha; 3. Phoenix (Folpet 500 g/l) at a rate of 1.50 l/ha; 4. Aviator XPRO (Bixafen 75 g/l + Protiocanazol 150 g/l) at a rate of 0.80 l/ha; 5. Zoxis (Azoxistrobin 250 g/l) at a rate of 1.00 l/ha + Protos (Protiocanazol 150 g/l) at a rate of 0.80 l/ha; 6. Priaxor EC (Fluxapyroxad 75 g/l + Piraclostrobin 150 g/l) at a rate of 1.00 l/ha; 7. Nativo Forte 280 EC (Protiocanazol 93.3 g/l + Spiroxamina 107 g/l + Trifloxistrobin 80 g/l) at a rate of 1.50 l/ha; 8. Revycare (Mefentrifluconazol 100 g/l + Piraclostrobin 100g/l) at a rate of 1.50 l/ha; 9. Elatus ERA (Benzovindiflupir 75 g/l + Protiocanazol 150 g/l) at a rate of 1.00 l/ha; 10. Flexity (Metrafenone 300 g/l) at a rate of 0.50 l/ha; 11. Phoenix (Folpet 500 g/l) at a rate of

1.50 l/ha + Decis Expert 100 EC (Deltametrin 100 g/l) 0.075 l/ha; 12. Flexity (Metrafenone 300 g/l) at a rate of 0.50 l/ha + Wizard (Esfenvalerat 5 %) at a rate of 0.20 l/ha; 13. Priaxor EC (Fluxapyroxad 75 g/l + Piraclostrobin 150 g/l) at a rate of 1.00 l/ha + Karate Zeon (Lamda-cihalotrin 50 g/l) at a rate of 0.15 l/ha; 14. Revycare (Mefentrifluconazol 100 g/l + Piraclostrobin 100g/l) at a rate of 0.50 l/ha + Mospilan (Acetamiprid 200 g/kg) at a rate of 0.10 kg/ha; 15. Zoxis (Azoxistrobin 250 g/l) at a rate of 1.00 l/ha + Sivanto Energy 85EC (Deltametrin 100g/l + Flupiradifuron 75 g/l) at a rate of 0.75 l/ha.

The treatment was applied on BBCH 30-31 - beginning of stem elongation: pseudostem and tillers erect, first internode begins to elongate, top of inflorescence at least 1 cm above tillering node. The experiences were applied using the BOOM SPRAY-SCHACHTNER equipment, and the amount of water used was 300 l/hectare.

Climate data regarding temperature, humidity, and precipitation during the growing season is obtained using the DTN LLC platform.

The data obtained during the research period was verified and processed using the ARM - Agriculture Research Manager software.

RESULTS AND DISCUSSIONS

The treatments were applied during the 2025 growing season, at the BBCH 30-31 vegetation stage, under normal climatic conditions (temperature, humidity, and soil conditions) on April 23, 2025. The data are presented in Table 3.

Table 3. Field condition at application, crop (BBCH), and climate condition (soil, temperature, humidity, and wind), 23.04.2025 data

Crop stage BBCH	T° C Soil 10 cm	T° C Air	Humidity %	Time	Wind
					Mps / Direction
30-31	12.2	14.7	64.5	10:00	0.3 / N

The research period is characterized by low rainfall in April (16.80 mm) and June (4.30 mm) and high rainfall in May (70.50 mm). Thus, due to increased precipitation and high temperatures, optimal conditions for the development of the agents *Z. tritici* and *B. graminis* appeared. *Z. tritici* develops intensely under high humidity and moderate temperatures of 15-20°C (Takele et al., 2015). *B. graminis* f. sp. *tritici* develops at

moderate temperatures (15-22°C) and high atmospheric humidity, without requiring free water on the leaves (Tables 3 and 4).

Table 4. Agrometeorological conditions during the growing seasons of autumn wheat for the trial development of 2025 (source: DTN LLC)

Month	Prep. (mm)	Temperature °C			Humidity %		
		Min.	Max.	Avg.	Min.	Max.	Avg.
April	16.80	7.77	19.13	13.45	41.97	83.23	62.59
May	70.50	11.19	20.07	15.63	56.26	88.81	73.14
June	4.30	18.48	30.58	25.25	53.20	92.17	73.08

During the test development period, the pathogens moved from the basal leaves, leaves 3, 4, and 5, to the upper levels, specifically leaves 1, 2, and 3. *B. graminis* showed a positive trend during the research period, recording a 218.57% increase in A4 compared to A0 in the untreated variant. Isolated in A2 - 14 DAA from *Z. tritici* showed a decrease in development of -16.85% compared to the previous variant A0, but due to favorable climatic conditions, it recorded an increase of 267.10% in A4. On A4 42 - DAA, the *Z. tritici* strain showed a 48.44% increase compared to *B. graminis* (Tables 5 and 6).

Table 5. Development of *Zymoseptoria tritici* on untreated variant during of trial development, at A0 (23.04.2025), A2 (07.05.2025), A3 (24.05.2025), and A4 (04.06.2025) moments (L1-leaf 1, L2-leaf 2, L3-Leaf 3, L4- leaf 4, L5-Leaf 5, Avg.-average)

Moment	L1	L2	L3	L4	L5	Avg.
A0 0-DAA	-	-	1.53	7.67	19.44	9.55
A2 14-DAA	-	2.67	7.17	14.67	-	8.17
A3 28-DAA	2.70	13.20	28.53	-	-	14.81
A4 42-DAA	10.17	23.50	42.83	-	-	25.50

Table 6. Development of *Blumeria graminis* on untreated variant during trial development, at A0 (23.04.2025), A2 (07.05.2025), A3 (24.05.2025), and A4 (04.06.2025) moments; (L1-leaf 1, L2-leaf 2, L3-Leaf 3, L4- leaf 4, L5-Leaf 5, Avg.-Average)

Moment	L1	L2	L3	L4	L5	Avg.
A0 0-DAA	-	-	1.38	5.38	22.64	9.80
A2 14-DAA	-	2.13	7.50	22.13	-	10.59
A3 28-DAA	3.63	11.88	21.38	-	-	12.60
A4 42-DAA	8.25	18.63	37.38	-	-	21.42

After applying the treatments, the severity of the pathogens was low, highlighting the effectiveness of the applied phytosanitary products. Thus, recording control over plant development and disturbances.

During the testing, no symptoms of phytotoxicity or changes in vigor were observed; they recorded 0 phytotoxicity and 100% vigor throughout the experimental period. *Zymoseptoria tritici* is a fungus and causes the fungal disease known as wheat leaf blotch, a particularly important disease (Quaedvlieg et al., 2011; Abeba, 2023), this particularly affects the leaves, where elongated, brownish-gray spots appear, bordered by veins, and within which black dots (pycnidia) can be observed. *Z. tritici* is an apoplastic pathogenic species with a hemibiotrophic life cycle (Ponomarenko et al., 2011; Fones and Gurr, 2015; Savary et al., 2019).

For the control of the pathogen *Z. tritici*, treatments Priaxor EC⁶, Nativo Forte 280 EC⁷ and Revycare⁸ showed a very good response in controlling the pathogen's development, recording low severity ranging from 6.00-6.78% and high efficacy of 77.77-80.36%. Treatments Input 460 EC², Zoxis+Protos⁵ and Elatus ERA⁹ showed a good response, recording low severity of 7.28-9.00% and high efficacy of 68.68-74.59%. An average response was observed in treatments Aviator XPRO⁴, Phoenix³ and Phoenix+Decis Expert 100 EC¹¹, which recorded an average severity of 10.00-11.61% and an efficacy with values ranging between 58.28-64.85%. A poor response was recorded for treatments Phoenix+Decis Expert 100 EC¹¹ and Zoxis+Sivanto Energy 85EC¹⁵, with a severity ranging between 12.33-13.17% and an efficacy of 51.74-55.31%. And a very poor response was recorded for treatments Revycare+Mospilan¹⁴, Flexity+ Wizard¹² și Flexity¹⁰ with a severity ranging between 14.06-15.83 and poor efficacy ranging between 41.08-48.17% (Tables 7 and 8).

Table 7. Severity (%) of *Zymoseptoria tritici* on autumn wheat against at moment A2 (07.05.2025) Leaf 2, 3 and 4, A3 (24.05.2025) Leaf 1,2 and 3, and moment A4 (04.06.2025) Leaf 1, 2 and 3

No	Moment A2			Moment A3			Moment A4		
	L2	L3	L4	L1	L2	L3	L1	L2	L3
1	2.67	7.17	14.67	2.70	13.20	28.53	10.17	23.50	42.83
2	0.00	2.00	8.50	0.00	2.83	8.00	1.83	6.00	14.00
3	0.00	2.67	9.67	0.33	4.33	11.50	2.83	9.50	20.50
4	0.00	2.50	9.67	0.00	3.83	11.00	2.50	8.67	18.83
5	0.00	2.17	8.83	0.00	3.17	9.17	2.00	6.67	16.17
6	0.00	1.50	7.67	0.00	2.17	6.17	1.00	4.83	12.17
7	0.00	1.67	8.00	0.00	2.33	6.33	1.33	5.33	12.67
8	0.00	1.83	8.17	0.00	2.50	7.50	1.50	5.67	13.17
9	0.00	2.33	9.33	0.00	3.67	10.33	2.17	7.67	17.17
10	1.07	4.00	11.83	1.13	6.83	17.33	5.33	13.33	28.83
11	0.67	3.00	10.33	0.67	5.00	13.83	3.67	10.33	23.00
12	1.00	3.67	11.67	1.07	6.33	16.00	4.83	12.67	27.17
13	0.50	2.83	10.17	0.50	4.83	12.17	3.17	10.33	21.33
14	0.83	3.33	11.17	1.00	5.83	15.17	4.50	12.17	25.50
15	0.67	3.17	10.67	0.83	5.33	14.33	4.00	11.67	23.83

Table 8. Efficacy (%) of foliar treatment applied on autumn wheat against *Zymoseptoria tritici* at moment A2 (07.05.2025) Leaf 2, 3 and 4, A3 (24.05.2025) Leaf 1,2 and 3, and moment A4 (04.06.2025) Leaf 1, 2 and 3

No	A2			A3			A4		
	L2	L3	L4	L1	L2	L3	L1	L2	L3
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	100.00	72.31	41.64	100.00	78.56	71.81	82.04	74.44	67.29
3	100.00	63.08	33.42	88.57	66.93	59.53	72.18	59.44	52.06
4	100.00	65.30	33.75	100.00	71.10	61.58	75.36	63.15	56.03
5	100.00	69.74	39.17	100.00	75.99	67.75	80.45	71.62	62.24
6	100.00	78.97	47.67	100.00	83.54	78.33	90.14	79.35	71.59
7	100.00	77.09	45.44	100.00	82.36	77.65	86.97	77.22	70.40
8	100.00	74.53	44.20	100.00	80.97	73.59	85.21	75.83	69.28
9	100.00	67.52	35.32	100.00	72.28	64.03	78.86	67.31	59.88
10	60.00	43.93	19.30	56.70	47.91	38.96	47.37	43.33	32.55
11	75.56	57.95	29.33	75.87	62.15	51.58	63.74	55.97	46.22
12	62.22	49.06	20.53	59.37	52.07	44.14	52.63	46.11	36.52
13	81.11	60.51	30.56	80.63	63.39	57.07	68.67	55.97	50.19
14	68.89	53.50	23.39	61.27	55.78	46.67	55.81	48.33	40.38
15	74.44	55.73	27.09	69.21	59.53	50.07	60.57	50.42	44.23

Blumeria graminis f. sp. *tritici* is the pathogen that causes wheat powdery mildew, a common disease in wheat crops, characterized by the appearance of a whitish, floury coating on leaves, stems, and sometimes on ears, which later turns gray. The attack reduces photosynthesis and weakens the plants (Cowger et al., 2018). For control during the growing season, treatments Revyicare⁸, Input 460 EC², Flexity¹⁰ and Priaxor EC⁶ showed a very good response in controlling the development of pathogens, recording low severity ranging from 4.84-5.80% and high efficacy of 77.94-82.43%. Treatments Nativo Forte 280 EC⁷, Flexity+

Wizard¹², Elatus ERA⁹ and Aviator XPRO⁴ showed a good response, recording low severity of 7.04-8.92% and high efficacy of 63.20-71.89%. A poor response was recorded for treatments Zoxis+Protos⁵, Phoenix³ and Revyicare+ Mospilan¹⁴ with a severity ranging between 9.63-10.71% and an efficacy of 55.04-60.28%. And a very poor response was recorded for treatments Phoenix+Decis Expert 100 EC¹¹, Priaxor EC+Karate Zeon¹³ and Zoxis+Sivanto Energy 85EC¹⁵ with a severity ranging between 11.50-12.71 and a weak efficacy ranging between 43.47-50.58% in controlling the pathogen *Blumeria* (Tables 9 and 10).

Table 9. Severity (%) of *Blumeria graminis* on autumn wheat against at moment A2 (07.05.2025) Leaf 2, 3 and 4, A3 (24.05.2025) Leaf 1,2 and 3, and A4 (04.06.2025) Leaf 1, 2 and 3

No	A2			A3			A4		
	L2	L3	L4	L1	L2	L3	L1	L2	L3
1	2.13	7.50	22.13	3.63	11.88	21.38	8.25	18.63	37.38
2	0.00	1.63	6.00	0.00	1.75	5.25	0.63	3.75	11.38
3	0.63	2.88	11.00	0.88	4.13	9.50	2.63	7.88	19.88
4	0.38	2.50	9.63	0.50	3.13	8.63	2.13	6.88	17.75
5	0.50	2.63	10.25	0.75	3.63	9.25	2.38	7.38	19.13
6	0.00	1.75	6.88	0.00	2.00	5.88	0.88	4.38	12.13
7	0.00	2.00	7.50	0.00	2.38	7.13	1.38	5.25	14.50
8	0.00	1.38	5.38	0.00	1.50	4.63	0.50	3.38	10.63
9	0.00	2.38	8.50	0.38	2.88	8.13	1.88	6.25	16.75
10	0.00	1.88	6.75	0.00	2.13	6.50	1.13	4.88	13.25
11	0.75	3.25	11.75	1.13	5.25	10.63	3.13	9.38	22.00
12	0.00	2.13	7.75	0.25	2.63	7.50	1.63	5.75	15.88
13	0.80	3.38	12.13	1.38	5.50	11.63	3.50	9.88	23.00
14	0.75	3.13	11.63	1.00	4.88	9.88	2.88	8.13	21.13
15	0.85	3.50	13.13	1.50	5.88	12.00	4.13	10.38	23.63

Table 10. Efficacy (%) of foliar treatment applied on autumn wheat against *Blumeria graminis* at moment A2 (07.05.2025) Leaf 2, 3 and 4, A3 (24.05.2025) Leaf 1,2 and 3, and moment A4 (04.06.2025) Leaf 1, 2 and 3

No	A2			A3			A4		
	L2	L3	L4	L1	L2	L3	L1	L2	L3
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	100.00	77.92	72.64	100.00	85.28	75.49	92.46	79.89	69.63
3	70.42	60.56	50.14	75.89	65.26	55.29	67.58	57.85	47.07
4	83.75	65.00	56.19	86.16	73.64	59.27	74.06	62.85	52.69
5	75.42	63.33	53.51	79.46	69.43	56.43	71.42	60.35	49.08
6	100.00	76.53	68.86	100.00	83.11	72.51	89.83	76.33	67.66
7	100.00	72.50	65.74	100.00	79.94	66.53	82.65	71.89	61.14
8	100.00	80.97	75.47	100.00	87.36	78.45	93.78	81.76	71.76
9	100.00	66.67	61.00	89.29	75.77	61.86	77.39	66.06	55.13
10	100.00	74.58	69.38	100.00	82.02	69.50	85.99	73.77	64.65
11	65.42	55.42	46.82	69.20	55.71	50.05	61.10	49.28	41.37
12	100.00	70.42	64.55	92.86	77.85	64.70	80.02	69.39	57.52
13	62.92	53.33	45.11	62.05	53.62	45.53	56.45	46.71	38.55
14	65.42	57.08	47.37	72.32	58.97	53.73	64.95	56.60	43.57
15	60.92	51.67	40.44	58.48	50.50	43.56	49.87	43.80	36.74

Figure 3 shows the efficacy of treatment recorded, treatments Revycare⁸, Priaxor EC⁶, Input 460 EC² and Nativo Forte 280 EC⁷ showed

high efficacy in controlling the pathogens *Z. tritici* and *B. graminis*, recording the highest efficacy values, between 78.7% and 81.30%.

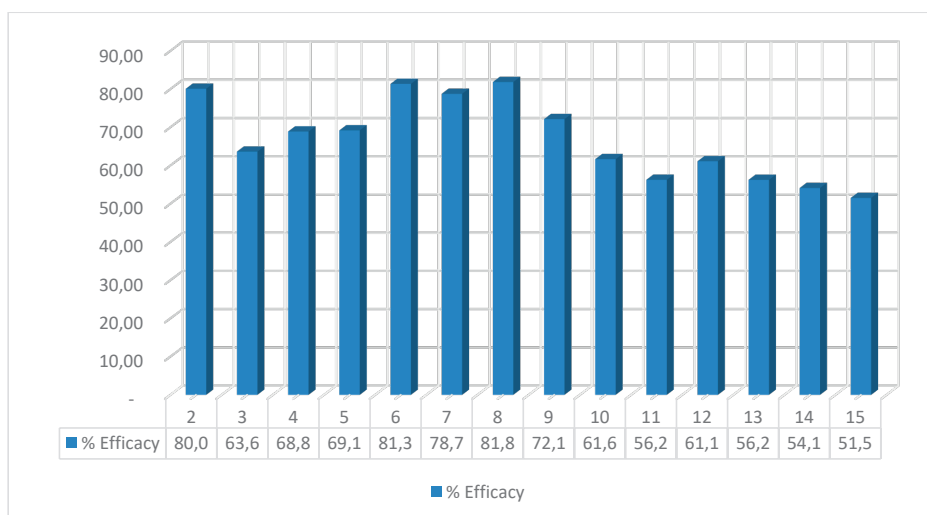


Figure 3. Average efficacy (%) of foliar treatment applied on autumn wheat against *Zymoseptoria tritici* and *Blumeria graminis* at A2 (07.05.2025), A3 (24.05.2025), and A4 (04.06.2025) moments

The timing of fungicide application—specifically determining the optimal moment—is the most critical factor in plant protection. In wheat, fungicide applications are concentrated on specific developmental stages: T1 is applied between the first and second nodes (BBCH 31-32); T2 occurs at flag leaf emergence (BBCH 37-39); and T3 is applied at head emergence (BBCH 49-59) (Borwing et al., 2011).

The T1 application is of particular importance as it significantly reduces disease progression by arresting it at the basal leaves. This protects the upper leaves and extends the time window before they become infected. Data from Tables 6 and 8 demonstrate a notable difference in pathogen severity recorded on the flag leaf and Leaf 2. The most effective treatments yielded control values between 80.02% and 90.14% for *Zymoseptoria tritici*, and 80.45% to 93.78% for *Blumeria graminis*. Conversely, the least effective treatments showed significantly lower control ranges, falling between 47.37% and 60.57% for *Z. tritici* and 49.87% to 61.10% for *B. graminis*.

The T2 application is considered the most critical link in the protection strategy for winter wheat. This intervention directly targets the protection of the flag leaf, which is responsible for approximately 43-45% of the total photosynthesis required for grain filling. Maintaining the green integrity of this leaf by controlling pathogens such as *Z. tritici* and

Puccinia spp. is essential for maximizing yield potential (Loyce et al., 2008).

The importance of these interventions is underscored by the fact that the top three leaves generate nearly 70% of the total grain yield through their photosynthetic contribution. Specifically, the flag leaf contributes 43%, Leaf 2 contributes 23%, and Leaf 3 contributes 7%. Additionally, the green area of the ear (head) contributes a further 22% to the final yield. Consequently, applying fungicides at these key moments of leaf development provides the greatest contribution to overall disease protection and crop productivity (Poole & Arnaudin, 2014).

CONCLUSIONS

The strategic management of foliar diseases in winter wheat depends critically on the precision of fungicide application timing, correlated with the key developmental stages of the crop. The present study demonstrates that the success of phytosanitary protection is ensured by the synergy between the T1 and T2 stages, each playing a decisive role in securing the yield. Applying fungicides at these optimal moments is not merely a biological control measure, but an economic necessity. The significant differences in efficacy recorded between the various treatment options underscore the fact that choosing the correct timing and product

guarantees yield stability and a high return on investment

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