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REVIEW

Availability constraints of plant protection products in Polish winter cereal production – a post-EU accession perspective

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Abstract

Due to their extensive cultivation and the significant impact of pests causing economically relevant losses, winter cereal crops require effective chemical protection. A major challenge in their protection is the steadily diminishing range of available plant protection products (PPPs), specifically the active substances (AS) they contain. Although the core principles of the European Green Deal have been temporarily suspended, the European Commission has continued to phase out several active substances. As a result, dozens of these substances have been withdrawn from the market in recent years, creating increasing difficulties in crop protection - particularly for winter cereals. This is partly due to the growing resistance of pests, stemming from reduced opportunities for rotating products with different mechanisms of action. Further reductions in active substances, in the absence of viable alternative methods for agrophage control, may potentially lead to a decrease in both the cultivated area and overall production volumes for economic reasons. Moreover, such a scenario increases the risk of illegal imports or off-label use of plant protection products (PPP).

Keywords: agronomics constraints, cereal sustainability, crop protection policy, EU pesticide regulation, integrated pest management,

Introduction

In Poland, winter cereals have dominated the sown area for many years, currently covering approximately 4.5 million hectares (SP 2024, 2025). Agroclimatic conditions, including recurring spring droughts (IMWM–NRI 2025), provide more favorable conditions for the cultivation of winter cereal varieties, which typically have higher yields than their spring counterparts (IAFP–NRI 2024). In the autumn of 2024, winter cereal sowing was led by winter wheat, which occupied 2.2 million hectares, followed by winter triticale (1.2 million ha), winter rye (0.7 million ha), and winter barley (0.4 million ha) (SP 2024, 2025). The extensive cultivation of winter wheat and the intensity of its production contribute to significant pest threats, with as many as 100 economically important species identified. A similar level of pest pressure – approximately 90 species – is observed in winter barley. In Poland, slightly lower pest incidence is reported for winter triticale (around 80 species), with the lowest pressure recorded in winter rye plantations, which are affected by about 70 pests (Strażyński *et al.* 2024).

In the European Union, since January 1, 2014, all professional users have been required to implement integrated plant protection systems, which has led to a reduction in the use of chemical agents in agricultural production, including winter cereals (OJEU 2009; IAFP–NRI 2024). The application of the general principles of integrated plant protection by professional users of plant protection products is regulated in Poland by the Act of March 8, 2013 on Plant Protection

Products (Journal of Laws 2013, item 455), as well as by the Regulation of the Minister of Agriculture and Rural Development of April 18, 2013 on the Requirements of Integrated Plant Protection (Journal of Laws 2013, item 505). Within integrated protection, non-chemical methods – agrotechnical, biological, and breeding-based practices – are prioritized for reducing pest pressure. Nevertheless, crops such as winter cereals still require chemical protection. Although the number of microbiological plant protection products is gradually increasing, their availability remains insufficient (MARD 2025). However, under the Integrated Plant Production eco-scheme, their use in cereals (as well as in other crops for which Integrated Production methodologies have been developed) is a mandatory requirement.

The withdrawal of active substances (ASs) from plant protection products is a legally regulated process designed to safeguard human and animal health, protect the environment, and ensure food quality (OJEU 2009; Alix and Lewis 2010; MacLeod *et al.* 2010; Cilia and Kandris 2023). If an active substance is deemed unsafe or fails to meet regulatory standards, it may be withdrawn from the market (Mie and Rudén 2022; Slunge *et al.* 2023; Solé *et al.* 2024). This process typically involves several stages, including scientific risk assessment and formal administrative decisions (MARD 2025):

Risk and Safety Assessment: Regulatory bodies such as the European Food Safety Authority (EFSA) and national authorities evaluate the risks associated with the active substance. The assessment considers potential health impacts on humans and animals, environmental consequences, and the risk of contamination in groundwater or agricultural products.

Administrative Decisions: If the active substance poses an unacceptable risk, regulatory authorities may decide to withdraw it from use. In the European Union, this process is coordinated by the European Commission, which can prohibit the use of the substance across all Member States. Such decisions are formalized through regulations or directives.

Loss of Marketing Authorization: A withdrawn active substance loses its marketing authorization, meaning that it can no longer be manufactured, sold, or applied. This withdrawal may affect the substance in all uses or be restricted to specific applications considered particularly hazardous.

The diversity of cropping systems across Europe, driven by significant geographic and climatic variation, presents substantial challenges for harmonized crop protection strategies. The economic viability of European agriculture is increasingly constrained by stringent regulatory frameworks, particularly the prohibition of numerous pesticides previously authorized within the EU but still in use globally. This regulatory landscape has the potential to place EU agricultural production at a competitive disadvantage, prompting European farmers to seek scientific support to develop and implement Integrated Pest Management (IPM) strategies. Achieving stable yields and high crop quality while simultaneously reducing dependence on chemical plant protection products remains a key challenge for the sector. The substantial biophysical and socio-economic heterogeneity across European regions further complicates efforts to meaningfully reduce pesticide use (Lamichhane *et al.* 2016; Jørgensen *et al.* 2019).

Over the past decade, the use of major conventional pesticides in European agriculture has shown considerable variability, with no consistent downward trend despite multiple policy initiatives. This fluctuation is partly attributable to interannual climatic variability, which affects pest incidence and, consequently, pesticide application levels. Moreover, the reduced availability of certain active substances may have led to increased use of alternative compounds, often at higher application rates. For instance, in Denmark, pesticide use (measured in $kg \cdot ha^{-1}$) declined between 1981 and 2000 but has subsequently increased. These trends have been influenced by factors such as changes in pesticide taxation and anticipated regulatory restrictions on specific active ingredients. Similar patterns have been observed in France, where pesticide use has risen in recent years. Data from the German Reference Farm Network also reveal significant year-to-year and crop-specific variability in pesticide application intensity (Freier *et al.* 2013).

The aim of this paper was to assess the current constraints on the availability of plant protection products in Polish winter cereal production, with particular attention to regulatory, market, and agronomic factors shaped by Poland's EU accession. The scope of the paper includes a comparative analysis of product registrations, and national-level consequences of EU policy changes.

Protective treatments in winter cereals

Polish agriculture, in comparison to many other European Union countries, is characterized by moderate and stable consumption of plant protection products per 1 ha of crops (Zieliński *et al.* 2025a). In Poland, winter wheat receives the highest number of protective treatments among winter cereal crops, with an average of 8.76 applications of plant protection products (PPP) per growing season. This is followed by winter barley (5.89 treatments), winter triticale (4.75 treatments), and winter rye, which has the lowest number of applications at 3.59 treatments per season. The greatest number of fungicide treatments is also observed in winter wheat, averaging 4.22 applications. This is followed by winter barley (3.00), winter triticale (1.90), and winter rye (1.33), which receives nearly three fewer fungicide treatments than winter wheat. Herbicide applications are most frequent in winter wheat (3.10 treatments), followed by winter triticale (2.53), winter barley (2.21), and winter rye (1.84), indicating lower sensitivity to weed pressure. Insecticide treatments are generally limited across all winter cereals. Winter wheat receives an average of 0.47 applications, winter barley 0.27, winter triticale 0.10, and winter rye the fewest at 0.06 treatments. The application of plant growth regulators is highest in winter wheat (0.98 treatments), followed by winter barley (0.53), winter rye (0.37), and winter triticale (0.21). For comparison, in the United Kingdom, winter wheat plantations typically receive a total of nine protective treatments, a number comparable to that in Poland. These include three fungicide applications, three herbicide treatments, two applications of growth regulators, and one treatment for pest control (IAFP–NRI 2024; Zieliński *et al*. 2025a).

Consumption of active substances in winter cereals

Currently, the highest consumption of active substances among winter cereals occurs in the cultivation of winter wheat (*Triticum aestivum*), with an average application rate of 1.24 kg · ha^{-1}) (Table 1). Slightly lower amounts are applied in winter triticale (*x Triticosecale*) (1.16 kg · ha^{-1}) and winter barley (*T. vulgare*) (1.14 kg · ha^{-1}). The lowest consumption is observed in winter rye (*Secale cereale*), at 0.31 kg · ha^{-1}), which is 0.93 kg · ha^{-1}) less than in winter wheat. Fungicides are used most extensively in winter barley (0.45 kg · ha^{-1}), followed by winter wheat (0.44 kg · ha^{-1}), winter triticale (0.29 kg · ha^{-1}), and winter rye (0.08 kg · ha^{-1}), representing a 0.36 kg · ha^{-1} difference between winter wheat and rye. In terms of herbicide use, the highest consumption is recorded in winter triticale (0.74 kg · ha^{-1}), followed by winter barley (0.60 kg · ha^{-1}) and winter rye (0.17 kg · ha^{-1}), indicating a 0.57 kg · ha^{-1} difference between triticale and rye. The highest insecticide use is found in winter wheat, at 0.024 kg · ha^{-1}, while no insecticides are currently registered for use in winter rye. A similar pattern is seen in the application of molluscicides, with the highest usage in winter wheat and the lowest in winter barley (IAFP–NRI 2024).

Number of registered plant protection products in winter cereals

The sheer number of available products does not equate to effectiveness. A large number of products is registered for winter cereals but the number of new and effective products with new modes of action have diminished over the past years. Presently, the Ministry of Agriculture and Rural Development in Poland,

Table 1. Consumption of active substances (kg · ha^{-1}) in winter cereals in selected years

Years	Fungicides	Herbicides	Insecticides	Molluscicides	Total
WINTER WHEAT					
2020	0.444	0.444	0.024	0.256	1.239
2017	0.55	0.41	0.005	0.31	1.32
2011	0.50	0.62	0.03	0.35	1.49
2003	0.64	0.73	0.02	0.46	1.85
WINTER TRITICALE					
2022	0.29	0.74	0.01	0.12	1.16
2016	0.24	0.44	0.01	0.08	0.77
2010	0.16	0.51	0.01	0.06	0.74
WINTER BARLEY					
2024	0.45	0.60	0.01	0.01	1.13
2005	0.42	0.81	0.01	0.13	1.37
WINTER RYE					
2024	0.08	0.17	0.00	0.06	0.31
2012	0.04	0.23	0.00	0.04	0.30
2003	0.13	0.33	0.00	0.06	0.53

Source: Own elaboration based on data from the Ministry of Agriculture and Rural Development responsible for registering plant protection products, has approved the highest number of such products for winter wheat – 1,192 in total (Table 2). This is followed by winter triticale (793), winter barley (711), and winter rye, which has the lowest number at 662 registered products – 530 fewer than winter wheat (MARD 2025). The European Union has released a list of active substances that are slated for substitution or potential removal. The withdrawal of these substances is expected to have the greatest impact on winter wheat, with up to 19 active substances at risk of being phased out. Similar reductions may occur in winter rye (18 substances), winter triticale (16), and to a slightly lesser extent in winter barley (15). The potential withdrawal of active substances could lead to significant reductions in available fungicidal seed dressings – by as much as 93% in winter barley, 86% in winter triticale, and 85% in both winter wheat and winter rye.

Table 2. Number of registered plant protection products for winter cereals in Poland (June 2025)

Type of PPP	Total Number of Preparations	Number of Preparations Remaining after Reduction	Reduction Level [%]
WINTER WHEAT			
Herbicides	471	352	25
Fungicides	422	311	26
Insecticides	86	61	29
Molluscicides	31	31	0
Growth regulators	98	97	0
Insecticide dressings	0	0	0
Fungicyde dressings	84	13	85
TOTAL	1192	865	27
WINTER TRITICALE			
Herbicides	334	241	28
Fungicides	267	207	23
Insecticides	24	11	54
Molluscicides	28	28	0
Growth regulators	71	71	0
Insecticide dressings	0	0	0
Fungicyde dressings	69	10	86
TOTAL	793	568	28
WINTER BARLEY			
Herbicides	253	182	28
Fungicides	272	221	19
Insekticides	17	6	65
Molluscicides	29	29	0
Growth regulators	71	71	0
Insecticide dressings	0	0	0
Fungicyde dressings	69	5	93
TOTAL	711	514	28
WINTER RYE			
Herbicides	280	192	31
Fungicides	210	151	28
Insecticides	19	8	58
Molluscicides	29	29	0
Growth regulators	58	58	0
Insecticide dressings	0	0	0
Fungicyde dressings	66	10	85
TOTAL	662	448	32

Source: Own elaboration based on data from the Ministry of Agriculture and Rural Development

Weed control in winter cereal plantations

On a global scale, potential crop losses for the six major crops (wheat, rice, maize, potatoes, soybeans, and cotton) amount to 69%. Weeds account for the largest share of these losses at 34%, followed by pests at 19% and diseases at 16% (Oerke 2006). Weeds pose a significant economic threat to winter cereals, particularly winter wheat, where they contribute most substantially to yield reduction. The highest number of herbicides

Table 3. Number of herbicides registered in Poland for weed control in winter cereals (June 2025)

Weeds	Current Registration	After Possible Withdrawal
WINTER WHEAT		
Geranium pusillum	90	56
Centaurea cyanus	197	121
Viola arvensis	273	167
Stellaria media	375	268
Papaver rhoeas	275	163
Matricaria perforata	282	189
Apera spica-venti	220	161
Veronica persica	207	114
Galium aparine	209	193
Brassica napus (self-sown)	233	176
Capsella bursa-pastoris	338	265
WINTER TRITICALE		
Geranium pusillum	86	47
Centaurea cyanus	162	121
Viola arvensis	202	160
Stellaria media	271	182
Papaver rhoeas	234	171
Matricaria perforata	230	158
Apera spica-venti	165	111
Veronica persica	162	119
Galium aparine	230	182
Brassica napus (self-sown)	185	143
Capsella bursa-pastoris	250	174
WINTER BARLEY		
Geranium pusillum	51	27
Centaurea cyanus	109	58
Viola arvensis	134	75
Stellaria media	200	141
Papaver rhoeas	157	108
Matricaria perforata	143	101
Apera spica-venti	107	70
Veronica persica	110	71
Galium aparine	158	102
Brassica napus (self-sown)	128	83
Capsella bursa-pastoris	178	127

Table 3. Number of herbicides registered in Poland for weed control in winter cereals (June 2025) – continuation

Weeds	Current Registration	After Possible Withdrawal
	WINTER RYE	
Geranium pusillum	75	38
Centaurea cyanus	138	101
Viola arvensis	164	122
Stellaria media	226	133
Papaver rhoeas	198	144
Matricaria perforata	191	127
Apera spica-venti	143	98
Veronica persica	150	106
Galium aparine	197	150
Brassica napus (self-sown)	162	124
Capsella bursa-pastoris	217	132

Source: Own elaboration based on data from the Ministry of Agriculture and Rural Development

registered for weed control is found in winter wheat. Among these, the most common are herbicides targeting *Stellaria media*, with as many as 375 registered products (Table 3). This is followed by 271 in winter triticale, 226 in winter rye, and 200 in winter barley (MARD 2025). Consequently, the potential reduction in available herbicides due to regulatory changes is likely to be greatest in winter wheat. Conversely, winter barley is expected to experience the smallest reduction, with a projected decrease of only 59 registered herbicides. An increasingly serious problem will arise with the control of herbicide-resistant species, such as *Apera spica-venti* (Mayerová *et al.* 2018; Adamczewski *et al.* 2019; Marcinkowska *et al.* 2023; Bhattacharya *et al.* 2025).

Control of winter cereal pathogens

In Poland, pathogens that affect winter wheat have the greatest economic significance. A total of 318 fungicides is registered for the control of powdery mildew in this crop, compared to 165 in winter barley, and the fewest in winter rye, with only 39 registered fungicides – 279 fewer than those available for winter wheat (MARD 2025) (Table 4). The most significant phytopathogens include fungi from the genera *Fusarium* and *Puccinia*, along with *Zymoseptoria tritici* and *Parastagonospora nodorum* (Duba *et al.* 2018). For example, yield losses of winter wheat caused by pathogen infection can exceed 20% (Savary *et al.* 2019). Effective control of these diseases often relies on triazole-based fungicides such as epoxiconazole and tebuconazole, both of which face regulatory restrictions or phase-out in the EU (Marchand 2023a, b; Solé *et al.* 2024).

Control of pests in winter cereals

Pests pose the greatest economic significance on winter wheat plantations. For aphid control in this crop,

Table 4. Number of foliar fungicides registered in Poland for disease control in winter cereals (June 2025)

Disease	Pathogen(s)	Current Registration	After Possible Withdrawal
	WINTER WHEAT		
Brown leaf spot	*Pyrenophora tritici-repentis*	220	161
Fusarium head blight	*Fusarium* spp.	206	148
Powdery mildew of cereals	*Blumeria graminis*	318	252
Cereal stem breakage	*Oculimacula* spp.	62	49
Brown rust	*Puccinia recondita*	315	258
Yellow rust	*Puccinia striiformis*	120	90
Septoria nodorum blotch	*Parastagonospora nodorum*	175	126
Wheat leaf banded septoriosis	*Mycosphaerella graminicola*	371	273

Table 4. Number of foliar fungicides registered in Poland for disease control in winter cereals (June 2025) – continuation

Disease	Pathogen(s)	Current Registration	After Possible Withdrawal
WINTER TRITICALE			
Brown leaf spot	*Pyrenophora tritici-repentis*	48	29
Fusarium head blight	*Fusarium* spp.	32	12
Fusarium stem base and root rot	*Fusarium* spp.	7	7
Cereal stem breakage	*Oculimacula* spp.	18	17
Powdery mildew of cereals	*Blumeria graminis*	141	128
Brown rust	*Puccinia recondita*	161	112
Yellow rust	*Puccinia striiformis*	48	30
Cereal rhynchosporiosis	*Rhynchosporium secalis*	53	30
Septoria nodorum blotch	*Parastagonospora nodorum*	68	38
Septoria leaf blotch	*Zymoseptoria tritici*	168	122
WINTER BARLEY			
Sooty mould black mould on wheat ears	*Cladosporium herbarum*, *Alternaria* spp.	23	23
Fusarium head blight	*Fusarium* spp.	55	25
Fusarium stem base and root rot	*Fusarium* spp.	8	8
Cereal stem breakage	*Oculimacula* spp.	25	17
Powdery mildew of cereals	*Blumeria graminis*	165	128
Barley rust	*Puccinia hordei*	142	102
Cereal rhynchosporiosis	*Rhynchosporium secalis*	194	153
WINTER RYE			
Brown leaf spot	*Pyrenophora tritici-repentis*	25	7
Fusarium head blight	*Fusarium* spp.	22	1
Fusarium stem base and root rot	*Fusarium* spp.	1	1
Cereal stem breakage	*Oculimacula* spp.	10	9
Powdery mildew of cereals	*Blumeria graminis*	39	26
Brown rust	*Puccinia recondita*	182	136
Yellow rust	*Puccinia striiformis*	3	2
Cereal rhynchosporiosis	*Rhynchosporium secalis*	161	126
Septoria nodorum blotch	*Parastagonospora nodorum*	1	1

Source: Own elaboration based on data from the Ministry of Agriculture and Rural Development

44 insecticides are registered, followed by 20 in winter triticale, and the fewest in winter barley and winter rye, with 15 preparations registered for each (Table 5). For several decades there have been no repellents registered for use in winter cereal crops to prevent damage caused by animals (MARD 2025). Among the pests of greatest economic importance are aphids (primarily due to their role as virus vectors) and *Oulema* spp. The most prevalent aphid species in cereal crops is *Rhopalosiphum padi*, which contributes significantly to virus transmission (Finlay and Luck 2011; Strażyński and Ruszkowska 2015). Losses caused by aphids due to viral infections can reach up to 30% (Singh *et al*. 2020).

Application of microbiological agents in winter cereals

Currently, only three microbiological agents are registered in Poland for the protection of winter wheat against selected pathogens and pests (Table 6). For other winter cereal species, such options are not available (MARD 2025). Microbiological agents, despite their potential, must be both effective and economically viable. The adoption of diverse biocontrol methodologies is environmentally benign, harmless, and has enough potential to significantly boost plant production (Pandit *et al*. 2022; Šunjka and Mechora 2022; Bakr *et al*. 2025). Increasingly, research is being conducted on

Table 5. Number of insecticides registered in Poland for pest control in winter cereals (June 2025)

Pests	Current Registration	After Possible Withdrawal
WINTER WHEAT		
Zabrus tenebrioides	1	1
Aphididae	44	25
Oulema spp.	44	32
Gastropoda	28	28
Eurygaster testudinaria	9	9
WINTER TRITICALE		
Zabrus tenebrioides	1	1
Aphididae	20	7
Oulema spp.	11	3
Gastropoda	28	28
WINTER BARLEY		
Zabrus tenebrioides	1	1
Aphididae	15	4
Oulema spp.	6	0
Gastropoda	29	29
WINTER RYE		
Zabrus tenebrioides	1	1
Aphididae	15	4
Eurygaster testudinaria	3	3
Gastropoda	29	29

Source: Own elaboration based on data from the Ministry of Agriculture and Rural Development

Table 6. Microbiological preparations currently registered for use in winter wheat in Poland (June 2025)

Pathogen/Pest	Active Substances (Microorganism)	Number of Preparations
Blumeria graminis	*Bacillus amyloliquefaciens* strain QST 713	1
Fusarium spp.	*Pythium oligandrum*	1
Aleyrodidae Thripidae Tetranychidae Elateridae	*Beauveria bassiana* strain ATTC 74040	1

Source: Own elaboration based on data from the Ministry of Agriculture and Rural Development

the effective utilization of natural enemies of pests (Dainese *et al*. 2017; Liu and Chen 2024).

Use of resistant and tolerant varieties against winter cereal pathogens

The withdrawal of active substances from plant protection products in winter cereal production by the European Commission necessitates the accelerated introduction of new varieties that are resistant or tolerant to pathogens. This approach aligns with the principles of integrated plant protection and sustainable crop production (Góral *et al*. 2015; Rudnicki and Piekarczyk 2019; Dyda *et al*. 2022; Spetsov 2022; Dracatos *et al*. 2023; Zhang *et al*. 2023b; Wallace *et al*. 2024; Han *et al*. 2025; Madajska *et al*. 2025). In Poland, the resistance levels of winter cereal varieties to key pathogens are assessed by the Research Centre for Cultivar Testing (RCCT). Varieties deemed suitable for integrated production (IP) are included in the National Register maintained by RCCT and are also featured in the List of Recommended Varieties for individual voivodeships. This classification indirectly contributes to reducing the reliance on chemical plant protection products. All winter cereal species are susceptible to powdery mildew of cereals and grasses. According to the 9-point RCCT resistance scale, an average resistance level (i.e., score of 5) to powdery mildew is recorded in 86.8% of all winter rye varieties, followed by winter barley (67.4%), winter wheat (52.4%), and winter triticale

(46.5%). A resistance level above the average is most common in winter triticale varieties (37.2%), followed by winter wheat (27.0%), winter barley (5.2%), and winter rye (4.4%). The highest proportion of varieties with low resistance is found in winter wheat and winter triticale (both 4.6%), while the lowest is observed in winter barley (2.1%) (RCCT 2025).

Certified integrated production of winter cereals

In Poland, starting in 2023, the Ministry of Agriculture and Rural Development (MARD) implemented funding for a voluntary, yet certified Integrated Production (IP) system as part of the eco-scheme framework (Journal of Laws 2023, item 412). Upon its introduction in 2023, the area under certified winter wheat cultivation was 3,352 hectares, which expanded significantly to 61,345 hectares in 2024. A similar upward trend was observed for winter barley, with certified IP cultivation rising from 1,014 hectares in 2023 to 6,028 hectares in 2024 (MARD 2025). Prior to the introduction of the IP eco-scheme (2019–2022), the certified cultivation area for winter wheat remained limited, ranging between only 431 and 536 hectares (SPHSIS 2025). A key requirement of the IP system includes the mandatory use of certified seed from varieties that exhibit resistance or tolerance to pests, thereby contributing to a reduced need for plant protection products (RCCT 2025). Furthermore, only plant protection products listed on an officially maintained and regularly updated registry may be used in certified IP systems (Strażyński *et al.* 2024). Zieliński *et al.* (2024, 2025a,b) emphasize the importance of the Integrated Production (IP) system as one of the key tools supporting sustainable agricultural practices. However, they point out differences in the implementation of eco-schemes depending on the size of farms and their location.

Challenges and uture outlook

Simplification of winter cereal production technologies, coupled with climate change – including the absence of prolonged winter conditions – and the ongoing withdrawal of active substances (AS) in plant protection products by the European Commission, may significantly increase economic challenges related to pest management and crop protection (Strażyński and Ruszkowska 2015; Strażyński *et al.* 2016; Goulet *et al.* 2023; Marchand 2023a, b). Over the past several decades, an increasing resistance of pests to the prolonged and unilateral use of active substances in agricultural crops has been observed (Peterson *et al.* 2019; Nakka *et al.* 2019; Gruner *et al.* 2020; Gong *et al.* 2021; Synowiec *et al.* 2021; Luo *et al.* 2022; Wacławowicz *et al.* 2022; Wenda-Piesik *et al.* 2022; Stankiewicz-Kosyl *et al.* 2023) or the occurrence of mycotoxins in products (Kosicki *et al.* 2020). Further reductions in the availability of active substances, in the absence of effective alternative solutions, are likely to exacerbate this issue (Metcalfe *et al.* 2024; Wynn and Webb 2022). This situation may lead to an increase in the occurrence of counterfeit plant protection products or those originating from illegal imports (Streloke 2018). Additionally, there have been reported cases of the use of formulations containing withdrawn active substances, as well as the misuse of approved products – such as their application on crops or against pests not listed on the product label.

The aforementioned conditions necessitate, among other measures, the rapid introduction of new crop varieties that are resistant or tolerant to pests. A notable example of breeding progress is the development of winter barley varieties with resistance and tolerance to viral infections (Zhang *et al.* 2023a; RCCT 2025). Significant emphasis is also being placed on the development and application of novel biopreparations (Villaverde *et al.* 2013; Bänziger *et al.* 2022; Marchand 2023c, d). However, the current number of available products remains insufficient. Promising alternatives under investigation include ionic liquids (Kaczmarek *et al.* 2019; Pernak *et al.* 2022; Marcinkowska *et al.* 2023).

In the foreseeable future, chemical plant protection will likely remain the primary strategy for managing pests in winter cereals. Consequently, there is a pressing need for innovative formulations of plant protection products – characterized by prolonged efficacy, high selectivity, and rapid environmental degradation – to ensure both effectiveness and safety for human health and the environment. In particular, such innovations are especially desirable in the form of seed treatments (Dufour *et al.* 2021). In addition to the need to introduce new varieties or innovative plant protection products (safe for humans and the environment, and at the same time effective), the improvement of agrotechnical methods is considered to be of great importance (Brévault and Clouvel 2019; Turner *et al.* 2021; Yamini *et al.* 2025).

Sustainable biological control is achievable under a favorable environment. This means that sustained investments in scientific research and innovation, socio-economic and ecological studies, and influencing consumers' value systems are imperative (Harding and Raizada 2015; Šunjka and Mechora 2022; Nchu 2024).

In light of the overproduction of cereal grains and the insufficient share of leguminous crops in Poland, it is necessary to promote crop diversification as a means to improve crop rotation. Instead of relying solely on the rotation of active substances, the integration of crop rotation, breeding resistant varieties, and the application of non-chemical plant protection methods must be prioritized. To counteract the narrowing spectrum of PPPs, national authorities should simplify the approval process for low-risk and biological agents, offer incentives for companies registering innovative active substances, and strengthen monitoring of counterfeit products. Industries, on the other hand, should invest in research on biopesticides and resistant cultivars, and engage in farmer education on IPM (Sawińska *et al*. 2020). The question remains whether, with limited possibilities of chemical protection of winter cereals, will it be possible to produce food profitably. Non-chemical methods are usually more labor-intensive and expensive and do not always guarantee the expected effect. Nevertheless, the current systems of subsidies for agricultural crops allow for obtaining a beneficial economic effect.

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