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Suitability of winter triticale varieties for composing crop mixtures

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ABSTRACT

The Directive of the European Parliament and of the Council 2009/128/CE establishing a framework for Community action to achieve the sustainable use of pesticides in Annex III "General principles of integrated pest management" emphasizes the use of all possible methods which reduce populations of pests to the level of harmlessness. One of the relatively cheap and easy methods to prolong the genetic resistance of modern varieties is their cultivation in different types of mixtures and in complex interbred populations according to the concept of evolutionary plant cultivation. A three-year field experiment was carried out in two locations to assess the suitability of five winter triticale varieties (Elpaso, Mikado, Tomko, Pigmej and Borowik) for constructing crop mixtures (10 two-component mixtures and 10 three-component mixtures). The suitability of varieties for creating crop mixtures was analysed through the comparison of real and expected yields of mixtures. Coefficients of variation for the yields of variety monocultures ranged from 1.24 % (for Borowik in Bąków 2014) to 37.51 % (for Borowik in Winna Góra 2016). Yield stability for two-component mixtures expressed as CV was from 2.39 % (for Tomko/Borowik in Winna Góra 2015) to 36.16 % (for Mikado/Tomko in Winna Góra 2016), and for three-component mixtures from 2.89 % (for Elpaso/Tomko/Borowik in Winna Góra 2015) to 34.43 % (for Elpaso/Mikado/Borowik in Bąków 2016). Overall, the highest variability of the coefficients of variation was found for variety monocultures (75.91 %), lower for three-co0mponent mixtures (67.67 %) and the lowest for two-component mixtures (66.52 %). The study demonstrated that the Elpaso and Mikado varieties were most suitable for composing high-yielding mixtures; when grown in monocultures their yield was not the highest, but they caused a significant increase in the yield of mixtures (the highest in four out of six locations).

1. Introduction

The general principle in integrated control is to use methods which are most effective and least harmful to the natural environment in a particular period of the development of the cultivated plant. In practice, integrated pest control means using, wherever possible, alternative methods to chemical pest control. The main objective of modern pest management plans is that they must be compatible with the concept of sustainable agriculture, which should be economically beneficial, environmentally friendly, as well as socially accepted and in line with the principles of good plant protection practice [1,2].

One of the cheaper and relatively easy ways to diversify and prolong the genetic resistance of modern varieties is to grow them in various mixed cropping systems. The term "mixed cropping" refers both to planting different species together (cereal + legume or cereal + cereal), as well as planting mixtures of varieties of the same species. The most important benefits from the co-cultivation of cereals include increased biodiversity, which due to the differences between grown plants allows for the better use of environmental resources, without disturbing the biological balance [1–4].

Agricultural experiments and practice revealed up to 40–50 % lower vulnerability to diseases in well-matched variety mixtures, compared to the mean infestation of their components in monocultures, and even greater, 50–60 %, reduction when different crop species were planted together. Mixed cropping reduces production costs, is beneficial in terms of environmental protection, and limits the use of fungicides and insecticides by minimizing the number of chemical treatments [1,3,5–8].

Many experimental studies and scientific reports point to higher and more stable yields of mixtures compared to varieties grown in a monoculture. In view of the above benefits from the cultivation of variety mixtures, it is important to understand the interaction of plants in mixed cropping systems in order to match suitable varieties. The yield of varieties in mixed cropping depends on complementary, compensatory and competitive interactions between plants. Complementation

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concerns positive interactions between plants of different varieties during their growth. Compensation relates to the different use of space by individual components of a polyculture. Another important aspect is competition between plants, which consists in the diversification of plants at particular growth stages. Competition between plants representing different varieties promotes better utilization of the space around plants.

To describe interactions between plants, introduced the term ecological combining ability [9]. Varieties with a high ecological combining ability and good competitive traits yield better when planted with other varieties compared to when grown separately in a monoculture. The yield of mixtures can be higher than the maximal yield of their component grown in a monoculture or lower than the minimal yield of their component. The first case is referred to as transgressive overyielding, and the second case as transgressive underyielding [10, 11]. So far, many attempts have been made to develop methods for estimating the suitability of varieties for mixed cropping [4,10–12].

The aim of our study is to assess the yield level and stability, as well as the suitability of winter triticale varieties for mixed cropping.

2. Material and methods

Experiments with variety monocultures and variety mixtures of winter triticale were carried out in three growing seasons between 2013/1014 and 2015/2016 in two locations: Hodowla Roślin Smolice Sp. z o.o. – Grupa IHAR, a farm in Bąków (Opolskie province) on 10 m^2 plots, and in the Field Experimental Station, Institute of Plant Protection NRI in Winna Góra (Wielkopolskie province) on 16.5 m^2 plots in four replicates. Soil types: podsolic soil and leached brown soil (Bąków); leached brown soil and acid brown soil (Winna Góra).

Five varieties of winter triticale were used in the experiment: Elpaso, Mikado, Tomko, Pigmej and Borowik, in all combinations of two-component and three-component mixtures. Five varieties can be combined into 10 two-component mixtures and 10 three-component mixtures. The sowing rate was 450 grains/m^2, and the proportion of the mixture components was 1:1 or 1:1:1 for three-component mixtures. No fungicide or insecticide treatments were used on the experimental fields. In the study years, plants were treated once with a herbicide at the stage of 2–3 leaves developed (Bąków) and at the tillering stage (Winna Góra).

During the vegetation seasons triticale was mainly infected by powdery mildew (*Blumeria graminis*), brown rust (*Puccinia tritici*) and rhynchosporium (*Rhynchosporium secalis*). The most frequently observed pests are cereal leaf beetles (Oulema spp.) and aphids (*Sitobion avenae* and *Rhopalosiphum padi*).

The effect of mixed cropping on grain yield was assessed by comparing real yields (R) of individual mixtures with their expected yields (E). The real yield was the grain yield obtained per plot, while the expected yield for each mixture was the mean of the grain yield of the mixture components in the variety monoculture. The suitability of varieties for mixed cropping was estimated based on the sum of differences between the yields of a given variety in monoculture and in mixed cropping.

The normality of distribution of the yield traits was tested. Three-way analysis of variance (ANOVA) was performed to verify the hypotheses of lack of effects of locations, years and varieties/mixtures, and the hypotheses about a lack of all interactions on the variability of yield. Real and expected mean values, as well as coefficients of variation were calculated for yield. Moreover, Fisher's least significant differences (LSDs) were also estimated at the significance level $\alpha = 0.05$. The stability of yield was assessed using the coefficient of variation (CV), after determining the significance of the genotype-location interaction, independently for each location. Contrast analysis was performed to test the difference in yield between particular varieties and their mixtures, between varieties and all mixtures, between varieties and v in two components, between varieties and varieties in three components, as well as between two-component and three-component mixtures. Data analysis was performed using GenStat version 18.2.

3. Results

The analysis of variance indicated that yield was influenced by the location, year, variety/mixture, interactions of location × year, years × varieties/mixtures, as well as interaction of location × years × varieties/mixtures. Only location × variety/mixture interaction did not influence the yield (Table 1).

Experiments in Bąków revealed the greatest yield for monocultures of two winter triticale varieties: Tomko (93.62 dt/ha in 2014 and 65.93 dt/ha in 2016), and Borowik (82.42 dt/ha in 2015) (Table 2). The lowest yield was found for Mikado (83.83 dt/ha in 2014), Pigmej (64.33 dt/ha in 2015) and Elpaso (53.27 dt/ha in 2016).

Considering mixed cropping, in 2014 the greatest yield was found for the two-component mixture Tomko/Borowik (97.47 dt/ha). The highest increase in yield (above 5 dt/ha) in relation to the expected (mean yields of mixture components in monocultures) was noted for Elpaso/Mikado, Elpaso/Mikado/Tomko and Tomko/Borowik. The Elpaso/Mikado mixture showed a high yield and yield increase in relation to expected, despite the fact that the Mikado variety grown separately had the lowest yield in 2014 compared to all varietal monocultures. In general, there were no significant differences between the yield of individual varieties and their mixtures analysed together; similarly, there were no differences between the yields of two-component and three-component mixtures (Table 3).

In 2015 the yield of triticale mixtures planted in Bąków was from 64.53 dt/ha (Mikado/Pigmej) to 77.76 dt/ha (Tomko/Borowik). The highest increase in yield compared to the means of components was found for two mixtures: Elpaso/Tomko/Pigmej (9.20 dt/ha) and Tomko/Pigmej (7.83 dt/ha). In both these mixtures Pigmej was the only component which in 2015 produced the lowest yield among all variety monocultures. Generally, mixtures containing Mikado yielded much better than Mikado in a monoculture, and similar observations were made for the Pigmej variety (Table 3). The yield of Borowik was greater than mean yields of mixtures composed with this variety (Table 3). The yield of most two- and three-component mixtures was significantly greater compared to the means of their components grown in monocultures (Table 3).

In 2016 in Bąków the greatest yield was again obtained for the two-component mixture Tomko/Borowik (63.47 dt/ha), and the lowest yield for Elpaso/Mikado (54.35 dt/ha). The highest increase in real yield (2.11 dt/ha) in relation to the expected was noted for the Elpaso/Mikado mixture. As in previous years, the mixture with the highest yield increase contained one component which when grown in a monoculture in 2016 produced the lowest yield (Elpaso – 53.27 dt/ha) (Table 2). Contrast analysis showed no significant differences between any of the nine comparisons (Table 3).

Experiments in Winna Góra revealed the greatest yield for

Table 1
Mean squares from two-way analysis of variance for yield.

Source of variation	Degrees of freedom	Sum of squares	Mean squares
Location	1	408.41	408.41*
Year	2	118322.02	59161.01***
Variety/Mixture	24	4892.33	203.85***
Location × Year	2	14430.89	7215.44***
Location × Variety/Mixture	24	1570.30	65.43
Year × Variety/Mixture	48	5560.02	115.83**
Location × Year × Variety/Mixture	48	3210.49	66.89
Residual	450	30268.32	67.26

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 2
Mean values (real – R and expected – E) and coefficient of variation for the yield in Bąków.

Year	2014				2015				2016			
Variety/Mixture	R	E	R-E	cv%	R	E	R-E	cv%	R	E	R-E	cv%
Borowik	91.23			1.24	82.42			5.09	61.00			23.13
Elpaso	88.75			4.11	72.65			4.89	53.27			23.91
Elpaso/Borowik	92.80	89.99	2.81	6.45	81.67	77.54	4.14	5.60	57.63	57.14	0.49	27.35
Elpaso/Mikado	90.97	85.29	5.68	9.07	70.00	68.69	1.32	9.13	56.45	54.35	2.11	22.64
Elpaso/Mikado/Borowik	91.12	87.27	3.85	4.04	74.65	73.26	1.39	6.56	56.68	56.56	0.12	34.43
Elpaso/Mikado/Pigmej	89.72	85.12	4.60	10.09	72.38	67.23	5.15	8.35	57.60	55.51	2.09	22.39
Elpaso/Mikado/Tomko	93.30	88.07	5.23	8.70	74.93	70.16	4.77	9.07	59.00	58.21	0.79	12.69
Elpaso/Pigmej	85.28	86.77	−1.49	5.47	69.08	68.49	0.59	7.32	55.35	55.56	−0.21	13.09
Elpaso/Pigmej/Borowik	92.05	88.25	3.80	8.08	72.80	73.13	−0.33	4.70	56.73	57.37	−0.64	22.21
Elpaso/Tomko	84.70	91.19	−6.49	14.25	75.55	72.88	2.68	6.89	59.50	59.60	−0.10	20.36
Elpaso/Tomko/Borowik	88.78	91.20	−2.42	7.45	76.62	76.06	0.56	8.31	59.53	60.07	−0.54	24.95
Elpaso/Tomko/Pigmej	93.95	89.05	4.90	10.06	79.23	70.03	9.20	7.39	56.38	59.02	−2.64	20.62
Mikado	81.83			3.44	64.72			3.27	55.42			19.99
Mikado/Borowik	88.25	86.53	1.72	5.19	75.98	73.57	2.41	6.69	54.32	58.21	−3.89	20.02
Mikado/Pigmej	83.65	83.31	0.34	9.98	70.12	64.53	5.60	3.44	51.60	56.64	−5.04	19.38
Mikado/Pigmej/Borowik	83.88	85.95	−2.07	4.56	73.75	70.49	3.26	7.35	54.62	58.09	−3.47	18.36
Mikado/Tomko	78.83	87.73	−8.90	12.78	70.00	68.91	1.09	6.61	60.08	60.68	−0.60	14.80
Mikado/Tomko/Borowik	89.92	88.89	1.03	6.04	77.43	73.41	4.02	5.98	59.92	60.78	−0.86	20.80
Mikado/Tomko/Pigmej	90.25	86.74	3.51	13.52	73.30	67.38	5.92	8.93	57.92	59.73	−1.81	15.79
Pigmej	84.78			7.06	64.33			8.10	57.85			18.59
Pigmej/Borowik	85.30	88.01	−2.71	5.73	72.95	73.38	−0.42	5.44	46.67	59.43	−12.76	29.87
Tomko	93.62			5.89	73.10			3.77	65.93			10.78
Tomko/Borowik	97.47	92.43	5.04	9.18	80.58	77.76	2.82	5.44	56.38	63.47	−7.09	21.84
Tomko/Pigmej	88.95	89.20	−0.25	11.03	76.55	68.72	7.83	8.73	54.52	61.89	−7.37	14.51
Tomko/Pigmej/Borowik	88.83	89.88	−1.05	5.36	75.73	73.28	2.45	6.19	56.65	61.59	−4.94	22.90
$LSD_{0.05}$	10.23				7.04				16.89			

Table 3
Assessment of differences in the yield value between varieties and their mixtures.

Contrast	Bąków 2014	Bąków 2015	Bąków 2016	Winna Góra 2014	Winna Góra 2015	Winna Góra 2016
Elpaso - Elpaso in mixtures	−1.5	−2.0	−4.2	−3.6	−8.5**	−12.9*
Mikado - Mikado in mixtures	−6.2	−8.5**	−1.4	−4.1	−21.0***	6.2
Tomko - Tomko in mixtures	4.1	−2.9	7.9	−3.2	1.0	11.5*
Pigmej - Pigmej in mixtures	−3.4	−9.3***	3.0	−6.0	−0.3	−2.7
Borowik - Borowik in mixtures	1.4	6.2*	5.1	−2.7	4.6	−3.4
Varieties - varieties in all mixtures	−0.9	−3.2*	2.3	−3.9*	−4.8**	−0.3
Varieties - varieties in 2 components	0.4	−2.8*	3.4	−3.9*	−4.4**	−0.6
Varieties - varieties in 3 components	−2.1	−3.6*	1.2	−3.9*	−5.1**	0.0
Two-component mixtures - three-component mixtures	−2.6	−0.8	−2.3	0.0	−0.7	0.7

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

monocultures of two winter triticale varieties: Borowik (78.24 dt/ha in 2014 and 94.58 dt/ha in 2015) and Tomko (62.02 dt/ha in 2016). The lowest yield was found for Pigmej (73.45 dt/ha in 2014 and 44.18 dt/ha in 2016) and Mikado (63.45 dt/ha in 2015) (Table 4).

Considering mixed cropping, in 2014 the greatest yield was found for the two-component mixture Tomko/Borowik (78.20 dt/ha). The highest increase in yield (above 7 dt/ha) in relation to the expected (mean yields of mixture components grown separately) was noted for Elpaso/Mikado, Mikado/Tomko/Borowik and Mikado/Tomko/Pigmej. The Mikado/Tomko/Pigmej mixture showed a high real yield and yield increase in relation to expected, despite the fact that the Pigmej variety when grown separately had the lowest yield in 2014 compared to all varietal monocultures. In general, the mean yield of all varieties was significantly lower than the mean yield of all mixtures; similarly, the mean yields of all the varieties were lower than the means of two- and three-component mixtures (Table 3).

In 2015 the yield of triticale mixtures grown in Winna Góra was from 70.65 dt/ha (Elpaso/Mikado) to 91.88 dt/ha (Pigmej/Borowik). The highest increase in yield compared to the means of components was found for the Mikado/Pigmej mixture (11.72 dt/ha) and for Elpaso/Borowik, Elpaso/Mikado, Elpaso/Mikado/Pigmej and Mikado/Tomko/Pigmej mixtures (over 9 dt/ha). In most of these mixtures the Mikado variety was the only component which when grown separately in 2015 had the lowest yield among all variety monocultures. The yields of Elpaso and Mikado monocultures were significantly lower compared to those of their mixtures. In general, the yield values of two-component, three-component and two- and three-component mixtures combined were significantly higher than the means of varieties grown in monocultures (Table 3).

In 2016 in Winna Góra the greatest yield was obtained for the two-component mixture Mikado/Tomko (59.19 dt/ha), and the lowest yield for Elpaso/Pigmej (38.64 dt/ha). The highest increase in yield in relation to the expected was noted for Elpaso/Mikado (10.76 dt/ha) and Pigmej/Borowik (6.90 dt/ha). As in previous years, the mixture which showed the highest yield increase contained one component which yielded lowest when grown in a monoculture in 2016 (Pigmej – 44.18 dt/ha) (Table 4). The mean yield of mixtures containing Elpaso was significantly greater compared to the yield of Elpaso monocultures

Table 4
Mean values (real – R and expected – E) and coefficient of variation for the yield in Winna Góra.

Year	2014				2015				2016			
Variety/Mixture	R	E	R-E	cv%	R	E	R-E	cv%	R	E	R-E	cv%
Borowik	78.24			7.69	94.58			3.79	45.53			37.51
Elpaso	77.27			9.04	77.85			6.78	33.10			11.73
Elpaso/Borowik	81.61	77.76	3.86	11.03	95.29	86.22	9.08	3.29	37.65	39.32	−1.67	33.57
Elpaso/Mikado	84.91	77.03	7.88	9.91	80.39	70.65	9.74	10.41	55.48	44.73	10.76	13.26
Elpaso/Mikado/Borowik	80.94	77.43	3.51	9.80	83.91	78.63	5.28	5.21	47.45	44.99	2.46	23.01
Elpaso/Mikado/Pigmej	75.85	75.84	0.01	6.77	86.21	76.83	9.38	4.45	40.78	44.54	−3.76	14.87
Elpaso/Mikado/Tomko	78.27	77.40	0.87	13.91	77.12	76.13	0.99	4.92	53.52	50.49	3.03	13.43
Elpaso/Pigmej	79.06	75.36	3.70	10.20	90.64	83.52	7.13	7.80	42.55	38.64	3.91	8.09
Elpaso/Pigmej/Borowik	82.58	76.32	6.26	7.45	89.45	87.20	2.25	5.87	43.77	40.94	2.83	28.18
Elpaso/Tomko	81.67	77.71	3.96	6.97	80.06	82.47	−2.41	2.48	46.33	47.56	−1.23	7.79
Elpaso/Tomko/Borowik	80.30	77.89	2.41	4.88	87.97	86.51	1.46	2.89	47.50	46.88	0.62	11.02
Elpaso/Tomko/Pigmej	83.12	76.29	6.83	8.44	92.27	84.71	7.56	6.96	44.88	46.43	−1.55	18.92
Mikado	76.79			9.11	63.45			11.76	56.35			10.41
Mikado/Borowik	82.03	77.52	4.52	3.06	87.08	79.02	8.07	7.71	54.33	50.94	3.39	21.85
Mikado/Pigmej	80.55	75.12	5.43	9.03	88.03	76.32	11.72	7.29	48.03	50.27	−2.24	19.67
Mikado/Pigmej/Borowik	78.24	76.16	2.08	5.78	87.94	82.40	5.54	9.96	44.25	48.69	−4.44	34.08
Mikado/Tomko	80.03	77.47	2.56	6.14	74.24	75.27	−1.03	4.47	47.45	59.19	−11.74	36.16
Mikado/Tomko/Borowik	84.88	77.73	7.15	4.12	90.50	81.71	8.79	7.69	57.55	54.63	2.92	23.11
Mikado/Tomko/Pigmej	83.52	76.13	7.39	5.93	89.02	79.91	9.11	5.19	52.75	54.18	−1.43	19.74
Pigmej	73.45			8.73	89.18			8.25	44.18			17.52
Pigmej/Borowik	74.97	75.85	−0.88	9.22	94.36	91.88	2.48	8.59	51.75	44.86	6.90	9.54
Tomko	78.15			10.00	87.09			4.38	62.02			8.72
Tomko/Borowik	84.58	78.20	6.39	10.87	91.94	90.84	1.10	2.39	55.05	53.78	1.27	14.94
Tomko/Pigmej	77.45	75.80	1.65	4.72	86.58	88.14	−1.56	7.36	50.17	53.10	−2.93	20.83
Tomko/Pigmej/Borowik	79.55	76.61	2.94	8.84	90.82	90.28	0.54	6.03	49.58	50.58	−1.00	31.77
$LSD_{0.05}$	9.48				8.01				14.41			

(Table 3). The yield of Tomko was better than mean yields of mixtures containing this variety (Table 3).

Coefficients of variation for the yields of variety monocultures ranged from 1.24 % (for Borowik in Bąków 2014) to 37.51 % (for Borowik in Winna Góra 2016) (Tables 2 and 4). Yield stability for two-component mixtures expressed as CV was from 2.39 % (for Tomko/Borowik in Winna Góra 2015) to 36.16 % (for Mikado/Tomko in Winna Góra 2016), and for three-component mixtures from 2.89 % (for Elpaso/Tomko/Borowik in Winna Góra 2015) to 34.43 % (for Elpaso/Mikado/Borowik in Bąków 2016). Overall, the highest variability of the coefficients of variation was found for variety monocultures (75.91 %), lower for three-component mixtures (67.67 %) and the lowest for two-component mixtures (66.52 %). Such large differences in the stability of varieties and mixtures resulted from the very high yield variability in 2016 compared to the first two years of the experiment in both locations (Tables 2 and 4). Results and their analysis demonstrated better yield stability for two- and three-component mixtures compared to the yield of variety monocultures.

The influence of particular varieties on the yield of mixtures was assessed based on the values of real and expected yields. In Winna Góra in 2014 only Pigmej/Borowik produced real yield lower than the expected yield calculated from the means of component varieties grown in monocultures (Table 4). Other mixtures yielded better than expected from the yield of variety monocultures. Real yields were greater than expected for variety mixtures grown in Winna Góra in 2015 and in Bąków in 2014 and 2015. In 2016 differences between real and expected yields were less promising. In Bąków only five out of 20, and in Winna Góra 10 out of 20 mixtures provided real yields higher than expected based on the yields of variety monocultures (Tables 2 and 4). The study demonstrated that the Elpaso and Mikado varieties were most suitable for composing high-yielding mixtures; when grown in monocultures their yield was not the highest, but they caused a significant increase in the yield of mixtures (the highest in four out of six locations).

4. Discussion

The most important advantage of growing cereals in a mixed cropping system is an increase in biodiversity, which in turn allows for better utilization of habitat resources thanks to different qualities of varieties/species grown together. However, varieties for mixtures should be well-matched, because the interactions between plants may be positive or negative, and therefore experimental field trials, as well as detailed studies on plant health and genetics, must be carried out to identify candidate mixtures. Many reports point to the fact that variety/species mixtures, due to their genetic diversity, are more tolerant to poor habitats and agrotechnical conditions compared to monocultures [1,2,4,5].

In recent years in Poland about 17 % of general growing area has been sown with mixtures (cereal and cereal-leguminous). The selection of varieties for mixtures, both intervarieties and interspecies, cannot be optional. The choice of mixtures composition should be preceded by research aimed at population of pathogens and genetic resistance of varieties (species) [1,2]. The necessary supplement to these works should be field experiments aimed at determining and verifying the usefulness of varieties (species) for mixtures composing. Components of mixed stands should have the appropriate growth, agronomic and adaptive properties allowing their cultivation in mixed stands [3,5,6].

Field conditions that are unfavourable for various reasons for one of the components can be beneficial to another component of the mixture. This does not always result in a significant increase in yield but, more importantly, improves yield stability. The analysis of yields of winter triticale varieties in mixed cropping indicated a positive effect of some varieties on the composed mixtures. Two varieties of winter triticale, Elpaso and Mikado, showed the best suitability for composing crop mixtures, by contributing to the largest increase in yield. Better yield stability was found for mixtures of winter triticale varieties, especially those with two components, compared to the means of variety monocultures.

5. Conclusions

The mixed cropping can be recommended in any agricultural production system, especially in sustainable and ecological agriculture, and in the context of guidelines set forth in Directive 2009/128/EC of the European Parliament and of the Council establishing a framework for Community action for the sustainable use of pesticides. Mixed cropping should also be considered when developing and implementing integrated plans for cereal protection in agricultural practice as an environmentally friendly method of yield improvement.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

CRediT authorship contribution statement

Anna Tratwal: Investigation, Data curation, Methodology, Validation, Writing - original draft. **Jan Bocianowski:** Supervision, Conceptualization, Methodology, Software, Formal analysis, Writing - review & editing.

Declaration of Competing Interest

The authors report no declarations of interest.

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