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ORIGINAL ARTICLE

Interaction of herbicides with mepiquat chloride and prohexadione calcium in winter wheat

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Abstract

New solutions in plant protection applications are still highly desirable. Aiming at higher efficiency, environmental safety and profitability of production which, in addition to reducing the costs of the application of plant protection products, limits the destruction of soil structure combined use of agrochemicals seems to be one of the most important method in modern agriculture. In 2016 and 2017, the Plant Protection Institute – National Research Institute in Poznań, Poland, conducted field experiments on the possibility of combining two popular herbicides used to control monocotyledonous weeds: pinoxaden and fenoxaprop-P-ethyl, with a two-component plant growth and development regulator (mepiquat chloride and prohexadione calcium) on KWS Ozon winter wheat. The tested substances were applied at the BBCH 24 stage of winter wheat – herbicide only, and at the BBCH 31 stage – a mix of herbicides with a plant growth and development regulator. Regardless of the method of application of pinoxaden (herbicide only or mixed), high effectiveness of *Apera spica-venti* control was obtained in both years of the study. The mix of pinoxaden with mepiquat chloride and prohexadione calcium reduced the wheat crop height to a similar extent as separate application of the substances. The combined application of fenoxaprop-P-ethyl with mepiquat chloride improved the effectiveness of wheat crop height control. The method of application of the substances had no significant effect on winter wheat yield. Grain yields harvested from plots treated with the above substances were significantly higher than control only in the case of high weed infestation of winter wheat. The technological value of wheat grain depended on the year of study, while the method of application did not have a significant impact on the evaluated parameters.

Keywords: *Apera spica-venti*, fenoxaprop-P-ethyl, lodging, phytotoxity, pinoxaden, stem height, yield

Introduction

In agricultural production, profitability is driven by two main forces: stable yield and minimization of production costs. Therefore, there is a need to implement new solutions in plant protection, aiming at higher efficiency, environmental safety and profitability of production (Głazek and Mrówczyński 1999). In terms of plant protection, an example of such a method is the combined use of agrochemicals, which, in addition to reducing the costs of the application of plant protection products, limits the destruction of soil structure and allows for a modernisation of work organisation on farms. An intangible benefit of the combined use of plant protection products is the possibility of a synergistic effect, which in turn improves their effectiveness. According to the available literature, a combined application of herbicides can be used in order to increase the spectrum of controlled species (Skrzypczak *et al.* 2011). There are also reports on the benefits of combined use of plant growth and development regulators with foliar fertilizers and adjuvants, as well as with fungicides (Stachecki *et al.* 2004; Matysiak and Kaczmarek 2013; Miziniak *et al.* 2017), as well as reports on the beneficial effects of combining herbicides with fungicides, insecticides or nematocydes (Pereira *et al.* 2005; Chahal *et al.* 2013, Barrett 2018). The factor that significantly limits this type of treatment in almost all cases is the time of application of these substances. A prerequisite for such application is the maximum coincidence of application dates, so that the application of the mix would not limit its effectiveness in pest control and would not have a negative impact on further growth and development of the crop. In intensive cereal farming, obtaining high, good quality yield depends, among other things, on the level of applied plant protection during vegetation, i.e. weed control and protection of crops against lodging. Weeds occurring in the crops, especially common wind grass (*Apera spica-venti* L.), strongly compete against crop plants for the basic nutrients necessary for optimal growth and development and also worsen the phytosanitary condition of the crops by increasing the risk of infestation with fungal diseases. The limitation of permanent crop lodging is an equally important factor in stabilizing yields, as crop lodging often results in reduced yields. However, the negative impact of crop lodging is not limited only to the reduction of yields but is also connected with higher harvest costs (harvest time) and decreased grain quality (Sterry 1980; Kelbert *et al.* 2004; Tripathi *et al.* 2004). In order to minimise the risk of crop lodging, exogenous compounds limiting the growth and development of plants, i.e. growth retardants, are generally applied in intensive cereal farming. The products aimed at preventing crop lodging of cereals are based on a number of active substances, including chlorocholine chloride, mepiquat chloride, paclobutrazoles, etephon, trinexapac-ethyl and prohexadione calcium. Their main role is to shorten and stiffen the stems, although in the light of today's research it has already been established that these substances, acting as growth and development regulators, allow for exploiting the yield potential more fully also in the absence of crop lodging (Matysiak 2006; Espindula *et al.* 2009; de Souza *et al.* 2010; Espindula *et al.* 2011). The reduction of stem length as a result of using retardants is closely related to the reduction of gibberellin synthesis – this is how trinexapac-ethyl, chlormequat chloride, mepiquat chloride, paclobutrazol, prohexadione-calcium work – or to the increase of ethylene synthesis (ethephon). The application of plant growth and development regulators results in a change of the proportions in the concentration of endogenous phytohormones, interactions between them, and changes in the sensitivity of plants to them. There is also a hypothesis that by inducing growth inhibition, plant growth and development regulators transport the excess assimilates to other parts of the plant, where they are used e.g. in the process of grain filling. Recent studies have shown that plant growth and development regulators can play a key role in protecting crops from abiotic stress (Jespersen and Huang 2017; Jung and Rademacher 2018; Karimi *et al.* 2019). However, combined application of herbicides and growth retardants requires an appropriate date of application, as it is connected with early application of the herbicide that depends on the stage of development of weeds and late application of growth retardants determined by the mechanism of their action. The available literature provides reports on the combined use of herbicides from different chemical groups with some plant growth and development regulators (chlormequat, trinexapac-ethyl and etephon) (Delchev 2011; Miziniak 2014), as well as reports on the application of growth regulators in combination with fungicides and adjuvants (Matysiak and Kaczmarek 2013; Miziniak and Matysiak 2016).

The aim of the study was to determine the effect of combined application of pinoxaden and fenoxaprop-P-ethyl with a two-component growth and development regulator (mepiquat chloride and prohexadione calcium) on the effectiveness of the control of common wind grass (*A. spica-venti*), as well as on qualitative and quantitative parameters of winter wheat yield.

Materials and Methods

Experimental set-up

Field experiments were conducted in Experimental Station (Torun, 53°1" N, 18°36" E) of Institute Plant Protection in Poznan, Poland, during the 2016 and 2017 growing seasons (September – July). The field trials were carried out on winter wheat cv. KWS Ozon and they were designed as randomized complete block designs with four replicates. The plot size equaled 12 m^2. In the first year of the study, the previous crop of winter wheat was spring barley and in the second one spring wheat. Wheat was sown at density 450 m^2 and the interrow spacing was 12.5 cm. Soil preparation consisted of plowing followed by harrowing and mineral fertilization (150 kg N, 40 kg P_2O_5, 60 kg K_2O ha^{-1}) applied pre-sowing. The soil of the experimental site was loam the organic matter content was 1.16%, and depending on experimental year pH varied from 6.3 to 6.6. Disease and dicotyledonous weed control were carried out with regard to good agricultural practice. In the field experiment included up to 6 treatments and one untreated control. There were used two popular herbicides against monocotyledonous weeds control Axial 50 EC – pinoxaden (5.05%) and Puma Universal 069 EW – fenoxaprop-P-ethyl (6.54%) and plant growth regulator Medax Top – mepiquat chloride + prohexadione calcium (25.5% + 4.4%).

Experimental treatments consisted of: (1) Pinoxaden applied at dose 45 a.i. · ha^{-1} in BBCH 31; (2) Pinoxaden +

+ mepiquat chloride + prohexadione calcium applied as a mixture at doses responsively 45 + 375 + 62.5 a.i. · ha^{-1} in BBCH 31; (3)Pinoxaden applied at dose 45 a.i. · ha^{-1} in BBCH 24 followed by mepiquat chloride + prohexadione calcium applied at dose 375 + 62.5 a.i. · ha^{-1} in BBCH 31; (4) Fenoxaprop-P-ethyl applied at dose 82.8 a.i. · ha^{-1} in BBCH 31; (5) Fenoxaprop-P-ethyl + + mepiquat chloride + prohexadione calcium applied as a mixture at dose 82.8 + 375 + 62.5 a.i. · ha^{-1} in BBCH 31; (6) Fenoxaprop-P-ethyl applied at dose 82.8 a.i. · ha^{-1} in BBCH 21 followed by mepiquat chloride + prohexadione calcium applied at dose 375 + + 62.5 a.i. · ha^{-1} in BBCH 31.

Spraying parameters

Applications were carried out using a bicycle-mounted Victoria sprayer equipped with TeeJet 110 02 VP sprayers using 200 l of spray liquid per ha, with operating pressure of 0.25 MPa.

Observations

Wind grass is very popular and dangerous monocotyledonous species in Poland especially in winter cereals and also in these trials winter wheat was mostly infested by this weed. Weed control were estimated using frame method at the booting stage of wheat. Measure of crop height was done based on 25 randomly collected plants from each plot at BBCH 85. During each vegetation season phytotxity was observed systematically.

Before harvest plant lodging was observed and number of plants per 1 m^2 on each plot was counted. The weight of thousand grains (TGW) was assessed on the basis of five replications of 100 grains. Number of grains per ear was determined by twenty five ears randomly collected from each plot. Grain yield was collected with a Wintersteiger Classic plot combine. Grain yield was determined at 14% grain moisture and then calculated per surface area of 1 ha. The qualitative grain analysis (protein and gluten content as well as Zeleny's value) was conducted with an InfratecTM 1241 Grain Analyser (FOSS).

Statistical analysis

The results of the research were subjected to statistical analysis for two-factor experiments. The results of the Fisher test were evaluated at 1 and 5% significance level. Upon discovering significant differences, a detailed comparison of means using the Student's t-distribution test was performed, determining the lowest significant difference at a 5% significance level.

It was decided to present the results separately for each experimental year, because of different weather conditions during the years 2016 and 2017 (Table 1).

Results

The effectiveness of plant protection products depended on weather conditions. In both years of field experiments, a varied distribution of temperatures in the period of application of growth regulators was observed. In 2016, in the period of 14 days after the application of mepiquat chloride + prohexadione calcium (growth

Table 1. Air temperature during14 days after application growth regulators in winter wheat

Number of days	Air temperature in 2016			Air temperature in 2017		
	maximum	minimum	avarage daily	maximum	minimum	avarage daily
1	13.2	0.0	6.0	22.5	8.0	15.9
2	16.5	6.0	10.6	25.0	12.0	19.0
3	15.0	3.5	11.6	26.0	12.2	19.0
4	19.0	6.0	12.1	26.0	13.0	19.9
5	21.5	6.0	13.4	25.0	11.8	16.3
6	20.0	10.0	13.6	22.0	9.0	15.6
7	21.0	4.5	12.5	21.0	9.0	14.6
8	21.6	5.0	14.4	20.0	13.0	15.2
9	24.4	6.2	16.2	17.5	8.0	12.8
10	25.0	8.0	17.8	23.0	12.0	16.7
11	25.5	10.0	16.6	23.0	9.0	16.2
12	23.5	10.0	17.8	26.0	11.5	19.8
13	25.0	11.0	15.8	27.2	15.0	22.3
14	22.2	10.0	15.9	25.5	12.5	19.3
Avarage	–	–	13.9	–	–	17.3

regulators or a mix with herbicides), lower daily mean air temperatures were recorded than in an analogous period of 2017, and equaled 13.9°C and 17.3°C, respectively (Table 1). Varied temperature conditions affected the effectiveness of mepiquat chloride + prohexadione calcium in both years of the study. Additionally, in the first year of the study, right after the application of growth and development regulators, low temperatures at night ranging from 0 to 6°C were observed, having negative impact on the effect of this group of plant protection substances. Regardless of the method of application of pinoxaden (used alone or mixed with growth regulators), no differences in the effectiveness of *A. spica-venti* control were found in both years of the study. Similar relations were observed in the evaluation of fenoxaprop-P-ethyl mixture with mepiquat chloride + + prohexadione calcium in 2016. However, in the second year of the study, a decreased effectiveness of weed control after the application of the mix (Table 2) was observed. Despite the differences in the effectiveness of common wind grass control, the mean values obtained from each of the variants did not differ significantly.

Considering the biological effectiveness of different methods of application of mepiquat chloride + prohexadione calcium (used alone or mixed with pinoxaden) on controlling the stem height, the growth regulator mix applied in a separate treatment was found to be more effective. Different relations were observed when analyzing the results of the measurement of stem height from plots treated with a mix of growth regulators and fenoxaprop-P-ethyl. In both years of the study, the mixes showed higher effectiveness than the above mentioned substances used separately. Depending on the year, stem shortening ranged from 4.5 to 12.3%. Statistical analysis showed that mepiquat chloride + + prohexadione calcium, used separately or mixed with herbicides, significantly reduced the height of wheat crops in comparison to control. However, the above relations were not observed when analyzing the mean values regarding the method of retardant application (Table 2). Crop lodging was not observed in either year of the study.

In addition, the two-year field study evaluated the impact of mepiquat chloride + prohexadione calcium and herbicides on individual elements of yield components (Table 3). Generally, the method of application of the substances had no effect on the individual elements of yield components (stem density, thousand grain weight, number of grains per ear). In 2016, the high intensity of *A. spica-venti* (175.2 panicles per 1 sqm) observed in the control (Table 2) resulted in an increase in winter wheat yield on plots where the tested substances were used (Table 3). It was only in this study year (2016) when significant differences in yield between treated plots and control plots were obtained. For comparison, a lower weed intensity in the second year of the study (49.5 panicles per 1 sqm) did not affect the crop yield. In 2016, the highest yield (6–9% higher than with other treatment combinations) was recorded after separate use of pinoxaden (BBCH 24) and mepiquat chloride + prohexadione calcium (BBCH 31). Using the calculated correlation coefficients, a highly significant effect of individual elements of the yield structure on the crop yield was found, especially with regard to the TGW and the number of grains per ear (Table 4). The biggest differences were observed in the first year of the study (2016). All objects where the preparations were applied exhibited higher TGW and higher number of grains per ear in comparison with the control object, but the highest TGW was recorded after application of herbicides only (pinoxaden or fenoxaprop-P-ethyl) and the highest number of grains per ear was obtained in the object where pinoxaden was applied at the BBCH 24 stage and growth and development regulators were applied at the BBCH 31 stage (Table 3).

Regardless of the year of the study, the method of application of the tested substances did not affect the quality of wheat grain. The above relations were observed in the case of all of the grain quality parameters analyzed in the experiment (protein, starch, gluten and Zeleny's value (Table 5). The calculated correlation coefficients proved that regardless of the method of application of growth retardants (retardant alone or mixed with herbicide or adjuvant), the percentage content of starch was negatively correlated with the protein and gluten content and the Zeleny's value (Table 6).

Summing up the results obtained from the experiments, it can be stated that the manner of application of pinoxaden (alone or mixed with mepiquat chloride + + prohexadione calcium) had no impact on the effectiveness of common wind grass control (*A. spica-venti*), whereas the combined application of retardant with fenoxaprop-P-ethyl showed varied effectiveness in both years of the study. Regardless of the year of the study, the mix of pinoxaden with mepiquat chloride + + prohexadione calcium reduced the wheat crop height to a similar extent as the separate application of the substances, whereas the combined use of fenoxaprop-P-ethyl with mepiquat chloride + prohexadione calcium improved the effectiveness of wheat crop height control. It was also proved that the method of application had a significant effect on winter wheat yields. The yields harvested from plots treated with the tested preparations were significantly higher than the control only in the case of intensive weed infestation of winter wheat. The technological value of wheat grain depended on the year of the study, while the method of application did not have a significant impact on the evaluated quality parameters. In both years of the study no phytotoxic effect of the tested mixes on KWS Ozon winter wheat was found.

Table 2. Influence of mix application of pinoxaden and fenoxaprop-P-ethyl with mepiquat chloride + prohexadione calcium on the effectiveness of some growth regulators in winter wheat

No.	Treatment	Dose [l · ha^{-1}]	Time of application in wheat (BBCH)	Control of *Apera spica-venti* [%]		Phytotoxicity [%]		Height of winter wheat [cm]				Lodging [%]	
				2016	2017	2016	2017	2016	height reduction [%]	2017	height reduction [%]	2016	2017
1.	Untreated	–	–	175 plants per 1 m^2	50 plants per 1 m^2	0	0	68.5 a	–	69.0 a	–	0	0
2.	Pinoxaden	45	31	100 a	100 a	0	0	65.8 b	–3.9	66.1 ab	–4.2	0	0
3.	Pinoxaden + mepiquat chloride + prohexadione calcium	45 + 375 + 62.5	31	100 a	100 a	0	0	66.5 ab	–2.9	62.8 bc	–9.0	0	0
4.	Pinoxaden/mepiquat chloride + prohexadione calcium	45/375 + 62.5	24/31	100 a	100 a	0	0	65.9 b	–3.8	61.3 c	–11.2	0	0
5.	Fenoxaprop-P-ethyl	82.8	31	99.0 a	99.8 a	0	0	64.5 b	–5.8	66.3 ab	–3.9	0	0
6.	Fenoxaprop-P-ethyl + mepiquat chloride + prohexadione calcium	82.8 + 375 + 62.5	31	99.0 a	84.5 a	0	0	65.4 b	–4.5	60.5 c	–12.3	0	0
7.	Fenoxaprop-P-ethyl/mepiquat chloride + prohexadione calcium	82.8/375 + 62.5	21/31	99.5 a	99.5 a	0	0	66.3 b	–3.2	63.2 bc	–8.4	0	0

Table 3. Influence of mix application pinoxaden and fenoxaprop-P-ethyl with mepiquat chloride + prohexadione calcium on some yield parameters of winter wheat

No.	Treatment	Dose [l · ha^{-1}]	Time of application in wheat (BBCH)	Number of plants per m^2		Weight of thousand grains [g]		Number of grains per ear		Yield [t · ha^{-1}]	
				2016	2017	2016	2017	2016	2017	2016	2017
1.	Untreated	–	–	386 b	596 a	27.7 b	33.4 a	28.9 b	30.0 a	3.06 b	5.98 a
2.	Pinoxaden	45	31	526 a	636 a	33.9 a	32.5 a	36.0 a	29.6 a	6.38 a	6.09 a
3.	Pinoxaden + mepiquat chloride + prohexadione calcium	45 + 375 + 62.5	31	548 a	668 a	32.7 a	31.3 a	36.8 a	28.4 a	6.60 a	5.93 a
4.	Pinoxaden/mepiquat chloride + prohexadione calcium	45/375 + 62.5	24/31	544 a	628 a	33.6 a	31.3 a	38.3 a	29.7 a	7.00 a	5.80 a
5.	Fenoxaprop-P-ethyl	82.8	31	604 a	639 a	34.8 a	33.7 a	31.8 b	30.7 a	6.59 a	6.61 a
6.	Fenoxaprop-P-ethyl + mepiquat chloride + prohexadione calcium	82.8 + 375 + 62.5	31	561 a	601 a	31.9 ab	32.4 a	36.8 a	30.6 a	6.61 a	5.95 a
7.	Fenoxaprop-P-ethyl/mepiquat chloride + prohexadione calcium	82.8/375 + 62.5	21/31	550 a	669 a	31.9 ab	31 ,0 a	36.9 a	29.4 a	6.44 a	6.09 a

Table 4. Correlation coefficients between the yield and other elements of the yield components during the experimental years

	Yield	
Variable	significance [2016]	significance [2017]
Plants per 1 sqm	0.830*	0.108
Weight of thousand grains	0.651*	0.608*
Number of grains per 1 ear	0.759*	0.523*

*significance at 0.01 level

Discussion

Weather conditions influence the effectiveness of all groups of plant protection products, with the plant growth and development regulators being affected the most. The above applies both to the temperature at the time of application and a few days after the treatment. The optimal temperature for the application of growth and development regulators is the daily temperature of 7–10°C, which is directly related to the physiological activity of the plant. Synthetic plant growth and development regulators act on plant hormones, as their biosynthesis is regulated by ambient temperature (Lougheed and Franklin 1972; Evans *et al.* 1999; Matysiak 2006; Bahuguna and Jagadish 2015).

The influence of ambient temperature immediately after the treatment is also visible in the studies presented in this paper. However, it was in the year when less favorable weather conditions occurred that more varied effects of the tested substances were obtained. It is probably related to the applied herbicides: pinoxaden and fenoxaprop-P-ethyl, which in the studies conducted by Xie *et al.* (1994) and Collings *et al.* (2003) are presented as substances highly dependent on weather conditions, hence the decrease in the effectiveness of *A. spica-venti* destruction observed in the presented studies after the application of fenoxaprop-P-ethyl separately and in combination with growth and development regulators in the second year of the experiments. According to some authors, the combined application of herbicides with growth retardants contributes to the increase of weed-control effectiveness of mixes (Kieloch *et al.* 2010; Marczewska-Kolasa and Kieloch 2012). A different opinion was published by Krawczyk (2006) who studied mixes of florasulam with growth retardants and saw an improvement in the effectiveness of weed control only after adding an adjuvant to spray liquid containing the herbicide and growth regulators (trinexapak-ethyl and CCC).

The presented studies prove that herbicides do not limit the retardant properties of plant growth and development regulators and are not affected by the application method (used separately or in a mix). The obtained results are confirmed by the works of other authors (Wünsche 1974; Krawczyk 2006). Some literature data show a synergistic effect of the regulator and the herbicide. In their studies, Pietryga and Mączyńska (1999) and Pietryga and Drzewiecki (2000) prove that the use of growth retardants mixed with herbicides improves their effectiveness. According to Wünsche (1974), mixes of chlorocholine chloride (CCC) with herbicides from the group of growth regulators improve the effectiveness of the retardant by 30.9% compared to separate application of the preparations. Our research shows that the biggest stem height reduction occurred after using the regulators in a mix with fenoxaprop-P-ethyl, whereas in the case of pinoxaden, better effects were achieved by applying the substances separately. The available literature also provides information about retardation properties of some active substances of herbicides. Such an effect is commonly known in the case of herbicides from the group of growth regulators (Soltani *et al.* 2006; Sikkema *et al.* 2007). However, there are also reports on the effect of herbicides from other chemical groups on crop height reduction, including acetyl-CoA inhibitors and the herbicides (Miziniak 2014). Our own research did not unequivocally confirm this theory.

Some authors state that the applied growth retardants contribute to the improvement of grain yielding. Taking into account their influence on individual elements of yield components, most researchers believe they have a beneficial effect on stem density and grain number per spike (Peltonen and Peltonen-Sainio 1997; Starczewski *et al.* 2002). Among the available scientific reports, the most varied opinions concern the influence of regulators on the TGW (Giltrap and Garstang 1991; Woolley 1991; Starczewski *et al.* 2002). This has not been unequivocally confirmed in the presented studies because these properties were significantly affected by weather conditions and significant differences were obtained in the year when the temperatures in the period immediately after the treatment were less favorable.

Our experiments shows that the substances, both herbicides and plant growth and development regulators, did not have any effect on the content of protein, starch, gluten and the Zeleny's value. These results are similar to those presented by Pawłowska and Dietrych-Szóstak (1994). According to the authors, the regulators do not cause any significant changes in protein

Table 5. Influence of mix application pinoxaden and fenoxaprop-P-ethyl with mepiquat chloride on some parameters of winter wheat grains

No.	Treatment	Dose [l · ha^{-1}]	Time of application	Protein content [%]		Starch content [%]		Gluten content [%]		Zeleny's value [%]	
				2016	2017	2016	2017	2016	2017	2016	2017
1.	Untreated	–	–	13.6 a	14.1 a	67.4 a	66.8 a	33.0 a	34.2 a	46.0 a	49.8 a
2.	Pinoxaden	45	31	13.6 a	14.0 a	67.7 a	66.9 a	33.6 a	34.3 a	48.1 a	49.1 a
3.	Pinoxaden + mepiquat chloride + prohexadione calcium	45 + 375 + 62.5	31	13.6 a	14.1 a	67.9 a	66.2 a	33.3 a	34.7 a	47.2 a	49.9 a
4.	Pinoxaden/mepiquat chloride + prohexadione calcium	45/375 + 62.5	24/31	13.6 a	14.0 a	67.4 a	66.7 a	33.3 a	34.3 a	46.8 a	48.3 a
5.	Fenoxaprop-P-ethyl	82.8	31	13.7 a	13.5 a	66.9 a	67.5 a	33.8 a	32.7 a	47.5 a	44.4 a
6.	Fenoxaprop-P-ethyl + mepiquat chloride + prohexadione calcium	82.8 + 375 + 62.5	31	13.7 a	13.6 a	67.1 a	67.3 a	33.3 a	32.9 a	47.1 a	45.4 a
7.	Fenoxaprop-P-ethyl/mepiquat chloride + prohexadione calcium	82.8/375 + 62.5	21/31	13.7 a	14.4 a	66.6 a	66.2 a	33.5 a	35.2 a	46.6 a	51.6 a

Table 6. Correlation coefficients between the content of starch and other grain quality parameters during the experimental years

Variable	Starch	
	significance [2016]	significance [2017]
Protein	–0.83199*	–0.89470*
Gluten	–0.68103*	–0.83457*
Zeleny's value	–0.68695*	–0.87849*

*significance at 0.01 level

content in grains. Leszczyńska and Nieróbca (2004) and Cacak-Pietrzak *et al.* (2006) presented a similar view. Although the above-mentioned authors proved a lack of a significant influence of the applied growth regulators on the majority of the analysed properties, they also indicated that the applied substances may increase or decrease some of them. In both years of the study no phytotoxic effect of the tested mixes on KWS Ozon winter wheat was found. The studies conducted by Krawczyk (2006), Kieloch *et al.* (2010), and Miziniak (2014) also confirm the possibility of a combined use of herbicides with retardants without phytotoxic effects on winter wheat.

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