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Two tank-mix adjuvants effect on yield and quality attributes of wheat treated with growth retardants

Aplicação combinada de retardadores de crescimento com adjuvantes sobre a produtividade e a qualidade do grão de trigo

Wojciech Miziniak[I] Kinga Matysiak[II]

ABSTRACT

The objective of this study was to evaluate the quality of seeds and yield of winter wheat under different retardants application. The two years field trials on winter wheat were carried out in the Institute of Plant Protection - National Research Institute in Poznan (Poland). Treatments consisted of trinexapac-ethyl, chlormequat and prohexadione calcium applied in mixtures with paraffin oil adjuvant or organosilicone surfactant in BBCH 31 growth stage of winter wheat. No lodging occurred in any experimental year. The retardants had varying effect on the quality parameters of wheat grain. The highest fluctuations in the content of protein, gluten and the Zeleny value were observed after the application of chlormequat chloride. Starch content in wheat grain, regardless of the retardant application method, was negatively correlated with others grain quality parameters evaluated in the experiment. Depending on the year of study and weather conditions, increased or decreased wheat quality.

Key words: *trinexapac-ethyl, prohexadione calcium, chlormequat, organosilicone surfactant, oil adjuvant, grain quality.*

RESUMO

O objetivo deste estudo foi avaliar o tamanho e a qualidade do grão de trigo de inverno em condições de aplicação de diferentes retardadores e a possibilidade de os combinar com adjuvantes e herbicidas. Durante dois anos, o Instituto de Proteção de Plantas – Instituto Nacional de Pesquisa em Poznań (Polônia) realizou ensaios no campo de trigo de inverno. Os tratamentos consistiram em: trinexapac-etil ou clormequat ou prohexadiona-cálcio, aplicados em misturas com óleo adjuvante ou surfactante organossilicone na fase BBCH 31. Não se observou acamamento de plantas em nenhum ano dos ensaios. Os retardadores apresentaram efeitos variados sobre os parâmetros de qualidade do grão de trigo. As maiores variações no teor de proteínas, glúten e no índice de Zeleny foram observadas após a aplicação de clormequat. O teor de amido no grão, independentemente do retardador utilizado e do modo da sua aplicação, foi negativamente correlacionado com outros parâmetros de qualidade avaliados nos ensaios. Dependendo do ano de estudos, aumentava ou reduzia a qualidade do grão.

Palavras-chave: *trinexapac-etil, prohexadiona-cálcio, clormequat, surfactante organossilicone, óleo adjuvante, qualidade de grão.*

INTRODUCTION

Plant growth retardants also known as plant growth regulators are generally applied to limit the risk of crop lodging, in case of grains intensive cultivation. They are traditionally and almost exclusively used in high-input cereal management to increase lodging resistance (RAJALA & PELTONEN-SAINIO, 2000). Lodging in cereals often results in the decrease of the photosynthetic capacity of crops, disruption of the absorption of nutrients and water by the plants, resulting in significant crop losses and decline in the grain quality - increased amount of chaff and decreased baking quality of flour (CACAK-PIETRZAK et al., 2006; MATYSIAK, 2006). Growth retardants (i.e. chlormequat chloride, etephone, trinexepac-ethyl, prohexadione-calcium) can prevent lodging by reducing stem elongation and improving the stem mechanical strength. It is proved that activity of them depends on the rate, crop growth stage and environmental conditions. Plant growth regulators used

[I]The Experimental Station of the Institute of Plant Protection, National Research Institute, Pigwowa 16, 87-100, Toruń, Poland.
[II]Weed Science Department, Institute of Plant Protection, National Research Institute, Władysława Węgorka 20, 60-318, Poznań, Poland. E-mail: K.Matysiak@iorpib.poznan.pl. Corresponding author.

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in manipulating growth of small-grain cereals improve quantity and quality indirectly rather than directly and enhanced photosynthate production and portioning into grain (RAJALA & PELTONEN-SAINIO, 2002; STACHECKI et al., 2004). To support the action of some plant protection products and for increase their biological activity a very common practice is adding adjuvants to them. The role of adjuvants on the activity of plant growth regulators is rather poorly documented but some studies confirm that adjuvants could improve biological activity of growth retardants (STACHECKI et al., 2004). Adjuvants and surfactants can improve the physico-chemical properties of the spray solution. They reduce the surface tension of spray solution, increase the chance of droplets to stay on the plant surface and increase the droplets spread on leaf surface and thus they allow to reduce rates of growth retardants without compromising their effectiveness as well as they reduced treatments costs. Most adjuvants are products intended for use mainly with herbicides and only few of t hem can be used with other agents (e.g. retardants, fungicides) (STAGNARI et al., 2007; MOUSAVINIK et al., 2009; KWIATKOWSKI et al., 2012; HARASIM et al., 2014).

In the present study, a hypothesis was made that quality attributes of wheat grain can be modified by retardants. Moreover, growth retardants activity can be enhanced by adjuvants, allowing to use growth retardants in lower rates. In this study it was included three growth retardants with similar mode of action in plants (antigibberelins); two of them (trinexapac-ethyl and prohexadione calcium) belong to the same chemical group – (cyclohexanediones) and all of them are recommended to use in cereals (RADEMACHER, 2000). The aim of this investigation was to determine the effect of growth retardants as well as combined application of growth retardants with adjuvants on yield and quality attributes of winter wheat grain.

MATERIALS AND METHODS

Experimental set-up

Field experiments were conducted in the Experimental Station (Torun, 53° 1′ N, 18° 36′ E) of the Institute Plant Protection in Poznan, Poland, during 2011 and 2013 growing seasons (September – July). The field trials were carried out on winter wheat cv. 'Alcazar' and they were designed as randomized complete block designs with four replicates. The plot size equaled $12m^2$. In both years under study, the winter wheat was fore cropped by spring barley. Wheat was sown at density $450m^{-2}$ and the interrow spacing was 12.5cm. Wheat cultivar 'Alcazar' is characterized by medium lodging resistance and height resistance against diseases. Soil preparation consisted of plowing followed by harrowing and mineral fertilization (150kg N, 40kg P2O5, 60kg K2O ha^{-1}) applied at pre-sowing. Soil of the experimental site was loam, the organic matter content was 1.14%, and depending on the experimental year pH varied from 6.4 to 6.6. Disease, pest and weed control were carried out with regard to good agricultural practice. The field experiment included up to 9 treatments and one untreated control. Three retardants 1) trinexapac-ethyl (Moddus 250 EC, 25.5%); 2) chlormequat (Antywylegacz płynny 725 SL, 72.5%), 3) prohexadione calcium (Regalis 10 WG, 10%) were applied separately at full (recommended) doses: 100g ha^{-1} of trinexapac-ethyl (TE); 1450g ha^{-1} of chlormequat (CCC) and 50g ha^{-1} of prohexadione calcium (PC) and as a tank-mix with organosilicone surfactant 80g ha^{-1} (Slippa; 90%) or paraffin oil adjuvant 1140g ha^{-1} (Atpolan 80 EC, 80%) in reduced doses: TE - 50g ha^{-1}; CCC - 725g ha^{-1} and PC - 37g ha^{-1} respectively. All these substances were applied at growth stage BBCH 31 of the crop.

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 0.25MPa. Before harvest plant lodging, it was observed a number of plants per $1m^2$ and each plot was counted. The thousand gain weight 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 combined. Grain yield was determined at 14% grain moisture and then calculated per surface area of 1ha. The qualitative grain analysis was conducted with an InfratecTM 1241 Grain Analyser (FOSS).

Statistics

Results of the research were subjected to statistical analysis for two-factor experiments, in accordance to the experiment model, with the use of FR - ANALWAR - 4.3 software. 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 completely different weather conditions during the years 2011 and 2013 (Table 1).

Table 1 - Weather conditions during the investigation years.

Year	Month									
	X	XI	XII	I	II	III	IV	V	VI	VII
	Average temperature (^{0}C)									
2011	6.6	5.1	-6.1	-15.8	-2.5	5.1	12.0	14.1	18.2	18.3
2013	8.4	5.2	-2.6	-3.6	-0.6	-1.5	7.7	15.3	17.4	18.4
	Rainfall (mm)									
2011	5.3	156.7	55.8	23.7	14.4	10.4	11.3	53.8	63.0	244.5
2013	26.4	62.0	27.0	63.6	24.5	40.1	19.0	87.0	46.6	104.3

RESULTS AND DISCUSSION

The experiments showed that there was no significant influence of growth retardants on the yield structure elements in comparison with untreated control. The available literature provides different information as to the influence of growth retardants on grain yield. According to MATYSIAK (2006) the cereal grain yield may also be increased in case of a lack of permanent crop lodging. Some authors observed that retardants have influence on the number of seeds per ear and the mass of thousand grains but the influence is often the retardant type or rate depended (ESPINDULA et al., 2009; ESPINDULA et al., 2011).

On the basis of our own data it has been established that in case of winter wheat sprayed with growth retardants, regardless of the method of application, number of spikes·m^2 was similar to the results from the control (Table 2). In the research on four wheat varieties described by GRIJALVA-CONTRERAS et al. (2012), trinexapac-ethyl did not affect the number of spikes·m^{-2} of any wheat variety but decreased the number of grains per spike. Our own studies show that, in case of weight of thousand grains the results were depended on the experimental year. Decrease value of weight of thousand grains were observed on plots were prohexadione calcium were applied (Table 3). In any experimental year we have not obtained the yield decrease as a result of growth retardants use, but decrease of wheat grain yield following trinexapac-ethyl or chlormequat chloride application was recorded by GRIJALVA-CONTRERAS et al. (2012) and SHEKOOFA & EMAM (2008). STACHECKI et al. (2004) stated that wheat yield response to chlorocholine chloride

Table 2 - Influence of mix application growth regulators with adjuvants on number of spikes per square meter and number of grains in wheat ears.

Treatments	Dose g·ha^{-1}	No. spikes·m^{-2}		No. grains/ear	
		Experimental years			
		I	II	I	II
TE	100	515a	532ab	38.8a	36.8a
TE + OS	50 + 80	597a	581ab	35.0a	38.3a
TE + POA	50 + 1140	495a	536ab	38.3a	38.5a
CCC	1450	560a	577ab	38.9a	39.3a
CCC + OS	725 + 80	481a	584ab	38.0a	38.4a
CCC + POA	725 + 1140	494a	519b	39.9a	41.3a
PC	75	523a	563ab	37.9a	40.9a
PC + OS	37 + 80	567a	612a	37.0a	37.5a
PC + POA	37 + 1140	579a	591ab	38.1a	40.8a
Control	0.0	471a	572ab	42.8a	38.1a
LSD (0.05)		ns	85.56	ns	ns

TE - Trinexapac-ethyl; CCC – Chlormequat; PC - Prohexadione calcium; OS - Organosilicone surfactant; POA - Paraffin oil adjuvant.

Table 3 - Influence of mix application growth regulators with adjuvants on thousand grain weight and grain yield of wheat.

Treatments	Dose g·ha^{-1}	TGW (g)		Grain yield (t·ha^{-1})	
		Experimental years			
		I	II	I	II
TE	100	36.9a	36.2bc	7.38ab	7.07b
TE + OS	50 + 80	37.0a	35.6bc	7.61ab	7.95ab
TE + POA	50 + 1140	36.6a	38.8a	6.93ab	8.01ab
CCC	1450	34.8a	36.3c	7.57ab	8.22ab
CCC + OS	725 + 80	35.1a	35.6bc	6.43b	7.98ab
CCC + POA	725 + 1140	35.1a	37.2ab	6.92ab	7.97ab
PC	75	36.5a	34.6bc	7.20ab	7.90ab
PC + OS	37 + 80	36.5a	36.0bc	7.59ab	8.28ab
PC + POA	37 + 1140	36.4a	36.6abc	8.02a	8.85a
Control	0.0	37.4a	36.4abc	7.29ab	7.93ab
LSD (0.05)		ns	2.48	1.391	1.213

TE - Trinexapac-ethyl; CCC – Chlormequat; PC - Prohexadione calcium; OS - Organosilicone surfactant; POA - Paraffin oil adjuvant.

and prohexadione-calcium is strongly influenced by weather conditions.

The technological value of winter wheat grain depends on its physio-genetic properties that are modified by climate conditions and the applied agricultural practices (LESZCZYŃSKA & CACAK-PIETRZAK, 2004). The above relation was confirmed in own studies. In 2011, during the grain ripening period, a lower air temperature and higher precipitations were recorded than in the corresponding period of 2013 (Table 1). Therefore, the wheat grain from the 2011 harvest was of lower quality in terms of protein, gluten and Zeleny index than the 2013 grains (Table 4 and 5).

However, some research reports concluded that foliar application of chlormequat and trinexapac-ethyl did not affect the physiological quality of wheat seeds (SOUZA et al., 2010), most publications point to the decrease of protein content, gluten content and the falling number (CACAK-PIETRZAK et al., 2006) after application of growth retardants. The investigations showed a varying impact of retardants on the evaluated

Table 4 - Influence of mix application of growth regulators with adjuvants on protein and starch content in wheat grains.

Treatments	Dose g·ha^{-1}	Protein (%)		Starch (%)	
		Experimental years			
		I	II	I	II
TE	100	11.1ab	12.4bc	72.1a	68.8a
TE + OS	50 + 80	11.3ab	13.3ab	71.9a	67.5ab
TE + POA	50 + 1140	10.7ab	12.5abc	72.5a	68.9a
CCC	1450	11.7a	12.0c	70.8a	69.0a
CCC + OS	725 + 80	10.0b	12.1c	72.0a	69.0a
CCC + POA	725 + 1140	10.3ab	12.7abc	71.9a	68.2ab
PC	75	10.6ab	12.7abc	72.1a	68.1ab
PC + OS	37 + 80	10.5ab	13.1abc	71.9a	67.5ab
PC + POA	37 + 1140	10.5ab	12.6abc	72.2a	68.3ab
Control	0.0	10.5ab	13.7a	71.7a	66.6b
LSD (0.05)		1.46	1.20	1.78	1.94

TE - Trinexapac-ethyl; CCC – Chlormequat; PC - Prohexadione calcium; OS - Organosilicone surfactant; POA - Paraffin oil adjuvant.

Table 5 - Influence of mix application of growth regulators with adjuvants on gluten content and Zeleny value in wheat grains.

Treatments	Dose g·ha^{-1}	Gluten (%)		Zeleny value	
		Experimental years			
		I	II	I	II
TE	100	24.8ab	30.9bc	27.5ab	36.1bc
TE + OS	50 + 80	25.4ab	33.9ab	30.1a	44.0ab
TE + POA	50 + 1140	23.6ab	31.5abc	26.2ab	37.6abc
CCC	1450	26.9a	29.7c	30.9a	33.2c
CCC + OS	725 + 80	21.3b	29.8c	22.6b	33.4c
CCC + POA	725 + 1140	22.7ab	31.9abc	24.2ab	38.5abc
PC	75	23.3ab	32.0abc	24.5ab	38.8abc
PC + OS	37 + 80	23.1ab	33.1abc	25.4ab	42.7abc
PC + POA	37 + 1140	22.8ab	31.6abc	24.6ab	38.6abc
Control	0.0	23.1ab	35.1a	24.7ab	47.17a
LSD (0.05)		4.72	3.84	7.38	10.44

TE - Trinexapac-ethyl; CCC – Chlormequat; PC - Prohexadione calcium; OS - Organosilicone surfactant; POA - Paraffin oil adjuvant.

technological values. In 2011, lower quality parameters of grain were recorded in comparison with the control and the plots sprayed with chlormequat. However, in the second year of the study, a significant increase of the protein and gluten content in the grain of wheat obtained from the treatment sprayed with chlormequat chloride in comparison with the control and the treatments sprayed with prohexadione-calcium (Table 4 and 5). Statistical analysis showed a significant increase of the Zeleny value of grains from treatments where trinexapac-ethyl or chlormequat were applied (Table 5).

In 2011, no significant differences in the evaluated quality parameters of grain were observed between the untreated control and the plots treated with full-dose retardants (Table 4 and 5). The highest protein and gluten content, as well as the highest value of the Zeleny value were observed in grain obtained from plots sprayed with chlormequat. Opposite results were observed in the next year of trials. Chlormequat chloride, when applied in the recommended dose, had significant influence on decreasing the protein and gluten content and the Zeleny sedimentation value in comparison with the control (Table 4 and 5). Hereby, the study results did not show a distinctive influence of chlormequat on the quality parameters of the wheat grain. CACAK-PIETRZAK et al. (2006) and LESZCZYNSKA & CACAK-PIETRZAK (2004) indicated that chlormequat has no effect on the protein content in wheat grains.

In case of quality evaluation of the grain harvested from the plots sprayed with the mixes of chlormequat chloride and the organosilicone surfactant, a significant decrease of the protein and gluten content, as well as of the sedimentation index, has been observed in comparison with the control and the study variants where chlormequat chloride was applied in full dose or in combination with paraffin oil adjuvant (Table 4 and 5). These relations were also observed in the second year of the study. In comparison with the results obtained in 2011, a significant decrease of quality of the grain was observed only in comparison with the control and the mix of chlormequat chloride with paraffin oil adjuvant.

According to HARASIM & WESOŁOWSKI (2013), trinexapac-ethyl does not have any significant impact on the quality parameters of wheat grain. Our studies showed similar relations. Trinexapac-ethyl and prohexadione-calcium and their mixes with adjuvants had no significant impact on wheat grain quality parameters (Table 4 and 5). However, a two-year study showed some improvements of the evaluated parameters in case of the wheat grain sprayed with a mix of trinexapac-ethyl and the organosilicone surfactant. In case of all of the study variants in which the retardants were applied, an increase in the content of starch and hardness of kernels was observed in comparison with the untreated control (Table 4 and 5).

The calculated correlations coefficients proved that regardless of the method of application of growth retardants (retardant alone, mix with herbicide or adjuvant), the percentage content of starch was negatively correlated with the protein and gluten content and the Zeleny index (Table 6).

Table 6 - Correlation coefficients between the content of starch and other grain quality parameters of wheat.

Variable	Correlation coefficients: Significance level P<0.05	P<0.01	P<0.001
	Starch		
Protein	-0.96338*	-0.96338**	-0.96338***
Gluten	-0.97765*	-0.97765**	-0.97765***
Zeleny value	-0.96184*	-0.96184**	-0.96184***
	Gluten		
Protein	0.995511*	0.995511**	0.995511***
Zeleny value	0.985479*	0.985479**	0.985479***
	Zeleny value		
Protein	0.992423*	0.992423**	0.992423***

Results of the study confirm that growth retardants, affect yield components and quality attributes of wheat grain. Differences in action of active substances, on yield and its components have been apparent regardless of adjuvant addition and type of the adjuvant. The knowledge acquired in this study, confirms that rate of growth retardants can be reduced by tank-mix application with adjuvants and it can be obtained, without any risk of negative influence on quantity and quality attributes of yield. Further studies should; however, be broadened with field trials performed under the high risk of lodging occurrence.

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REFERENCES

CACAK-PIETRZAK, G. et al. Effect of some retardants on baking quality of winter wheat. **Progress in Plant Protection**, v.46, n.2, p.89-92, 2006.

ESPINDULA, M.C. et al. Rates of nitrogen and growth retardant trinexapac-ethyl on wheat. **Ciência Rural**, v.41, p.2045-2052, 2011. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-84782011001200002&lng=en&nrm=iso>. ISSN 0103-8478. doi: S0103-84782011001200002. Accessed: Mar. 23, 2015.

ESPINDULA, M.C. et al. Use of growth retardants in wheat. **Planta Daninha**, v.27, n.2, p.379-387, 2009. Available from: <http://www.scielo.br/scielo.php?script=sci_pdf&pid=S0100-83582009000200022&lng=en&nrm=iso&tlng=en>. Accessed: Mar. 23, 2015.

GRIJALVA-CONTRERAS, R.L. et al. Effects of trinexapac-ethyl on different wheat varieties under desert conditions of Mexico. **Agricultural Sciences**, v.3, p.658-662, 2012. Available from: <http://www.scirp.org/journal/PaperInformation.aspx?PaperID=22566#.VUtWyPntlBc>. Accessed: Feb. 20, 2015.

HARASIM, E.; WESOŁOWSKI, M. The effect of retardant Moddus 250 EC and nitrogen fertilization on yielding and grain quality of winter wheat. **Fragmenta Agronomica**, v.30, n.3, p.70-77, 2013. Available from: <http://www.up.poznan.pl/pta/pdf/2013/FA%2030(3)%202013%20Harasim.pdf>. Accessed: Feb. 20, 2015.

HARASIM, E. et. al. The effect of reduced growth retardant rates on weed infestation of a winter wheat (***Triticum aestivum*** L.) crop. Romanian Agricultural Research, v.31, p.271-281, 2014. Available from: <http://www.incdafundulea.ro/rar/nr31/rar31.33.pdf>. Accessed: Feb. 20, 2015.

KWIATKOWSKI, C.A. et al. The effect of adjuvants and reduced rates of crop protection agents on the occurrence of agricultural pests and on winter wheat productivity. **Annales Universitatis Mariae Curie-Skłodowska Lublin – Polonia**, v.67, n.3, p.12-21, 2012. Available from: <http://wydawnictwo.up.lublin.pl/annales/Agricultura/2012/streszczenie2012_3/02.pdfTable>. Accessed: Sept. 11, 2015.

LESZCZYŃSKA, D.; CACAK-PIETRZAK, G. Influence of retardants on yields and some quality characters of winter wheat. **Electronic Journal of Polish Agricultural Universities**, v.7, n.2, p.1-11, 2004. Available from: <http://www.ejpau.media.pl/volume7/issue2/food/art-11.html>. Accessed: Mar. 25, 2015.

MATYSIAK, K. Influence of trinexapac-ethyl on growth and development of winter wheat. **Journal of Plant Protection Research**, v.46, n.2, p.133-143, 2006. Available from: <http://www.plantprotection.pl/PDF/46%282%29/JPPR_46%282%29_2_Matysiak.pdf>. Accessed: Feb. 20, 2015.

MOUSAVINIK, A. et al. Ability of adjuvants in enhancing the performance of pinoxaden and clodinafop propargyl herbicides against grass weeds. **Iranian Journal of Weed Science**, v.5, p.65-77, 2009. Available from: <http://www.sid.ir/en/VEWSSID/J_pdf/102820090206.pdf>. Accessed: Mar. 25, 2015.

RAJALA, A.; PELTONEN-SAINIO, P. Timing applications of growth regulators to alter spring cereal development at high latitudes. **Agricultural and Food Sciences in Finland**, v.11, p.233-244, 2002. Available from: <https://jukuri.luke.fi/bitstream/handle/10024/451516/afsf11233.pdf?sequence=1>. Accessed: Sept. 11, 2015.

RAJALA, A.; PELTONEN-SAINIO, P. **Manipulating yield potential in cereals using plant growth regulators**. In: BASRA, A.S. Plant growth regulators in agriculture and horticulture. Their role and commercial uses. Chapt.2, p.27-58, 2000.

RADEMACHER, W. Growth retardants: Effects on gibberellin biosynthesis and other metabolic pathways. **Annual Review of Plant Physiology and Plant Molecular Biology**, v.51, p.501-531, 2000. Available from: <http://www.botanik.kit.edu/botzell/downloads/intern_Rademacher_2000.pdf>. Accessed: Sept. 11, 2015.

SHEKOOFA A.; EMAM Y. Effects of nitrogen fertilization and plant growth regulators (PGRs) on yield of wheat (***Triticum aestivum*** L.) cv. 'Shiraz'. **Journal of Agricultural Science and**

Technology, v.10, p.101-108, 2008. Available from: <http://jast.modares.ac.ir/pdf_4403_20487c899967a3e1f7a2056bd82075a1.html>. Accessed: Mar. 25, 2015.

SOUZA, L.T. et al. Growth retardants in wheat and its effect in physiological quality of seeds. **Ciência Rural**, v.40, n.6, p.1431-1434, 2010. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S01038478201000060003 1&lng=en&nrm=iso>. Accessed: Mar. 25 2015. doi: 10.1590/S01038478201000600031.

STACHECKI, S. et al. Adjuvant effects on plant growth regulators in winter wheat. **Journal of Plant Protection Research**, v.44, n.4, p.365-371, 2004. Available from: <http://www.plantprotection.pl/PDF/44(4)/JPPR%2044(4)_11.pdf>. Accessed: Sept. 11, 2015.

STAGNARI, F. et al. Influence of fluorinated surfactants on the efficacy of some postemergence sulfonylurea herbicides. **Journal of Pesticide Science**, v.32, n.1, p.16-23, 2007. Available from: <https://www.jstage.jst.go.jp/article/jpestics/32/1/32_1_16/_pdf>. Accessed: Sept. 11, 2015.