

ADJUVANT EFFECTS ON PLANT GROWTH REGULATORS IN WINTER WHEAT

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Abstract: The influence of adjuvants on the efficacy of the plant growth regulators: chlormequat chloride (CCC) and prohexadione-calcium was investigated in winter wheat in 2002 and 2003. Field trials were carried out in the Agricultural Experimental Farm in Winna Góra. The plant growth regulators were applied alone at normal rate and at a reduced rate with and without adjuvants. Two adjuvants were used: Adpros 85 SL, a methylated rapeseed oil and Break-Thru S-240, an organosilicone surfactant. Crop height, lodging, yield and quality of the harvested crop were assessed. Physicochemical properties of spray solution were measured. Adjuvants improved the biological activity of both, CCC and prohexadione-calcium, especially when reduced doses were applied. Efficacy of the plant growth regulators used at normal rate without adjuvant and at reduced rates with adjuvants was similar. Break-Thru S-240 increased the efficacy of CCC and prohexadione-calcium more compared to Adpros 85 SL measured in terms of reduction of plant height.

Key words: plant growth regulators, winter wheat, chlormequat chloride, prohexadione-Ca, methylated rape seed oil, organosilicone surfactant, adjuvants

INTRODUCTION

Plant lodging is a serious problem in cereal production in many areas. The synthetic plant growth regulators (PGRs) such as chlormequat chloride (CCC), etephone, trinexepac-ethyl and prohexadione-calcium can prevent lodging by reducing stem elongation and improving mechanical strength of the stem. The activity of PGRs depends on the rate of active ingredient, growth stage of plants and environmental conditions, especially temperature. The role of adjuvants on efficacy of foliar herbicides and some fungicides is well known whereas the influence of adjuvants on the activity of PGRs is poorly documented. The studies conducted so far indicated that some adjuvants could improve biological activity of CCC and trinexepac-ethyl (Baker 1995; McCabe and Gallagher 1997; Miller et al. 2001).

There are very few results on the use of prohexadion-calcium with adjuvants. However, it is known that using calcium binding and acidifying adjuvants (Rademaher and Kober 2003) can increase the efficacy of this compound. In this study two adjuvants, a methylated fatty acids from rapeseeds oil and an organosilicone surfactant, were used to improve the efficacy of CCC and prohexadione-calcium on winter wheat.

MATERIALS AND METHODS

Chemicals

PGRs used in this study included Stabilan 750 SL (750 g l⁻¹ chlormequat chloride, Nufarm GmbH) and Regalis 10 WG (10 g kg⁻¹ prohexadione-calcium; BASF AG).

Two adjuvants were used: Adpros 85 SL (850 g l⁻¹ methylated fatty acids from rape seeds oil; Varichem) and Break-Thru S-240 (trisiloxan surfactant); Degussa-Goldschmidt AG.

Surface tension and wettability measurements

The static surface tension was measured using Lauda Drop-Volume-Tensiometer TVT. The wetting effect was determined on an artificial target (26 × 76 mm strips of water sensitive paper placed in the spray chamber with 20° angle of inclination) and was measured with a MultiScan v. 4.01 system. Data were presented as a percentage of strip area covered by droplet marks (wetting effect).

Field experiments

Field trials were carried out in 2002–2003 in the Agricultural Experimental Farm in Winna Góra near the City of Poznań. Winter wheat, cultivar Korweta, was planted in the beginning of October at 225 kg of seeds per ha. The total amount of nitrogen fertiliser applied was 152 kg N ha⁻¹. Weeds were controlled at growth stage BBCH 13 using of 0.35 kg ha⁻¹ Expert Met 56 WG herbicide; Bayer CropScience AG. CCC and prohexadione-calcium were applied alone at their recommended rates and at reduced rates with and without adjuvant at growth stages BBCH 31 and BBCH 37 (see tables). The plots were sprayed with a plot sprayer fitted with XR 11003 flat-fan nozzles operated at 3.0 bar delivering 200 l ha⁻¹ of spray solution. The experimental design was a completely randomised block with four replications. Plot size was 16.5 m².

Lodging was assessed visually at growth stage BBCH 89 and expressed as a lodging coefficient (*L*) calculated using the following equation:

$$L = \frac{A \times D}{100\%}$$

where *L* was the lodging coefficient (%), *A* was the area of lodged stems in relation to total plot size (%) and, *D* was the degree of lodging (0%: all plants standing upright; 100%: complete lodging).

The height of stems and internodes was determined by measuring 25 plants collected at random from each plot at growth stage BBCH 83. The average number of grains in the ear was calculated by sampling 25 ears at random from each plot.

Thousand grain weight (TGW) was determined during harvest (average from 3 samples of 250 grains from each plot). The yield was taken with a small plot combine equipped with the load cells.

Statistic

Data were subjected to an analysis of variance. The means were compared using Fisher's Least Significant Difference (LSD) Test at the 5% probability level.

RESULTS AND DISCUSSION

Surface tension and wettability

CCC used alone did not influence the static surface tension of the spray solution compared to water (73 mN m^{-1}) while prohexadione-calcium reduced the static surface tension to 52 mN m^{-1} . As shown in table 1 adjuvants strongly decreased surface tension of the spray solutions and improved wettability.

Treatments with Break-Thru S-240 were characterised by the lowest surface tension and the highest wetting effect. Low surface tension leads to increasing deposition and adhesion of droplets and maintains CCC in an amorphous form (Baker 1995). Adjuvants slightly affected the pH of spray solutions.

Table 1. Influence of adjuvants on physicochemical properties of spray solutions

Treatments	Rates per ha	pH	Static surface tension [mN m^{-1}]	Wetting effect [%]
Water	–	7.3	73.0	12.1
CCC	1350g	7.6	73.0	14.3
CCC	450g	8.1	73.0	10.8
CCC + Break Thru S-240	450g+0.1%	7.8	18.9	31.4
CCC + Adpros 85 SL	450g+0.5%	7.8	32.4	15.4
Prohexadione-Ca	50 g	7.6	51.8	11.2
Prohexadione-Ca	25 g	7.7	52.7	15.4
Prohexadione-Ca+ Break Thru S-240	25 g+ 0.1%	7.7	20.2	21.2
Prohexadione-Ca+ Adpros 85 SL	25 g+ 0.5%	7.6	42.6	13.6

Stem length and lodging

PGRs as well as environmental factors influenced crop growth. In 2003 the growing season was very dry and the crop canopy on untreated plots were on average 14–16 cm lower than of 2002. Adjuvants increased the activity of both PGRs and diminished crop lodging (Tabs. 2, 3).

Results shown in table 4 and 5 have indicated that both PGRs did not significantly influence the length of the first internode. Significant differences were recorded for the other internodes. Adjuvants improved the biological activity of both PGRs. In most cases Break-Thru S-240 was more effective than Adpros 85 SL. Other studies indicated that the amount of organosilicone surfactant per unit area was more important than the surfactant concentration in the spray solution (Woźnica et al. 1995).

Measurements of stem diameters showed that the largest differences were found for the 3rd and 4th internodes. Stems from plots sprayed with PGRs in mixture

Table 2. Influence of CCC used alone and in tank-mixtures with adjuvants on canopy height and lodging (data from the years 2002 and 2003)

Treatments	Rates per 1ha	Canopy height [cm]		Lodging index [%]	
		2002	2003	2002	2003
Check	–	99	79	53	0
CCC	1350 g	87	69	8	0
CCC	450 g	90	74	32	0
CCC + Break-Thru S-240	450 g+0.1%	83	72	2	0
CCC + Adpros 85 SL	450 g+0.5%	88	70	15	0
	LSD (0.05)	3.9	4.7	–	–

Table 3. Influence of prohexadione-calcium used alone and in tank-mixtures with adjuvants on canopy height and lodging (data from the years 2002 and 2003)

Treatments	Rates per ha	Canopy height [cm]		Lodging index [%]	
		2002	2003	2002	2003
Check	–	102	76	53	0
Prohexadione-Ca	50 g	95	69	16	0
Prohexadione-Ca	25 g	99	74	34	0
Prohexadione-Ca + Break-Thru S-240	25 g+ 0.1%	96	70	23	0
Prohexadione-Ca + Adpros 85 SL	25 g+ 0.5%	99	71	30	0
	LSD (0.05)	3.6	ns	–	–

ns – not significant difference

Table 4. Influence of CCC used alone and in tank-mixtures with adjuvants on the length of internodes (data from the years 2002 and 2003)

Treatments	Rates per 1 ha	2002				2003			
		internode length [cm]							
		1 st	2 nd	3 rd	4 th	1 st	2 nd	3 rd	4 th
Check	–	6.5	15.9	26.5	40.3	6.4	12.2	17.3	31.4
CCC	1350 g	7.0	12.9	22.2	34.5	5.0	9.4	15.1	27.5
CCC	450 g	7.4	13.5	24.1	37.2	5.2	9.8	17.1	30.2
CCC + Break-Thru S-240	450 g+0.1%	7.1	12.9	22.1	34.0	5.3	9.8	16.2	29.0
CCC + Adpros 85 SL	450 g+0.5%	7.2	13.2	23.2	36.5	5.2	10.2	16.2	28.2
	LSD (0.05)	ns	1.01	1.05	1.78	ns	1.06	1.35	1.90

ns – not significant difference

with Adpros 85 SL were thicker than from the corresponding treatments with Break-Thru S-240, especially in dry weather season of 2003 (Tabs. 6, 7).

Yield

Grain yield taken from plots treated with PGRs was higher than of the control plots. However, yield response to PGRs was strongly influenced by weather conditions. CCC used alone at recommended rate slightly increased yield in the dry sea-

Table 5. Influence of prohexadione-calcium used alone and in tank-mixtures with adjuvants on the length of internodes (data from the years 2002 and 2003)

Treatments	Rates per 1 ha	2002				2003			
		internode length [cm]							
		1 st	2 nd	3 rd	4 th	1 st	2 nd	3 rd	4 th
Check	–	9.4	17.5	27.4	40.4	6.6	13.0	17.2	30.6
Prohexadione-Ca	50 g	8.9	16.0	23.0	39.2	6.3	13.5	16.2	24.1
Prohexadione-Ca	25 g	9.0	17.1	25.4	40.2	6.6	12.5	16.4	29.1
Prohexadione-Ca + Break Thru S-240	25 g + 0.1%	9.5	16.3	23.0	39.4	5.8	12.7	15.9	27.4
Prohexadione-Ca + Adpros 85 SL	25 g + 0.5%	8.7	15.8	25.6	40.9	6.0	12.9	15.7	26.8
	LSD (0.05)	1.04	1.34	1.50	ns	0.80	0.94	2.4	3.91

ns – not significant difference

Table 6. Influence of CCC used alone and in tank-mixtures with adjuvants on the diameter of the stems (data from the years 2002 and 2003)

Treatments	Rates per 1 ha	2002				2003			
		internode diameter [mm]							
		1 st	2 nd	3 rd	4 th	1 st	2 nd	3 rd	4 th
Check	–	3.3	3.6	3.7	3.6	3.0	3.4	3.3	2.6
CCC	1350 g	3.5	3.8	3.8	3.6	2.9	3.4	3.4	2.7
CCC	450 g	3.5	3.8	3.9	3.9	3.2	3.5	3.5	2.6
CCC + Break Thru S-240	450 g+0.1%	3.4	3.6	3.6	3.3	3.0	3.4	3.3	2.6
CCC + Adpros 85 SL	450 g+0.5%	3.6	3.9	4.1	3.9	3.2	3.6	3.5	2.5
	LSD (0.05)	ns	ns	0.23	0.18	ns	ns	ns	ns

ns – not significant difference

Table 7. Influence of prohexadione-calcium used alone and in tank-mixtures adjuvants on the diameter of the stem (data from the years 2002 and 2003)

Treatments	Rates per 1 ha	2002				2003			
		internode diameter [mm]							
		1 st	2 nd	3 rd	4 th	1 st	2 nd	3 rd	4 th
Check	–	3.8	3.8	3.9	3.7	3.1	3.5	3.3	2.6
Prohexadione-Ca	50 g	3.7	3.8	4.1	4.0	3.4	3.7	3.6	2.5
Prohexadione-Ca	25 g	3.8	3.9	4.0	3.8	3.1	3.4	3.3	2.3
Prohexadione-Ca + Break Thru S-240	25 g + 0.1%	3.8	3.9	4.1	3.8	3.1	3.5	3.3	3.4
Prohexadione-Ca + Adpros 85 SL	25 g + 0.5%	3.8	3.9	3.8	3.7	3.2	3.6	3.5	2.4
	LSD (0.05)	0.80	0.23	0.24	0.30	0.36	0.17	0.26	0.38

son (2003) while in the season with sufficient rainfall (2002) the yield increase was pronounced (0.8 t ha⁻¹). The use of adjuvants in the spray solutions increased grain yield compared to the treatments without adjuvant (Tabs. 8, 9).

All CCC treatments reduced TGW with the exception of CCC + Adpros 85 SL applied in 2003. Prohexadione-calcium had a negative influence on TGW in 2003 only.

Table 8. Influence of CCC used alone and in tank-mixtures with adjuvants on the yield of winter wheat (data from the years 2002 and 2003)

Treatments	Rates per 1 ha	TGW [g]		Grains per ear		Yield [t ha ⁻¹]	
		2002	2003	2002	2003	2002	2003
Check	–	49.6	41.2	36.0	36.6	7.2	5.7
CCC	1350g	46.9	38.4	36.1	36.1	8.0	5.8
CCC	450g	44.3	39.0	33.5	37.6	7.4	5.9
CCC + Break Thru S-240	450g+0.1%	45.5	39.8	33.5	34.9	7.3	6.2
CCC + Adpros 85 SL	450g+0.5%	43.4	41.3	38.7	34.4	8.2	6.6
	LSD (0.05)	ns	ns	4.58	ns	0.37	0.49

ns – not significant difference

TGW – Thousand grains weight

Table 9. Influence of prohexadione-calcium used alone and in tank-mixtures with adjuvants on the yield of winter wheat (data from the years 2002 and 2003)

Treatments	Rate per 1 ha	TGW [g]		Grains per ear		Yield [t ha ⁻¹]	
		2002	2003	2002	2003	2002	2003
Check	–	43.1	39.9	36.9	36.8	6.7	5.5
Prohexadione-Ca	50 g	44.4	38.6	35.5	33.4	6.8	6.8
Prohexadione-Ca	25 g	45.8	36.4	38.6	37.7	6.7	5.9
Prohexadione-Ca + Break Thru S-240	25 g+ 0.1%	46.5	37.6	34.0	32.7	6.9	6.4
Prohexadione-Ca + Adpros 85 SL	25 g+ 0.5%	44.3	38.4	40.1	37.4	6.7	6.4
	LSD (0.05)	3.59	3.83	4.37	8.99	0.31	0.87

TGW – Thousand grains weight

CONCLUSIONS

Two-years of field trials showed that adjuvants improved the biological activity of both CCC and prohexadione-calcium growth regulators used on winter wheat cultivar Korweta. The efficacy of PGRs applied as a standard treatment (without adjuvant) and at reduced rates with adjuvants was similar. The results showed that the organosilicone surfactant Break-Thru S-240 increased the efficacy of CCC and prohexadione-calcium more than the modified methylated vegetable oil adjuvant Adpros 85 SL considering crop canopy height and lodging.

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POLISH SUMMARY

WPŁYW ADIUWANTÓW NA DZIAŁANIE REGULATORÓW WZROSTU ZASTOSOWANYCH W PSZENICY OZIMEJ

Celem badań była ocena wpływu adiuwantów na biologiczną aktywność dwóch regulatorów wzrostu: chlorku chloromekwatu i proheksadionu wapnia. Doświadczenia prowadzono w okresie 2 lat (2002 i 2003 w Pracowni Doświadczalnictwa Polowego w Winnej Górze koło Poznania) w pszenicy ozimej odmiany Korweta. Regulatory wzrostu stosowano pojedynczo w zalecanej i w obniżonej dawce oraz w dawce obniżonej w mieszaninach zbiornikowych z adiuwantami Adpros 85 SL (metylowany ester oleju rzepakowego) i Break Thru S-240 (organosilikonowy surfaktant). Badano zarówno właściwości fizykochemiczne cieczy opryskowych tj. pH cieczy, napięcie statyczne cieczy, stopień zwilżenia opryskiwanych powierzchni oraz wykonano pomiary biometryczne na roślinach pszenicy oceniając wyleganie roślin, wysokość roślin, długość i średnicę międzywęźli, plon ziarna, masę 1000 ziaren, liczbę ziaren w kłosie. Adiuwanty poprawiły biologiczną aktywność obydwu regulatorów wzrostu zastosowanych w obniżonych dawkach. Efektywność regulatorów wzrostu zastosowanych w zalecanej bez adiuwantów i zastosowanych z adiuwantami w dawce obniżonej była zbliżona. Break-Thru S-240 silniej zwiększał retardacyjne działanie CCC i proheksadionu wapnia niż Adpros 85 SL.