CHEMICAL WEED CONTROL IN TRITICALE (x *TRITICOSECALE* WITTMACK): REVIEW OF FIVE YEARS OF FIELD EXPERIMENTS

V. DERYCKE[1], G. HAESAERT[1], J. LATRE[2]

[1]Faculty of Applied Bioscience Engineering, University College Ghent, Valentin Vaerwyckweg 1, B- 9000 Gent, Belgium
[2] Faculty of Science and Technology, University College Ghent, Valentin Vaerwyckweg, 1, B-9000 Gent, Belgium

SUMMARY

During five subsequent growing seasons field experiments were carried out at the experimental farm of the University College Ghent (Belgium) to evaluate the selectivity and efficacy of herbicides for chemical weed control in triticale (x *Triticosecale* Wittmack).
The experiments were set up on a sandy loam soil, according to a completely randomised block design with four replicates. Several herbicides and combinations of herbicides were applied pre- and post-emergence, at different rates. The influence of the different treatments on weed diversity, weed density, growth inhibition and chlorosis of the crop and grain yield was studied. Results obtained from these field trials indicated differences between the different treatments.

INTRODUCTION

Halfway the 20th century triticale (x *Triticosecale* Wittmack) was introduced into commercial farming in Belgium. The triticale growing area in Belgium amounts to approximately 7000 ha. This is merely 5 % of the total cereal area in Belgium, but the growing area of triticale is increasing the last years (+ 7,6 % in 2010). Firstly, triticale has lower input requirements compared to wheat, giving it both economic and environmental advantages. Furthermore, disease resistance is considered as one of the most important and durable advantages of triticale.

In many crop species sensitivity to (selective) herbicides has been reported. Cultivar susceptibility to herbicides is hardly affected by weather conditions during the vegetative growth stage, type of herbicide and sowing rate (Drews et al., 2009). In wheat (*Triticum aestivum*) varietal differences in susceptibility to chlortoluron and metoxuron were experienced in the past. In rye problems with susceptibility to phenoxy-propion acid derivatives were experienced. Because both wheat and rye are the parent species of triticale an increased herbicide sensitivity and varietal differences in susceptibility to herbicides may be expected in triticale.

In triticale certain doses and times of application of mecoprop caused chlorosis and growth inhibition. Chlortoluron applied pre-emergence seemed to be safer for triticale than when it was applied post-emergence. Isoproturon and methabenzthiazuron generally cause more crop injury than chlortoluron (Haesaert et al., 1990). Higher doses of isoproturon in triticale result in crop damage, which results in not negligible yield losses. Therefore, it is advised in triticale not to exceed a dose of 1200 g/ha isoproturon on light soils and 1000 g/ha on heavy clay soils.

The present study gives a review of the results of five-year field experiments concerning chemical weed control in triticale. The objective was to compare the activity of several herbicides and herbicide combinations against weeds and their safety towards winter triticale under field conditions.

MATERIAL AND METHODS

Field experiments

During five subsequent growing seasons, field experiments were carried out at the experimental farm of the University College Ghent in Belgium to evaluate the selectivity and efficacy of herbicides for chemical weed control in winter triticale.

The experimental field trials were conducted during five growing seasons (2007-2008; 2008-2009; 2009-2010; 2010-2011 and 2011-2012).
The experimental design was always a completely randomised block design with four replications. The sowing density was 350 - 400 seeds per m². The surface of each elementary plot was 15 m² (1.5 m by 10 m). Normal crop husbandry measures for Belgium growing conditions were taken, including three nitrogen fertilizations according to the nitrogen-index established by the Soil Service of Belgium. In addition, the plant growth regulator chlormequat was applied to reinforce the antilodging effect. A fungicide was applied at Zadoks growth stage 59 – emergence of inflorescence completed. All plots were harvested mechanically at hard dough stage. Detailed information about the experimental site and the crop husbandry measures of each trial is summarised in table 1. Experiments were laid out on a sandy loam or light sandy loam soil and a crop rotation with cereals, potatoes, maize,.. was preserved on the different fields. In Belgium only winter triticale is grown, spring triticale is not usual. Therefore, sowing date is always situated during autumn, between October and the beginning of November. Commonly sown commercial winter triticale varieties were used in the experiments. These varieties were Talentro, Cultivo, Agrano and Joyce.

Table 1. Detail information about the experimental site and crop husbandry measures of the field experiments between 2007-2012

	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
soil	sandy loam	sandy loam	light sandy loam	light sandy loam	light sandy loam
previous crop	corn maize	potatoes	onions	potatoes	potatoes
sowing density	400 k/m²	400 k/m²	350 k/m²	350 k/m²	350 k/m²
sowing date	7/11/2007	30/10/2008	28/10/2009	14/10/2010	24/10/2011
cultivar	Talentro	Cultivo	Agrano	Cultivo	Joyce

Chemical treatments were carried out with an AZO knapsack sprayer. The spray boom was equipped with TeeJet nozzles (Teejet XR 11003 VK) spaced 50 cm apart. The water volume was always 300 l/ha.
The weed control treatments included three possible times of application: (1) pre-emergence applications or (2) post-emergence applications at 1 – 3 leaf stage in winter or (3) post-emergence applications at tillering stage in spring. Sometimes one herbicide application before winter (1) or (2) is not sufficient to control the weed population. A second herbicide application during spring can possibly correct the first application in order to have a sufficient control of the different weed species. However, this combination of autumn and spring application was not included in our trials.

Evaluation

Three weeks after post-emergence herbicide applications for each weed species, the number of plants per m² was counted in 16 quadrats (25 x 25 cm) randomly placed within the field plots.
Possible crop damage was evaluated by visual observations. Crop chlorosis and growth inhibition was weekly recorded for each plot until 4 weeks after treatment using a 1-9 scale with 1: no chlorosis or no growth inhibition and 9: extensively chlorated or growth inhibition.
Grain yield was calculated at 15 % moisture content.

Statistical analysis
Yield data were processed with the statistical software program SPSS 11.0. All data were tested for normal distribution with the "One sample Kolmogorov-Smirnov Test". If the assumptions of normality and homoscedasticity were statisfied, the data were processed with a one way Anova and a post hoc Tuckey test to detect if data were statistically significant.

RESULTS

Weed density m^{-2}
Weed density per unit area is an important parameter in evaluating the impact of herbicide treatments on weed growth (Hussain et al., 2013). The greater the presence of the weeds, the greater is their completion for nutrients from the soil with the crop plants.
The experiments were set up on fields naturally infested by weed species. The weed population over the five years of field experiments did not differ extensively. The presence of the weed species are presented in figure 1. For each growing season a pie chart illustrates the relative importance of the different weed species. Across the five growing seasons following weed species were most abundant: *Stellaria media* (common chickweed), *Poa annua* (path grass or goos grass), *Viola arvensis* (field violet), *Matricaria chamomilla* (wild chamomile), *Senecio vulgaris* (bird seed), *Geranium molle* (cranesbill geranium) and *Spergula arvensis* (corn spurry). In much lower number also *Papaver rhoeas* (common poppy), *Trifolium repens* (white clover), *Apera spica-venti* (wind grass), *Chenopodium album* (fat hen), *Echinochloa crus-galli* (cockspur grass), *Lamium purpureum* (read deadnettle), *Polygonum persicaria* (ladysthumb) *Veronica arvensis* (corn speedwell) and *Vicia cracca* (bird's tare).
These weed species are typical for the light sandy loam soils and the crop rotation that is preserved at the experimental farm in Bottelare. Winter annuals such as deadnettle, common chickweed, corn speedwell are well presented in the population. They emerge after sowing in autumn and over-winter as (small) seedlings and complete their life cycle during spring. Winter annuals compete with the crop and slow the rate of crop development potentially reducing yield.

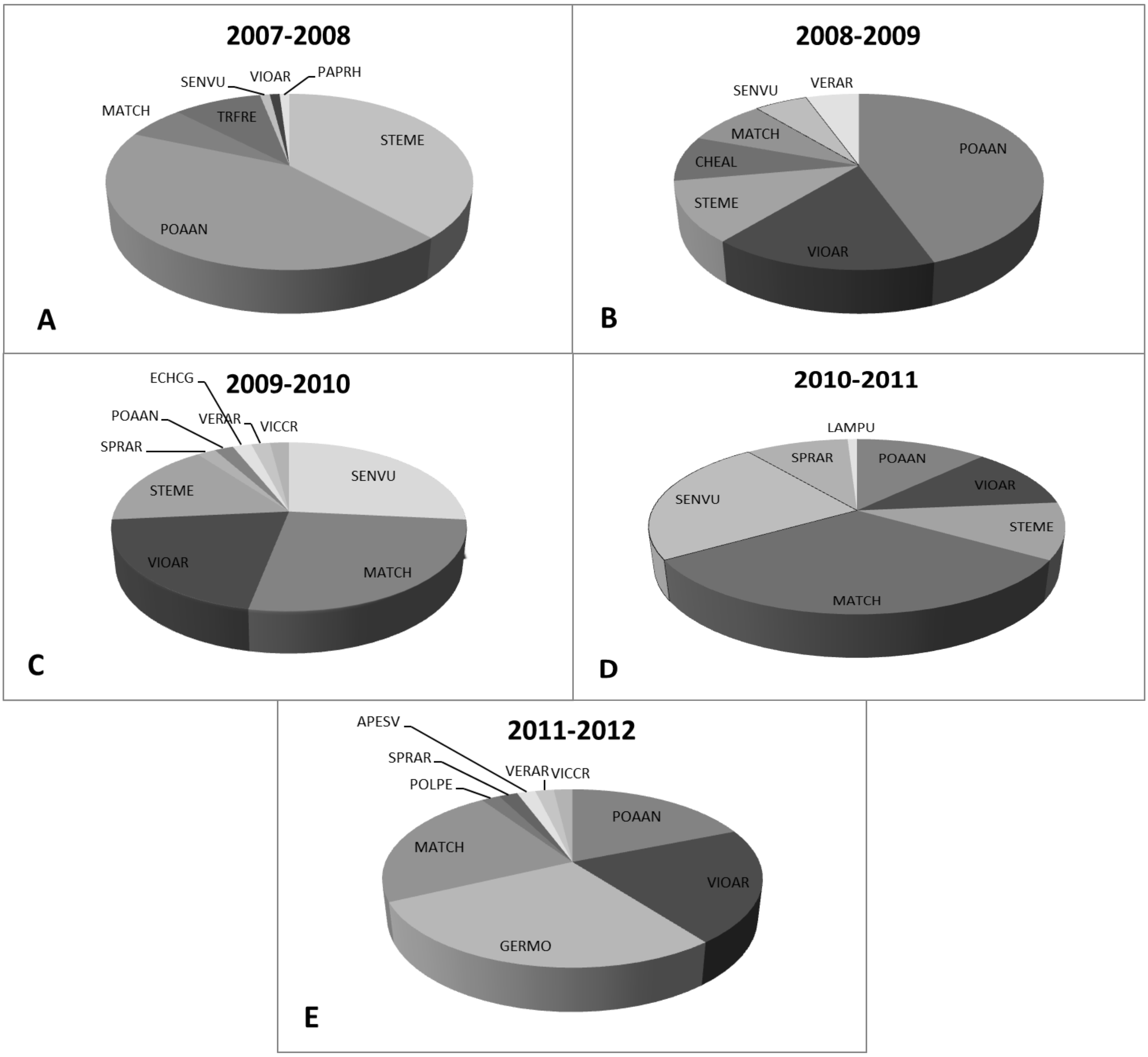

Figure 1A-E. Relative presence of different weed species during five growing seasons.

Pre emergence applications

In table 2 the results of the field experiments for the pre-emergence applications are presented. The choice in possible herbicide treatments for pre-emergency application is rather small. Only five different herbicide treatments were included in the field experiments during the five growing seasons. Most treatments include the application of the commonly used soil herbicide ‘isoproturon’ a phenyl urea herbicide. Isoproturon is effective against annual monocotyledons, with a side effect against some dicotyledons e.g. *Stellaria media* and *Matricaria chamomilla*. Because isoproturon has no effect against some dicotyl weed species (such as *Viola arvensis*, *Veronica* sp., *Papaver* sp., *Vicia* sp., etc.) it is completed with diflufenican or diflufenican + flurtamone. Both active ingredients result in a bleaching effect on the sensitive weed species, caused by inhibition of the carotenoid biosynthesis. The combination of isoproturon + diflufenican + flurtamone and beflubutamide increases the efficiency against *Viola arvensis*, *Capsella bursa-pastoris* and *Apera spica-venti*.

A totally different pre-emergence treatment is the combination of prosulfocarb (a thiocarbamate), which is most effective against grasses (monocotyledons) and some

dicotyledons, but has to be completed with isoxaben for its efficacy against *Matricaria*, *Viola arvensis*, …
All the applied herbicides have a good performance against the weeds present in the field. Regularly, the weed species are reduced for 100 % compared to the corresponding control. However, it is very important to mention that humid soil conditions at the moment of the herbicide treatments are crucial for the efficacy of these pre-emergence treatments.

Table 2. Relative reduction of the weed species after pre-emergence herbicide applications in % to the corresponding control

Common name	STEME	POAAN	MATCH	TRFRE	SENVU	VIOAR
isoxaben + prosulfocarb	96	93	100	89	100	100
isoproturon + diflufenican	100	-	100	-	100	100
isoproturon + diflufenican + flurtamone	100	-	100	-	100	100
isoproturon + diflufenican	95	98	84	100	-	-
beflubutamide + isoproturon + diflufenican + flurtamone	-	100	100	-	100	100

STEME: *Stellaria media*; POAAN: *Poa annua*; MATCH: *Matricaria chamomilla*; TRFRE: *Trifolium repens*; VIOAR: *Viola arvensis*

Table 3. Relative yield, growth inhibition and crop chlorosis after pre-emergence herbicide applications

Common name	N° trials	Yield[1]	GI/Cl²
isoxaben + prosulfocarb	3	106.2	1
isoproturon + diflufenican	2	112.1	1
isoproturon + diflufenican + flurtamone	1	113.1	1
isoproturon + diflufenican	2	102.8	1
beflubutamide + isoproturon + diflufenican + flurtamone	1	98.9	1

[1] Relative yield as a % of the corresponding control; no significant differences between the different treatments for p<0.05
² E.W.R.C. 1-9 scale: 1 = no damage; 9 = 100 % damage
GI: growth inhibition; Cl: chlorosis

In table 3 the number of trials on which the data are based on: the relative yield of the different treatments in % compared to the corresponding control and the growth inhibition and chlorosis on a 1 to 9 scale is presented.
All treatments, except the treatment with more complex treatment with beflubutamide + isoproturon + diflufenican + flurtamone have a yield higher than the untreated yield. The addition of beflubutamide may have caused this slight increase of the grain yield. No growth inhibition or chlorosis was recorded.

Post-emergence applications: 1-3 leaf stage in winter
A herbicide application in winter at the 1-2 leaf stage until 2-3 leaf stage of the crop is a second possibility. This time of treatment provides more time and flexibility for choosing the right moment of treatment. In this stage a greater product choice is also available. Not only soil activity, but also leaf activity of the treatments is possible.

In table 4 the results of the field experiments for the post-emergence applications in 1-3 leaf stage are presented. Again the two combinations isoxaben + prosulfocarb or diflufenican + flurtamone can be applied. However, some other active ingredients are available: flufenacet; pendimethalin or picolinafen. Flufenacet is used for its activity against monocots, often completed with pendimethalin or picolinafen (or both) for the activity against dicots.
The data regarding weed density m² indicate that all the herbicidal treatments convincingly suppressed the weed growth. Furthermore, all the applied herbicides had a good performance against the weeds species.

Table 4. Relative reduction of the weed species after post emergence: 1-3 leaf stage herbicide applications in % to the corresponding control

Common name	STEME	SENVU	VIOAR	MATCH	POAAN	SPRAR
isoxaben + prosulfocarb	100	88.9	100	96.6	100	98.7
diflufenican + flurtamone	100	100	100	100	100	100
pendimethalin + picolinafen + prosulfocarb	98.9	100	99	100	100	100
pendimethalin + picolinafen + isoproturon	-	100	100	100	100	-
flufenacet + pendimethalin	-	100	100	100	100	-
flufenacet + pendimethalin + isoproturon	-	100	100	100	100	-
pendimethalin + diflufenican + flurtamone	100	100	-	100	100	100

STEME: *Stellaria media*; SENVU: *Senecio vulgaris*; VIOAR: *Viola arvensis*; POAAN: *Poa annua*; SPRAR: *Spergula arvensis*

Table 5. Relative yield, growth inhibition and crop chlorosis after post emergence: 1-3 leaf stage herbicide applications

Common name	N° trials	Yield[1]	GI/Cl[2]
isoxaben + prosulfocarb	1	102.4	1
diflufenican + flurtamone	1	108.7	1
pendimethalin + picolinafen + prosulfocarb	3	103.0	1
pendimethalin + picolinafen + isoproturon	1	103.9	1
flufenacet + pendimethalin	1	99.8	1
flufenacet + pendimethalin + isoproturon	1	101.1	1
pendimethalin + diflufenican + flurtamone	1	96.8	1

[1] Relative yield as a % of the corresponding control; no significant differences between the different treatments for $p<0.05$
[2] E.W.R.C. 1-9 scale: 1 = no damage; 9 = 100 % damage
GI: growth inhibition; Cl: chlorosis

In table 5 the relative yield of the different treatments in % compared to the corresponding control is shown, as well as the number of trials on which the data are based on and the growth inhibition and crop chlorosis.

For the treatments with flufenacet + pendimethalin and pendimethalin + diflufenican + flurtamone the grain yield was lower than the yield of the untreated plot, however not significantly. Possible caused the more complex combination of these mixtures with pendimethalin this slight yield increase. The slight yield decrease is possibly due to the presence of pendimethalin in this two mixtures.

None of the treatments resulted in growth inhibition and no chlorosis was recorded.

Post-emergence applications: tillering stage in spring

The post-emergence treatments in spring are mostly a combination of contact and systemic herbicides, which should result in an activity against a broad range of weed species. When products are applied, good weather and crop conditions are required, otherwise chlorosis or growth inhibition can be expected. The active ingredients used in spring time applications often show less selectivity to the crop. Therefore, the climatic and soil conditions are more important than the crop stage. Otherwise, a greater leaf effect of the treatments may be expected.

In table 6 the results of the field experiments for the post-emergence applications at tillering stage in spring are presented. Table 6 shows a lower reduction of the weed species present in the field in comparison to the treatments in winter. This can generally be explained by the fact the weed species have more developed during spring.

The reduction of *Poa annua* is not always satisfactory. Most of the time, this can be explained by the growth stage of the grass plants. When the spring applications are performed after winter the *Poa annua* plants are already too much developed and tillered. Among the better scoring objects are the objects in which isoproturon is included in the mixture.

Some broad leaved dicots e.g. *Viola arvensis* or other dicots e.g. *Stellaria media*, *Matricaria* sp. also withstand very well the herbicide treatments. The plant density of these weed species after treatment is sometimes very high. It is known that some sulfonylurea have a too low efficacy against these dicots and therefore these herbicides have to be completed with a specific product to obtain an efficient weed control.

Table 6. Relative reduction of the weed species in % compared to the corresponding control after post-emergence herbicide applications in tillering stage

Common name	STEME	POAAN	MATCH	SENVU	VIOAR	SPRAR	GERMO
carfentrazon-ethyl + metsulfuron-methyl + isoproturon	89.0	93.0	100.0	-	-	-	-
isoproturon + carfentrazon-ethyl + florasulam + fluroxypyr	100.0	-	100.0	100.0	100.0	-	-
iodosulfuron-methyl-natrium + mesosulfuron-methyl + mefenpyr-diethyl + metsulfuron-methyl + fluroxypyr + oil	100.0	86.0	100.0	-	-	100.0	100.0
tritosulfuron + iodosulfuron-methyl + mesosulfuron-methyl-natrium + mefenpyr-diethyl + oil	-	90.0	100.0	-	100.0	-	98.3
tritosulfuron + iodosulfuron-methyl + mesosulfuron-methyl-natrium + mefenpyr-diethyl + pendimethalin + oil	-	100.0	100.0	-	100.0	100.0	100.0
tritosulfuron + cloquitocet-mexyl + pyroxsulam + oil	91.7	82.1	68.0	90.6	79.3	100.0	100.0
tritosulfuron + cloquitocet-mexyl + pyroxsulam + florasulam + oil	100.0	-	68.6	84.9	100.0	100.0	100.0
iodosulfuron-methyl-natrium + mefenpyr-diethyl + propoxycarbazone-Na + cloquintocet-mexyl + pyroxsulam + florasulam	-	90.0	100.0	-	100.0	100.0	95.0
iodosulfuron-methyl-natrium + mefenpyr-diethyl + propoxycarbazone-Na + amidosulfuron + oil	100.0	-	52.9	69.8	100.0	100.0	100.0
cloquintocet-mexyl + pyroxsulam + florasulam + oil	88.5	75.8	85.3	98.9	96.8	97.7	95.0
pendimethalin + picolinafen + iodosulfuron-methyl + mesosulfuron-methyl + mefenpyr-diethyl + oil	73.0	12.0	100.0	-	-	100.0	100.0
pendimethalin + picolinafen + cloquintocet-mexyl + pyroxsulam + oil	75.0	-	68.6	84.9	100.0	100.0	100.0
iodosulfuron-methyl-natrium + mesosulfuron-methyl + mefenpyr-diethyl + oil	97.2	76.1	86.0	79.3	86.8	95.5	96.7
isoproturon + diflufenican	-	100.0	100.0	-	100.0	100.0	98.3
flupyrsulfuron-methyl + metsulfuron-methyl + iodosulfuron-methyl-natrium + mesosulfuron-methyl + mefenpyr-diethyl + oil	92.0	81.0	100.0	-	-	100.0	100.0
flupyrsulfuron-methyl + metsulfuron-methyl + cloquintocet-mexyl + pyroxsulam + oil	100.0	-	37.3	100.0	80.0	100.0	100.0
flupyrsulfuron-methyl + metsulfuron-methyl + sulfosulfuron	47.0	57.0	67.0	-	-	100.0	100.0
diflufenican + iodosulfruon-methyl-natrium + mefenpyr-diethyl + mesosulfuron-methyl + iodosulfuron-methyl-natrium + mefenpyr-diethyl	81.3	88.4	97.0	93.5	93.3	97.7	100.0
picolinafen + dichloorprop-P-potassium + iodosulfuron-methyl-natrium + mesosulfuron-methyl + mefenpyr-diethyl + oil	93.8	92.0	95.3	89.8	94.2	100.0	90.0

STEME: *Stellaria media*; POAAN: *Poa annua*; MATCH: *Matricaria chamomilla*; SENVU: *Senecio vulgaris*; VIOAR: *Viola arvensis*; SPRAR: *Spergula arvensis*; GERMO: *Geranium molle*

Table 7. Relative yield, growth inhibition and crop chlorosis after post emergence herbicide applications at tillering stage in spring

Common name	N° trials	Yield[1]	GI/Cl²
carfentrazon-ethyl + metsulfuron-methyl + isoproturon	1.0	100.8	1
isoproturon + carfentrazon-ethyl + florasulam + fluroxypyr	1.0	108.8	1
iodosulfuron-methyl-natrium + mesosulfuron-methyl + mefenpyr-diethyl + metsulfuron-methyl + fluroxypyr + oil	1.0	100.1	1
tritosulfuron + iodosulfuron-methyl + mesosulfuron-methyl-natrium + mefenpyr-diethyl + oil	1.0	103.7	1
tritosulfuron + iodosulfuron-methyl + mesosulfuron-methyl-natrium + mefenpyr-diethyl + pendimethalin + oil	1.0	102.5	1
tritosulfuron + cloquitocet-mexyl + pyroxsulam + oil	4.0	108.1	1*
tritosulfuron + cloquitocet-mexyl + pyroxsulam + florasulam + oil	1.0	111.3	1
iodosulfuron-methyl-natrium + mefenpyr-diethyl + propoxycarbazone-Na + cloquintocet-mexyl + pyroxsulam + florasulam	1.0	102.3	1*
iodosulfuron-methyl-natrium + mefenpyr-diethyl + propoxycarbazone-Na + amidosulfuron + oil	1.0	114.8	1*
cloquintocet-mexyl + pyroxsulam + florasulam + oil	4.0	106.3	1
pendimethalin + picolinafen + iodosulfuron-methyl + mesosulfuron-methyl + mefenpyr-diethyl + oil	3.0	103.6	1
pendimethalin + picolinafen + cloquintocet-mexyl + pyroxsulam + oil	2.0	105.7	1
iodosulfuron-methyl-natrium + mesosulfuron-methyl + mefenpyr-diethyl + oil	4.0	103.9	1
isoproturon + diflufenican	1.0	102.1	1
flupyrsulfuron-methyl + metsulfuron-methyl + iodosulfuron-methyl-natrium + mesosulfuron-methyl + mefenpyr-diethyl + oil	2.0	107.9	1
flupyrsulfuron-methyl + metsulfuron-methyl + cloquintocet-mexyl + pyroxsulam + oil	1.0	111.1	1
flupyrsulfuron-methyl + metsulfuron-methyl + sulfosulfuron	1.0	104.0	1
diflufenican + iodosulfruon-methyl-natrium + mefenpyr-diethyl + mesosulfuron-methyl + iodosulfuron-methyl-natrium + mefenpyr-diethyl	2.0	100.6	1
picolinafen + dichloorprop-P-potassium + iodosulfuron-methyl-natrium + mesosulfuron-methyl + mefenpyr-diethyl + oil	2.0	99.2	1

[1] Relative yield as a % of the corresponding control; no significant differences between the different treatments for $p<0.05$

² E.W.R.C. 1-9 scale: 1 = no damage; 9 = 100 % damage

GI: growth inhibition; Cl: chlorosis

* Growth inhibition and chlorosis reported on other location

Each treatment, except the last treatment resulted in a higher yield than the untreated plots (table 7). Although the weed control was not always completely successful, the herbicide treatments have a positive effect on the grain yield. This is caused by the fact that competition of the weed plants for nutrients with the crop plants is extensively reduced.
No growth inhibition or chlorosis was recorded. However, an asteriks * in table 7 means that crop chlorosis and growth inhibition was reported in another similar field experiment on a nearby location (St-Niklaas) during the same growing season. These symptoms disappeared within time.

Table 8. Average relative yield and % reduction of weeds for each time of application

Time of application	N° of treatments	% reduction of weed species	Yield[1]
pre-emergence	9	97.5	106.6
post-emergence: 1-3 leaf stage in winter	9	99.2	102.2
post-emergence: tillering stage in spring	34	92.5	105.1

[1] Relative yield as a % of the corresponding control; no significant differences between the different treatments

In table 8 the average % reduction of the weed population and the average grain yield is summarised for each time of application.
The best results in reducing the weed population are obtained when herbicides are applied in autumn/winter at 1-3 leaf stage or at pre emergence stage. Applications after winter in spring time still leave too much weed plants unharmed. However, this does not automatically have a negative effect on the grain yield.

CONCLUSIONS

In general triticale is more susceptible to herbicides than wheat. Higher doses of isoproturon in triticale result in crop damage which results in not negligible yield losses. Therefore, it is advised in triticale not to exceed a dose of 1200 g/ha isoproturon on light soils and 1000 g/ha on heavy clay soils. A careful approach is necessary when combinations of different active ingredients are applied.
An efficient chemical weed control in triticale is an achievable objective. There are a range of active ingredients available to realize a sufficient reduction of the weed population.
A greater efficacy of applications in winter (post or pre-emergence) can be expected. However, for farmers a herbicide application in winter is less a habit or is not always possible because of the weather or soil conditions. Therefore, in time application of herbicide treatments in spring is advisable.
No varietal differences in susceptibility to herbicides were recorded in the experiments at the experimental farm in Bottelare during the five growing seasons.

REFERENCES

DREWS S., NEUHOFF D. & KÖPKE U. (2009). Weed suppression of three winter wheat varieties at different row spacing under organic farming conditions. Weed Research 49 (5): 526-533.
HAESAERT G., DE BAETS A., VAN HIMME M. & BULCKE R. (1990). Varietal differences in triticale's reaction to herbicides.Proceedings of the second international triticale symposium. Passo Fundo, Rio Grande do Sul, Brazil. pp. 200-206.

HUSSAIN Z., MARWAT K.B., MUNSIF F., SAMAD A. & ALI K. (2013). Evaluation of various herbicides and their combinations for weed control in wheat crop. Pakistan Journal of Botany, 45(1): 55-59.