ACTA AGROBOTANICA
Vol. 64 (4): 259–266
2011

THE ROLE OF THE GROWTH STAGE OF WEEDS IN THEIR RESPONSE TO REDUCED HERBICIDE DOSES

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Received: 15.04.2011

Abstract

The influence of weed growth stage on the efficacy of selected herbicides applied at reduced doses was investigated under pot experiments at the Institute of Soil Science and Plant Cultivation – State Research Institute in Wrocław. Three weed species were used as tested plants: *Anthemis arvensis* L., *Chenopodium album* L. and *Stellaria media* L., which were sprayed at different growth stages: 2-4, 6-8, and 10-12 leaves. The experiment included the following herbicides: tribenuron-methyl, iodosulfuron methyl sodium + amidosulfuron, and metribuzin + amidosulfuron, used at full doses and reduced by 25 and 50%. Three weeks after treatment, fresh weight of weeds was determined. Weed control was significantly related to weed species, growth stage, type of herbicide and its dose. Among the tested weed species, *S. media* showed the weakest reaction to the herbicides used and it was only slightly affected by herbicide rate and growth stage. Later herbicide treatments, when the weeds reached the stage of 6-8 and 10-12 leaves, resulted in diversification at the level of herbicide effects and doses.

Key words: weed growth stage, fresh weight reduction, herbicide, reduced dose

INTRODUCTION

It is well known that the full recommended dose of herbicide is appropriate for farming practice to ensure a good level of weed control and prevent yield loss. Previous investigations showed that a good weed control level could also be obtained in case of reduced rate application, which is beneficial to the natural environment and economically profitable. Therefore, the current trend in agriculture is towards a reduction in the amount of active ingredients introduced to arable fields during plant protection treatments. It is aimed at maintaining weed infestation at an acceptable degree that is harmless to crops, rather than obtaining total weed control (Domardzki, 2006; Krawczyk, 2008). Reduced rate applications are not always reasonable, because herbicide activity can be affected by some factors related to weeds and crop status such as weed density, weed growth stage, and crop vigour as well as abiotic factors i.e. weather conditions, soil properties etc., and accordingly the herbicide effect can be decreased under adverse circumstances. Thus, a reduction in herbicide rates requires numerous detailed investigations concerning the influence of these factors on herbicide efficacy (Kudsk, 2008).

The most sensitive to herbicides are young weeds when their growth stage does not exceed 4-6 leaves, but previous research has proved that more developed weeds can be also satisfactorily controlled (Dobrzański and Adamczewski, 1998; Barros et al. 2007).

The objective of this investigation was to evaluate the influence of weed growth stage on reaction of selected weed species to herbicides applied at reduced doses.

MATERIALS AND METHODS

Three series of an outdoor pot experiment were conducted at the Institute of Soil Science and Plant Cultivation in Wrocław, during the following periods: 21.04–17.06.2007 (series I), 27.07–08.09.2007 (series II), and 12.05 – 04.07.2008 (series III). Average daily temperature for series I ranged between 11.2-23.9°C (average 17.5°C), for series II 15.4-25.4°C (average 19.9°C), and for series III 15.2-24.7°C (average 17.9°C). The study included three weed species: *Anthemis arvensis* L., *Chenopodium album* L., and *Stellaria media* L., which were sown into 10 cm diameter and 300 ml volume plastic pots filled with the mixture

containing sphagnum peat and sand (2: 1 w/w), providing all necessary nutrients. Seeds of each species were collected from crop fields located in the area of Wrocław and were sown at weekly intervals to give three different growth stages at the time of spraying. Seven seeds were placed into one pot at a depth of 0.5 cm. Directly after sowing the pots were placed outdoors on tables and stayed there until harvest. The plants were watered everyday with a volume of water ensuring that optimal soil moisture for plant growth was maintained. One day before herbicide treatment the number of plants was reduced to 4 per pot. At the time of herbicide application, weeds were at three different growth stages: 2-4 leaves (BBCH 12-14), 6-8 leaves (BBCH 16-18), and 10-12 leaves (BBCH 20-22).

The herbicide treatments were made using a laboratory pot sprayer fitted with a boom equipped with TeeJet XR 11003-VS flat fan nozzles**.** The nozzles were operated at a speed of 2.5 km×ha^{-1} and a pressure of 200 kPa producing a spray volume of 250 l×ha^{-1}.

The study included three herbicides: tribenuron methyl as well as the mixtures iodosulfuron methyl sodium + amidosulfuron and metribuzin + amidosulfuron. All the tested herbicides were applied at three rates – full and reduced by 25 and 50%. The herbicides and their doses are described in Table 1.

The experiment followed a completely randomised design with three replications and two factors: 1. weed growth stage, 2. combination of type of herbicide and its dose (including untreated plots as the "zero" dose). One herbicidal treatment comprised 27 pots (3 weed species x 3 growth stages x 3 replications).

Three weeks after spraying, weeds were harvested and fresh weight of all plants from each pot was determined. The fresh weight value of individual weed species (per pot) was calculated as percentage of the control treatment and then transformed according to the Bliss formula. The transformed data were calculated for individual weed species using analysis of variance procedures to evaluate the significance of interactions between growth stage and herbicide dose at a level of 0.05. Variability between experimental series was insignificant, therefore each series was taken into account as a replication.

Table 1.
Herbicide doses used in the experiment

Herbicide	Trade name	Dose (g×ha^{-1})		
		1N	3/4N	1/2N
tribenuron methyl 75%	Granstar 75 WG	15.0	11.25	7.50
iodosulfuron methyl sodium 1.25% + amidosulfuron 5%	Sekator 6,25 WG	3.75 + 15.0	2.81 + 11.25	1.875 + 7.50
metribuzin 50% + amidosulfuron 15%	Segal 65 WG	60.0 + 18.0	45.0 + 13.50	30.0 + 9.0

RESULTS

Anthemis arvensis

Tribenuron-methyl effectively reduced biomass (91-96%) of the youngest plants of *A. arvensis*, irrespective of the dose. Weed response to herbicide was significantly reduced at later growth stages, at each rate level. The full dose and the dose reduced by 25% resulted in fresh weight reduction in the range 71-74% for plants in the middle phase (6-8 leaves). The weakest reaction to tribenuron methyl, producing only 47% biomass reduction in the plants at the stage of 6-8 leaves, was observed after the application of the lowest dose. A similar result for the oldest plants was found, independently of herbicide rate (Fig. 1).

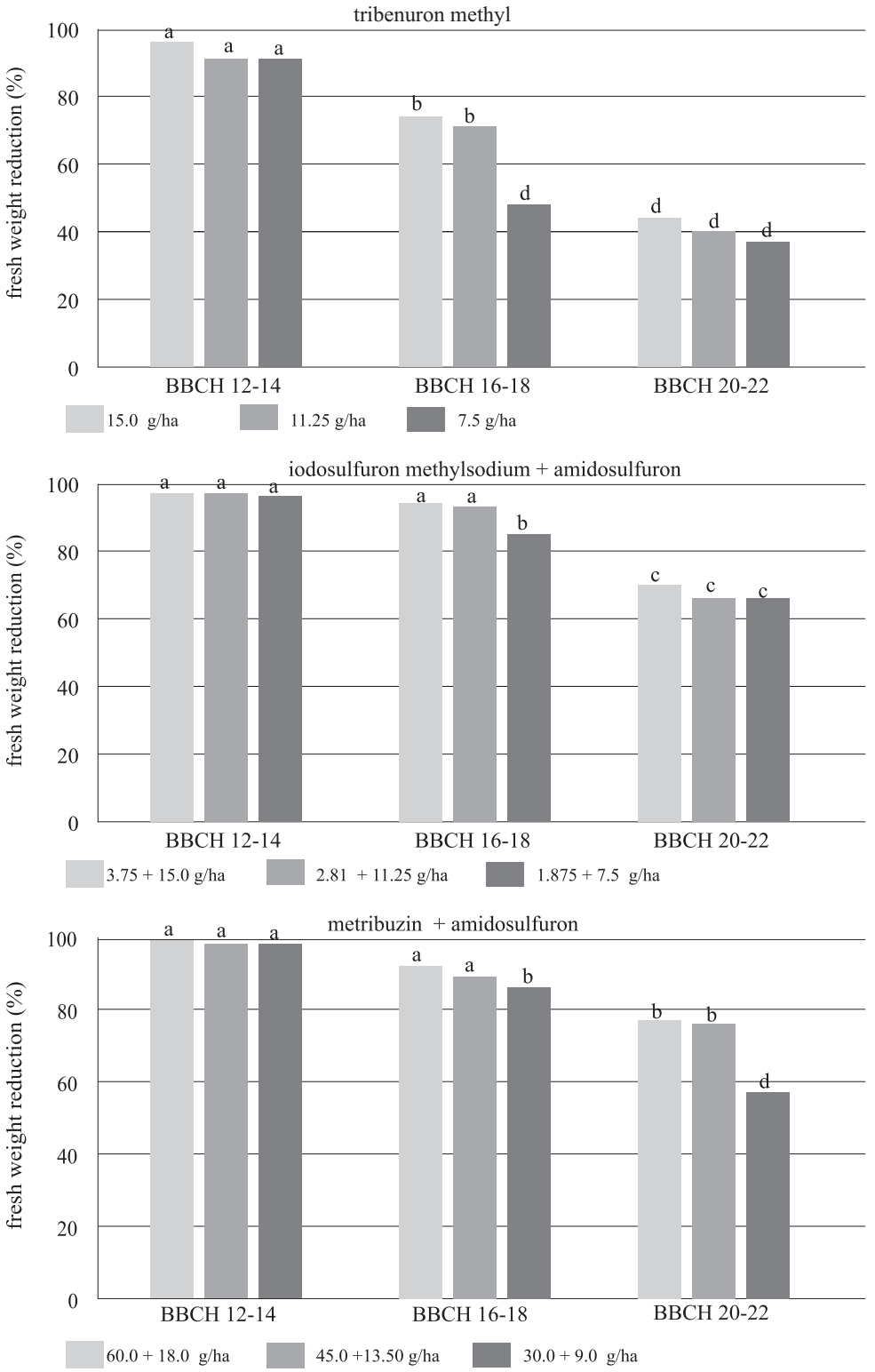
Similarly to the above-mentioned herbicide, the mixture iodosulfuron methyl sodium + amidosulfuron reduced biomass of the youngest weeds effectively (96-97%), regardless of herbicide rate. High sensitivity was also found for the plants at the stage of 6-8 leaves sprayed with a full dose and lowered by 25%. When the lowest dose was used, weed sensitivity decreased and amounted to 84%. The oldest weeds were the weakest controlled (66-70%), without any difference between doses (Fig. 1).

The mixture metribuzin + amidosulfuron was strongly effective for both the youngest and more developed plants (up to 6-8 leaves), regardless of herbicide dose. The successive delay of herbicide treatment resulted in a significant decrease in weed sensitivity. The full dose and lowered by 25% reduced fresh weight of *A. arvensis* by 76 and 77% respectively, whereas the lowest dose showed considerably weaker weed control, resulting in 57% biomass reduction (Fig. 1).

Chenopodium album

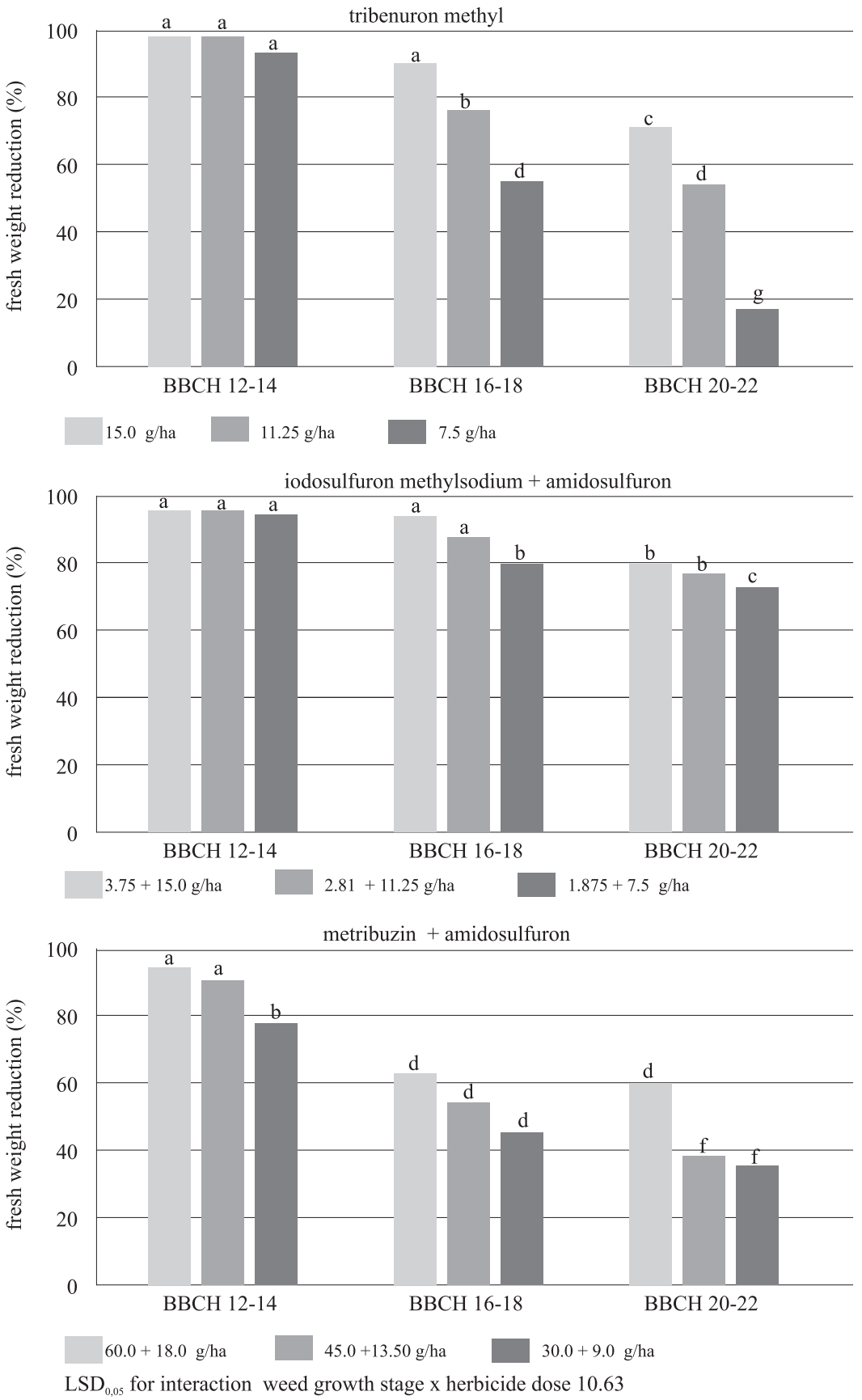
The youngest plants of *Ch. album* treated with tribenuron methyl were very sensitive to all tested doses. High sensitivity (90% biomass reduction) was also achieved when the full dose was used to control older plants (6-8 leaves). As the herbicide rate decreased,

plant sensitivity diminished, reaching 55% of fresh weight reduction at the lowest dose. Fresh weight of the oldest plants (10-12 leaves) was reduced by 71% when the full dose was used. The activity of other doses significantly decreased as the herbicide dose was reduced, giving only 16% weed control for the lowest rate (Fig. 2).



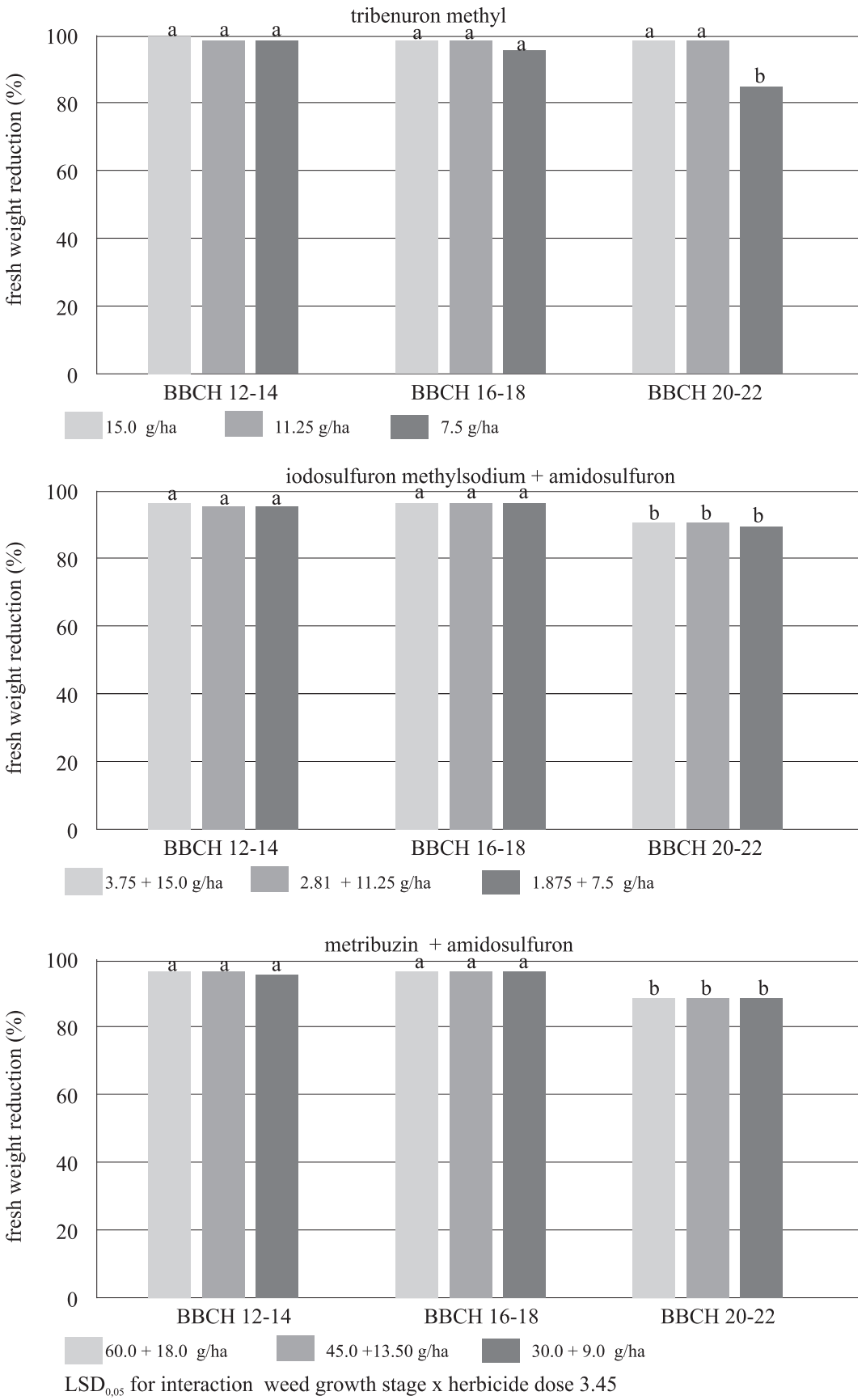
$LSD_{0,05}$ for interaction weed growth stage x herbicide dose 8.40

Figure 1. The influence of growth stage of *Anthemis arvensis* on the efficacy of herbicides applied at different doses



$LSD_{0,05}$ for interaction weed growth stage x herbicide dose 10.63

Figure 2. The influence of growth stage of *Chenopodium album* on the efficacy of herbicides applied at different doses



$LSD_{0,05}$ for interaction weed growth stage x herbicide dose 3.45

Figure 3. The influence of growth stage of *Stellaria media* on the efficacy of herbicides applied at different doses

Biomass reduction of the youngest plants of *Ch. album* treated with the mixture iodosulfuron methylsodium + amidosulfuron ranged between 94-97%, with respect to the herbicide dose. Older weeds (6-8 leaves) were susceptible to the full rate and lowered by 25%, resulting in biomass reduction in the range 89-95%, but the lowest dose gave considerably lower weed control (81%). When the herbicide was applied to the oldest plants, no high susceptibility was observed, even for the full dose treatment. Fresh weight reduction approximated between 74-81%, depending on herbicide dose (Fig. 2).

Plants of *Ch. album*, at the stage of 2-4 leaves, were satisfactorily controlled when the full dose of the mixture metribuzin + amidosulfuron and the dose reduced by 25% were used. The lowest rate caused a considerable weakening of weed response. In case of the later herbicide treatment, when weeds developed 6-8 and 10-12 leaves, there was no satisfactory weed control, even when the plants were treated with the full dose. Biomass reduction for the full dose was similar for both growth stages, but it was significantly lower when the reduced rate was applied to the oldest plants (Fig. 2).

Stellaria media

The youngest plants of *S. media* proved very high sensitivity to tribenuron methyl, resulting in biomass reduction in the range 99-100%. Comparable sensitivity of older plants, at the stage of 6-8 leaves, was observed. In case of application of the lowest dose to the most developed weeds, sensitivity was significantly reduced compared to those that were treated with the full dose and lowered by 25% (Fig. 3).

The mixture iodosulfuron methyl sodium + amidosulfuron resulted in high efficacy (90-98%), regardless of weed growth stage and herbicide dose, although, according to statistical analysis, for the oldest plants weed control was significantly lower than for the younger ones. Similar activity was observed for the mixture metribuzin + amidosulfuron (Fig. 3).

DISCUSSION

Application of herbicides at reduced doses is the current trend in plant protection in some countries of the European Union. Despite its economic and environmental benefits, this weed control system is not always recommended, because it requires specific biotic, abiotic and agrotechnical conditions for herbicide treatments which ensure the level of weed control not endangering the crop and weakening weed vigour. Therefore, the introduction of this trend to agricultural practice forces researchers to investigate this issue with respect to detailed factors and herbicides. Herbicides differ in their ability to control weeds with the application of reduced rates. Some of them can be satisfactorily used at doses reduced even by 75% compared to the recommended rate; however, there is a group of products that are efficient at doses reduced by 25%, but not less (Klingman et al. 1992; Domaradzki, 2006). The results obtained from this experiment show that the mixture of iodosulfuron methyl sodium + amidosulfuron was more effective than metribuzin + amidosulfuron and tribenuron methyl and this finding corresponds to the diversified ability of the tested herbicides to reduce weed biomass when they are applied at reduced doses. Among the investigated herbicides, the activity of iodosulfuron methyl sodium + amidosulfuron was the least affected by the used rate, whilst the greatest variations were observed for the metribuzin + amidosulfuron.

Herbicide efficacy is strongly related to sensitivity of individual weed species to the active ingredient of an herbicide, the used dose and weed growth stage at the time of spraying. As the growth stage of weeds advances, the sensitivity of individual species to herbicides can be essentially limited in comparison to plants sprayed at an early phase of development (Barros et al. 2007; Faccini and Puricelli, 2007; Javaid, 2007). Collings et al. (2003) reported that herbicide treatment at a reduced dose, carried out under adverse weather conditions, resulted in a significant decrease in efficacy compared to optimal conditions. Similarly to climate regimes, it is also expected that an advanced weed growth stage can be a limiting factor in reduced rate application. This investigation showed that the tested herbicides gave a similar effect for all doses, but only in case of the treatment of the youngest weeds. Significant differences between the activity of particular herbicides were found for older weeds and they became more pronounced along with plant development. Among the investigated herbicides, the activity of iodosulfuron methylsodium + amidosulfuron was the least affected by the used rate, whilst the greatest variations were observed for the metribuzin + amidosulfuron.

The results obtained from this experiment clearly point out that different weed species gave a dissimilar reaction to reduced doses of herbicides and it is in agreement with earlier research (Klingman et al. 1992; Rosales-Robles et al. 1999; Bellinder et al. 2003). This property is probably due to morphological and physiological features of individual species determining herbicide uptake, translocation and metabolism (Petersen and Hurle, 2001; Wang, 2007). One of the weed species tested under the present study, *S. media*, is distinctive because of its high sensitivity to the examined herbicides, regardless of experimental factors such as growth stage, dose and type of herbicide. Our previous papers reported *S. media* as very susceptible to the majority of herbicides

and therefore its biomass reduction was weakly dependent on the interaction of herbicides with other factors such as weather conditions, dose level, form of application, growth stage, etc. (Kieloch, 2006; Domaradzki and Kieloch, 2007).

The content of herbicide labels generally gives information concerning herbicide efficacy under optimal conditions and for the application of the full recommended rate, but there is a lack of data about the efficacy of herbicides used under unfavourable conditions for their activity. Most herbicides are required to be applied when weeds are very young to obtain good weed control, but from the practical point of view, herbicide treatment is not always possible to be carried out at early weed growth stages, because of the weather conditions in the early spring. This problem requires investigation if an individual herbicide can be used for older weeds without risk of its efficacy reduction.

The application of reduced rates is beneficial from the economic and ecological point of view, because it reduces plant protection costs and side effects of herbicides on the natural environment. As regards the diminished sensitivity of more developed weeds to herbicides, their efficacy should be particularly investigated for different weed species and herbicides.

CONCLUSIONS

The response of weeds to herbicides was related to weed species, their growth stage, type and dose of herbicide. The highest susceptibility was observed at an early growth stage, when weeds were at the stage of 2-4 leaves, and it decreased along with plant development and reduction of herbicide doses.

Among the tested herbicides, the activity of the mixture iodosulfuron methylsodium + amidosulfuron was the least affected by the dose. The least efficient was the mixture metribuzin + amidosulfuron, especially with respect to *Chenopodium album*. It proved high efficacy only when applied to the youngest plants, but at later growth stages (6-8 and 10-12 leaves) the effect of the herbicide considerably decreased.

Stellaria media was the most strongly reactive to the investigated herbicides, which was reflected in great biomass reduction even at an advanced growth stage and the lowest dose treatment.

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Rola fazy rozwojowej chwastów w ich reakcji na obniżone dawki herbicydów

S t r e s z c z e n i e

Przeprowadzono badania szklarniowe nad oceną wpływu fazy rozwojowej chwastów na skuteczność wybranych herbicydów stosowanych w zredukowanych dawkach. Uwzględniono w nich trzy gatunki chwastów: *Anthemis arvensis* L., *Chenopodium album* L. i *Stellaria media* L., które w momencie stosowania herbicydów znajdowały się w trzech różnych fazach rozwojowych – 2-4, 6-8 i 10-12 liści. W doświadczeniu badano następujące środki: tribenuron metylu, jodosulfuron metylosodowy + amidosulfuron oraz metrybuzyna + amidosulfuron, które aplikowano w dawkach zalecanych oraz obniżonych o 25 i 50%. Po upływie trzech tygodni od wykonania zabiegu oznaczono świeżą masę chwastów. Poziom zniszczenia chwastów w znaczący sposób zależał od gatunku chwastu, rodzaju herbicydu i jego dawki. Spośród badanych gatunków chwastów, *S. media* wykazała najsłabszą reakcję na zastosowane środki, gdzie redukcja jej biomasy tylko w niewielkim stopniu zależała od dawki i fazy rozwojowej. Zabieg wykonany na chwasty bardziej zaawansowane w rozwoju spowodował wystąpienie różnic na poziomie działania herbicydów oraz ich dawek.