ISSN 1392-3196
Zemdirbyste-Agriculture, vol. 95, No. 3 (2008), p. 227–234
UDK 633.11:632.954

EVALUATING HERBICIDES IN A RANGE OF DOSES FOR INTEGRATED PLANT PROTECTION IN LATVIA

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Abstract

Weed management must be based on integrated plant protection methods that minimise economically unacceptable loss of crop yield but preserve the contribution of weeds to biodiversity. The on-line decision support system "Weeds" has been developed to assist in achieving this balance by the selection of appropriate herbicides and the calculation of appropriate doses to control the weeds present in individual fields. The results of field trials in spring wheat in Latvia in 2006 and 2007 showed that satisfactory weed control could be achieved and increases of yield obtained where herbicides were applied at reduced doses. Economic analyses showed that the reduced dose treatments were the most profitable.

Keywords: spring wheat, weeds, herbicides, doses, efficacy, integrated plant protection, economic evaluation.

Introduction

In Latvia a programme to determine good plant protection practice is being undertaken to contribute to the development of systems of integrated plant protection. Common standards of integrated plant protection are being developed to introduce them to users of plant protection products. An integrated plant protection approach to weed management must take into the need to suppress weeds that could cause economically unacceptable loss of yield and the important contribution that weeds make to biodiversity. One approach to achieving this balance is the observation of the occurrence of weed species and their density in the field before weed control to allow the selection of an appropriate herbicide and the calculation of the appropriate dose for application. The on-line, computer-based, decision support system "Weeds" has been developed for this purpose and allows the integration of data on the biological efficacy of herbicides on a spectrum of weed species with the economics of the response of the crop. Similar systems with similar objectives have been developed elsewhere /Jensen, Nielsen, 2000; Collings et al., 2003/. If farmers and agronomists are to have confidence in such a decision support system, it is important that it will give weed control recommendations that are economically optimal under differing conditions of seasonal weather and weed spectra and densities. The recommendations must be field specific, as concluded by Mitchell (1998).

The data from field trials in the contrasting seasons of 2006 and 2007 for a range of herbicides commonly used for weed control in spring wheat in Latvia, applied at a range of doses, will make a useful contribution to the database of the "Weeds" decision support program. The herbicides, of three different chemical classes, which were already registered for weed control in spring cereals, were applied at three doses: label standard (1N), half of label standard (½N) and one-quarter of label standard (¼N). A full economic analysis was made of the differing dose-responses, taking into account all the relevant costs.

Materials and Methods

In 2006 and 2007 the field trials were carried out on the Research and Study Farm "Peterlauki" in the Jelgava district, about 70 km south of Riga, on a brown lessive loamy fine sand soil with an organic matter content of 1.9–2.1% and with pH 6.9. The spring wheat cultivar was 'Vinjett'. The preceding crop in 2006 was spring barley and in 2007 was winter wheat. The trials were arranged in randomized blocks with 4 replicates with a plot size of 30 m². In both years conventional soil tillage was used and 200 kg ha^{-1} of 16:16:16 NPK mineral fertilizer was applied at sowing time. Supplementary fertilizers were applied twice: in 2006, 41 kg N ha^{-1} at growth stage (GS) 29–30 BBCH and 34 kg N ha^{-1} at GS 32–33 and in 2007, 52 kg N ha^{-1} at GS 26–27 BBCH and at GS 32–33.

The herbicides were applied in a spray volume of 300 L ha^{-1} with a knapsack sprayer (flat-fan nozzles, 3.0 bar pressure). Herbicides Granstar Premia 50 SX (tribe-nuron-methyl 50%, DuPont), Kemira MCPA 750 SL (MCPA 750 g L^{-1}, Nufarm UK), Mustang SE (florasulam 6.25 g L^{-1} + 2,4-D 2-ethylhexyl ester 300 g L^{-1}, Dow Agro-Sciences), Logran 20 WG (triasulphuron 200 g kg^{-1}, Syngenta), Harmony Extra 75 WG (tribenuron-methyl 250 g kg^{-1} + thifensulfuron-methyl 500 g kg^{-1}, DuPont) were applied at their normal (1N), ½N and ¼N dose-rates. The herbicides were applied when the crop was at the end of tillering stage and broad-leaved weeds had 2–6 true leaves. Weed assessments were carried out with the aid of a 0.25 m² frame at three places in each plot 4–6 weeks after application of the herbicides. The weeds were counted and weighed separately by species and the data converted to give values per m². Grain from each plot (21.0 m²) was harvested by small plot combine. Yield results were adjusted to 15% moisture content and 100% purity.

In 2006 the herbicides were applied on 7 June. The weather around herbicide application during the first 10-day period of June was dry and cold (the air temperature was 2.8° C below the norm for that period). The first rainfall after herbicide application occurred 15 days after treatment. The precipitation in June was only 42% of the long-term average and very dry weather continued in July when precipitation was only 51% of the average, but in August the precipitation was about normal. During the period from June to August the weather overall was warm, with above average air temperatures. In 2007 the herbicides were applied on 28 May when the weather conditions were not favourable for herbicide application: the temperature during the applications was +22° C. The weather during the third 10-day period of May was unusually warm (the air temperature was 6.1° C above the norm) and very dry (precipitation was only 6% of long-term average for that period). The first rainfall occurred one day after herbicide treatment. During June and up to harvest time in the second 10-day period of August, air temperatures were above of the long-term values. Overall the precipitation in June was 89% of the norm, but in July the precipitation was nearly twice the long term-average.

The data were subjected to analysis of variance using GenStat for Windows for a randomised block design with two factors plus an untreated control and treatment means were separated at the 5% probability level (LSD) using Student's t-test.

Results and Discussion

In 2006 very dry weather conditions before and after herbicide application affected weed growth and development. The total number of dicotyledonous weeds in the untreated plots was 73.7 plants per square metre (range 52.0–97.3, $LSD_{5\%}$ 15.53), but their fresh weight was only 36.3 g m^{-2} (range 17.5–53.1, $LSD_{5\%}$ 7.13) at the weed assessment four weeks after herbicide application. Fourteen dicotyledonous weed species were recorded. The predominant weed species which accounted for $^2/_3$ of the total population in the untreated plots were annuals: *Lamium purpureum* L. (27% of total population), *Chenopodium album* L. (25%), *Euphorbia helioscopia* L. (15%) and *Galium aparine* L. (10%).

In contrast, in 2007 at the weed assessment 6 weeks after herbicide application, the infestation of dicot-weeds in the untreated plots was high: 366.7 plants per square metre (range 249.3–656.0, $LSD_{5\%}$ 82.5) and their fresh weight was 205.2 g m^{-2} (range 141.0–322.9, $LSD_{5\%}$ 35.56). A wide spectrum of 21 weed species was recorded. The dominant species were quite different from 2006, but annual species were again predominant: *Atriplex patula* L. (40% of total population), *Stellaria media* (L.) Vill. (12%), *Chaenorhinum minus* (L.) Lange (11%), *Galium aparine* (8%) and *Viola arvensis* Murray (8%).

Despite the differences in the levels of weed infestation and in the spectrum of species, the overall patterns of efficacy of the five different herbicides on the dicotyledonous weeds were similar in both years (Table 1).

All the herbicide treatments gave significant reductions of both total weed density and total weed fresh weight compared with the untreated but had less effect on weed density than on weed fresh weight. The decrease of weed density ranged from 46% (weed density 39.7 plants m^{-2}) to 81% (14.3 plants m^{-2}) in 2006 and from 55% (167.0 plants m^{-2}) to 80% (74.7 plants m^{-2}) in 2007. The reductions of weed fresh weight ranged from 64% (weed fresh weight 13.1 g m^{-2}) in 2006 and 71% (59.9 g m^{-2}) in 2007 up to 92% in both years (2006: 2.9 g m^{-2}; 2007: 16.9 g m^{-2}). Similar differences in efficacy on weed density and fresh weight were noted in spring barley trials in Estonia when there was a spring drought and the plants were in a state of stress at the time of herbicide application (Talgre et al., 2004).

The differences in efficacy among the herbicides were smaller for the full dose treatments than for the ¼N dose treatments; the differences among the ½N dose treatments were intermediate. The differences between the efficacy of the full dose and ¼N dose treatments were larger for weed density than for weed fresh weight and were larger in 2006 than in 2007. The largest difference between the efficacy of the full dose treatment and the ¼N dose of an individual herbicide was for Kemira MCPA 750 SL in 2006; the smallest differences were for Harmony Extra in both years.

Table 1. Efficacy of 5 herbicides at 3 doses on total dicotyledonous weed density and fresh weight expressed as percentage decrease from the untreated control

Treatments, dose ha^{-1}	Dose	% decrease of weed density		% decrease of weed fresh weight	
		2006	2007	2006	2007
Granstar Premia 50 SX, 22.5 g*	1N	76.0	79.3	85.4	91.6
Granstar Premia 50 SX, 11.25 g*	½N	69.7	70.5	82.1	89.1
Granstar Premia 50 SX, 5.6 g*	¼N	54.8	56.1	74.4	85.9
Kemira MCPA 750 SL, 2.0 L	1N	80.6	79.6	92.0	84.6
Kemira MCPA 750 SL, 1.0 L	½N	71.5	69.4	85.7	80.0
Kemira MCPA 750 SL, 0.5 L	¼N	46.1	64.0	65.8	76.3
Mustang SE, 0.6 L	1N	70.6	66.2	90.4	85.6
Mustang SE, 0.3 L	½N	65.1	60.5	84.6	79.5
Mustang SE, 0.15 L	¼N	49.8	54.5	72.5	70.8
Harmony Extra 75 WG, 15.0 g*	1N	78.7	79.4	86.2	91.8
Harmony Extra 75 WG, 7.5 g*	½N	77.9	74.3	86.2	87.0
Harmony Extra 75 WG, 3.75 g*	¼N	74.2	70.6	86.0	86.0
Logran 20 WG, 37.5 g**	1N	73.3	75.2	85.1	86.5
Logran 20 WG, 18.75 g**	½N	62.4	68.2	79.9	80.0
Logran 20 WG, 9.38 g**	¼N	53.5	62.4	63.9	78.3

* With Kemivets Plus, 0.15 L
** With Kemivets Plus, 0.3 L

All the herbicide treatments significantly reduced the plant density of the predominant weed species in both years: 2006 *Lamium purpureum* (untreated: 20.0 plants m^{-2}; $LSD_{5\%}$ = 6.22); 2007 *Atriplex patula* (untreated: 144.7 plants m^{-2}; $LSD_{5\%}$ = 65.92). However, there were important differences among the herbicides in overall efficacy and in the shape and slope of the dose-responses (Figures 1, 2).

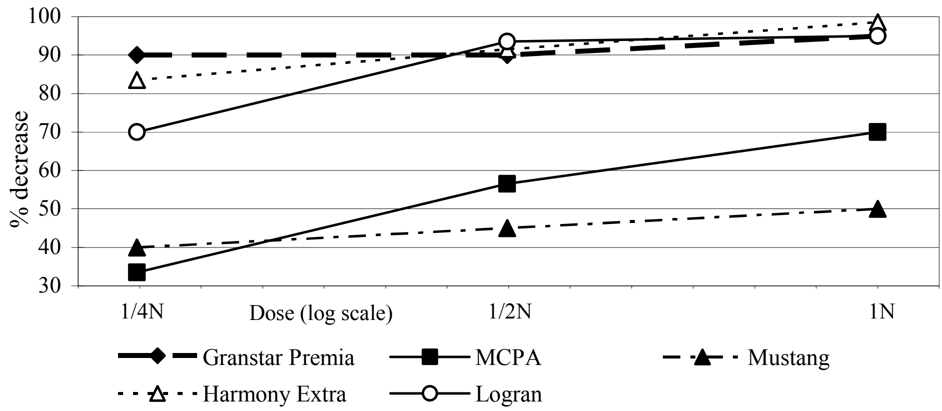

Figure 1. Efficacy (percentage decrease in plant density from untreated control) of 5 herbicides at 3 doses on *Lamium purpureum*, the predominant weed species in 2006

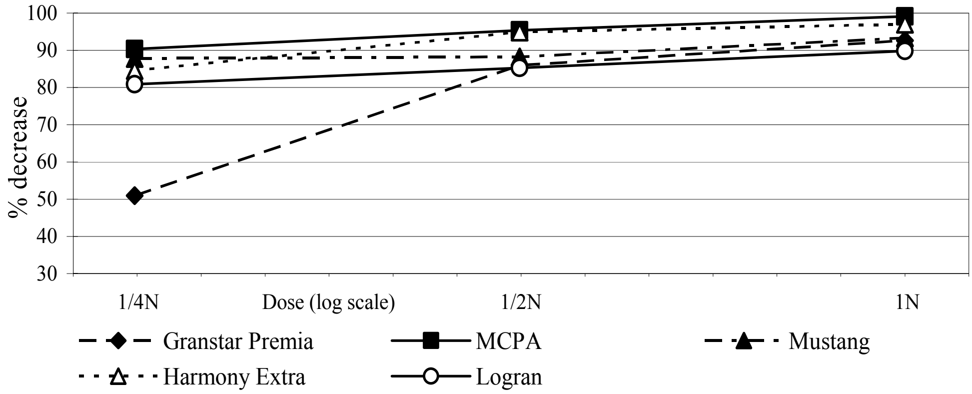

Figure 2. Efficacy (percentage decrease in plant density from untreated control) of 5 herbicides at 3 doses on *Atriplex patula*, the predominant weed species in 2007

Efficacy on *Lamium purpureum* ranged from 98% (Harmony Extra at full dose) down to 34% (Kemira MCPA 750 SL at ¼N dose) and there were significant differences among the herbicides at all doses. The efficacies of Mustang SE and Kemira MCPA 750 SL were lowest at all doses. The poor performance of Mustang SE on *Lamium purpureum*, even at full dose, was noted in reduced dose trials in Estonia (Talgre et al., 2004). The dose-response of Logran curved downward away from the straight line; the dose-responses of the other four herbicides were linear. The dose-response for Kemira MCPA 750 SL had the steepest slope, with efficacy declining from 70% at full dose to 34% at ¼N dose; this effect of Kemira MCPA 750 SL was even greater for fresh weight: 71% at full dose, 14% at ¼N dose.

The efficacy of all herbicide treatments on *Atriplex patula* was much more consistent with the exception of Granstar Premia at ¼N dose. At full dose the efficacies ranged from 90% to 99%; at ½N dose the efficacies ranged from 85% to 95%; at ¼N dose the efficacies of four of the herbicides ranged from 81% to 90%, with Granstar at 51%. The dose-response of Granstar thus curved downward away from the straight line; the dose-responses of the other four herbicides were linear.

The yield of grain from the untreated plots was around 4.5 t ha^{-1} in both years. In 2006 all but two of the herbicide treatments increased yields (average increase 3.9%) but none of the increases were statistically significant. In 2007 all the herbicide treatments increased yield (average increase 10.7%) and all but three of the increases were significant. These results contrast with those quoted by O'Mahony and Mitchell (2004) for the effects of reduced doses on winter cereals and spring barley in Ireland where ½N dose treatments had given satisfactory weed control with no loss of yield, but ¼N dose treatments had given only moderate weed control and lower crop yields. In trials on spring cereals in Poland, the reduced doses did not give any significant reduction in crop yield /Domaradzki, 2003/.

In 2006 the highest yields were obtained from the ½N dose treatments of all five herbicides (Figure 3). This curvature in the dose-response was most marked for Harmony Extra although the difference between the highest yield and the lowest yield for this herbicide was not statistically significant. The dose-response to Mustang SE showed a similar tendency.

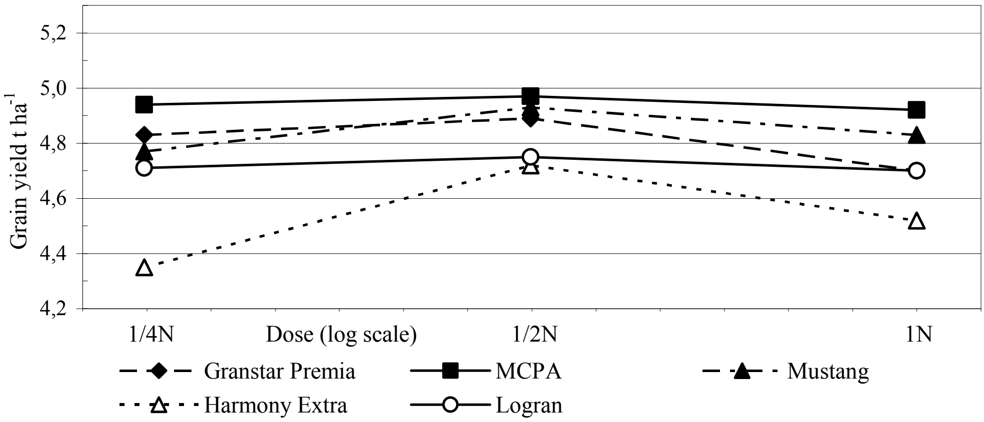

Figure 3. Grain yield of spring wheat treated with 5 herbicides at 3 doses in 2006

In 2007 the highest yields were obtained from the ¼N dose treatments of all herbicides; the full dose treatments gave the lowest yields (Figure 4). Similar results were reported for spring wheat trials in Finland /Salonen, 1993/. All the dose-response lines were very flat and none of the differences in yield between the ¼N dose and full dose treatments was significant.

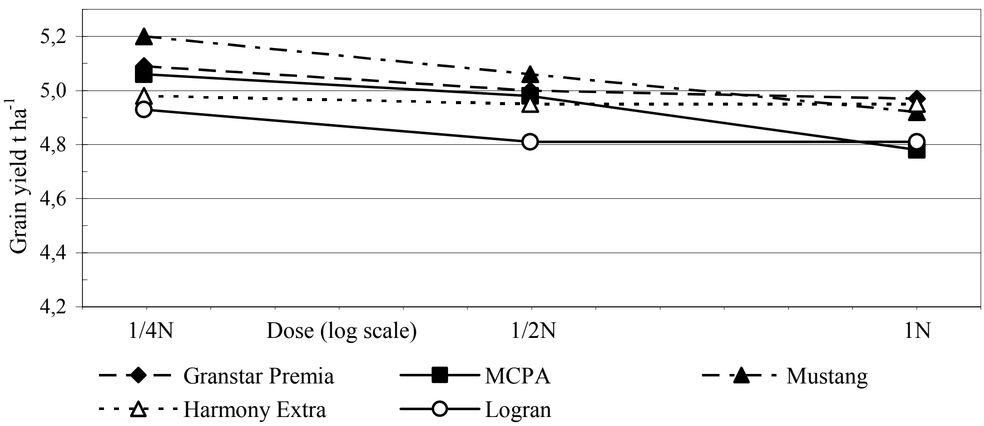

Figure 4. Grain yield of spring wheat treated with 5 herbicides at 3 doses in 2007

The economic evaluation (at 2007 prices excluding VAT) took into account the cost of the dose of herbicide applied with additive where required (range €2.74 to €12.95 ha^{-1}), the cost of application (€12.32 ha^{-1}) and the cost of drying the grain to the commercial standard of 14% moisture (€4.18 per 1% of moisture removed) and set these against the value of the dried, cleaned grain, sold either for animal feed (€120.77 t^{-1}) or for human consumption (€139.88 t^{-1}).

If the grains were sold for animal feed, three of the herbicide treatments in 2006 would have given a net return less than that from the “do nothing” untreated; in 2007 all the treatments would have given a greater net return than the untreated (Table 2). In 2006 the highest return was given by the ¼N dose treatment of Kemira MCPA 750 SL and the second highest by the ½N dose treatment of the same herbicide. In 2007 the highest return was given by the ¼N dose treatment of Mustang SE, closely followed by the ¼N dose treatment of Granstar Premia. The most profitable treatments would have given an advantage over the untreated of €42 ha^{-1} in 2006 and €128 ha^{-1} in 2007.

Table 2. Net return* from herbicide treatments in spring wheat for grain sold for animal feed (€ ha^{-1})*

Treatments	2006			2007		
	Full dose	½ dose	¼ dose	Full dose	½ dose	¼ dose
Granstar Premia 50 SX	468	493	485	1043	1059	1073
Kemira MCPA 750 SL	499	507	511	992	1042	1058
Mustang SE	480	495	490	1026	1064	1077
Harmony Extra 75 WG	448	479	434	1045	1046	1048
Logran 20 WG	474	489	471	1008	1007	1037

* Net return = value of cleaned, dried grain less costs of herbicide, herbicide application and drying of grain to 14% moisture
2006: net return from untreated €469 ha^{-1}; $LSD_{5\%}$ 45.56
2007: net return from untreated €949 ha^{-1}; $LSD_{5\%}$ 83.27

Table 3. Net return* from herbicide treatments in spring wheat for grain sold for human consumption (€ ha^{-1})

Treatments	2006			2007		
	Full dose	½ dose	¼ dose	Full dose	½ dose	¼ dose
Granstar Premia 50 SX	558	587	577	1205	1222	1240
Kemira MCPA 750 SLMCPA 750 SL	593	602	606	1148	1205	1223
Mustang SE	572	589	581	1187	1229	1246
Harmony Extra 75 WG	534	569	517	1207	1208	1210
Logran 20 WG	564	579	561	1165	1164	1198

* Net return = value of cleaned, dried grain less costs of herbicide, herbicide application and drying of grain to 14% moisture
2006: net return from untreated €557 ha^{-1}; $LSD_{5\%}$ 50.80
2007: net return from untreated €1096 ha^{-1}; $LSD_{5\%}$ 95.55

If the grains were sold for human consumption, the same treatments would have given the highest returns, but the returns and the advantage over the untreated would have been higher (Table 3). In 2006 the ¼N dose treatment of Kemira MCPA 750 SL gave a return of €606 ha^{-1}, an advantage over untreated of €49 ha^{-1}. In 2007 the ¼N dose treatment of Mustang SE gave a return of €1246 ha^{-1}, an advantage over untreated of €150 ha^{-1}.

Conclusions

1. The differences in efficacy among herbicides were greater when the products were applied at ¼N dose than at full dose.
2. The dose-responses for efficacy of the individual herbicides depended on the susceptibility of the weed population present to the respective herbicides.
3. The herbicides reduced weed density less than weed fresh weight and the decrease of efficacy with dose was greater for weed density than for weed fresh weight.
4. The herbicides Harmony Extra (sulphonylurea mixture) and Granstar Premia (sulphonylurea) showed more consistency of efficacy over the three doses than did Kemira MCPA 750 SL (phenoxy acid).
5. Although the differences among herbicide treatments were not statistically significant, there was a tendency for higher yields where ½N and ¼N doses were applied.
6. The highest net returns on weed control were obtained from the ¼N and ½N dose treatments.

Received 2008-06-06
Accepted 2008-08-06

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