# EFFECT OF ADJUVANTS AND STAGE OF GROWTH ON THE EFFICACY OF THREE SULFONYLUREA HERBICIDES TO GRASS WEEDS

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## SUMMARY

The effects of plant growth stage and six adjuvants on the efficacy of rimsulfuron, nicosulfuron and primisulfuron on three warm zone grass weeds were investigated in four pot experiments. Rimsulfuron and nicosulfuron had similar levels of activity and were more active on grass weeds than was primisulfuron. Smooth witchgrass (*Panicum dichotomiflorum*) was more readily controlled than rough bristle grass (*Setaria verticillata*) and summer grass (*Digitaria sanguinalis*). The most successful application time was generally when the grasses had two to four leaves. The adjuvants Pulse and Ethokem were the most effective. In a corresponding field trial in a maize crop, Ethokem increased the activity of both rimsulfuron and primisulfuron.

**Keywords:** adjuvants, nicosulfuron, primisulfuron, rimsulfuron, maize

## INTRODUCTION

New sulfonylurea herbicides are being developed for a variety of uses. Their low application rates, broad spectrum of weed control and favourable toxicological properties have contributed to the success of this group of herbicides. Rimsulfuron is a recently developed post-emergence sulfonylurea herbicide that controls most annual and perennial grass weeds in maize (Green and Green 1993; Reinke *et al.* 1991). Nicosulfuron is a closely related chemical which has shown promise for control of certain troublesome perennial grasses such as couch (*Elytrigia repens*) and Johnson grass (*Sorghum halepense*) at the same rates required for annual grass weeds and many broadleaf weeds in maize (Kimura *et al.* 1989; Rahman and James 1993). Primisulfuron is another sulfonylurea herbicide which controls a weed spectrum similar to that of nicosulfuron in maize (Bhowmik *et al.* 1990; Maurer *et al.* 1987). All three herbicides have been evaluated in New Zealand over the past few years but to date only primisulfuron is registered for use in this country.

Our early development work with these three herbicides in the field indicated that none of them provided adequate control of summer grass, a major annual grass weed of maize crops in New Zealand (Rahman 1988). Oil and surfactant adjuvants have been reported to increase the efficacy of many post-emergence herbicides including the sulfonylureas, and maintain their effectiveness across varied environments (Fielding and Stoller 1990; James and Rahman 1992; Nalewaja *et al.* 1991). In addition to enhancing control of specific weeds, additives can also widen the spectrum of weed species controlled, improve control of large weeds and lower herbicide use rates (Fielding and Stoller 1990).

The objectives of the present study, comprising both pot and field experiments, was to determine whether certain adjuvants and additives can enhance the efficacy of these three sulfonylurea herbicides on the major warm zone grass weeds of maize fields in New Zealand.

*Proc. 47th N.Z. Plant Protection Conf. 1994: 11-16*

## MATERIALS AND METHODS

### Pot experiments

Four experiments were conducted on grass weeds grown outdoors in pots during the summer over a 2 year period. The grasses were established by placing in pots soils known to contain a natural seed bank of the desired species and then removing unwanted plants by hand. In Experiments 1 and 2, initiated on 8 January and 1 February 1990 respectively, summer grass and rough bristle grass were grown. Experiments 3 and 4, started on 21 December 1990 and 3 January 1991 respectively, included summer grass and smooth witchgrass.

In all experiments the herbicides were applied at three rates to each of three growth stages, viz. 2-leaf, 4-leaf and 6-leaf, with a variety of adjuvants (Tables 1 and 2). The herbicides used were rimsulfuron (Titus 25% ai.), primisulfuron (Beacon 75% ai.) and nicosulfuron (Accent 75% ai.). Rimsulfuron was applied at 10, 15 and 20 g/ha at the 2 and 4-leaf stages and at 15, 20 and 30 g/ha at the 6-leaf stage while nicosulfuron and primisulfuron were used at 30, 45 and 60 g/ha at the 2 and 4-leaf stages and at 45, 60 and 80 g/ha at the 6-leaf stage. The adjuvants used were an emulsifiable vegetable oil (Codacide Oil), a white emulsifiable crop oil (BP Crop Oil), an organo-silicone co-polymer surfactant silwet-M (Pulse), a cationic wetting agent polyethanoxy alkyl amine (Ethokem) and the non-ionic surfactants, alkylarylpolyglycol ether (Citowett) and alkylarylpolyether alcohol (Triton X-45). In all experiments the herbicide/adjuvant combinations were pre-mixed according to label instructions and applied with a moving belt $CO_2$ powered sprayer, fitted with a TeeJet 8003 even spray nozzle, delivering 300 litres/ha at 200 kPa. As each growth stage was reached, four pots of each weed were selected at random for treatment, after which the pots were placed in a randomised block layout for the duration of each experiment. At each time applications were made in a glasshouse, during the morning of a sunny day when air temperatures were in the range of 15 - 18°C. The pots were watered every 2-3 days as required to maintain the soil between 70 and 90% field capacity. Maximum day temperatures were between 20 and 25°C, with night temperatures sometimes dropping to 10°C. Herbicide response was evaluated by regular visual assessments of damage and by counting the surviving plants 4-6 weeks after spraying.

### Field trial

A field trial was conducted in maize, on a Horotiu sandy loam soil with 61% sand, 16% clay, 5.8% organic C and a pH of 5.6. The maize cv. Pioneer 3475 was planted on 20 October 1992 with a Nodet Gougis vacuum seeder at 88,000 seeds/ha and 75 cm row spacing. The standard treatment of alachlor (Lasso Micro-Tech 48%) was applied 7 days after planting and all other treatments (Table 3) were applied on 18 November 1992, 29 days after planting, when maize plants had 3-4 leaves, grass weeds 3-5 leaves and broadleaf weeds 4-6 leaves. Conditions for the post emergence treatments were overcast and 17°C, and 4.3 mm of rain fell within 24 h after treatment. The trial was of a randomised block design with four replicates and individual plots were 10 x 3 m. All treatments were applied with a $CO_2$ powered precision sprayer in 300 litres/ha water at 210 kPa.

Visual assessments for weed control, relative weed abundance and crop damage were made at regular intervals after treatment. Weed dry matter production was determined 6 weeks after planting by harvesting duplicate 0.5 $m^2$ quadrats from each plot and dissecting into grass and broadleaf weeds before drying at 80°C for 24 h. Grain yields were determined by harvesting 25 cobs from each of the two central rows of each plot. The cobs were shelled, weighed and the moisture content of the grain measured. Grain yields presented in Table 3 are adjusted to 14% moisture levels.

## RESULTS

### Pot experiments

The results from Experiments 1 and 2, on summer grass and rough bristle grass, were very similar and are presented in Table 1 as the average of the two experiments. Similarly, the results of Experiments 3 and 4, on summer grass and smooth witchgrass,

were comparable and are presented in Table 2 as the average of the two experiments. In all cases only data for the middle rate of the three rates used are presented. The other rates evaluated gave similar trends, differing only in their absolute values which were rate related. Initially all three herbicides stopped plant growth for a period of about 2 weeks following treatment. In this period, slight to moderate chlorosis often occurred in the younger leaves, in particular in the emerging leaf. After this time the plant either regrew, often from new basal shoots, or died. Chlorosis, and later sometimes necrosis, occurred earlier in those treatments containing an adjuvant compared to the sulfonylurea herbicides used alone. Generally, where plant death occurred, plants that were treated at the 2-leaf stage died within 4 weeks of treatment while those treated at more advanced stages usually died between 4 and 6 weeks after treatment.

**TABLE 1: Effect of adjuvants and plant growth stage on the percent control of summer grass and rough bristle grass by two sulfonylurea herbicides. Assessments are averages of Experiments 1 and 2, made 28 - 36 days after treatment.**

| Adjuvant | Rate | Summer grass | | | Rough bristle grass | | |
|---|---|---|---|---|---|---|---|
| | | 2-leaf[1] | 4-leaf | 6-leaf | 2-leaf | 4-leaf | 6-leaf |
| **Rimsulfuron (15 g ai/ha)** | | | | | | | |
| - | - | 48 | 57 | 40 | 53 | 40 | 45 |
| Citowett | 0.2% v/v | 65 | 75 | 65 | 60 | 65 | 67 |
| Pulse | 0.2% v/v | 72 | 72 | 60 | 55 | 73 | 75 |
| Triton X-45 | 0.2% v/v | 57 | 80 | 60 | 50 | 67 | 70 |
| Codacide oil | 1 litre/ha | 57 | 77 | 73 | 57 | 67 | 80 |
| LSD (P<0.05) | | 11 | 10 | 8 | 9 | 10 | 11 |
| **Primisulfuron (30 g ai/ha)** | | | | | | | |
| - | - | 28 | 48 | 0 | 28 | 78 | 47 |
| Citowett | 0.2% v/v | 33 | 55 | 0 | 30 | 82 | 55 |
| Pulse | 0.2% v/v | 35 | 67 | 0 | 28 | 82 | 70 |
| Triton X-45 | 0.2% v/v | 37 | 68 | 0 | 32 | 88 | 50 |
| Codacide oil | 1 litre/ha | 53 | 62 | 0 | 30 | 80 | 48 |
| LSD (P<0.05) | | 9 | 12 | - | 5 | 8 | 10 |

[1] The 2, 4 and 6-leaf stages correspond to 2, 3 and 4 weeks after planting respectively.

Summer grass was the most difficult of the three grass weeds to control because of its ability to produce basal shoots and to grow rapidly 3 - 4 weeks after treatment. Without the addition of adjuvants none of the herbicides applied at any growth stage gave a level of control which exceeded 50% in any of the experiments (Tables 1 and 2). All adjuvants significantly improved the performance of rimsulfuron applied at the 2 and 4-leaf stage with Pulse and Ethokem both giving 85% control in Experiments 3 and 4 (Table 2). Nicosulfuron with Ethokem applied at the 2-leaf stage gave 100% control but none of the other adjuvants improved the performance of this herbicide enough to give a high percentage kill. Adjuvants did not affect the performance of primisulfuron and this herbicide had no visible effect on the summer grass at the 6-leaf growth stage.

Rimsulfuron by itself gave poor control of rough bristle grass but application with adjuvants at the 4 and 6-leaf stage significantly improved its performance (Table 1). Levels of control exceeding 70% were obtained only with the addition of Pulse at the 4-leaf stage and of Pulse, Triton X-45 and Codacide oil at the 6-leaf stage. Primisulfuron alone gave 78% control of rough bristle grass when applied at the 4-leaf stage, with Triton X-45 the only adjuvant to significantly increase the level of control. Application of primisulfuron at the two other growth stages gave poor control.

**TABLE 2: Effect of adjuvants and plant growth stage on the percent control of smooth witchgrass and summer grass by three sulfonylurea herbicides. Assessments are averages of Experiments 3 and 4, made 28 - 36 days after treatment.**

| Adjuvant | Rate | Smooth witchgrass 2-leaf[1] | Smooth witchgrass 4-leaf | Smooth witchgrass 6-leaf | Summer grass 2-leaf | Summer grass 4-leaf | Summer grass 6-leaf |
|---|---|---|---|---|---|---|---|
| | | **Rimsulfuron (15 g ai/ha)** | | | | | |
| - | - | 70 | 55 | 20 | 45 | 42 | 30 |
| Citowett | 0.2% v/v | 100 | 67 | 25 | 78 | 50 | 38 |
| Pulse | 0.2% v/v | 100 | 70 | 40 | 85 | 53 | 45 |
| Triton X-45 | 0.2% v/v | 100 | 80 | 37 | 75 | 45 | 35 |
| Codacide oil | 1 litre/ha | 100 | 80 | 40 | 65 | 75 | 55 |
| Ethokem | 1 litre/ha | 100 | 83 | 45 | 85 | 88 | 80 |
| crop oil | 2 litres/ha | 100 | 95 | 40 | 75 | 65 | 60 |
| LSD (P<0.05) | | - | 9 | 12 | 8 | 10 | 14 |
| | | **Primisulfuron (30 g ai/ha)** | | | | | |
| - | - | 87 | 37 | 38 | 50 | 0 | 0 |
| Citowett | 0.2% v/v | 97 | 60 | 43 | 50 | 0 | 0 |
| Pulse | 0.2% v/v | 98 | 50 | 40 | 62 | 0 | 0 |
| Triton X-45 | 0.2% v/v | 97 | 48 | 42 | 49 | 0 | 0 |
| Codacide oil | 1 litre/ha | 98 | 72 | 40 | 52 | 0 | 0 |
| Ethokem | 1 litre/ha | 100 | 82 | 72 | 55 | 0 | 0 |
| crop oil | 2 litres/ha | 100 | 69 | 68 | 49 | 0 | 0 |
| LSD (P<0.05) | | 5 | 12 | 8 | 8 | - | - |
| | | **Nicosulfuron (30 g ai/ha)** | | | | | |
| - | - | 66 | 21 | 30 | 48 | 22 | 18 |
| Citowett | 0.2% v/v | 83 | 58 | 42 | 52 | 38 | 40 |
| Pulse | 0.2% v/v | 90 | 52 | 40 | 61 | 43 | 42 |
| Triton X-45 | 0.2% v/v | 88 | 60 | 48 | 52 | 43 | 21 |
| Codacide oil | 1 litre/ha | 95 | 52 | 53 | 48 | 36 | 34 |
| Ethokem | 1 litre/ha | 100 | 100 | 91 | 100 | 72 | 58 |
| crop oil | 2 litres/ha | 93 | 63 | 42 | 57 | 44 | 28 |
| LSD (P<0.05) | | 8 | 15 | 10 | 12 | 14 | 15 |

[1] The 2, 4 and 6-leaf stages correspond to 2, 3 and 4 weeks after planting respectively.

All three herbicides gave good control of smooth witchgrass (Table 2) with the use of adjuvants further improving the level of control in each case. Plants were more susceptible at the 2-leaf stage and became more difficult to control as they grew larger. The best control at more advanced growth stages was achieved with the addition of Ethokem to either primisulfuron or nicosulfuron, or with rimsulfuron plus crop oil applied at the 4-leaf stage only.

**Field trial**

The most abundant weeds in the trial were summer grass, smooth witchgrass and fathen (*Chenopodium album*) in roughly equal proportions, with lesser amounts of willow weed (*Polygonum persicaria*), docks (*Rumex* spp.) and thorn apple (*Datura stramoniun*).

When used alone, rimsulfuron and primisulfuron failed to adequately control both summer grass and smooth witchgrass. In combination with the adjuvants control of smooth witchgrass was considerably improved. However, only rimsulfuron plus Ethokem provided a significant reduction of summer grass. Primisulfuron also gave

good control of broadleaf weeds which resulted in the grass weeds becoming dominant in these plots (Table 3). Despite this, grain yields in the primisulfuron plus adjuvant treatments were twice that of the untreated plots, and not significantly different from the standard alachlor treatment.

**TABLE 3: Effect of different herbicide/adjuvant combinations on grass and broadleaf weeds in maize and grain yields. Maize planted on 20.10.92 and all treatments except alachlor applied on 18.11.92.**

| Herbicide | Rate (g ai/ha) | Adjuvant | % Weed control Grass 7.12.92 | % Weed control Broadleaf 7.12.92 | Weed DM (kg/ha) Grass 5.1.93 | Weed DM (kg/ha) Broadleaf 5.1.93 | Grain yield (t/ha) |
|---|---|---|---|---|---|---|---|
| rimsulfuron | 10 | - | 47.5 | 58.8 | 481 abc | 752 ab | 7.25 |
| rimsulfuron | 10 | Ethokem 3 litres/ha | 81.3 | 61.3 | 102 d | 326 bc | 8.15 |
| rimsulfuron | 10 | Pulse 0.2% | 81.3 | 65.0 | 166 bcd | 768 ab | 7.31 |
| rimsulfuron | 10 | Citowett 0.2% | 77.5 | 75.0 | 307 bcd | 328 bc | 7.73 |
| primisulfuron | 30 | - | 48.8 | 58.8 | 501 ab | 684 b | 7.80 |
| primisulfuron | 30 | Ethokem 3 litres/ha | 65.0 | 98.8 | 1191 a | 110 c | 8.76 |
| primisulfuron | 30 | Pulse 0.2% | 70.0 | 98.8 | 907 a | 227 bc | 8.81 |
| alachlor | 3500 | - | 95.0 | 80.0 | 21 e | 841 ab | 9.49 |
| untreated | - | - | 0 | 0 | 106 cd | 3378 a | 4.40 |
| LSD (P<0.05) | | | 12.9 | 19.4 | -[1] | -[1] | 1.62 |

[1] Analysis performed on log transformed data, numbers followed by different letters are significantly different at the 5% level using LSD test.

None of the adjuvants used with rimsulfuron significantly improved the control of broadleaf weeds over rimsulfuron alone but rimsulfuron plus Ethokem significantly reduced broadleaf weeds compared with the untreated. Rimsulfuron plus Ethokem also had the lowest overall weed dry matter and a significantly higher grain yield than either rimsulfuron alone or with Pulse.

In this trial atrazine-resistant fathen was not controlled by either herbicide alone, but was controlled by primisulfuron plus Ethokem and severely reduced by primisulfuron plus Pulse and rimsulfuron with either Ethokem or Citowett. The standard treatment of alachlor gave significantly better control of grass weeds than any other treatment but the level of broadleaf weed control was similar to the other treatments except primisulfuron plus Ethokem which was significantly better.

All treatments were well tolerated by the maize crop with no visual injury apparent at any stage. Grain yields were highest in the standard alachlor treatment. However yield reductions in the other treatments can mostly be attributed to the high level of competition by broadleaf weeds in the early stage of crop growth (Table 3).

## DISCUSSION

In the pot experiments on grass weeds the level of control achieved was in the absence of interspecific competition. Under field conditions however, significant competition could be expected from both the crop and other weeds with a consequent improvement in the level of weed control. Of the three grass weeds evaluated summer grass and smooth witchgrass were more readily controlled as smaller plants (2-leaf growth stage), while rough bristle grass appeared to be more susceptible at the 4 and 6-leaf growth stages. In these experiments the different growth stages were treated on different days, but applications were made under similar conditions and every effort was made to minimise differences due to time.

The results of the field trial related very well to those of the pot experiments, as significant increases in herbicide efficacy were recorded from the use of adjuvants. The higher susceptibility of smooth witchgrass compared to that of summer grass was also confirmed in the field trial.

The results of both the pot and field experiments show that adjuvants can be used to improve the efficacy of sulfonylurea herbicides on some grass weeds. It may also be possible to achieve satisfactory control of grass weeds at an advanced growth stage by the use of an adjuvant. Overall, Ethokem provided the most consistent improvement to the efficacy of these three herbicides, although the other adjuvants proved equally effective in some cases.

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