SESSION 7C

POSTGRADUATE RESEARCH

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Poster Papers 7C-1 to 7C-16

THE EFFECT OF MULCH FROM THREE MULTIPURPOSE TREES (MPTS) ON WEED COMPOSITION AND BIOMASS IN MAIZE.

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ABSTRACT

Data on weed growth and composition were collected from maize fields mulched with prunings from three multi-purpose trees(MPTS) during the 1995 and 1996 growing seasons. In both years there were more weeds in the unmulched plots than in the mulched with the exception of *Leucaena* plots which had 56% more weeds than the control 3 weeks after planting in 1995. Weed reduction by the mulches was in the order *Gliricidia* > *Senna* > *Leucaena*. Sedges were the dominant species in all the treatments in 1995 except in *Gliricidia* plots where *Talinum* and other broad leaf species were dominant. In 1996, *Talinum* and other broadleaf species dominated in the mulch plots. Results from this study suggested that *Gliricidia* and *Senna* were effective in reducing weed biomass and density whereas *Leucaena* promoted weed growth. Because *Senna* mulch persisted on the ground longer than *Gliricidia*, the better suppressive effect of *Gliricidia* seems to be not only from physical suppression of germinating weeds but could probably be attributed to allelopathic effects.

INTRODUCTION

Fast growing nitrogen fixing multipurpose trees are increasingly used in tropical countries for land restoration, fallow improvement, and erosion control. However, in addition to soil improvement, mulch from the hedgerow suppresses weed growth (Budelman 1988). Moreover, shade from the hedgerow species suppresses undergrowth. Besides shading, effective weed control depends on the persistence of the applied mulch layer. This persistence is controlled by the rate of decomposition of the mulch. Budelman (1988) showed that *Gliricidia sepium* and *Leucaena leucocephala* mulch cannot control weeds because of their faster decomposition rate compared to *Flemingia macrophylla* which had a higher persistence. In addition to physical suppression of weeds, the decomposition of plants residues can also release phytotoxic compounds that inhibit crop and weed growth (Akobundu, 1986). Purvis *et al.* (1988) found pear, sunflower, sorghum and wheat residues to reduce grass weeds considerably as compared to the non- residue crop plots. The objective of this work was to assess the potential of mulch from three MPTs trees for their effect on weeds and weed dynamics in maize.

MATERIALS AND METHODS

Field experiments were conducted during the 1995 (July-October) and repeated in the same plots in 1996 (May-August) growing seasons at the International Institute of Tropical Agriculture

(IITA) in Ibadan, Nigeria. Treatments consisted of mulch from *Gliricidia sepium, Leucaena leucocephala* and *Senna siamea* applied to maize crop at the rate of 5 tons DM/ha at 3 weeks after planting (WAP) and 3 tons DM/ha at 8 WAP. Unmulched plots fertilized with 90 kg N/ha or without fertilizer applications were controls. Weed data were collected in three diagonally fixed quadrats/plot at 3 and 8 (WAP)

RESULTS

In both years, weed density and biomass were lower in the mulched plots than the unmulched plots with and without nitrogen fertilizer at all times of sampling except *Leucaena* mulch which promoted weed growth by 56% at 3 WAP in 1995 (Table 1). Total weed density was higher in 1996 than 1995.

At all times of sampling in 1995, *Talinum triangulare* and sedges dominated the species in all treatments. *Chromolaena odorata* , though the predominant fallow species before cultivation, was absent in the mulched plots. In 1996, there was a shift to *Talinum triangulare* in all the treatments. Although *Tridax procumbens* was negligible in *Gliricidia* plots, it was the second most important in the other treatments.

Table 1. Effect of Mulch from three Multipurpose Trees on weed density (Weeds/M^2)

	1995		1996	
Treatments	3 WAP	8 WAP	3 WAP	8 WAP
Gliricidia	8c	29c	47c	39c
Leucaena	156a	98b	98bc	74b
Senna	29b	32c	59c	36c
90 Kg N/ha	234a	189a	180ab	93ab
Control	99ab	186a	224a	110a

Within columns figures with the same letters are not significantly different according to Duncan's Multiple Range Test.

ACKNOWLEDGEMENT

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SUPPRESSION OF WEEDS IN MAIZE INTERCROPS IN KENYA

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ABSTRACT

2 rows of beans grown between maize rows gave good weed suppression and improved maize yields in unweeded crops. Potato suppressed weeds well but was itself competitive with maize.

INTRODUCTION

Much agronomic work on maize intercrops has been carried out in Kenya without providing any data on whether they provide any weed suppression benefits.

MATERIALS AND METHODS

The experiments reported were carried out at the field station of the Faculty of Agriculture at Kabete, 12Km N.W. of Nairobi. The maize cultivar H511 was used throughout, grown in rows 75cm apart at intra row spacings of 30cm (44,444 plants /ha^{-1}). *Phaseolus vulgaris* cv. Rose Coco were grown as one row (intra row spacing = 5cm) or two equally spaced rows (intra row spacing = 10cm) between maize. Monocrop bean was at the 2 row intercrop spacing. There were 3 replicates of the 4 cropping treatments shown in Table 1, with or without a hoe weeding at 3 weeks after planting (WAP).

In the potato experiment seed tubers of the varieties Dutch Robijn (early maturing spreading bushy type) and Roslyn Eburu (upright canopy and medium maturity) were planted midway between maize rows at 30cm intra row spacing. There were 3 replicates of the treatments shown in Table 2 with or without weeding at 4 WAP. Fertiliser and crop protection treatments were according to local usage.

RESULTS

In unweeded crops the 2 row bean intercrop suppressed weed growth very considerably and more than the farmer's current 1-row intercropping (Table 1). After weeding at 3 WAP little new weed growth occurred in any treatment. Maize yields without weeding were nearly doubled to yields similar to weeded maize when maize was grown with the 2-row bean intercrop. Maize decreased bean yields in intercrops especially in the 1 row system.

There were large amounts of weed suppression by potato in the unweeded potato/maize intercrops especially with Dutch Robijn which was also suppressive as a monocrop. Maize yields were decreased whenever they had potato as an intercrop and potato yields were much decreased by maize particularly with Roslyn Eburu. (Table 2)

Table 1 Crop Yield and Weed Dry Weight in Bean Intercrop

		Maize alone	Maize + 1 Row Beans	Maize + 2 Rows Beans	Beans alone
Weed Dry Wt.	-W	147	100	32	50
gm^2 at 7WAP(SE=14)	+W*	24	19	11	15
Maize yield	-W	2.9	3.8	5.5	-
t/ha^{-1} (SE=0.8)	+W	6.1	6.8	6.0	-
Bean yield	-W	-	0.6	0.9	1.7
t/ha^{-1} (SE=0.2)	+W	-	0.9	1.4	2.7

* +W = One hoe weeding

Table 2 Crop Yield and Weed Dry Weight in Maize Potato Intercrops

		Maize alone	Maize + DR[1]	Maize + RE[2]	DR alone	RE alone
Weed Dry Wt.						
g/m^2 at 9WAP	-W	273	17	70	83	210
(SE=18.5)	+W*	10	3	5	6	7
Maize yield	-W	5.4	4.9	4.7	-	-
t/ha^{-1} (SE=0.6)	+W	7.3	5.1	6.0	-	-
Tuber yield	-W	-	22	10	30	16
t/ha^{-1} (SE=1.5)	+W	-	23	14	32	27

* +W = 1 hoe weeding
1 = Dutch Robijn potato 2 = Roslyn Eburu potato

Total crop yields from the intercrops (assessed as Land Equivalent Ratios, the areas of both monocrops needed for the same yield production) had LERs of 1.5 to 2.1 for beans and 1.4 to 1.6 for the potato intercrops. This gave larger crop returns for the same weeding effort in the intercrops than the monocrops. Improvements in planting system (beans) or choice of the most suitable cultivar (potato) can give better results than some existing practices.

ACKNOWLEDGEMENTS

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WEED CONTROL IN COTTON UNDER THREE CULTIVATION SYSTEMS

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ABSTRACT

An experiment was conducted in Greece during 1996 to investigate the effects of various herbicides on weed control in cotton under different tillage systems. Alachlor, prometryn and fluometuron were applied pre-emergence alone and in mixture. Weed infestations were reduced to the greatest extent by ploughing and treatment with fluometuron and alachlor +fluometuron. At final harvest cotton yield was greatest under conventional tillage following treatment with alachlor +fluometuron.

INTRODUCTION

Cotton is currently grown on 410,000 hectares in Greece (8% of the agricultural area), yet it is the most important agricultural source of foreign currency. However, due to increased production costs reduced price support and adverse climatic conditions, interest in reduced tillage systems has increased. Such systems offer advantages of reduced labour, fuel and machinery cost, greater timeliness of operation, but may necessitate greater herbicide use. The recent development of microencapsulated herbicide formulation offers potential for improved weed control in such systems. The objective of this research was to compare three contrasting tillage regimes and various herbicide treatments on weed control and yield of cotton.

MATERIAL AND METHODS

The experiment consisted of a randomised complete block in a split plot design replicated four times. Main plot treatments consisted of three tillage regimes and sub-plots were of various herbicide comparisons. Main plots were 3.8x64m and sub-plots 3.8x6m. Conventional tillage involved mouldboard ploughing followed by chisel plough and one pass with a flexi-tine cultivator prior to sowing. Strip tillage plots were sub-soiled at intervals of 95 cm to a depth of 25-30 cm and cultivated with a narrow-crop cultivator. Minimum tillage plots received a single pass with a flexi-tine cultivator. Cotton cv. Acala (Zeta 2) was sown at a seed rate of 24 kg/ha, a row spacing of 95 cm to a depth 3.5 cm on 2 May 1996.The experiment was located at Larissa, Greece on a clay soil (1% OM) and the crop was managed according to local practice.Pre-emergence herbicide comparisons were alachlor, prometryn and fluometuron applied individually and of alachlor formulated as EC and CS mixtures with prometryn or fluometuron. In addition a hand weeded and a weedy control were included for evaluation of crop phytotoxicity and herbicide efficacy respectively.Crop and weed were assessed throughout, but data is presented for the final assessment only (14 July).

RESULTS AND DISCUSSION

The weed flora was dominated by *Xanthium strumarium* and *Amaranthus retroflexus,* but also included other *Amaranthus*, *Echinochloa* and *Setaria spp*. There were significantly fewer weeds in conventional than strip tillage ($P<0.05$) whilst all herbicide treatments reduced weed number relative to the weedy control ($P<0.05$) . All weeds were controlled adequately with the exception of *X. strumarium* which was controlled only partially with fluometuron treatments (Fig.1). There was a significant tillage x herbicide interaction ($P<0.05$). Under conventional tillage treatment with fluometuron resulted in least weed infestation, but was significantly less effective under strip or minimum tillage. Weed biomass was significantly greater for strip tillage ($P<0.01$) or minimum tillage ($P<0.05$). Weed biomass was not reduced significantly for all herbicide treatments compared to the unweeded control except following treatment with alachlor + fluometuron. There was a significant tillage x herbicide interaction such that biomass was less for alachlor + fluometuron treatment in conventional tillage relative to strip tillage ($P<0.01$) and minimum tillage ($P<0.05$). Cotton yield was lower in strip tillage ($P<0.01$) and minimum tillage ($P<0.05$) relative to conventional tillage with a yield of 1332 kg/ha. Maximum yield (1886 kg/ha) was obtained from the weed free plots and differences between herbicide treatments, were not significant except for alachlor + prometryn which yielded (472 kg/ ha) compared with 1096 kg/ha for alachlor + fluometuron.

Effect of herbicide treatments on weed density (no/m^2) [Fig. 1] and on cotton yield (kg/ha) [Fig. 2] (Mean of three tillage regimes)

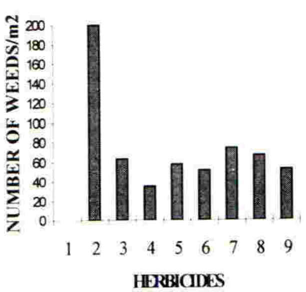

Fig.1

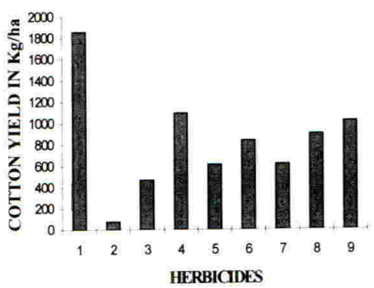

Fig.2

1.Weed free control, 2. Weedy control, 3. Alachlor(CS)+prometryne, 4. Alachlor(CS)+fluometuron, 5. Alachlor(EC)+prometryne, 6. Alachlor(EC)+fluometuron, 7. Alachor(EC), 8.Prometryne, 9. Fluometuron.

In conclusion the results indicate that the use of fluometuron under conventional tillage provide more effective weed control and greater yield production compared to that of the other two regimes.

WEED CONTROL WITH HERBICIDES AND HAND-HOE WEEDING IN COTTON IN UGANDA

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ABSTRACT

Digitaria abyssinica (*scalarum*), *Cynodon dactylon*, *Cyperus* spp and *Oxalis latifolia* are weeds of major economic importance in cotton production in Uganda and are difficult to control by hand-hoe weeding (3-5 times) alone. Weed control field trials of eight herbicides and one mixture in cotton carried out in 1993/94 at NAARI are reported. Of the herbicides cycloxydim alone and its mixture with bentazone gave high weed control (grasses and total weeds respectively) and both treatments gave high cotton yields; all of which were comparable to those of a hand-hoe weeding.

INTRODUCTION

Weeds remain one of the major constraints to cotton production in Uganda. The common weed species in the cotton growing areas are mainly perennial grass weeds such as *Digitaria abyssinica*, *Cyperus* spp., *Cynodon dactylon* and *Imperata cylindrica*. Other weeds include; *Panicum maximum*, *Eleusine indica*, *Bidens pilosa*, *Galinsoga parviflora*, *Oxalis latifolia*, *Commelina* spp. (mainly *C. benghalensis*), *Fallopia convulvolus*, *Ageratum conyzoides* and *Amaranthus* spp.

The objective was to field evaluate the efficacy of a range of currently available post and pre-emergence herbicides for weed control in cotton. Amongst others, grass selective herbicides were included in this preliminary study as their weed control capabilities could combine well with hand-hoe weeding in the cotton crop. It was intended to evaluate the use of low dosage herbicides combined with hand-hoe weeding following this field trial.

MATERIALS AND METHODS

After land preparation, cotton, *Gossypium hirsutum* (variety BPA 89) was planted (70cm x 50cm) at Namulonge Agricultural and Animal Production Research Institute (NAARI), Uganda, during the cotton season of 1993/94 using plots of 5.1m x 4.9m (three replications). The following herbicides were tested; fluometuron WP (pre-emergence) at 2500g a.i./ha, cycloxydim EC (post-emergence) at 400g a.i./ha, bentazone EC (post-emergence) at 600g a.i./ha, pendimethalin EC (pre-emergence) at 1250g a.i./ha and 2000g a.i./ha, mixture of cycloxydim (400g a.i./ha) and bentazone (600g a.i./ha), quizalofop EC (post-emergence) at 437.5g a.i./ha, diclofop-methyl EC (post-emergence) at 475g a.i./ha, fenoxaprop EC (post-emergence) at 120g a.i./ha and oxadiazon EC (post-emergence) at 375g a.i./ha. The pre-emergence herbicides were applied immediately after planting the cotton, while the post-emergents were applied on the actively growing weed species. In addition to the untreated control plots with no herbicide there were plots only hand-hoe weeded four times, at; three weeks after emergence, establishment stage, before flowering and before boll maturity.

Weed counts were made in all plots by using a 0.3m x 0.3m quadrat, randomly thrown three times in each plot. Data on the crop responses i.e. plant height (cm), number of sympodia, number of bolls and seed yield (g/plot) were also collected.

RESULTS AND DISCUSSION

Analysis of variance showed that cycloxydim at 400g a.i./ha significantly ($P \leq 0.05$) controlled grasses (75-81%). Similar findings were reported by Chambers *et al* 1995 and Vleeschauwer *et al* 1992. High levels of control of all weeds were achieved by hand-hoe weeding as well as the tank mix of cycloxydim (400g a.i./ha) plus bentazone (600g a.i./ha). The mixture and hand-hoe weeding were not significantly ($P \leq 0.05$) different from each other in the control of both grasses and broad-leaf weeds. Pendimethalin at 1250 and 2000g a.i./ha suppressed some grasses (mainly annuals) such as *Panicum maximum* and *Eleusine indica* (69-78) and various broad-leaf weed species (70-78%). All herbicides (except bentazone) gave some control of nutsedges (41-46%) but inferior to hand-hoe weeding (61%).

Overall all the crop responses and especially seedcotton yields (1.47 kg/plot) were highest with the mixture (cycloxydim plus bentazone). This was not significantly different ($P \leq 0.05$) from the hand-hoe weeding (1.32 kg/plot) but was compared to cycloxydim on its own (1.05 kg/plot). However, the yield components measured showed no significant differences comparing cycloxydim alone with the four times hand-hoe weeding, emphasizing the importance of grass weed control in crop responses and the potential for the use of grass weed herbicides combined with hand-hoe weeding.

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WEEDING EFFECTS ON COFFEE PRODUCTION AND SOIL WEED SEED NUMBERS IN ESTABLISHING COFFEE IN UGANDA

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ABSTRACT

Weed seed numbers in the soil decreased during the first 1½ years of establishment by about 75% with a clean weeding, herbicide weeding or intercrop + weeding establishment programme and only by about 30% with slash weeding. Coffee canopy growth and yield were also poor with slash weeding systems. Best early yield was from clean weeding, followed by herbicide use. While intercrops provided some returns early, they delayed the onset of coffee yields.

INTRODUCTION

Much of the coffee currently being grown in Uganda is from old planting material that was seriously neglected during the past period of internal conflict. Emphasis is now being given to replacing this material with new clonal coffee types of superior performance. The present study investigated the type of weeding practices which could help to establish these trees well and possibly to diminish future weed problems while they are in production.

MATERIALS AND METHODS

The experiment reported was carried out at the Kituza farm of the Coffee Research Centre. A base fallow for 11 years was cleared of tree and shrub vegetation in early 1993 leaving a site dominated by perennial broadleaved weeds and a mixture of other species. The land was cleared by tractor discing for planting coffee in October 1993 with 6 month old clonal populations on individual plots of 42 trees at 3x3m spacings. Trees were watered in for a few months, fertilised, pruned and cared for using normal commercial practices.

Six weeding treatments were applied replicated 4 times

1. **Clean Weeding.** Hoe weeding once a month wherever possible.
2. **Hoe and Slash Weeding.** Hoe weeding 2 times per year and slashing with a cutlass once or twice per month.
3. **Ring Weeding.** A circle about 1m around each tree hoe weeded, the remaining weeds slashed at intervals.
4. **Herbicide Weeding.** Glyphosate at 2 kg ai ha^{-1} twice a year and paraquat at 0.4 kg ai ha^{-1} several times each year.
5. **Intercrop Weeding.** Groundnut or Phaseolus beans depending on the season, planted, after hoeing, and handweeded once or twice before harvest.

6. **Integrated Weeding.** 2 hoe weedings each year, one glyphosate application and slashing at intervals between these.

Twenty soil cores per plot (6cmx25cm deep) were mixed thoroughly, large plant materials removed and the soil was then placed for germination in seed trays 22x13x6cm to a depth of 3cm. The trays were placed outdoors under a plastic sheeting rain cover in a randomised design and watered as needed. Seedlings which germinated were counted, identified and removed and the soil was disturbed every 8 weeks approximately until few new germinations occurred, usually after about 6 months. The numbers obtained are regarded as the main transient seed bank.

RESULTS

The coffee data reported are tree canopy diameters in July 1996 and the first seasons clean coffee yields for 1995-96 season.

Table 1 Weed seed numbers and coffee growth data

Weeding Treatment	Weed seed numbers $m^{-2} \times 10^3$ Nov. '93	Weed seed numbers $m^{-2} \times 10^3$ April '95	Coffee Canopy diam. m	Coffee Clean Coffee kg ha^{-1}
Clean	16.2	3.7	2.34	464
Hoe + Slash	14.6	9.8	1.72	106
Ring + Slash	18.1	11.1	1.55	82
Herbicides	14.9	3.7	2.30	230
Intercrop	14.0	4.2	2.05	87
Integrated	14.1	5.7	2.00	157
Mean	15.3	3.8	1.99	188
LSD	(5.1)	(3.6)	(0.34)	(104)

The transient weed seed bank had 15.3×10^3 seed at planting time. After 1½ years of the weeding programmes these numbers had decreased to about 4×10^3 in the clean weeding, herbicide and intercrop treatments which were clearly successful in limiting weed seed return. In the Hoe+Slash and Ring+Slash treatments there was about 10×10^3 seed present. Coffee canopy growth was poorest in these same two weeding treatments and best in the clean or herbicide weeding. Coffee yield was much better with clean weeding or herbicides. Competition from the legume intercrops decreased early coffee yield even though the trees grew quite well vegetatively. However the extra income from the legume crops would offset this disadvantage and help to cover the costs of the weeding programme. Slashing treatments were generally the poorest. Herbicide treatments were the least labour intensive but quite expensive to apply. The integrated treatment needs further improvement to make it more effective and this is being checked.

ACKNOWLEDGEMENTS

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THE SEED BANK AND WEED SEEDLING EMERGENCE IN SUGARCANE IN SRI LANKA

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ABSTRACT

The relationship between the seed bank and weed seedling emergence was examined in sugarcane fields in Sri Lanka in 1995 and 1996. The similarity between species in the seed bank and emerged seedling population in the field was low. At only two sites out of six was there a significant relationship of abundance of common species in the seed bank and the emerged seedling population in the field.

INTRODUCTION

Weeds cause considerable production losses in sugarcane. Weed competition for sugarcane is most critical for about 14 to 16 weeks after planting (Peng, 1984). Cultivated soil contains a large number of weed seeds, which under favourable conditions germinate and interfere with growing crops. Characterisation of the soil seed bank and likely weed seedling emergence would provide information on future weed population in the field, but few studies have examined the relationship between the seed bank and emerged seedlings in arable land and none in sugarcane fields in Sri Lanka. The relationship between the seed bank and the emerged seedling population following sugarcane planting in Sri Lanka is examined here.

MATERIAL AND METHODS

The seed bank in surface soil (0 - 4cm) and weed seedling emergence on the ridges and in the furrows of sugarcane planted fields were monitored after plantings in October 1995, January and April 1996 at the Sugarcane Research Institute (SRI) farm, Udawalawe, Sri Lanka (Lat. 6°21′N, Long. 80°48′E, Alt. 75m). The seed bank was estimated by taking soil samples and counting the number of seedlings which emerged when the samples were set out in trays in a shade house. Seedling emergence was monitored within fixed quadrats in the field. Seedlings emerging from soil samples and in the field were identified, counted and removed weekly for about 20 weeks.

RESULTS AND DISCUSSION

Exact probabilities were used to measure the association between presence or absence of species in the seed bank and in the emerged seedling population in the field. In all cases the values were not significant ($P \geq 0.05$) which implies that the presence and absence of species in the seed bank and the emerged seedling populations both on ridges and in furrows at each planting were not associated (Table 1).

Table 1. The number of weed species present or absent in the seed bank and in emerged seedling populations on ridges and in furrows of sugarcane fields

October 1995		Ridges				Furrows		
		Present	Absent			Present	Absent	
Seed-Bank	present	4	5		present	5	4	
	absent	4	0	*P*=0.10	absent	5	0	*P*=0.13
January 1996		Ridges				Furrows		
		Present	Absent			Present	Absent	
Seed-Bank	present	7	10		present	5	12	
	absent	1	0	*P*=0.44	absent	1	0	*P*=0.33
April 1996		Ridges				Furrows		
		Present	Absent			Present	Absent	
Seed-Bank	present	6	10		present	9	7	
	absent	1	0	*P*=0.41	absent	2	0	*P*=0.36

Next, the species found in the emerged seedling population were ranked separately according to their abundance on the ridges and in the furrows of each planting and these values were correlated with the rank order of the abundance of same species found in the seed bank. In two out of six comparisons, there was a significant relationship between the seed bank and species emerging in the field (Table 2).

Table 2 The correlation coefficient (r) between the ranked data of species abundance on ridges and in furrows in October, January and April planting and the same species in the seed bank.

	October		January		April	
	Ridges	Furrows	Ridges	Furrows	Ridges	Furrows
r	0.80	0.40	0.96	0.70	0.60	0.92
	NS	NS	*	NS	NS	*

NS = not significant ($P > 0.05$) * = significant ($P \leq 0.05$)

The present result suggests that it will be difficult to predict the composition of future weed populations from assessment of the weed seed bank. This is in contrast with the results of Naylor (1972) who developed a weed predictive index for the occurrence of the single species blackgrass (*Alopecurus myosuroides*). However, other studies have demonstrated differences between the total seed bank and the mixed vegetation arising from it (Mallik *et al.*, 1984).

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AGGRESSIVITY OF WHEAT CULTIVARS

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ABSTRACT

Crop competitiveness against weeds is particularly important in resource-poor farming systems. Four varieties of spring wheat were grown with fat hen (*Chenopodium album*). The value of the aggressivity coefficient was calculated to compare their performance and was related to their canopy structure. High crop aggressivity was associated with a high crop leaf area index, a low weed leaf area index and a smaller reduction in crop yield. Fat hen growing with a more aggressive cultivar showed a greater reduction in its shoot biomass and reduced in seed production. The implications for crop management in developing countries are considered.

INTRODUCTION

Environmental and economic reasons favour reducing the quantity of herbicides applied to the crop (Richards and Davies, 1991). One important approach is maximising crop competitiveness so that less reliance is placed on weed control by herbicides. In developing countries like Bangladesh, where no herbicide is used by the farmers, the use of competitive cultivars may reduce the cost of weeding. Aggressivity is a measure of crop competitiveness. Identifying competitive cultivars is important and understanding the nature of crop aggressivity would aid the process (Bueno & Froud-Williams, 1993). This study was undertaken to identify and characterise wheat cultivars which are more competitive against fat hen, an important weed of wheat, and to investigate the correlations between crop aggressivity and plant characteristics of wheat and the response of the weed.

MATERIALS AND METHODS

Four cultivars of spring wheat (Alexandria, Baldus, Canon and Tonic) were grown in pure stands and in mixture with fat hen in fields at Craibstone, Aberdeen during the period from May to October 1996. Monoculture of weed was also raised. The land was fertilized with N, P, K at the rate of 100, 50, 50 kg/ha. Wheat was sown in rows 17 cm apart on 15th May 1996 to raise 300 plants/m^2. Weed seeds were broadcast on the soil surface after wheat sowing to obtain 400 plants/m^2. Plots (1.3 x 1.3 m) were arranged in randomised blocks. Destructive sampling was done 5, 7, 9 and 11 weeks after crop sowing when eight plants of both species were collected randomly from the 2nd and 7th row of each plot. In the laboratory, leaf area was measured with a Delta-T Leaf Area Meter and dry weights were recorded. Two central rows of 1 meter length were harvested at maturity. Grain yield of wheat and seed yield of fat hen were recorded. Seed shedding of fat hen was assessed by trapping seeds fortnightly in seed rain traps. The aggressivity of wheat cultivars was calculated as the difference between relative shoot yields of wheat and the weed.

RESULTS AND DISCUSSION

Shoot weight of fat hen was significantly reduced by competition from wheat (Table 1). The highest suppression was by Alexandria (86% reduction) and the lowest from Baldus (62%). The leaf area index (LAI) of fat hen was reduced similarly. Seed production and seed shedding of fat hen was also affected by competition from wheat. The effect of the weed on LAI of wheat varieties was the opposite and was reflected in the cultivar grain yields. These results confirmed that substantial reduction of the effect of fat hen could be achieved by choosing a competitive cultivar. Bueno and Froud-Williams (1993) observed that although Alexandria was the highest yielding cultivar in monoculture compared to Tonic and Canon, it was the least competitive when grown in competition with barley or mustard. Obviously, the crop competitive ability is influenced by the weed species present with the crop (Wilson, 1989).

Table 1. (a) Shoot weight, leaf area index, seed yield and seed shedding of fat hen under different wheat cultivars, (b) per cent yield loss and aggressivity of the wheat cultivars

Plant character	No wheat	With wheat cultivar				LSD (P=0.05)
		Alexandria	Tonic	Canon	Baldus	
(a) Fat hen						
Shoot weight (g /plant)	1.72	0.24	0.32	0.65	0.66	0.17
Leaf area index	0.47	0.07	0.08	0.13	0.10	0.04
Seed yield (g /m^2)	243.72	21.95	50.23	60.08	73.66	26.09
Seed shedding (000 /m^2)	144.06	24.49	41.99	55.74	53.59	49.72
(b) Wheat						
Leaf area index	-	0.53	0.45	0.43	0.41	0.06
Yield loss (%)	-	26	31	34	47	13.88
Aggressivity	-	0.61	0.60	0.43	0.38	0.14

Crop aggressivity was positively correlated with crop LAI (r^2=0.45**) and per cent loss of weed shoot weight (r^2=0.88**). It was negatively correlated with weed LAI (r^2=0.68**) and per cent loss of wheat grain yield (r^2=0.45**). These results suggest that selection of a competitive cultivar may be an important component of integrated weed management and that varietal leafiness may be an important selection criterion.

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THE USE OF VARIETAL SELECTION AND SEED RATES FOR ENHANCED WEED SUPPRESSION IN WINTER WHEAT (*Triticum aestivum L.)*

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ABSTRACT

A field experiment was conducted during 1995-96 to evaluate the weed suppressive ability of six cvs. of winter wheat sown at various seed rates. Seed rate significantly affected weed suppression of a naturally occurring weed infestation dominated by *Poa spp*, *Matricaria spp* and *Stellaria spp* whilst varietal selection was less important.

INTRODUCTION

The demand for increased food supply necessitated by the increase of human population has become more acute. Improved agronomy has contributed greatly to recent increases in cereal yields, as has better control of pests and diseases whether by genetic or chemical control. On the other hand, the desire to reduce herbicide inputs with respect to environmental quality, food safety, avoidance of herbicide resistance and reduced cost of crop production have led the agricultural community to reconsider herbicide usage and to develop alternative strategies of integrated control. With regard to the latter consideration, this study was designed to investigate whether varietal selection based on differing growth habits in combination with reduced seed rates may suppress the natural weed infestation.

MATERIALS AND METHODS

A field experiment was conducted at the University of Reading field unit at Shinfield during 1995-96 in a randomised split-plot design. Six winter wheat cvs. were selected from the NIAB 1995 recommended list of cereals based on their different growth habits (Maris Huntsman, a traditional tall variety and five modern semi-dwarf cvs. Fresco, Riband, Flame, Buster, and Hussar of moderate straw strength) with three targeted seed rates (150, 250, 350 plants/m^2). The Plot size was 2×8m whilst the sample unit was a quadrat 30×30cm. Duplicate assessments with respect to weed flora were taken during May and June 1996. Samples were separated by species and density, fresh and dry weight, reproductive output, and leaf area (where appropriate) were recordered.

RESULTS AND DISCUSSION

Significant differences were obtained in June between actual crop densities (83, 131 and 178 plants/m^2) such that at low seed rates weeds were suppressed to a lesser extent (Tables 1, 2). Crop density affected weed dry weight and reproductive capacity of *Poa spp* ($P<0.001$), *Matricaria spp* ($P<0.01$).

Although main effects of seed rate were highly significant, effect of varieties was non significant, albeit there was a seed rate × variety interaction ($P<0.05$) whereby M. Huntsman was more suppressive at lower seed rates.

Table 1. Effects of crop density on *Poa spp* (mean of three crop densities)

Crop density (mean of the observed plants/m^2)	83	131	178	LSD	F pr
Weed dry weight (g/m^2)	243.1	213.5	147.9	84.24	***
Weed reproductive organs/m^2	3298	2885	2064	1016	***

Table 2. Effects of crop density on *Matricaria spp* (mean of three crop densities)

Crop density (mean of the observed plants/m^2)	83	131	178	LSD	F pr
Weed dry weight (g/m^2)	234	120	109	105	**
Weed reproductive organs/m^2	2496	1534	1141	1096	**

=1%, *=0.1% significance level.

The results from this study confirm the importance of crop density on weeds expressed as reduction of the dry matter accumulation. Similar results were obtained by Wilson et al. (1995). The reductions in weed biomass at high crop density may be attributed to greater shading caused by a dense and more uniform crop canopy.

At the low crop density, reproductive capacity of both species was increased (40, and 54% for *Poa spp* and *Matricaria spp* respectively) than at high crop density. Weed seed production was closely correlated with weed biomass in agreement with Wilson et al. (1995), both of which decreased with increased crop density. Reductions in weed seed production at high crop densities implies less contamination of the harvested grain and return to the soil seed bank.
In conclusion the results obtained suggest that in the absence of chemical weed control the use of greatly reduced seed rates of modern wheat cvs. will not achieve effective weed suppression.

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EFFECTS OF SUB-LETHAL DOSES OF METSULFURON-METHYL ON CROP-WEED COMPETITION IN TWO VARIETIES OF WINTER WHEAT

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ABSTRACT

A field experiment showed that two winter wheat cultivars with contrasting growth characteristics and different competitive ability have significant effects on herbicide performance in controlling oilseed rape (*Brassica napus*) as a model weed. Weed density also influenced the outcome of herbicide application. Thus, herbicide dose can be adjusted according to crop competitive ability and weed density.

INTRODUCTION

With the strong need to reduce environmental risk from herbicide use, several reports show that herbicide dose can be adjusted to different conditions, such as crop species, seeding rate and drilling time. Christensen (1994) showed that the competitiveness of crop varieties modified herbicide dose-response relationships. Brain *et al.* (personal communication) modelled crop yield loss versus herbicide dose for a range of weed biomasses and then estimated the herbicide dose that restricted yield loss to a chosen level.

It is thought that when reduced doses of herbicide are applied, the growth of weeds growing with a more competitive crop variety will be suppressed more than that of weeds growing with a less competitive one. Moreover, it is thought that at lower weed densities, lower doses of herbicide will be effective in maintaining weeds below the economic threshold level. Therefore, this experiment was carried out to evaluate the effect of a range of reduced herbicide doses on weed control in wheat cultivars with contrasting competitive abilities and to calculate the dose-response for a range of weed densities in these contrasting cultivars.

MATERIALS AND METHODS

A field experiment was carried out at Long Ashton Research Station in 1996/97. Two winter wheat cultivars, Avalon and Spark, with contrasting competitive abilities (Seavers and Wright, 1997) were drilled at a density of *c.* 300 plants m^{-2} soon after four different densities of oilseed rape (*B. napus*) as a model weed were sown by hand in October 1996. Target densities were 0, 25, 50 and 100 plants m^{-2}. Six doses, 0, 0.375, 0.75, 1.5, 3.0, and 6.0 g a.i. ha^{-1}, of metsulfuron-methyl 'Ally' were applied with 250 litres of water ha^{-1} on 15 April 1997. The experiment consisted of four replicates of a split-split plot design. The split-split plot size was 3 m x 3 m. Assessments were conducted once before and three times after herbicide application. A sample of 0.25 m^2 per plot was taken for the assessments before harvest and number of tillers, plant height, fresh and dry weight were recorded. Finally, grain yield and weed seed production were measured after a sample of 1 m^2 per plot was harvested at maturity in late July 1997.

RESULTS AND DISCUSSION

Table 1. Dry weight (g per m^2) of winter wheat and oilseed rape (*B. napus*) on 25 May

	B. napus			Winter wheat			
Density	25	50	100	0	25	50	100
Dose	in cv. Avalon plot			cv. Avalon			
0.0	24.7	49.0	63.8	714.6	668.3	622.7	571.6
0.375	21.8	51.7	60.7	786.3	701.2	661.2	582.6
0.75	19.3	39.4	61.0	741.9	666.5	658.9	648.5
1.5	11.3	28.4	51.1	713.1	692.0	644.9	625.1
3.0	6.3	16.4	26.3	728.1	682.6	662.5	679.5
6.0	5.4	14.1	24.7	729.4	700.4	664.6	719.5
	in cv. Spark plot			cv. Spark			
0.0	63.0	68.0	101.6	708.5	656.5	584.4	538.5
0.375	38.2	57.7	102.4	678.6	624.8	581.8	569.8
0.75	28.6	54.8	89.0	683.9	606.3	593.0	573.6
1.5	23.4	50.5	64.2	688.2	646.6	673.5	645.4
3.0	13.0	28.9	42.2	674.1	639.3	647.8	609.7
6.0	8.8	16.1	40.2	672.2	679.0	692.5	668.5

Density : plant density of *B. napus* (number of plants m^{-2})
Dose : application dose of metsulfuron-methyl (g a.i. ha^{-1})

The cv. Avalon was more competitive to oilseed rape than cv. Spark over the dose range of herbicide applied (Table 1). It is likely that long- or short-term economic threshold levels can be set higher in more competitive wheat varieties and, therefore, herbicide dose can be reduced, reflecting higher crop competitive ability and lower weed density.

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COMPETITION ABOVE AND BELOW GROUND BETWEEN FAT HEN (*CHENOPODIUM ALBUM*) AND TWO SUGAR BEET CULTIVARS

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ABSTRACT

A glass-house experiment was designed to investigate competition above and below ground, between *Chenopodium album* and two sugar beet *cvs.* of morphologically contrasting growth habit. Specific leaf weight (SLW) of sugar beet plants showed significant differences between the two *cvs.* and under the competition regimes 8 weeks after transplanting (WAT). Leaf chlorophyll content of sugar beet subjected to below-ground competition was greater than that subjected to full competition.

INTRODUCTION

In weed-crop competition experiments it has been reported that cultivars of sugar beet which are of prostrate growth habit and of early canopy closure may be more competitive (Lotz *et al.*, 1991). Abdollahian-Noghabi *et al.* (1997) reported that yield loss of sugar beet subjected to below-ground competition is greater than that subjected to above-ground competition. The aim of this study was to investigate effects of above and below ground competition with *C. album* on specific leaf weight and leaf chlorophyll content of two sugar beet cultivars.

MATERIALS AND METHODS

A factorial pot experiment under glass-house conditions (20±5°C; 16 h supplementary lighting) in a randomised complete block design with three replications was undertaken. *C. album* and two sugar beet *cvs.* 'Amethyst' and 'Celt', of morphologically contrasting growth habit (prostrate and erect respectively) were grown at four competition regimes as follows: Two below-ground competition treatments (± root competition); two above-ground competition treatments (± shoot competition). Two seedlings of sugar beet and four of *C. album* were transplanted at cotyledon stage in to plastic pots (44 cm diameter and 35 cm height) containing 30 litres soil (80% loam; 20% peat-moss). Plants were harvested 8 and 16 WAT. At each harvest leaf chlorophyll content, leaf area and lamina dry weight were determined.

RESULTS AND DISCUSSION

SLW of *cv.* Amethyst 8 WAT was greater ($P<0.05$) than *cv.* Celt (Table 1). However, 16 WAT there was no significant difference between SLW of the two sugar beet *cvs.* Greater SLW of Amethyst may be due to ploidy level - a triploid *cv.* - compared with *cv.* Celt a diploid. There was no significant difference in leaf chlorophyll content between the two sugar beet *cvs.*

Table 1. Mean specific leaf weight (SLW) and total leaf chlorophyll content of the two sugar beet *cvs*. 8 and 16 WAT (Mean of four competition regimes).

Sugar beet *cv*.	SLW (g dm^{-2}) 8 WAT	SLW (g dm^{-2}) 16 WAT	Total leaf chlorophyll content (mg g^{-1}) 8 WAT	Total leaf chlorophyll content (mg g^{-1}) 16 WAT
Amethyst	0.40	0.59	2.58	2.45
Celt	0.36	0.53	2.49	2.69
LSD (5 %)	0.033	0.084	0.211	0.279

Table 2. Mean specific leaf weight (SLW) and total leaf chlorophyll content of the two sugar beet *cvs*. subjected to above and below ground competition 8 and 16 WAT.

Competition	SLW (g dm^{-2})		Total leaf chlorophyll content (mg g^{-1})			
	8 WAT	16 WAT	8 WAT	16 WAT		
				Amethyst	Celt	Mean
Above-ground	0.37	0.53	2.50	2.62	2.22	2.42
Below-ground	0.42	0.60	2.73	2.37	3.16	2.77
Above and below	0.35	0.59	2.37	2.53	2.67	2.60
LSD (5 %)	0.047	0.119	0.298	0.557		0.394

SLW of sugar beet subjected to below-ground competition was greater ($P<0.05$) than that subjected to above-ground competition, only at 8 WAT (Table 2). However, 16 WAT competition treatments had no effect on SLW of sugar beet. The reason for this difference between SLW of sugar beet may be that following competition for light during the 8 WAT by *C. album*, sugar beet leaf thickness was reduced, as leaf area was unaffected (Abdollahian-Noghabi *et al*. 1997). Leaf chlorophyll content of sugar beet subjected to below-ground competition 8 WAT was greater ($P<0.05$) than that subjected to full (above and below) competition (Table 2). However, competition regimes had no significant effect on sugar beet leaf chlorophyll content 16 WAT. The interaction between sugar beet *cvs*. and competition regimes was significant ($P<0.05$) only for leaf chlorophyll content of sugar beet 16 WAT. After below-ground competition with fat hen, leaf chlorophyll content of Celt was greater ($P<0.01$) than Amethyst. However, for above-ground competition treatment there was no significant difference between the leaf chlorophyll content of the two sugar beet *cvs*. (Table 2).

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EFFECT OF HERBICIDES ON WEEDS, NODULATION, BIOLOGICAL NITROGEN FIXATION AND YIELD OF PEAS

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ABSTRACT

In peas terbutryn/terbuthylazine (350/150 g a.i./litre) was very effective in controlling all the broad-leaved and grassy weeds but bentazone (480 g a.i./litre) failed to control *Polygonum aviculare* and *Poa annua*. Nodulation, acetylene reduction activity and yield of peas decreased with higher rates of application of both the herbicides

INTRODUCTION

To obtain higher yields of various crops weeds can be controlled with different pre- and post-emergence herbicides. However, herbicides can also adversely affect legume-rhizobia symbiosis (Mårtensson, 1992). The purpose of this study was to determine if such herbicides have adverse effects on nodulation and biological nitrogen fixation (BNF) in peas (*Pisum sativum*).

MATERIALS AND METHODS

A field experiment was conducted to study the effects of a pre-emergence application of terbutryn/terbuthylazine 'Opogard 500 SC'; 350/150 g a.i./litre; Ciba Agriculture, applied at 1.4 (recommended rate), 2.8 or 5.6 kg a.i./ha and post-emergence application of bentazone 'Basagran'; 480 g a.i./litre; BASF, applied at 1.44 (recommended rate), 2.88 or 5.76 kg a.i./ha. on weeds, nodulation, BNF and yield of peas. The experiment included weedy (no weeding) and hand-weeded controls. Spring peas, cv. Rex were sown on 29 April 1996 in rows 12 cm apart in plots measuring 10 m x 1.2 m. The mixture of terbutryn/terbuthylazine was sprayed four days after sowing and bentazone was applied 6 weeks after sowing (WAS) when the pea plants tested safe to the Pea Leaf Wax Test. Both the herbicides were applied with a knap-sack sprayer with flat fan nozzles and using 800 litres/ha water. Number and dry weight of weeds were recorded 10 weeks after sowing (WAS). Biological nitrogen fixation was measured as acetylene reduction activity (ARA) 7 WAS by the method of Hardy *et al.* (1973).

RESULTS AND DISCUSSION

Knotgrass (*Polygonum aviculare*), common chickweed (*Stellaria media*), charlock (*Sinapis arvensis*), corn spurrey (*Spergula arvensis*), fat-hen (*Chenopodium album*), annual meadow-grass (*Poa annua*), dock (*Rumex spp.*), common fumitory (*Fumaria officinalis*) and redshank

(*Polygonum persicaria*) were the weeds present in the weedy plots. Terbutryn/terbuthylazine was very effective in controlling all the broad-leaved and grassy weeds but bentazone failed to control *P. aviculare*, and *P. annua* even at the highest dose, which is four-times the recommended field application rate. Visual observations showed that terbutryn/terbuthylazine at higher rates proved phytotoxic to peas and resulted in chlorosis and death of some plants. Bentazone also caused some yellowing of peas but all the plants survived. Nodulation, ARA and seed yield of peas decreased with higher rates of both the herbicides (Table 1), possibly due to their adverse effect on photosynthesis as these herbicides interfere with photosynthetic electron transport (Hance & Holly, 1990). Bentazone though had smaller adverse effects on BNF and seed yield but gave poorer weed control.

Table 1. Effect of herbicides and hand weeding on weeds, nodulation, acetylene reduction activity (ARA) and yield of peas

Treatment	Dose (kg a.i. /ha)	Total no. of weeds $/m^2$	Dry wt of weeds (g/m^2)	No. of nodules /plant	ARA (μ mol C_2H_4 produced /plant/h)	Seed yield (t/ha)
terbutryn/	1.40	0	0.0	5.6	4.37	3.49
terbuthylazine	2.80	0	0.0	3.6	3.19	3.21
	5.60	2	0.0	2.8	1.88	3.13
bentazone	1.44	176	25.3	7.7	6.03	3.57
	2.88	109	20.7	6.7	3.12	3.35
	5.76	166	20.0	5.8	3.95	3.30
No weeding		272	102.6	7.0	5.76	3.37
Hand weeded		0	0.0	9.8	4.47	3.77
SED (21 df)		55.7	19.23	2.30	1.717	0.532

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VARIATION IN CROSS-RESISTANCE IN BLACKGRASS (*ALOPECURUS MYOSUROIDES*) WITHIN AND BETWEEN POPULATIONS: IMPLICATIONS FOR MANAGEMENT

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ABSTRACT

A detailed investigation of eight UK populations of *Alopecurus myosuroides* showed noticeable intra- and inter-population phenotypic variation in patterns of cross resistance to chlorotoluron, fenoxaprop-P-ethyl and tralkoxydim. Half-sib analysis confirmed that response to herbicide selection and the expression of cross resistance will vary amongst populations because of differing levels of genetic variation amongst populations.

INTRODUCTION

Alopecurus myosuroides (Huds) is a serious weed of winter cereals and herbicide resistance has now appeared on over 700 farms in the UK. Populations differ in the extent of phenylurea resistance and exhibit cross resistance to over twenty-three different herbicides over a range of chemically unrelated herbicide classes. The resistance mechanism in most populations is enhanced metabolism although cases of target-site resistance have been reported (Moss, 1997). The possibility of at least two resistance mechanisms implies that populations may be expected to show varying levels of genetic variation for resistance. This paper reports preliminary findings of a study of genetic variation in cross resistance in this weed.

MATERIALS AND METHODS

Fifteen half-sib families were selected randomly from each of eight field populations, geographically separated in the UK. The responses of individual plants from each family to chlorotoluron, fenoxaprop-P-ethyl and tralkoxydim were examined at approximately the three leaf stage, three doses being used - control (0), half (0.5) and full (1) field rate. Populations were examined independently in a controlled environment (22 ± 1° C, 16 h d lighting) and a common reference population (a susceptible population maintained at IACR-Rothamsted) included in each trial. Shoot fresh weight yield was recorded 14 d after spraying.

Relative resistance within and between populations, for each herbicide, was calculated by expressing the performance of sprayed plants to that of the control, having corrected for plant size at time of spraying and the performance of the reference population. Analysis of variance was used to test for significance of between population and within population (among family) variance and to extract estimates of narrow sense heritability (Falconer, 1981). Heritability measures how much additive genetic variation is present in a population upon which selection may act.

RESULTS AND DISCUSSION

Table 1 gives relative resistance ratios at the population level in relation to herbicide and dose. In thirteen out of the forty-eight cases, significant ($p \leq 0.05$) intra-population variation was detected at the family level. In twenty-six cases high (> 0.3) heritability of relative resistance was evident.

Table 1. Patterns of cross-resistance to three herbicides in *Alopecurus myosuroides.* Data are relative resistance ratios. Items in bold indicate populations with significant intra-population variability. * indicates narrow sense heritability of resistance greater than 0.3.

	Half field rate			Full field rate		
Population	Chloro-toluron	Tralkoxydim	Fenoxaprop-P-ethyl	Chloro-toluron	Tralkoxydim	Fenoxaprop-P-ethyl
Abingdon	0.292	0.394*	0.716	0.217	0.270*	**0.569**
Aylesbury	0.486*	0.414*	1.016	0.381*	0.249*	0.881
Bletchley	0.552	**0.746***	0.691*	**0.437***	**0.495***	**0.557***
Canewdon	0.403	0.453	**0.731**	**0.322***	0.327	**0.730**
Faringdon	0.417*	0.348*	0.406*	0.251	0.187*	0.283*
Lincoln	**0.692**	0.261	0.920*	0.628*	**0.169**	**0.917**
Peldon	0.671*	0.495*	0.580*	0.557*	0.358*	0.353
Watlington	0.469	0.592*	**0.675**	0.511	0.490*	**0.683**

These data indicate that whilst there were phenotypic differences in relative resistance and in patterns of resistance to the three herbicides amongst populations, intra-population (among family) variation differed amongst them, according to herbicide-dose combination. Moreover the heritability estimates indicate that only certain populations may respond to further herbicide selection. Thus it may be hypothesised that some populations (e.g. Bletchley, Lincoln) may evolve differing patterns of cross resistance whilst others may not. Both lack of consistency in patterns of cross resistance amongst populations and varying degrees of genetic variation within them support the argument that herbicide resistance management strategies and the use of non-chemical control measures are essential in managing *A. myosuroides* populations.

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TOWARDS PREDICTION OF THE EFFECT OF WET DORMANCY ON *OROBANCHE* INFESTATIONS

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ABSTRACT

Seeds of three species of *Orobanche* were imbibed (i.e. conditioned) for periods of up to 30 weeks at 10-30°C in order to model relief of primary dormancy and induction of secondary (wet) dormancy. The rates of both processes depended on temperature but to a different extent among the species. Predictive models have been developed as an aid in assessing the feasibility of exploiting secondary dormancy as part of an integrated control strategy.

INTRODUCTION

Orobanche spp. are obligate parasitic weeds which cause major crop losses especially in Mediterranean and sub-tropical climates. Seeds of *Orobanche* require a moist pre-treatment (conditioning) before they can germinate in response to stimulants produced by host plants. Prolonging the conditioning period reduced the germination of *Orobanche crenata* (Van Hezewijk, 1994). The present investigation aims to provide a model for loss of primary dormancy and induction of secondary dormancy during conditioning.

MATERIALS AND METHODS

Seeds of *O. aegyptiaca*, *O. crenata* and *O. cernua* were conditioned (i.e. stored fully imbibed in water in darkness) under sterile conditions for up to 30 weeks at 10, 15, 20, 25 and 30°C. Samples were taken periodically and after superficial drying the seeds were then stimulated to germinate by adding 3ppm of the artificial stimulant GR24.

Viability of the seeds was checked by tetrazolium test. Furthermore, to confirm the dormancy status of the seeds, additional samples were taken, dried, reconditioned for two weeks and then stimulated with GR24.

RESULTS AND DISCUSSION

In all the species tested, the rate of loss of primary dormancy linearly increased with increase of temperature between 10 and 30°C. Primary dormancy was lost much faster in *O. aegyptiaca* than in the other two species which explains why its optimum conditioning period at 20°C is 4 days compared to 7 and 9 days in *O. cernua* and *O. crenata* respectively.

In marked contrast to results of analogous experiments on *Rumex* spp. (Totterdell and Roberts, 1979) the rate of induction of secondary dormancy tended to decrease with increase in temperature. Among the species, the rate of induction in *O. cernua* was least sensitive to temperature followed by *O. crenata* and *O. aegyptiaca*.

Viability was largely maintained during conditioning at 10-25°C. However, seeds conditioned at 30°C lost viability rapidly. Germination of all three species after conditioning could be accurately modelled assuming that the times to loss and induction of dormancy and loss of viability are normally distributed among the seeds in the population, and that these three processes act independently.

The findings have important implications for control of *Orobanche* especially where irrigation is practised. For autumn crops, keeping the soil moist as the temperature decreases (to around 10°C) for about ten weeks before planting should reduce infestations in *O. aegyptiaca* and *O. crenata* infested fields but the procedure is unlikely to be successful with *O. cernua*. In rainfed agriculture, delaying planting until December or January in countries with Mediterranean climate, could result in a low infestation level due to the higher rate of induction of secondary dormancy at low temperatures. Secondary dormancy induced at 10-25°C could, however, be broken at any time by drying the seeds and reconditioning them for a few days. Therefore, any attempt to limit the *Orobanche* infestation in the field by induction of secondary dormancy is subject to the crucial proviso that moisture must continually be available.

A more detailed but similar application of the model is to incorporate it into an integrated weed management model for *Orobanche*. It may then be possible to decide whether the penalties in yield incurred by delayed sowing will be compensated by a reduced level of infestation associated with the predicted induction of secondary dormancy at the soil temperature.

ACKNOWLEDGEMENTS

Our thanks to The Society for Protection of Science and Learning, The Africa Educational Trust, The Heinz and Anna Kroch Foundation, The Sir Richard Stapley Educational Trust, The Maximillian Trust, The Sidney Perry Foundation, The Churches Commission for Overseas Students, The Leonard Sutton Scholarship Fund and the Julius Silman Trust for partial financial support.

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CONTROL OF *MOLINIA CAERULEA* (L.) MOENCH IN UPLAND BRITAIN

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ABSTRACT

There is evidence that *Molinia caerulea* is replacing *Calluna vulgaris* in some areas of upland Britain. In order to develop a control strategy for *Molinia* we investigated the efficacy of a suite of selective herbicides which could potentially control *Molinia* whilst leaving *Calluna* unharmed. Our laboratory trials suggested that some of the selective herbicides investigated, quizalofop-ethyl and sethoxydim, may prove suitable.

INTRODUCTION

Molinia caerulea (L.) Moench, purple moor grass, is a tough, perennial grass perceived to be increasing in upland moorlands at the expense of *Calluna vulgaris* (L.) Hull (Welch, 1984). Little work has been done to assess the potential of herbicides for control of *Molinia* and thus promote the regeneration of dwarf shrub heath. Current legalisation permits the use of glyphosate in upland areas but previous studies have shown relatively low doses of this herbicide can damage or kill *Calluna* (Clipsam, 1984, Tabbush, 1984). Our aim was to test the efficacy of a suite of selective herbicides that could potentially control *Molinia* whilst leaving *Calluna* unharmed. These preliminary investigations were carried out under laboratory conditions to enable the calculation of dose-response relationships and ED_{50} values which could allow determination of potentially useful field rates.

MATERIALS AND METHODS

Molinia basal internodes were collected from Tinkers Hill, Barnsley (SK 169034) and individually planted into nutrient rich, acid compost. One year old plants of *Calluna vulgaris* 'Allegro' were obtained from a commercial nursery. Initial measures of performance were taken before spraying to be used as covariates in the final analysis. Each herbicide was applied at a range of concentrations (eight) to both species using a Mardrive precision spray cabinet (fixed nozzle, 90°, flat fan tip, 200 litres/ha, 2 bar pressure). Plants were harvested after 10 weeks. Dose response relationships were calculated for each herbicide and ED_{50} values estimated where possible.

RESULTS AND DISCUSSION

Despite the controlled conditions considerable variation was found in all dose-response relationships, probably as a result of inherent variability of the species used (Clipsam, 1984). This high variability made the calculation of ED_{50} values difficult. Of the eight herbicides tested, three reduced the growth of *Molinia* sufficiently to allow calculation of an ED_{50} (Table1). For *Molinia,* glyphosate was the most effective herbicide and the only herbicide to provide a reduction in root growth, suggesting this could reduce regeneration via the roots. Clethodim, cycloxydim, fluazifop-P-butyl and tralkoxydim produced reductions in *Molinia* but results were too variable to allow calculation of an ED_{50}. Our results confirm however that extremely low levels of glyphosate can reduce shoot growth in *Calluna* significantly (Table 2). There appears to be no dose at which glyphosate can control *Molinia* whilst leaving *Calluna* unharmed. Two selective herbicides tested, quizalofop-ethyl and sethoxydim, reduced *Molinia* and did not damage *Calluna*. Both of these herbicides reduced growth at levels lower than those recommended by the manufacturer. This implies reduced concentrations could be adequate, minimising herbicide residues and operator exposure. These two graminicides are recommended for further field trials.

Table 1. ED_{50} values calculated for *Molinia caerulea* treated with increasing concentrations of herbicide using several measures of plant performance

Active ingredient	Estimated ED_{50} (kg ai/ha)				
	Final tiller number.	Final - initial tiller number	Dry weight shoots	Dry weight roots	Final flower number
Glyphosate	0.62	0.67	0.46	0.41	0.55
Quizalofop-ethyl	0.28	0.10	0.18	-	1.20
Sethoxydim	0.37	0.49	0.39	-	-

Table 2. ED_{50} values for *Calluna vulgaris* treated with increasing concentrations of glyphosate using several measure of plant performance

Active ingredient	Estimated ED_{50} (kg ai/ha)		
	Final - initial shoot length	Final shoot length	Final fresh weight
Glyphosate	0.025	0.048	0.45

ACKNOWLEDGEMENTS

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AN ANALYSIS OF FARMER PARTICIPATION IN CONSERVATION ORIENTED MANAGEMENT ON SET-ASIDE LAND IN ENGLAND.

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ABSTRACT

Results are presented from two farm-based surveys which sought to determine the major factors which constrain and enable farmer participation in nature conservation based management on set-aside land. An initial baseline survey established that less than 1% of the set-aside area covered was being managed for conservation objectives. Four major factors constrained uptake ; a lack of financial incentives, opposition to set-aside policy, attitudes to nature conservation and a lack of awareness of, and advice on conservation options for set-aside land.

INTRODUCTION

In August 1992 MAFF commissioned the Institute of Terrestrial Ecology (ITE) to conduct research to determine habitats and species which could potentially benefit from set-aside, and to establish guidelines in order to realise this potential (Firbank *et al*, 1993). The results formed the basis of a leaflet giving guidelines to farmers for the management of set-aside land to achieve environmental objectives (MAFF, 1993). Participation is at the discretion of the individual farmer and does not encompass any system of economic or agronomic incentives. Previous farm-based studies examining the factors which constrain or enable farmer participation in agri-environmental programs (Wilson, 1996 ; Battershill and Gilg, 1996 ; Morris and Potter, 1995) have recognised the interdependence of structural (economic considerations, farm size, farm type) and attitudinal (attitudes to wildlife and environmental concerns) variables in determining uptake. This paper presents results from two farm-based surveys which examined these factors with respect to the extent of, constraints upon, and future prospects for conservation based management on set-aside land in England.

METHODS

In an initial baseline survey, conducted in June 1994, mail questionnaires were dispatched to 1076 farmers from three contrasting agricultural regions in England - the East, North-west and South-east. 261 completed questionnaires were returned. Following analysis and evaluation of these returns, a second questionnaire was designed and dispatched to a sample of 550 farmers in May 1996. This sought to explore in greater depth the factors constraining participation in conservation management on set-aside land.

RESULTS AND DISCUSSION

The initial survey covered a total set-aside area of 5,322 ha, of which 81% was managed as rotational, and 19% as non-rotational set-aside. Only 49 ha (<1%) was being managed specifically for conservation objectives.

44% of surveyed farmers indicated that they were satisfied with the outcome of the 1992 CAP reform process, 38% were indifferent and the remainder opposed. However, only 34% agreed with the principle of set-aside, suggesting widespread dislike and mistrust of this policy instrument. 90% of respondents indicated that they were interested in, and sympathetic towards farm wildlife, and despite widespread antipathy with regard to set-aside, 40% acknowledged it as an effective policy for enhancing the wildlife potential of arable land, whilst 35% believed that MAFF had done to little to incorporate wildlife concerns into set-aside policy (only 62% were aware of the existence of MAFF guidelines for conservation based management). In principle, these results are encouraging for the conservation interest, whilst in practice they are not reflected in observed levels of participation. Regional differences in circumstances and attitudes (Eastern farmers were most satisfied with CAP reform, South-eastern farmers least satisfied and more conservation oriented) confirm the importance of the geographical variable (farmland quality and 'farming culture') in determining attitudes, actions and perceptions.

The initial survey has identified an apparent contradiction between attitudes and actions on set-aside land. The second survey sought to explore this contradiction, by asking farmers to rank a number of factors in order of importance in accounting for low rates of uptake for conservation options. In order of importance these were ; a lack of financial incentives, the unpopularity of set-aside within the farming community, a lack of awareness of available options, a lack of available advice, and farmers disinterest in wildlife and nature conservation.

CONCLUSIONS

Survey results suggest that a regionally targeted program of conservation set-aside, with appropriate premiums in excess of basic set-aside payment rates would considerably enhance the conservation potential of set-aside land and overcome to some extent the unpopularity of set-aside policy amongst the farming community.

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INTERACTION OF DICLOFOP-METHYL AND MCPA AT THE PLANT PLASMA MEMBRANE

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ABSTRACT

Sugar beet (*Beta vulgaris* L.) and black-grass (*Alopecurus myosuroides* Huds.) plants were sprayed with field-rate MCPA (4-chloro-*o*-tolyoxyacetic acid) prior to isolation of purified plasma membrane (PM) vesicles, which were used to assess sensitivity of H^+-ATPase to diclofop-methyl (DM). Treatment with MCPA stimulated PM H^+-ATPase activity in sugar beet but not in black-grass. DM inhibited activity in both species.

INTRODUCTION

The mode of action of the graminicide DM involves the inhibition of lipid biosynthesis. However, since growth of susceptible plants rapidly ceases after application of DM, it is unlikely that this action is solely responsible for plant death. Furthermore, auxin-type herbicides antagonise the action of DM in the field and it has been proposed that this interaction occurs at the PM (Shimabukuro *et al* 1989). This study has investigated the effects of DM and MCPA on the H^+-ATPase of PM vesicles isolated from sugar beet and black-grass previously treated with MCPA.

MATERIALS AND METHODS

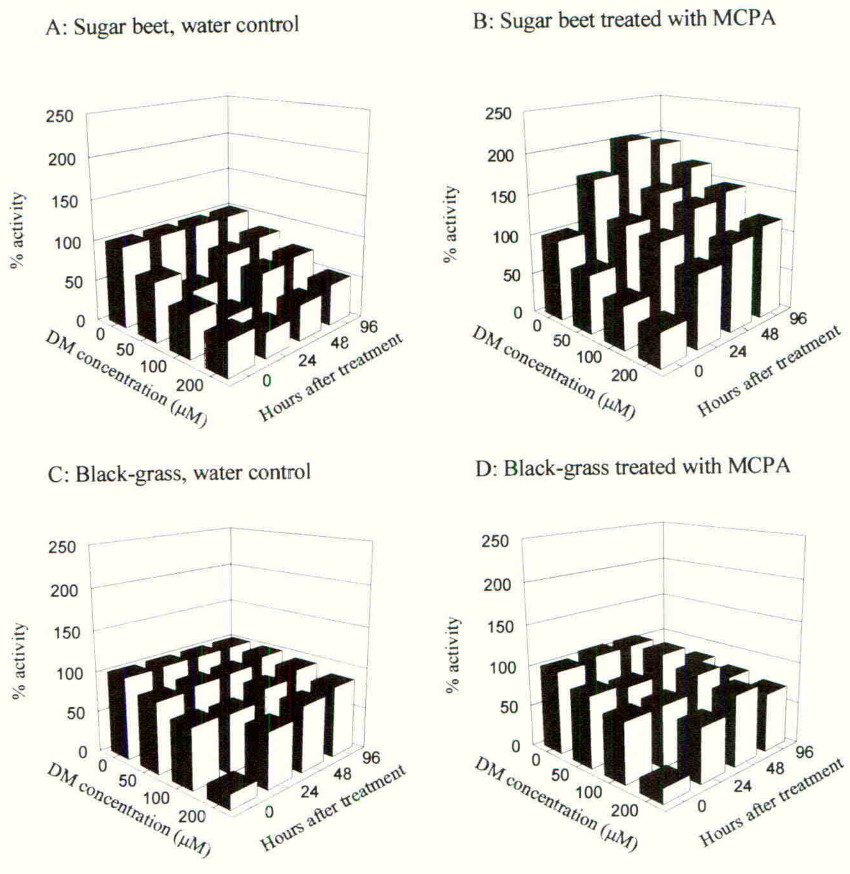
Sugar beet and black-grass were grown under glasshouse conditions to the 2-3 leaf stage and MCPA 'BASF MCPA Amine 50' was applied at field rate (1.75 kg a.i. ha^{-1}) using a Mardrive evaluation unit (fixed 80° flat fan tip, 200 l ha^{-1}, 3 bar pressure). Plants were harvested 0, 24, 48 and 96 h after treatment. The isolation and purification of plasma membranes and H^+-ATPase activity were according to Hull *et al* (1995). DM (99 %) and MCPA (97.5 %, both from British Greyhound, Birkenhead, U.K.) were dissolved in acetone and diluted with ATPase resuspension medium to a final concentration of 0.5 %, v/v. These were added to the assay at final concentrations of 0, 50, 100 and 200 μM.

RESULTS AND CONCLUSIONS

Treatment of sugar beet with MCPA resulted in a stimulation of PM H^+-ATPase activity by 60 and 100 % after 24 and 48 h (Fig. 1B), whilst MCPA had no effect on the PM H^+-ATPase of black-grass (Fig. 1D). 200 μM DM significantly inhibited H^+-

ATPase activity by 60 % and 40-80 % in sugar beet and black-grass, respectively. Sensitivity to inhibition by DM remained in sugar beet plants treated with MCPA.

Figure 1: The sensitivity of PM H^+-ATPase activity to DM following plant treatment with MCPA or water.



However, MCPA alone had no effect on untreated PM *in vitro* in accordance with Hull *et al* (1995). This implies that MCPA does not affect this enzyme directly.

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SESSION 7D

AGROCHEMICAL OPTIMISATION: STRATEGIES

Session Organiser DR C BROWN
Soil Survey and Land Research Centre, Derby, UK

Poster Papers 7D-1 to 7D-6

DYNAMIC AND STEADY-STATE DOSE RESPONSES OF SOME CHEMICAL INJECTION METERING SYSTEMS

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ABSTRACT

A number of chemical injection metering system technologies have been proposed. Some of these are experimental whilst others are commercially available. Papers presenting some of the characteristics of these systems have been published. However, it is difficult to compare the performance of these systems, mainly because of differences in experimental conditions and methodology. The aim of this study was to evaluate dynamic and steady-state dose responses of some injection metering systems, in order to compare their performance and to present a general view of the technology available. An experimental arrangement was designed to simulate applications by using these systems to meter salt and dye solutions of different viscosities. The steady-state dose response was evaluated by using colorimetry and electrical conductivity measurement of the spray solution. The results showed that the systems gave a good response when injecting water solutions. However, in some conditions, some systems were unable to operate when injecting high viscosity solutions. The dynamic behaviour of the systems, relating to both dose pulsation and time response for step changes in dose were evaluated by monitoring electrical conductivity of spray solution. Depending on the application conditions and the characteristics of each system, different patterns of dose pulsation and time responses were obtained.

INTRODUCTION

The main feature of chemical injection metering systems is the possibility of keeping water and chemical in separate containers, mixing them at the appropriate dose only when necessary during an application. A number of injection metering technologies have been proposed, e.g. Harrel *et al.* (1973), Reichard & Ladd (1983), Frost (1990) and Miller & Smith (1992), usually aimed at improving the safety and accuracy of pesticide application. Some of these systems are experimental while others are commercially available, and papers presenting some characteristics of injection systems have been published. Reichard & Ladd (1983) discussed problems related to dose pulsation; Landers (1992) reported a time response of 20 s for a dose step change from 5 to 3.75 litres/ha, while Rockwell & Ayers (1996) obtained 3.8 s for a change from 2.2 to 5.8 litres/ha. Paice *et al.* (1997) presented an average time response of 0.2 s for a speed step change from 1.1 to 3.3 m/s. However, it is difficult to compare the performance of these systems, mainly because of differences in experimental conditions and methodology. Characteristics such as dose stability and time response for dose step changes are fundamental to define the applicability of injection metering systems, but the results obtained are very dependant on methodologies used.

The aim of this study was to evaluate dynamic and steady-state dose responses of some injection metering systems, in order to analyse their performance and to present a general view of the technology available.

MATERIALS AND METHODS

Experimental arrangement

An experimental arrangement was designed to simulate applications by using injection systems to meter salt and dye solutions (Figure 1). In order to evaluate the influence of viscosity on the system behaviour, both water and viscous solutions were used, according to the British Standard BS 6356. Tests were performed applying total spray solution flow rates up to 26 litres/min and pressures up to 3.5 bar.

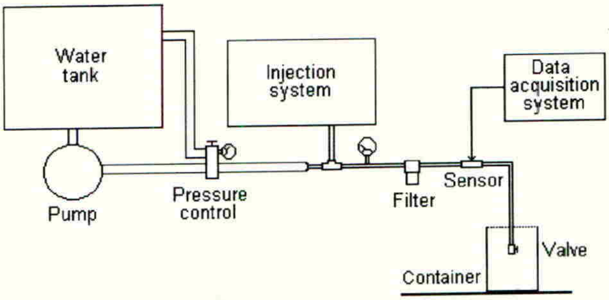

Figure 1. Experimental arrangement for testing the injection metering systems.

Steady-state accuracy of dose

The steady-state dose accuracy was evaluated using colorimetry and electrical conductivity measurement to estimate dye and salt concentration in the spray solution collected in the container (Figure 1). Several dose levels within the extremes of the range for each system were used applying water and viscous solutions, sampling the spray output for at least 20 s for each dose. The total spray flow rate was measured for each test, which allowed the injection flow rate to be calculated using the estimated concentration in the samples.

Dose pulsation

The dynamic behaviour of each system was evaluated by monitoring the electrical conductivity of the spray solution on-line using a conductivity sensor and a data acquisition system (Paice *et al.*, 1997). While samples for the steady-state accuracy were being collected, the data acquisition system was used to monitor the conductivity variation in the spray solution, showing the dose pulsation with time for each dose level.

Time response for dose step change

The time responses for dose step changes were evaluated by asking the injection systems to change injection flow rate in a ratio of 1:3:1 (i.e. from 0.5 to 1.5 litres/min and from 1.5 to 0.5 litres/min). This variation was performed by changing system inputs (e.g. the required dose level), keeping the total spray solution flow rate constant. In each test, salt concentration changes induced proportional electrical conductivity changes in the spray solution, which were measured by the conductivity sensor and recorded by the data acquisition system. The injection flow rate was calculated using the estimated concentration in the spray solution and the measured total flow rate. Dose rate rise and fall times were calculated taking the time needed to change from 10% of the mean initial dose level to within 10% of the mean desired dose level, after each step change.

Injection metering systems

Three different injection systems were evaluated, all commercially available, which present a general view of the technology available.

System A: this system consists of a two piston pump with variable stroke, electric motor, valves, sensors, chemical container and an electronic management system. There are adjustments for a number of parameters including dose rate and the number of active boom sections. The system is designed to inject chemicals in the carrier line to the booms, after the main pump and the pressure control system and the chemical flow rate is automatically controlled. There are nine different settings related to the stroke of the pistons, allowing chemical flow rates from 0.1 to 6.0 litres/min; lower flow rates, however, can be achieved with the same system by changing the pump. The longest stroke setting was used for the test.

System B: this system consists of a peristaltic pump, electric motor, valves, sensors, chemical container and an electronic control. There are adjustments for chemical dose rate, number of active boom sections and the chemical flow rate is automatically controlled. The system is designed to provide chemical flow rates from 0.03 to 3.0 litres/min, injecting into the carrier line from the water tank, before the main pump. A 3-way valve is used for pressure and flow control. The valve inlet receives the pump output, one of the outlets is a bypass line that returns part of the flow to the pump inlet and the other outlet carries the flow to the spray booms. All the steady-state dose response and dose pulsation tests were carried out using this arrangement. Time response for dose step changes tests were performed using the system injecting after the main pump, as it was used for system A and described in Figure 1.

System C: this system uses a low cost single acting water driven pump. Water passing through the pump drives a piston and valves arrangement, which sucks the chemical from the container and meters it into the water flow. The system is able to work with a carrier flow range from 8 to 133 litres/min and, by changing the effective cylinder length, it is possible to adjust the concentration of chemical in the carrier from 0.2 to 2.0%. However, this adjustment is manual and there is no electronic control. Therefore only tests related to steady dose accuracy and dose pulsation over the full range were performed for this system.

RESULTS AND DISCUSSION

Figure 2 shows the steady-state dose response for systems A and B. The systems showed good accuracy when injecting both water and viscous solutions, despite some tendency to overdose for system A and underdose for system B. However, both systems provide adjustments for correcting this kind of error by changing calibration inputs to the electronic control management. During the tests, both systems presented some instability when injecting at the lower end of the chemical flow rate range, where the electric motors had difficulty in keeping a constant speed. Both systems did not achieve the maximum flow rate defined by the manufacturers (injecting water, system A achieved 4.8 litres/min compared with a designed value of 6 litres/min whilst B achieved 2.4 litres/min, instead of the 3.0 litres/min expected).

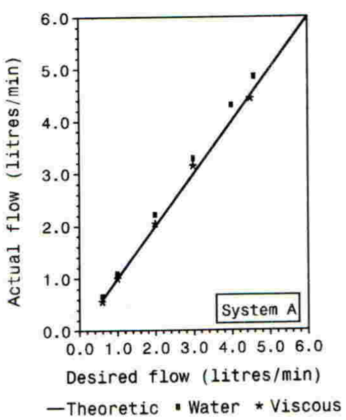

Figure 2. Steady-state dose response for systems A and B when injecting both water and viscous solutions.

Except for the instability at very low flow rates, dose pulsation was not detected in the spray solution for systems A or B. The piston pump output in system A is uniform and a filter after the injection point alone provided an adequate mixing of both the water and viscous solution. The peristaltic pump in the system B provides some pulsation in the output, but the circulation of the spray solution through the main pump after the injection point is enough to avoid dose pulsation.

Figure 3 shows the steady-state dose response and dose pulsation for system C. As a water driven pump, it delivers chemicals as a percentage of the total water flow rate. So the system was tested applying 11, 16 and 24 litres/min. When injecting a water solution, regardless the total carrier flow rate, there is a tendency for underdosing at very low dose rates and overdosing at higher dose rates. This problem could be solved by changing the scale in the dose adjustment device. The system was unable to inject the viscous solution at low rates and at higher rates there is constant underdosing. This could be due to the inappropriate sealing in the suction piston.

System C is a single acting water driven pump and for this reason some dose pulsation is expected, as shown in Figure 3. Since it is designed to inject into the boom supply line, after the main pump, it is necessary to provide an appropriate mixing chamber to minimise this problem. As a general observation, uniformity, amplitude and frequency of pulsation are influenced by both dose rate and total water flow rate.

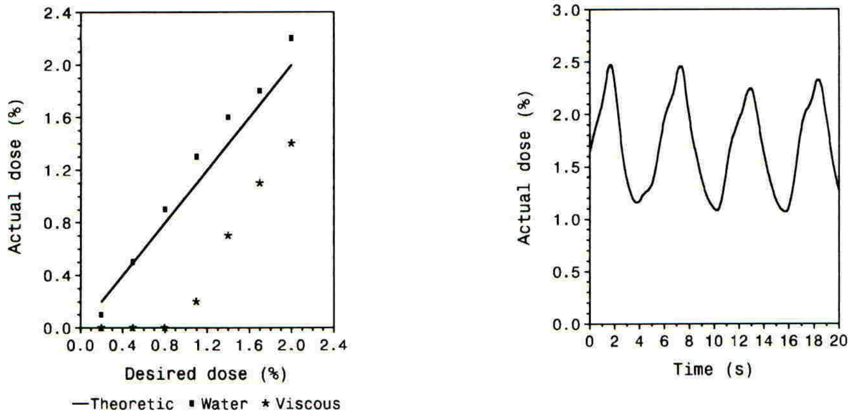

Figure 3. System C: steady-state dose response and dose pulsation when injecting 1.7 % of water solution in a 16 litres/min water flow rate.

Table 1 presents the time response for chemical flow rate step changes when operating systems A and B. The results show that B was quicker than A in all the tests and this characteristic is related to the control algorithm used by each system, the way that the electric motor is controlled in each case and the difference in the metering pumps (peristaltic or piston). Despite the quick response of system B (less than 2 seconds in average), it is significantly slower than some experimental systems. As an example, Paice *et al.* (1997) reported average time response of 0.2 s for a similar test.

Table 1. Systems A and B time response for chemical flow rate step changes in a 1:3:1 ratio.

Systems	Step change (litres/min)	Time response (s)	
		Water solution	Viscous solution
A	1.50 to 4.50	2.88	3.34
	4.50 to 1.50	3.06	3.37
B	0.48 to 1.44	1.20	1.46
	1.44 to 0.48	1.60	1.56

In practice, however, the difference in the time response at the spray nozzle between A and B can be very different, depending on the way that each system is fitted to an actual sprayer. In spite of the quicker response of system B, it can be potentially slower than A because of the injection point placed before the carrier pump. This arrangement provides recirculation of the spray solution between the bypass line and the carrier pump, as well as longer pipes between the injection point and the nozzles. The time response for this kind of system can be significantly influenced by changes in the carrier flow rate. As an example, when injecting before the main pump, as performed for the steady-state tests, a 25% reduction in the carrier flow rate (from 25.8 to 19.3 litres/min) was responsible for an increase of 60% in the time response for a 1:3 flow rate step change (from 9.44 to 15.28 s for the rise time).

CONCLUSIONS

Systems A and B presented good accuracy when injecting both water and viscous solutions despite some tendency to overdose or underdose. This can be easily corrected by changing calibration inputs to the electronic control management system. Except for some instability at very low flow rates, dose pulsation was not detected for these systems. When injecting water solutions, system C showed a tendency to underdose at very low dose rates and overdose at higher dose rates. It was also unable to inject the viscous solution at low rates and, at higher rates constant underdosing was detected. Dose pulsation was present for all the dose range, so system C must be fitted with an appropriate mixing chamber to minimise this problem. For the dose step change tests, despite the quicker response of system B, it can be potentially slower than A because of the injection point placed before the carrier pump.

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USE AND OPTIMISATION OF IMIDAZOLINONE HERBICIDES IN LEGUME PRODUCTION IN NIGERIA

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ABSTRACT

The imidazolinone herbicides: imazaquin and imazethapyr, are the most effective herbicides for weed control in the major food legumes in Nigeria: cowpea, groundnut and soybean. The attractive qualities of these herbicides include relatively low active rates, a broad spectrum of broadleaf weeds controlled and prolonged weed suppression compared with conventional herbicides used under the same conditions. In addition, they mix well with grass herbicides such as metolachlor and pendimethalin to give excellent weed control without carry-over problems frequently experienced under temperate conditions. Imazaquin and imazethapyr are yet to appear on the list of herbicides most frequently used in legumes in the country due to limited knowledge of their potentials and the need to adapt their use to the farmer's conditions. The optimisation of imazaquin and imazethapyr in the cropping systems of Nigeria and sub-Saharan Africa is discussed.

INTRODUCTION

Cowpea, groundnut and soybean are the major food legumes in Nigeria. Together they supply a high percentage of the protein and vegetable oil needs of the country. In 1988 the total land area devoted to these crops, both as sole and intercrop components, was in excess of 2 million ha (FAO, 1989). The major production areas are in the Guinea and Sudan savanna ecological zones which cover approximately 75% of the country's estimated 72 million ha of agricultural land.

Weed interference is a major yield depressing factor in legume production in Nigeria. Over 80% of farmers still rely entirely on manual weeding. The demand for these crops is increasing, but the proportion of the economically active population in agriculture is declining [71% in 1960, c. 64% in 1992 (Ayeni, 1995)]. Also, the average age of farmers rose from approximately 40 years in 1970 to 46 in 1990 (Adachaba, 1992). To maintain or increase the current production level, farming practices must become more efficient. A meaningful approach, with the greatest potential to impact legume production efficiency in Nigeria, is to facilitate weed management so the farmer can increase the land area cultivated using recommended varieties and other proven agronomic and crop protection practices. Currently, the average land area per legume farmer is 1 ha or less. To weed 1 ha manually, the farmer expends 10 to 20 man-days (md), depending on weed intensity and weather conditions. However, with chemical weed control, only 2 md/ha are required at the small farmer level and this is less under medium to large scale farming. The savings of 8 to 18 md/ha can be used to substantially increase the land area cultivated. Chemical weed control, therefore, has a central role to play in revolutionising agriculture in Nigeria and the rest of the sub-Saharan Africa.

Early chemical weed control research in legume production in Nigeria identified a commercial mixture of metolachlor plus metobromuron (Galex[R]) as an effective herbicide. This mixture has been used since the late 1970's. By the early 1980's, it was observed that the mixture was ineffective on some of the worst weeds in the legume production areas, including wild poinsettia (*Euphorbia heterophylla* L) and itchgrass [*Rottboellia cochinchinensis* (Lour) Clayton]. These weed species are highly competitive. In addition, the herbicide mixture is active for only 3 to 4 weeks after application which is too short a duration for most of the legumes grown in the country. It was, therefore, necessary to identify active ingredients with enough activity to eliminate the devastating effects of weeds on legume production in Nigeria. This paper highlights the results of herbicide trials in legume production conducted in different locations in the country between 1984 and 1994 with emphasis on imazaquin and imazethapyr.

MATERIALS AND METHODS

Between 1984 and 1994, herbicide trials were conducted in the forest and Guinea savanna ecological zones of Nigeria in collaboration with weed scientists and agronomists at the Institute of Agricultural Research and Training, Moor Plantation, Ibadan (7° 22' N; 4° 0' E); University of Ilorin, Ilorin (8° 30' N; 4° 33' E); National Cereals Research Institute, Mokwa Substation (9° 11' N; 5° 2' E); and Institute for Agricultural Research, Ahmadu Bello University, Zaria (11° 4' N; 7° 42' E). The herbicides used comprised single active ingredient formulations, as well as formulated mixtures. At all locations, experimental sites were selected based on suitability for the crop under investigation. The crop varieties used were those currently recommended to the farmer by the extension division of the State Agricultural Development Projects (ADPs). Trials were set up and managed following recommended agronomic and crop protection practices. In all the trials, the experimental design was randomised complete block with four replications. The plot size varied from 4 to 5 m to 6 by 6 m. Herbicide application was made pre- and post-emergence with the non-pressure retaining Couper Pegler (CP 3 or CP 15) knapsack sprayer calibrated to deliver between 200 and 300 l/ha as appropriate for each spraying exercise. Data were collected on weed control effectiveness and crop yield and subjected to ANOVA. Treatment means were compared using LSD at the 5% probability level or SE± as appropriate.

RESULTS AND DISCUSSION

The results from field experiments in Nigeria between 1984 and 1994 clearly showed that imazaquin and imazethapyr and their combination with metolachlor or pendimethalin offer the best weed control in the major food legumes of the country (Tables 1a to 6). These imidazolinones are active in small concentrations (imazethapyr: 0.05 to 0.1 kg a.i./ha; imazaquin: 0.09-0.27 kg a.i./ha compared with metobromuron, prometryne or terbutryne: 1.0 to 1.5 kg a.i./ha) which reduces the amount of chemical released into the soil environment, as well as the ultimate cost of product transportation. They are also safe on the crop as yields from treated plots compare favourably with the yield from handweeded plots. Unreported observations indicate that the herbicides fit into the prevailing crop rotations practiced in different parts of Nigeria.

Table 1a. Weed control in cowpea in forest (Ibadan) and southern Guinea savanna (Ilorin and Mokwa) ecologies of Nigeria (1988-1990)

Herbicide treatment (kg a.i./ha)	Location		
	Ibadan (7WAP*)	Ilorin (6WAP*)	Mokwa (9WAP*)
	Weed control rating (0-10 scale)**		
Imazaquin+pendimethalin (0.07+0.71)	9.8	6.8	7.2
Imazaquin+pendimethalin (0.09+0.95)	9.6	7.0	8.2
Imazethapyr+pendimethalin (0.07+0.95)	10.0	4.3	6.7
Imazethapyr+pendimethalin (0.09+1.27)	9.8	5.9	8.3
Metobromuron+metolachlor (1.25+1.25)	8.2	3.0	4.7
Handweeded check (3 & 6 WAP*)	10.0	10.0	9.3
Unweeded check	5.0	0.5	4.0

*WAP = Weeks after planting **0 = Zero weed control, 10 = Excellent weed control

Table 1b. Weed control in cowpea in the northern Guinea savanna of Nigeria (1989-1991)

Treatment (kg a.i./ha)		Weed control rating
Pre-emergence	Post-emergence	6WAP* (0-10 scale)
Imazethapyr+metolachlor (0.05+1.25)	--	6.7
Imazethapyr+pendimethalin (0.09+1.27)	--	6.8
Imazaquin+metolachlor (0.18+1.25)	SHW** (6WAP*)	7.7
--	Imazethapyr+pendimethalin (0.09+1.27) 3WAP*	6.0
Metobromuron+metolachlor (1.25+1.25)	SHW** (6WAP*)	3.7
Metolachlor+prometryne (1.0+1.0)	SHW** (6WAP*)	4.7
Handweeded check (3 & 6 WAP*)	--	7.8
Unweeded check	--	0.0

*WAP = Weeks after planting **SHW = Supplementary hand weeding

Table 2a. Effect of herbicide treatments on cowpea seed yield in the forest (Ibadan) and southern Guinea savanna (Ilorin and Mokwa) ecologies of Nigeria (1988-1990)

Herbicide treatment (kg a.i./ha)	Location		
	Ibadan	Ilorin	Mokwa
	Seed yield (kg/ha)		
Imazaquin+pendimethalin (0.07+0.71)	528	1038	446
Imazaquin+pendimethalin (0.09+0.95)	716	1107	552
Imazethapyr+pendimethalin (0.07+0.95)	906	1011	427
Imazethapyr+pendimethalin (0.09+1.27)	937	1212	542
Metobromuron+metolachlor (1.25+1.25)	597	771	294
Handweeded check (3 & 6 WAP*)	905	879	673
Unweeded check	736	470	258
LSD (0.05)	142.6	233.2	99.7

*WAP = Weeks after planting

Table 2b. Effect of herbicide treatments on cowpea seed yield in the northern savanna of Nigeria (1989-1991)

Treatment (kg a.i./ha)		Cowpea seed yield (kg/ha)
Pre-emergence	Post-emergence	
Imazethapyr+metolachlor (0.05+1.25)	--	1978
Imazethapyr+pendimethalin (0.09+1.27)	--	1627
Imazaquin+metolachlor (0.18+1.25)	SHW** (6WAP*)	1633
--	Imazethapyr+pendimethalin (0.09+1.27) 3WAP*	1536
Metobromuron+metolachlor (1.25+1.25)	SHW** (6WAP*)	1536
Metolachlor+prometryne (1.0+1.0)	SHW** (6WAP*)	1521
Handweeded check (3 & 6 WAP*)	--	1508
Unweeded check	--	608
LSD (0.05)		375.7

*WAP = Weeks after planting **SHW = Supplementary handweeding

Table 3. Effect of herbicide treatments on weed control and groundnut yield in the northern Guinea savanna of Nigeria (1990-1991)

Herbicide treatment (kg a.i./ha)	Weed control rating 9WAP* (0-10 scale)	Groundnut pod yield (kg/ha)
Imazethapyr (0.075)	6.0	1473
Imazaquin (0.18)	3.7	767
Imazethapyr+pendimethalin (0.09+1.27)	5.8	1073
Imazaquin+pendimethalin (0.07+0.71)	5.7	1010
Imazethapyr+metolachlor (0.075+1.0)	5.3	928
Prometryne+metolachlor (1.0+1.0)	4.3	1020
Terbutryne+metolachlor (1.25+1.25)	5.7	563
Metobromuron+metolachlor (1.25+1.25)	4.5	527
Handweeded check (3, 6 & 9 WAP*)	9.4	867
Unweeded check	0.0	317
LSD (0.05)		293.7

*WAP = Weeks after planting

In spite of the attractive qualities of imazethapyr and imazaquin in Nigeria, these herbicides are yet to impact legume production in the country. The greatest obstacle between these active ingredients and the legume farmer in Nigeria is lack of awareness. The government agricultural extension agencies are ill-staffed with professionally trained chemical weed control specialists who can demonstrate the effectiveness of the imidazolinone herbicides in legume production and effectively transfer the technology to the farmer. Manufacturers and/or marketers of these herbicides are in the best position to assist in the process of technology transfer by investing in aggressive product development.

Herbicides that have become commonly used in Nigeria were introduced and developed by manufacturers and marketers. Maize production increased from less than 1.2 million tonnes in 1970 to 2.2 million tonnes in 1992 due to the increase in the use of effective herbicides for weed management. This was made possible by the aggressive policy of the herbicide manufacturers and marketers who assisted herbicide development and technology transfer. This can happen with the imidazolinones and other effective herbicides in Nigeria and the whole of the sub-Saharan Africa.

The strategies for optimising the imidazolinone herbicides in Nigeria should focus on adapting application technology to suit the conditions of the farmer. The average legume farmer in Nigeria is resource poor and cannot read or write. He also operates on a small scale (≤1 ha). For this reason, the unit pack of herbicides should be small (<1 to 5 l pack) and accompanied by a safe standard measure whose use the extension agent can readily explain to the farmer. In Nigeria, the National Advisory Committee on Weed Control (NACWC) has developed certain techniques which have been found to work satisfactorily in certain circumstances. More still needs to be done to transfer herbicide technology to all categories of farmers. Also, research needs to be stepped up on post-emergence application of imidazolinones with the primary goal of reducing the total amount of chemical released into the agroecosystem.

Table 4. Effect of herbicide treatments on itchgrass (*Rottboellia cochinchinensis*) and groundnut yield in the northern Guinea savanna of Nigeria (1990-1991)

Herbicide treatment (kg a.i./ha)	Weed control rating at harvest (0-10 scale)		Groundnut pod yield (kg/ha)
	Itchgrass	Other weeds	
Imazethapyr+pendimethalin (0.05+1.4)	5.0	3.5	1696
Imazethapyr+pendimethalin (0.07+1.4)	7.0	8.0	2008
Imazaquin+pendimethalin (0.05+1.5)	6.0	4.5	1698
Imazaquin+pendimethalin (0.09+1.5)	7.5	7.0	1901
Imazethapyr+metolachlor (0.07+2.4)	3.5	5.5	1521
Terbutryne+metolachlor (1.25+1.25)	4.5	5.0	1639
Oxadiazon+pendimethalin (1.25+1.25)	6.5	4.5	1705
Handweeded check (3, 6 & 9 WAP*)	10.0	10.0	2053
Unweeded check	0.0	0.0	371
LSD (0.05)			365.1

*WAP = Weeks after planting

Table 5. Effect of herbicide treatments on weed control and soybean yield in the forest (Ibadan) and southern Guinea savanna (Ilorin and Mokwa) ecologies of Nigeria (1984-1986)

Herbicide treatment (kg a.i./ha)	Weed control rating (0-10 scale)			Soybean seed yield (kg/ha)		
	Ibadan 6WAP*	Ilorin 8WAP*	Mokwa 6WAP*	Ibadan	Ilorin	Mokwa
Imazaquin+pendimethalin (0.07+0.71)	9.0	4.2	8.7	1257	850	1960
Imazaquin+pendimethalin (0.09+0.95)	9.6	5.7	8.7	1860	1222	1810
Imazethapyr+pendimethalin (0.07+0.95)	8.3	5.2	8.3	1168	1584	1580
Imazethapyr+pendimethalin (0.09+1.27)	9.0	7.3	8.8	1163	1671	1720
Metobromuron+metolachlor (1.25+1.25)	8.0	7.3	8.0	820	966	1500
Handweeded check (3 & 6 WAP*)	10.0	8.0	9.5	1138	788	2160
Unweeded check	0.0	1.2	4.0	897	604	1280
LSD (0.05)				195.3	272.2	330.5

*WAP = Weeks after planting

Table 6. Effect of herbicide treatments on weed control and soybean yield in the northern Guinea savanna ecology of Nigeria (1990-1991)

Herbicide treatment (kg a.i./ha)	Weed control rating 6WAP* (0-10 scale)	Soybean seed yield (kg/ha)
Imazaquin (0.18)	4.0	1861
Imazaquin (0.27)	6.0	2171
Imazethapyr (0.025)	5.0	1667
Imazethapyr (0.05)	6.0	1751
Imazaquin+metolachlor (0.12+1.25)	8.7	2388
Imazaquin+metolachlor (0.18+1.25)	8.7	1669
Imazethapyr+metolachlor (0.05+1.25)	7.7	2002
Imazethapyr+metolachlor (0.075+1.25)	4.0	1939
Imazaquin+pendimethalin (0.12+1.25)	9.0	1526
Imazaquin+pendimethalin (0.15+1.25)	8.0	2300
Imazethapyr+pendimethalin (0.075+0.5)	7.3	1948
Imazethapyr+pendimethalin (0.09+1.27)	10.0	2240
Prometryne+metolachlor (1.0+1.0)	7.7	1839
Metobromuron+metolachlor (1.25+1.25)	8.0	1323
Handweeded check (3 & 6 WAP*)	10.0	1680
Unweeded check	0.0	1281
SE±		234.7

*WAP = Weeks after planting

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A SYSTEMS APPROACH FOR THE CONTROL OF RUSSIAN KNAPWEED

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ABSTRACT

Studies were initiated in Wyoming to determine the potential of grass competition as an alternative to repetitive herbicide treatment or other cultural practices for control of russian knapweed (*Centaurea repens*). An experiment was established to evaluate the effects of five grass species including russian wildrye. Applications of clopyralid plus 2,4-D and picloram, applied to russian knapweed during the first frost, reduced russian knapweed from an average of 80.1% live canopy cover which equates to 0% control. Untreated unseeded checks resulted in 83.9% and 81.1% control in tilled and non-tilled treated plots respectively. Grass cover increased in untreated seeded plots from an average of 11.3% and 8.2% in tilled and non-tilled plots, respectively, to 72.5% in tilled and 66% in non-tilled plots treated with clopyralid plus 2,4-D. Grass cover also increased 69.7% in tilled and 64% in non-tilled plots treated with picloram. There was no significant difference between grass varieties when compared to % russian knapweed cover. Reductions to 0% live canopy cover of russian knapweed were obtained with a single application of picloram. Economic feasibility thresholds were obtained from four out of five varieties including a significant difference provided by non-tilled russian wildrye treated with clopyralid plus 2,4-D.

INTRODUCTION

Russian knapweed, a perennial found throughout the western United States, is the most persistent of the knapweeds (Lacey, 1989) and is difficult to control. It competes with desirable forage and is of no value to cattle producers. Control can be maintained with single herbicide treatments for only three to five years, so after this time a re-treatment program must be implemented to maintain adequate control.

Although herbicides play an important part in the control of russian knapweed, alternative methods are available and may be used where persistent herbicides cannot be tolerated. This type of integrated weed management strategy is a multi-disciplinary, ecological approach to managing weed populations. There is no example of an extensive noxious weed infestation being eradicated by a single method (Lacey, 1991). Grass competition has long been recognized as a method of weed control. Crested wheatgrass has been used successfully in Saskatchewan, Canada to decrease the rate of vegetative spread, limit density, reduce seed production and suppress the growth of other perennial weeds.

Russian knapweed is highly competitive on disturbed sites and severely reduces land values. It is also allelopathic (Fletcher & Renney, 1963) so that areas must be tilled before newly established grass seedlings can survive. Without tillage, grass seedlings can survive only after russian knapweed residues have been exposed to moisture for two growing seasons.

Biological control of weeds is the planned use of living organisms to reduce their vigor, reproductive capacity, density, or effect. This broad definition also encompasses competitive grass species (Quimby *et al.*, 1991). Wheatgrasses, fescues and wildryes are among the most commonly used for reseeding western rangelands. Selection of rhizomatous species is appropriate where noxious weeds are a consideration (Callihan & Evans, 1991). Grasses selected for these studies were russian wildrye, thickspike wheatgrass, streambank wheatgrass, crested wheatgrass, and western wheatgrass because of their potential to provide both a competitive and production incentive. Using a production approach, there is economic incentive to control knapweed (Feuz *et al.*, 1996) The purpose of this research was to determine the potential of perennial grass competition as an alternative to repetitive herbicide treatment and other cultural practices for control of russian knapweed.

MATERIAL AND METHODS

Studies were established on the Wind River Indian Reservation near Arapaho and Fort Washakie in Wyoming. Study sites were located on Lander Complex sandy loam soils using a split-split plot design and were treated with herbicides after frost on 10 and 11 October 1991. Plots were tilled in May 1991. Metsulfuron (8.5 g. ai/ha), clopyralid (0.32 kg ai/ha) plus 2,4-D (1.65 kg a.i./ha), and picloram (0.28 kg ai/ha) were applied in August 1992 using a CO_2 pressurized backpack sprayer at 121.4 litres/ha/kPa at 270 kPa with 8004 nozzles. All herbicides, except picloram, were reapplied in August 1994. Russian knapweed had started into winter dormancy during the 1991 application, was in late bloom in 1992 and early bloom in 1994. Plots were seeded on 11 and 12 April 1992 at 20 cm row spacing with a double- disc opener Tye drill with streambank wheatgrass, thickspike wheatgrass, crested wheatgrass, and western wheatgrass at 11.2 kg pure live seed/ha, except russian wildrye which was seeded at 40 cm and 6.6 kg/ha. Plots were mowed in the fall of 1996 to emulate grazing and allow for realistic measurement of 1997 spring regrowth.

RESULTS AND DISCUSSION

Russian knapweed live canopy cover was reduced from an average of 80.1% and this was equated to 0% control. Untreated unseeded checks resulted in 86.9% in tilled and 81.2% control in non-tilled, as well as 80.4% in tilled and 83.6% control in non-tilled treatments of picloram and clopyralid plus 2,4-D respectively (Tables 1 and 2). There was no significant difference between grass varieties when compared to % russian knapweed cover. Reductions to 0% live canopy cover of russian knapweed were obtained with a single application of picloram.

A vegetative inventory using Levy and Madden's point method of pasture analysis (Carter, 1962) was used to determine live species canopy cover. A point-frame containing 10 equidistant points spaced at 5 cm was located at ten 0.92-m intervals on a permanent 10.22-m transect line within each treatment replicate. Three hundred pin point species identifications were taken to determine the species inventories per treatment. Counts for each species were converted to a percentage of the live canopy cover. Point transect readings were taken of earlier 1995 evaluations having 70% knapweed control or better on June 17/18 1997 and June18/19 1997 at Arapaho and Fort Washakie, respectively. Only seeded treatments receiving picloram and clopyralid plus 2,4-D averaging 98.1% and 93.9%, respectively, were evaluated in 1997. Burning (47%), mowing (50.6%) and metsulfuron (49.4%) treatments did not provide effective control.

Table 1. Percent Control of Russian Knapweed at Arapaho (AR) and Fort Washakie (FW)

Tilled % Control of Russian Knapweed

	Clopyralid		Picloram		Untreated/Seed	
Grass	AR%	FW%	AR%	FW%	AR%	FW%
Russian Wildrye	93	75	100	85	20	27
Crested Wheatgrass	*	*	91	51	25	18
Thickspike Wheatgrass	86	79	100	88	24	27
Western Wheatgrass	96	67	94	77	16	22
Streambank Wheatgrass	93	50	97	82	24	24
LSD (0.05)	11.6	39.6	11.8	20		
Mean	80		87		23	

1.Percent Knapweed control reflects untreated unseeded checks as 0.% control. counts/plot.
2.Herbicides were applied 10/91, 8/92, 3/94.
3.Grasses were seeded 4/92.
4.% Control was based on 100 point-frame
*Evaluations below 70% control in 1995 did not occur.

Table 2. Percent Control of Russian Knapweed at Arapaho (AR) and Fort Washakie (FW)

No-Till % Control of Russian Knapweed

	Clopyralid		Picloram		Untreated/Seed	
Grass	AR%	FW%	AR%	FW%	AR%	FW%
Russian Wildrye	94	72	100	87	21	25
Crested Wheatgrass	*	*	95	58	23	29
Thickspike Wheatgrass	*	*	*	*	22	32
Western Wheatgrass	*	*	95	55	22	22
Streambank Wheatgrass	*	*	93	64	24	34
LSD (0.05)			7.1	32.9		
Mean	83		81		25	

1.Percent Knapweed control reflects untreated unseeded checks as 0.% control.
2. Herbicides were applied 10/91, 8/92, 3/94.
3. Grasses were seeded 4/92.
4. % Control was based on 100 point-frame counts/plot.
*Evaluations below 70% control in 1995 and did not occur.

Stands of perennial grasses averaged 69.7% live grass cover in tilled and 66.4% live grass cover in non-tilled picloram treatments and 65.6% live grass cover in tilled and 66.3% live grass cover in non-tilled treatments of clopyralid plus 2,4-D. This compared to 10.4% and 9.3% for the untreated seeded tilled and non-tilled plots, respectively (Table 3 and 4). The two grasses with the highest overall establishment in tilled plots were streambank wheatgrass and thickspike wheatgrass with an average overall treatment of 76.6% live grass cover. The two grasses with the highest overall establishment in non-tilled plots were russian wildrye with 78.7% live grass cover and western wheatgrass with 65.8% live grass cover. The lowest amount of russian knapweed (0%) and the highest amount of live cover of grass (92.5% in non-tilled and 90% in tilled) were found in plots treated with picloram and seeded to russian wildrye (Tables 3 and 4).

Table 3. Percent grass cover at Arapaho (AR) and Fort Washakie (FW)

Tilled % Grass Cover

	Clopyralid		Picloram		Untreated/Seeded	
Grass	AR%	FW%	AR%	FW%	AR%	FW%
Russian Wildrye	81	52	90	55	8	6
Crested Wheatgrass	*	*	70	33	18	3
Thickspike Wheatgrass	68	65	83	70	14	17
Western Wheatgrass	80	48	81	60	5	6
Streambank Wheatgrass	88	41	85	68	16	20
LSD (0.05)	20.9	35.3	21	16.4		
Mean	65		69		11	

1.Percent Grass cover reflects untreated unseeded check with 1. 0% grass.
2.Herbicides were applied 10/91, 8/92, 3/94.
3.Grasses were seeded 4/92.
4.% Control was based on 100 point-frame counts/plot.
*Evaluations below 70% control in 1995 did not occur.

Table 4. Percent grass cover at Arapaho (AR) and Fort Washakie (FW)

No-Till % Grass Cover

	Clopyralid		Picloram		Untreated/Seeded	
Grass	AR%	FW%	AR%	FW%	AR%	FW%
Russian Wildrye	83	49	92	65	8	4
Crested Wheatgrass	*	*	78	43	10	5
Thickspike Wheatgrass	*	*	*	*	10	9
Western Wheatgrass	*	*	86	45	9	6
Streambank Wheatgrass	*	*	70	47	9	12
LSD (0.05)			24.1	26.4		
Mean	66		66		8	

1.Percent Grass cover reflects untreated unseeded check with 1.0.% grass
2.Herbicides were applied 10/91, 8/92, 3/94.
3.Grasses were seeded 4/92.
*Evaluations below 70% control in 1995 did not occur.

Forage samples were taken on June 17/18 1997 and June 18/19 1997 at Arapho and Fort Washakie, respectively, from 1 m^2 plots to evaluate yield and nutrient value. Research grasses averaged 489 kg/ha grass yield in tilled, and 1149 kg/ha grass yield in non-tilled clopyralid plus 2,4-D compared to 444 kg/ha grass yield in tilled and 500 kg/ha grass yield for picloram treatments (Table 5). All grasses with the exception of thickspike wheatgrass produced enough to reach an economic threshhold to warrant implementing a systems approach for the control of russian knapweed. The only significant treatment providing both yield and control was non-tilled russian wildrye treated with clopyralid.

Table 5. Grass yield at Arapaho (AR) and Fort Washakie (FW)

	Tilled				Non Tilled					
	Clopyralid		Picloram		Clopyralid		Picloram		Untreated/ Unseeded	
Grass (kg/ha)	AR%	FW %	AR%	FW %	AR%	FW %	AR%	FW %	AR %	FW%
Russian Wildrye	84	252	537	263	1492	805	1171	400	74	27
Crested Wheatgrass	*	*	1145	200	*	*	687	225	41	13
Thickspike Wheatgrass	527	289	480	244	*	*	*	*	*	*
Western Wheatgrass	885	213	618	191	*	*	804	259	48	16
Streambank Wheatgrass	668	237	401	260	*	*	263	193	35	12
LSD (0.05)	283	192	885	264			142	307	308	270
Mean	489		444		1149		500		33	

1.Herbicides were applied 10/91, 8/92, 3/94. 2.Grasses were seeded 4/92.

*Evaluations did not occur as they were below 70% control in 1995.

Critana thickspike wheatgrass and Sodar streambank wheatgrass are very genetically similar grasses. They are native perennial grasses which can be used to vegetate and reduce sites disturbed by erosion such as mined lands, roadsides, recreation areas, and construction sites. Both are excellent for reseeding range sites that are severely eroded or that have low fertility. Both are also strongly rhizomatous and grow to 25 to 30 cm in height on good sites. They produce abundant, fine, light green leaves and form a tight sod under dryland conditions. Both have excellent seedling vigor and are adapted to medium- to coarse-textured soils. They grow in the 25- to 51-cm precipitation zone in the northern Rocky Mountains and adjacent Great Plains regions. Both adapt to elevations ranging from 610 to 2287 m (USDA, 1981). These grasses gave the highest average percent live grass cover in the tilled study.

Hycrest crested wheatgrass is a winter hardy, drought resistant bunchgrass. Although the new cultivar is well adapted to sagebrush and juniper vegetation sites (30 cm of annual precipitation or lower), good to excellent stands have been established on shadscale, greasewood, and Indian ricegrass sites where annual precipitation is less than 20 cm. In southern areas, it is best adapted to elevations of 1500 m or more. The upper elevation limits are from 2590 to 2740 m. It performs well on a wide variety of soil types, but is particularly well adapted to sandy or sandy loam soils. In general, crested wheatgrass will not tolerate prolonged flooding and is only moderately tolerant of saline soils when compared to tall wheatgrass, quackgrass, or western wheatgrass (Asay & Horton, 1985). This grass had the greatest live grass cover in non-tilled plots along with rosanna western wheatgrass.

Rosana western wheatgrass, a native perennial grass, was developed for reseeding depleted rangelands and abandoned cropland in Montana and Wyoming. Seedling vigor also makes it a valuable grass for mine reclamation. The plants are blue-green, leafy, moderately fine stemmed, and easy to establish and are adapted to the moderately rolling topography of the northern Rocky Mountain region and the adjacent Great Plains. It does best on medium to fine textured soils, tolerates soils that are neutral to strongly alkaline, and is adapted to areas with 30 or more cm of precipitation. Rosana forms a tight sod under dryland conditions, and will produce excellent seed crops under irrigation (USDA, 1979).

Because of their performance in these studies, russian wildrye, thickspike wheatgrass, crested wheatgrass, western wheatgrass and streambank wheatgrass appear to provide both a financial return and effective competition with russian knapweed when either clopyralid plus 2,4-D or picloram and specific tillage practices are applied.

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THE EFFECTS OF SIX-YEARS OF REDUCED-RATE HERBICIDE USE AND ROTATION ON WEED LEVELS, YIELDS AND PROFITABILITY - TALISMAN RESULTS

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ABSTRACT

TALISMAN (Towards A Lower Input System Minimising Agrochemicals and Nitrogen) was completed after a six year rotation in summer 1996. Contrasting Standard and Alternative six-year rotations were tested, at three ADAS Research Centres, under Current Commercial Practice (CCP), applying full recommended rates of pesticides and a Low Input Approach (LIA) in which 50% of the nitrogen and up to 50% of the pesticides are applied. In each year there were comparisons between CCP and LIA levels of herbicide and nitrogen, giving 132 comparisons over the six year rotation. Total herbicide use was similar for both rotations, whilst herbicide use in the LIA was decreased by 54% at Drayton and High Mowthorpe, but less at Boxworth. Weed numbers were always greater at the LIA rate of herbicide and were greater in the Alternative Rotation at the LIA rate of nitrogen, but there were differences between sites. Yield losses were greater in the Alternative Rotation and tended to be greater in 1996 after six years of reduced herbicides than in 1993. Gross margins were affected to different degrees at the three sites.

INTRODUCTION

As a follow on from the Boxworth Project (Greig-Smith *et al.*, 1992), TALISMAN (Towards A Lower Input System Minimising Agrochemicals and Nitrogen) was designed to measure the economic, agronomic and, to a lesser extent, the environmental effects of adopting lower input cropping systems (Cooper, 1990). This paper reports the results from six years of full and reduced rates of both herbicides and nitrogen in Standard and Alternative rotations. A further experiment has been funded to study the recovery of the site under a full herbicide regime.

MATERIALS AND METHODS

TALISMAN was located at three ADAS research centres; Boxworth, Cambridge (well-structured clay), Drayton, Warwickshire (clay) and High Mowthorpe, North Yorkshire (silty clay loam). Standard and Alternative rotations were tested either under Current Commercial Practice (CCP) for pesticides and nitrogen or a Low Input Approach (LIA) where 50% of the nitrogen rate and a maximum of 50% of the pesticide rates applied to the CCP were used. The Standard Rotations were typical for individual sites; for Boxworth and Drayton winter oilseed rape was followed by two winter wheats, winter beans and a further two winter wheats. At High Mowthorpe the winter oilseed rape was preceded by winter barley. The Alternative Rotations were predominantly spring cropping (Table 1) and therefore usually had a lower requirement for pesticides and nitrogen. Each six-course rotation had two phases; Phase 1 started in the first year of the rotation and Phase II started at year 4. The Alternative Rotation at Boxworth had only one phase.

Table 1. Alternative rotations

Site	Boxworth	Drayton	High Mowthorpe
Year1	Spring linseed	Spring beans	Spring linseed
Year 2	Winter wheat	Winter triticale	Winter wheat
Year 3	Spring wheat	Winter triticale	Spring barley
Year 4	Spring beans	Spring oats	Spring beans
Year 5	Winter wheat	Winter triticale	Winter wheat
Year 6	Spring wheat	Winter triticale	Spring barley

Pesticides were applied at the manufacturers' label recommended rate to CCP, which provided a recognised standard against which comparisons can be made. Nitrogen rates were determined by the ADAS fertiliser planning service "Fertiplan", based upon previous cropping, soil type and yield prediction. Reductions in pesticides were made primarily by omitting applications to the LIA wherever possible. If predicted crop loss was estimated at greater than 10%, where a chemical was not used, then up to 50% of the CCP rate could be applied. In crop threatening situations a full rate of the pesticide could be applied to LIA treatments. At each site, cultivation, cultivar, sowing date and pesticide products were the same in both CCP and LIA.

TALISMAN was a split-plot design with rotation and nitrogen as main treatments and combinations of LIA and CCP rates of herbicides, fungicides and insecticides in sub-treatments (Table 2). This paper reports the effects of reduced-rate herbicide use and rotation on weed levels, yields and profitability

Table 2. Rates of pesticide applied to TALISMAN sub-treatments. (Current Commercial Practice (CCP) and Low Input Approach (LIA))

Sub-treatment code	Herbicide rate	Fungicide rate	Insecticide rate
CCC	CCP	CCP	CCP
LLL	LIA	LIA	LIA
LCC	LIA	CCP	CCP
CLC	CCP	LIA	CCP
CCL	CCP	CCP	LIA

RESULTS

Over the six years of the rotation, total herbicide use was similar in both the Standard and Alternative Rotations. Overall herbicide use was decreased by 45% in the LIA (Table 3). At the individual sites, the number of herbicide units applied was greatest at Drayton and least at High Mowthorpe. In the Standard Rotation, herbicide use was decreased by 51 and 55% at Drayton and High Mowthorpe respectively in the LIA; but by only 28% at Boxworth. Similarly in the Alternative Rotation, herbicide use was decreased by 51 and 57% at Drayton and High Mowthorpe and by 43% at Boxworth.

Table 3. Mean herbicide units used per crop year (herbicide unit = one full-rate application of a single active ingredient

	Standard Rotation		Alternative Rotation	
Site	CCP herbicide	LIA herbicide	CCP herbicide	LIA herbicide
Boxworth	3.4	2.4	3.0	1.7
Drayton	4.8	2.4	4.6	2.3
High Mowthorpe	2.3	1.1	2.4	1.1
Mean	3.5	1.9	2.8	1.4

Effects of treatments on weed population were similar at all sites (Table 4). Total weed numbers were lowest at Drayton, but similar at Boxworth and High Mowthorpe. At Boxworth in the Standard Rotation, populations were higher at LIA rates of nitrogen, but this was not the case in the Alternative Rotation. At Drayton weed populations were higher at LIA rates of herbicide in both the Standard and Alternative rotations. There were no consistent treatment differences at High Mowthorpe, but weed numbers in the LIA herbicide regime were often higher than the CCP especially in 1993, 1995 and 1996.

Overall, LIA herbicide resulted in higher total weed populations in the Alternative than the Standard rotation (Table 5). Weed numbers were greater at LIA herbicide levels in 87% of cases. . The pattern of response in weed numbers resulting from the two herbicide rates was similar at CCP and LIA nitrogen at all sites. The difference in weed numbers between the two herbicide rates was lowest at Drayton. The difference was more than 25 weeds/m^2 in 19% of cases in the Standard Rotation and 31% in the Alternative Rotation. Over the six-year period the mean difference in weed numbers between the nitrogen rates was less in the Standard Rotation (0.9 weeds/m^2) than in the Alternative (19.2 weeds/m^2).

The yield reductions between CCP herbicide and LIA herbicide tended to be greater in the Alternative Rotation. In this rotation there was a trend for larger negative yield differences in 1996 after six years of reduced herbicides than 1993, except at Drayton.

In the Standard Rotation, the differences in gross margin between CCP herbicide and LIA herbicide tended to be in favour of LIA. Other data shows margins tended to be higher at the LIA nitrogen level. At High Mowthorpe, in the Standard Rotation there was less difference between the two regimes, the exception being LIA nitrogen in 1993. The use of LIA herbicide reduced gross margin in the Alternative Rotation compared with the Standard Rotation in most cases. In some instances the use of LIA herbicide resulted in very large losses. The exception was in 1993 at High Mowthorpe. At Boxworth, decreases in margin for the alternative rotation were severe (up to £-153 ha^{-1}). At Drayton, gross margin differences were mainly positive.

Table 4. Total weed numbers for CCP and LIA herbicide treatments at CCP and LIA rates of nitrogen for the Standard and Alternative, between 1991and 1996 (weeds/m²).

	Standard Rotation				Alternative Rotation			
	CCP Nitrogen		LIA Nitrogen		CCP Nitrogen		LIA Nitrogen	
	CCP herbicide	LIA herbicide	CCP herbicide	LIA herbicide	CCP herbicide	LIA herbicide	CCP herbicide	LIA herbicide
Boxworth								
1991	53.5	87.8	55.3	92.5	-	-	-	-
1992	0.1	1.6	0.8	2.1	0.0	0.0	0.0	0.8
1993	12.8	28.0	23.5	26.8	74.5	59.5	84.5	258.0
1994	22.8	32.8	30.8	48.8	30.5	116.5	18.0	139.5
1995	14.3	24.4	37.5	30.8	14.5	21.5	49.0	60.0
1996	18.8	31.4	24.5	37.8	1249.0	1324.0	618.0	1067.0
Drayton								
1991	8.0	8.0	8.0	9.0	8.0	9.0	6.0	9.0
1992	3.7	10.7	7.9	12.7	2.0	12.1	1.7	10.1
1993	4.1	14.0	10.1	18.3	25.1	27.7	21.8	22.1
1994	1.7	27.4	7.7	37.2	22.4	27.7	23.0	32.0
1995	0.7	45.4	4.0	43.4	8.1	46.4	7.7	59.1
1996	2.7	10.7	2.9	13.4	6.7	32.4	4.0	24.4
High Mowthorpe								
1991	46.0	128.0	136.0	124.0	226.0	219.0	254.0	254.0
1992	2.0	1.8	1.0	1.8	0.6	2.0	0.9	1.6
1993	16.2	22.9	34.2	46.9	8.2	44.2	14.0	34.9
1994	46.3	54.4	50.7	51.4	107.2	104.9	116.5	90.9
1995	8.1	10.8	4.7	20.0	15.4	36.3	10.4	29.4
1996	75.7	121.1	74.4	164.7	2.8	66.9	3.2	66.0

Table 5. Differences in weed populations, yield and gross margin for LIA herbicide relative to those for CCP herbicide at CCP and LIA nitrogen rates, in Standard and Alternative Rotations, 1993 and 1996. (0=CCP herbicide)

	Standard Rotation				Alternative Rotation			
	1993		1996		1993		1996	
	CCP Nitrogen	LIA Nitrogen	CCP Nitrogen	LIA Nitrogen	CCP Nitrogen	LIA Nitrogen	CCP Nitrogen	LIA Nitrogen
Weeds (weeds/m²)								
Boxworth	27.9	26.0	25.8	26.0	-15.0	173.5	75.0	449.0
Drayton	10.0	8.2	8.1	10.0	2.6	0.3	25.7	20.4
High Mowthorpe	6.7	12.7	45.4	90.3	36.0	20.9	64.1	62.8
Yield (t/ha)								
Boxworth	-0.01	-0.07	0.03	-0.07	-0.02	-0.31	-1.21	-0.98
Drayton	-0.20	0.34	0.04	0.11	-0.18	-0.44	-0.14	-0.13
High Mowthorpe	0.15	-0.80	-0.46	-0.41	-0.11	0.69	-0.26	-0.37
Gross margin (£/ha)								
Boxworth	25.4	34.9	29.4	33.6	4.0	-32.0	-153.2	-111.3
Drayton	40.0	93.5	54.7	61.6	14.5	-11.5	37.1	38.0
High Mowthorpe	-4.0	-60.5	-1.4	4.0	12.3	89.8	-12.5	-13.6

DISCUSSION

The Alternative Rotation was introduced into the TALISMAN project as a means of reducing pesticide use. It was composed of a high percentage of spring crops, with one in six at Boxworth and High Mowthorpe, but only one in three at Drayton where winter triticale was used as a low input alternative winter cereal. Herbicide use was not decreased as these Alternative Rotation crops have a similar herbicide requirement to the winter sown crops. Herbicide use was highest at Drayton and weed populations were the lowest of all three sites. A range of herbicides including isoproturon, fenoxaprop-ethyl, diflufenican, ioxynil, bromoxynil, mecoprop and fluroxypyr was used for weed control. At Boxworth only full rate (2500 g a.i./ha) isoproturon was used in both treatments in winter cereals to control *alopecurus myosuroides*. This resulted in less use of fenoxaprop-ethyl and broad-leaved weed herbicides. In contrast at Drayton, a pre-drilling non-selective herbicide was also used in 1993 and 1995 prior to winter wheat crops. The use at Drayton of a greater number of selective and non-selective herbicides in the rotation kept weed numbers lower and increased the profitability. This could mean there was more scope to reduce herbicides than was tested in this series.

Weed numbers increased with successive low herbicide use over the six years and this was exacerbated by low nitrogen use. *Galium aparine* was a particular problem at Boxworth in the Standard Rotation phase I (Cook *et al.*, 1996). Total weed numbers increased in wheats at

Boxworth and Drayton over the six-year period. These effects may have been due to decreased crop competition resulting from low nitrogen use. This was particularly evident in winter oilseed rape at Boxworth in 1991 and Boxworth and Drayton in 1994 (Cook *et al*., 1995).

The worst scenario was at Boxworth where reduced herbicide in the Alternative Rotation gave increased weed numbers, lower yields and large decreases in margin. At this site, increased numbers of weeds and neutral effects on yield in the Standard Rotation resulted in small increases in margin.

In conclusion, TALISMAN has shown that changing the rotation did not reduce herbicide use. Weed numbers increased with successive use of low herbicides and weed control was made more difficult with the continued use of low nitrogen rates. Yields were only slightly affected by reduced herbicide rates. Gross margins were greatly decreased at Boxworth, relatively unaffected at High Mowthorpe and increased at Drayton. There is scope for decreasing the rates of herbicide from label rates, but there is a need for information on when and where these reductions can be made to best effect.

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COIRE: THE IMPACT OF THE PRESENCE OF WEEDS, PESTS AND DISEASES ON CROP QUALITIES

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ABSTRACT

A survey and data analysis methodology is described that can assist in understanding the complexity of interactions between variables associated with arable farming. The approach can assist in the modelling of the impact of change, and the development of more sustainable approaches to farming. It is illustrated by examining the associations found between weeds, pests and diseases, where there is an association with oil and glucosinolate levels of oilseed rape grain. In particular, the presence of weeds is positively correlated with downy mildew and pod botrytis levels, which along with pod alternaria, were associated with an unexpected reduction in glucosinolate level. Autumn leaf miner and spring slug damage were associated with an increase in glucosinolate, and these grazers were associated with autumn weed levels. Some diseases and peach potato aphid were associated with reductions in oil content. These and other associations have implications for crop protection and warrant further investigation.

INTRODUCTION

The pressures on farmers to reduce environmental impact, improve production efficiency and produce quality crops to preserve profitability, has encouraged research into improved decision-making in crop husbandry and protection, and in the application of inputs. Farming system research on rotations such as the LINK Integrated Farming Systems project (Ogilvy *et al.*, 1995) and similar research elsewhere (e.g. Jordan *et al.*, 1995) has shown that inputs can be reduced and profitability maintained with varying levels of change to current intensive approaches. Pesticide management programmes have also been developed which are intended to optimise pesticide use to minimise environmental loading (e.g. Secher, 1995) and there has been considerable research into the precision application of inputs.

In order to examine the impact of novel policies and technological or decision-making advances on farming, and its environment as a whole, a base-line understanding of the interactions between farming practices and inputs, and between these and environmental factors, is required. The complexity of the system currently encourages researchers to only examine interactions that are readily hypothesised, but may be masking interactions that are of importance in modelling the impact of change. The COIRE (Crop Optimisation by Integrated Risk Evaluation) project is an attempt to develop methods which assist in determining the interactions which exist between husbandry, input, pest, weeds and diseases and environmental factors in farming, and has used winter oilseed rape and winter wheat as model crops. In this paper we examine some of these factors and their interactions, and associations with the quality of grain produced.

METHODS

The general methodology of COIRE is described by McRoberts *et al.* (1994 and 1995). Part of the project is a survey of 148 crops of winter oilseed rape in three seasons between 1993 and 1996. The survey covered many data points related to the crop and its husbandry and inputs, and environmental factors associated with the field and crop. The survey data utilised in this report are those of weed, disease and pest infestations despite routine pesticide usage and the dominant flora of associated field boundaries. A grain sample was taken after harvest of each crop and analysed for oil content and glucosinolate levels at ADAS Analytical Laboratories, Wolverhampton and utilised as indicators of quality. A technical introduction to the methods of statistical analysis and software is described in the Genstat Manual (1987) and McRoberts *et al.* (1994). The results presented are based on multivariate analysis which produce scatter plots and correlations. The scatter plots display the extent to which sites are inter-related.

RESULTS

Geographic and Edaphic Factors

Figure 1 displays the associations of all crop fields surveyed with a scatter plot resulting from cluster analysis of twenty characteristics/field descriptions such as soil and boundary type; that is, a geographic fingerprint. There is a clear separation of fields from the north-east (NE) of Scotland with these of the south-east (SE) and south-west (SW). In Figure 2 we examine the separation of 78 of the oilseed rape fields on the basis of nine soil chemical and mineral characteristics. The regions still tend to separate and remain relatively homogeneous, with the SW straddling the other regional scatters. The first axis, accounting for 30% of the variation, separates mainly acidic soils at the negative end from neutral alkaline soils. The second axis, accounting for 17% of variation, was dominated by potassium, (higher towards top of the plot) copper and boron (higher towards the bottom). Total nitrogen and sulphur content did not effect the scatter, indicating homogeneity in levels.

Biotic Factors

Table 1 lists the significant associations derived for interactions tested between pests, weeds and diseases with crop grain oil and glucosinolate levels. Particular associations of interest are the reduction in oil content from pest and disease attack (downy mildew in spring, light leaf spot on pods and late peach potato aphid), but more surprisingly the differences in response of total glucosinolate levels to pests and diseases. The two pest associations were strongly positive, whereas the three disease associations were negative, with botrytis pod severity showing a particularly strong negative association ($P = 0.001$).

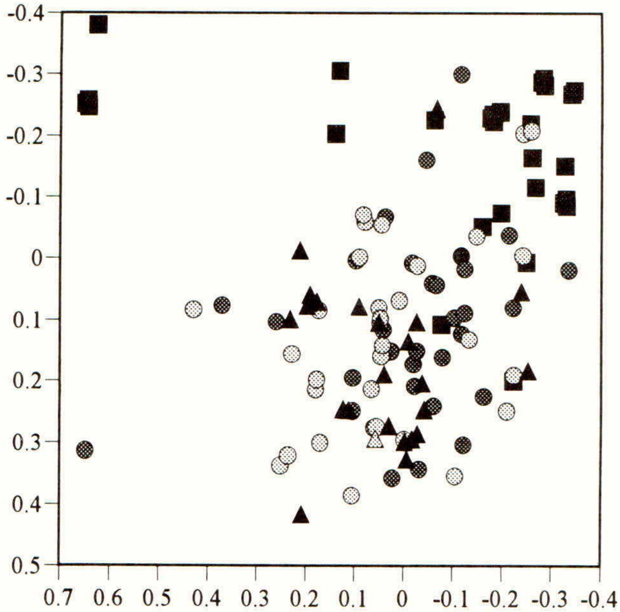

Fig. 1. Scatter plots of the relative similarity of 148 winter oilseed rape fields over three growing seasons, Symbols: squares, north-east; circles, two sets of observations for south-east; triangles, south-west.

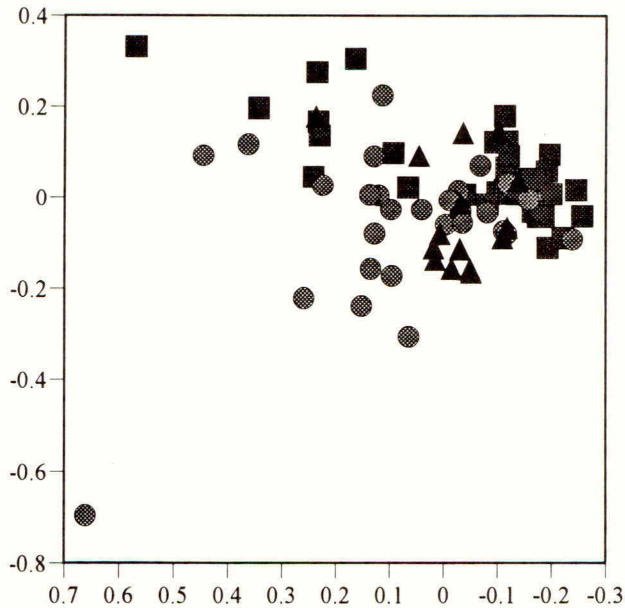

Fig. 2. Scatter plots of the separation of 78 oilseed rape fields from three regions on the basis on nine soil chemical and mineral characteristics. Symbols: squares, north-east; circles, south-east; triangles, south-west.

Weed cover in spring was marginally positively correlated (P = 0.05) with oil content, but more strongly associated with downy mildew in spring and botrytis on pods (P = 0.01).

Crop Qualities

There was a negative correlation between oil content and glucosinolate concentration in the seed (r = 0.330, 59 d.f., P = 0.01) overall. McRoberts *et al.* (1996) have shown with a subset of this data, that oil content tends to be higher in the NE.

DISCUSSION

Separation of the regions of Scotland in terms of the geographic and soil factors shown here is reflected in some of the biotic factors which are published elsewhere (e.g. weed levels: Davies *et al.*, 1997; light leaf spot: McRoberts *et al.*, 1996), and in oil: glucosinolate levels in seed (McRoberts *et al.*, 1996). The differences in oil and glucosinolate levels in grain may reflect the differences in geographic and soil factors, but evidence from these analyses indicate that differences in biotic factors may have an important function.

The complexity of the analysis of such data is exemplified by McRoberts *et al.*, (1996) who using a sub-set of this data, showed that there was a tendency for NE crops to have higher oil/lower glucosinolate levels in the grain and that light leaf spot levels are generally higher in the NE, although locally so in the SE. Given that light leaf spot is apparently associated with reduced oil content (Table 1), there is seemingly a contradiction. However, the association is not highly significant (P = 0.05) and presumably arises from a higher mean oil content base level in the NE. Weediness in the spring is also apparently correlated not just with increased oil content (P = 0.05), but also with downy mildew in the spring (P = 0.01) which is as indicated as above, associated with reduced oil content (P = 0.05). NE crops have been shown by Davies *et al.*, (1997), utilising this data base, to be generally weedier, so there is again an apparent conflict. This is explained by the analysis being for a reduction in oil content from a comparable base line.

This form of analysis is shown to be capable of producing associations which have hitherto remained undisclosed, although they have sometimes been suspected. For example, the close association of weediness in the spring with increased downy mildew (P = 0.01) could be associated with conditions within crop, particularly increased humidity. Similarly, the association between pod botrytis (P = 0.01) could be linked with the die-back of weeds as the crop canopy develops providing a source of inoculum. Given the apparent association with these diseases and reduced levels of glucosinolate in the seed, and that of downy mildew and oil content, we may be able to link weediness and crop quality effects. We cannot, as yet distinguish all possible interactions, so it must be emphasised that such correlations may be spurious or simply coincidental. However, certain associations warrant further investigation and we suggest the link between leaving weeds and disease levels in the crop with crop qualities is one such group of associations.

The differences in association with glucosinolate levels in the crop grain and crop grazing (in this case an increase in autumn leaf miner and spring slug damage) and disease (reductions in glucosinolates associated with downy mildew, alternaria and botrytis) also warrant further investigation. It is generally suggested that glucosinolate biosynthesis is stimulated by pest and pathogen attack (e.g. Wallsgrove *et al.*, 1995). The effects of pest attack are confirmed here for two pests, although perhaps surprisingly for early leaf miner infestation, but not for diseases. However, the glucosinolate analyses in this project were for grain alone, and the work of Wallsgrove *et al.* (1995) and others have concentrated on foliar synthesis. Nevertheless, these correlations may have repercussions for both disease and pest control strategies. We cannot yet distinguish through this analytical approach whether it is the diseases that are having the effect on glucosinolate, or whether some other environmental or crop variable is influencing both disease level and glucosinolate synthesis in a co-incidental manner. Certainly there are regional and environmental effects on crop growth and pest, weed and disease infestations, as well as oil: glucosinolate levels.

Table 1. Significant associations between pests, weeds and diseases and with grain oil content and glucosinolate levels (r = correlation coefficient; p = probability of significance)

Interaction		r (59 d.f.)	P
Downy mildew in early spring	x oil content	-0.268	*
Light leaf spot pod severity	x oil content	-0.268	*
Peach potato aphid (late)	x oil content	-0.375	**
Weediness in spring (% cover)	x oil content	0.289	*
Leaf miner damage in autumn	x glucosinolate level	0.442	***
Slug damage in late spring	x glucosinolate level	0.346	**
Downy mildew in late spring	x glucosinolate level	-0.315	*
Alternaria pod severity	x glucosinolate level	-0.271	*
Botrytis pod severity	x glucosinolate level	-0.444	***
Weediness in spring	x downy mildew in spring	0.337	**
Weediness in spring	x botrytis on pods	0.353	**

* 0.05; ** 0.01; *** 0.001

In conclusion, there is evidence of associations between overall weed levels and crop qualities, largely through links with disease levels. Of the pest associations noted, Davies *et al.* (1997) have noted a weakly significant (P=0.05) association between leaf miner attacks and the presence of volunteer potatoes. The former is also strongly associated with higher glucosinolate levels, as is spring slug damage, which is associated with autumn weed levels (P=0.05), as well as some specific weed species. It is unlikely, however, that overall weed levels are directly affecting crop grain oil or glucosinolate levels. Nevertheless, this relatively simple survey approach to examining the interactions between the variables associated with growing crops provides new insights into potential associations that could otherwise remain hidden, and will aid the characterisation of cropping systems. This can assist in the development of models which can be used to monitor potential effects of changes in productions systems and their environment, and may provide important insights to aid the development of more sustainable approaches to crop husbandry.

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INTEGRATION OF MECHANICAL AND CHEMICAL CULTIVATION (LOW RATES) FOR THE CONTROL OF *Panicum maximum* L. IN THE ROWS OF CITRUS (*Citrus cinensis* L.) CROP

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ABSTRACT

Herbicides for the control of weeds are normally used in bands (2 m each side) along the rows of citrus. Vegetation in the inter-rows is mechanically cultivated. During the spring-summer period (September-April), when high rainfall and temperature predominate, growth of vegetation is vigorous and residual herbicides have a shorter effective period of control, mainly in areas that are highly infested by *Panicum maximum*. For control, the producers use a mechanical cultivator at intervals of 20 - 30 days, in an attempt to keep these areas clear. This work discusses the application interval of herbicides (glyphosate and sulfosate) at low doses after *Panicum maximum* has been cut, but not waiting for the total growth, the normal production determined by the producer. Under the proposed system it is possible to apply 2.0 l/há (approximately 5.0 l/há) 20 - 30 days after cutting, on the plants with a low stand, and to obtain excellent levels of control. Using the mechanical cultivation integration, it is possible to reduce the final costs for the control of this weed, normally with 2 mechanical cultivations and 2 applications per year. This methodology provides a good level of control at low costs and lower risks for the environment.

INTRODUCTION

Nowadays, Brazil is the largest world producer of citrus, with a production of 16,700 millions ton in 95/96 and a planted area of 850,000 ha. (Agrianual 97, 1996). The crop is found all over the Country, and has a great economical and social importance for several States. (Amaro et al, 1991).

According to Blanco (1985), weeds competition in citrus orchards results in losses of about 40%. Blanco & Oliveira (1978) determined that the best time to control weeds is December to March, as a function of yield losses due to competition, besides reducing annual grasses as well annual and perennial dicotyledon, effects that do not occur in their totality when the control is made in any other time. According to Andersen (1966), the soil must be covered during the rainy season and free of weeds during the dry season; this is the reason that chemical control is recommended only in the bands of 4 m width along the planting line and using a mechanical cultivator (rainy season) to reduce erosion effects and harrowing during the dry season. With this system, a good weed control is achieved with economical viability. Durigan (1985) has already mentioned the hypothesis that the excessive use of mechanical control, cutting the roots (with a great loss of energy to form them again) and the lack of a hibernal period (resting period and reorganization of the plant cycle), would be the main factors responsible for the short useful life of the plants that constitute our orchards. Besides, mechanical cultivation can subject the plants to gummosis of *Phytophthora*.

The main weeds that occur in citrus orchard in Sao Paulo State, according to Victoria Filho (1988) are: *Brachiaria plantaginea*, *Digitaria horizontalis*, *Cenchrus echinatus*, *Eleusine indica*, *Cynodon dactylon*, *Panicum maximum*, *Rhynchelitrum roseum*, *Digitaria insularis*, *Paspalum notatum*, *Brachiaria decumbens*, *Cyperus rotundus*, *Commelina benghalensis*, *Bidens pilosa*, *Acanthospermum hispidum*, *Sida* spp, *Amaranthus* spp, *Emilia sonchifolia*, *Ageratum conyzoides*, *Galinsoga parviflora*, *Ipomoea* spp, *Portulaca oleracea*, *Richardia brasiliensis* and *Sonchus oleraceus*. Since many citrus plantations were planted in areas previously used for pastures, the problem is aggravated due to the competition and aggressiveness of *Panicum maximum*. This work aimed to compare the efficacy of sulfosate, glyphosate and paraquat+diuron herbicides, applied in the rows at low rates, supplemented with mechanical cultivation as necessary to control *P. maximum*. Pesticides were applied at initial stages of growth, rather than those recommended by the manufacturers of the products (higher stand - in relation to the equivalence of aerial part and radicular system). The assay was conducted in the field for two consecutive years.

Traditional tillage systems

Chemical weed control in citrus is a normal practice in the main producing region of Brazil. São Paulo State is the major producer with 84% of the Brazilian market (Agrianual 97, 1996). The application is normally made by tractor sprayer equipped with a protected side bar covering a band of 2.0 m width; on a round trip, it covers the two bands along the citrus rows, and the recommended dose is 2.0 or 3.0 l/ha of the commercial product glyphosate, sulfosate or paraquat+diuron. The central band (inter row) is controlled through mechanical cultivation which requires from one to three passes of the tractor depending on its cutting width. (Foloni, 1995).

MATERIALS AND METHODS

The trial was conducted in the central region of Sao Paulo State; the variety used was Valencia, planted in 1990 at a spacing of 4.0 x 8.0 m. The soil was Haplorthox, with 10.4 g/cm^3 of organic matter and pH 5.4. The experimented design was randomized blocks with three replicates, each plot containing 10 plants. Treatments (Tables 1 and 2) were made post-emergence along the citrus row at different intervals after cutting (mechanical cultivator). Eight applications were made in the first year at 1, 3, 5, 8, 12, 16 and 24 days and afterwards at 17 and 96 DAC (days after cutting). In the second year, applications were made at 8, 18, 22, 28, 31, 37 and 43 DAC. As a function of growing, it was necessary to mechanically cultivate again and to make the second application with paraquat+diuron at 30 and 132 DAC for all treatments (except for treatments 7 to 14 - mechanical cultivator was not used).

Weed infestation

Weeds infesting the experimental area were mainly *Panicum maximum* (80%), *Commelina benghalensis* (10%) and *Bidens pilosa* (10%).

Application and evaluations

In the first year, herbicides were applied on seven different dates, 1, 3, 5, 8, 12, 16 and 24 DAC, on January 19, 1996, through CO_2 sprayer operating at a pressure of 2.78 bar, equipped with 4 Spraying Systems nozzles XR 110.03, at the rate of 185-200 l/ha. Evaluations were made by visual scoring at 7, 15, 30 and 45 DAC (after the first and second applications) and also at 62 and 90 DAC (for the second application) in the first year. In the second year, evaluations were made at 7, 14, 21, 28, 35, 70 and 90 DAC (first application) and at 7, 14, 21, 43 and 60 DAC (second application). In the results, zero equals no control, whilst 100% equals to total death.

Table 1. Tested treatments in citrus rows and intervals from mechanical cutting (mechanical cultivator) and herbicide application - 1995/96 seasons

Treatments	Product	Dose (kg a.i./há)	1st. application	2nd. application
1	paraquat + diuron	0.40 + 0.15	1	17
2	glyphosate	0.96	(20.01.96)	(17.04.96)
3	sulfosate	0.96		
4	paraquat + diuron	0.40 + 0.15	3	17
5	glyphosate	0.96	(22.01.96.96)	(17.04.96)
6	sulfosate	0.96		
7	paraquat + diuron	0.40 + 0.15	5	17
8	glyphosate	0.96	(24.01.96)	(17.04.96)
9	sulfosate	0.96		
10	paraquat + diuron	0.40 + 0.15	8	17
11	glyphosate	0.96	(27.01.96)	(17.04.96)
12	sulfosate	0.96		
13	paraquat + diuron	0.40 + 0.15	12	17
14	glyphosate	0.96	(31.01.96)	(17.04.96)
15	sulfosate	0.96		
16	paraquat + diuron	0.40 + 0.15	16	17
17	glyphosate	0.96	(04.02.96)	(17.04.96)
18	sulfosate	0.96		
19	paraquat + diuron	0.40 + 0.15	24	17
20	glyphosate	0.96	(12.02.96)	(17.04.96)
21	sulfosate	0.96		
22	Check	-	-	-

1st. mechanical cutting (initial): 19.01.96; 2nd. mechanical cutting: 30.03.96, except treatments 7 to 14; 3rd. mechanical cutting: 08.02.96; Farm area: 1 mechanical cutting each 45 days (total of 5).

Table 2. Tested treatments in citrus rows and intervals from mechanical cutting (mechanical cultivator) and application of the herbicides - 1996/97 seasons

Treatments	Product	Dose (kg a.i./há)	1st. application	2nd. application
1	glyphosate	0.96	8	30
2	sulfosate	0.96	(14.12.96)	(17.04.97)
3	glyphosate	0.96	18	30
4	sulfosate	0.96	(14.12.96)	(17.04.97)
5	glyphosate	0.96	22	30
6	sulfosate	0.96	(28.12.96)	(17.04.97)
7	glyphosate	0.96	28	132
8	sulfosate	0.96	(03.01.96)	(17.04.97)
9	glyphosate	0.96	31	132
10	sulfosate	0.96	(06.01.96)	(17.04.97)
11	glyphosate	0.96	37	132
12	sulfosate	0.96	(01.14.96)	(17.04.97)
13	glyphosate	2.40	43	132
14	sulfosate	2.40	(20.01.96)	(17.04.97)
15	Check	-	-	-

1st. mechanical cutting (initial): 06.12.96; 2nd. mechanical cutting: 17.03.97, except treatments 7 to 14; 2nd herbicide application (2nd year): paraquat + diuron at 0.40 + 0.15 kg a.i./ha; 3rd. mechanical cutting: 30.07.97
Farm area: 1 mechanical cutting each 45 days (total of 6).

Table 3. First year. Percentage of control of *Panicum. maximum* after first application of herbicides at 7, 14, 30, 45 and 65 DAC and after second cutting and application of herbicides at 7, 15, 30, 45, 62 and 90 DAT, with the respective intervals from mechanical cultivation and application - Bariri - SP - Brazil - 1996/97 seasons

N°	Treatments	Dose (kg a.i./ha)		% control - First application				
			DAC	7	14	30	45	65
1	paraquat+diuron	0.40 + 0.15	1	70.0	63.3	0	0	0
2	glyphosate	0.96		45.0	36.7	13.3	0	0
3	sulfosate	0.96		50.0	36.7	10.0	0	0
4	paraquat+diuron	0.40 + 0.15	3	70.0	88.3	90.0	63.3	21.7
5	glyphosate	0.96		50.0	67.7	86.7	81.7	63.3
6	sulfosate	0.96		55.0	70.0	83.3	81.7	63.3
7	paraquat+diuron	0.40 + 0.15	5	75.0	75.0	0	0	0
8	glyphosate	0.96		46.7	70.0	46.7	20.0	13.3
9	sulfosate	0.96		50.0	68.3	43.3	20.0	0
10	paraquat+diuron	0.40 + 0.15	8	80.0	63.3	0	0	0
11	glyphosate	0.96		0	73.3	70.0	73.3	20.0
12	sulfosate	0.96		0	73.3	76.7	90.0	20.0
13	paraquat+diuron	0.40 + 0.15	12		71.7	20.0	20.0	0
14	glyphosate	0.96			71.7	73.3	83.3	60.0
15	sulfosate	0.96			73.3	81.7	90.0	63.3
16	paraquat+diuron	0.40 + 0.15	16		78.3	20.0	20.0	3.3
17	glyphosate	0.96			53.3	70.0	86.7	53.3
18	sulfosate	0.96			66.7	73.3	86.7	63.3
19	paraquat+diuron	0.40 + 0.15	24			56.7	20.0	0
20	glyphosate	0.96				70.0	100	98.3
21	sulfosate	0.96				68.3	98.3	95.0
22	Control	-		0	0	0	0	0
Treatments				74.9**	52.86**	15.36**	271.8**	159.59**
C.V./(%)				8.09	7.49	32.23	8.97	16.01
D.M.S. Tukey 5%				12.702	14.551	47.26	13.172	14.506

N°	Treatments	Dose		% control - Second application					
			DAC	7	14	30	45	62	90
1	paraquat+diuron	0.40 + 0.15	17	88.3	95.7	96.7	91.7	70.0	76.7
2	glyphosate	0.96		85.0	97.3	98.7	100	100	100
3	sulfosate	0.96		85.0	97.6	93.3	100	100	98.3
4	paraquat+diuron	0.40 + 0.15	17	96.7	96.0	96.7	90.0	73.3	86.7
5	glyphosate	0.96		83.3	95.7	97.3	100	100	98.3
6	sulfosate	0.96		83.3	95.0	96.3	100	100	98.3
7	paraquat+diuron	0.40 + 0.15	17	93.3	97.0	76.7	78.3	73.3	83.3
8	glyphosate	0.96		83.3	98.0	98.7	97.7	100	99.0
9	sulfosate	0.96		83.3	97.7	98.3	98.7	100	98.3
10	paraquat+diuron	0.40 + 0.15	17	96.7	94.0	95.7	78.3	83.3	80.0
11	glyphosate	0.96		81.7	96.7	98.7	98.3	99.3	98.3
12	sulfosate	0.96		81.7	95.7	98.7	96.7	98.3	99.3
13	paraquat+diuron	0.40 + 0.15	17	96.7	96.3	98.3	93.3	96.7	91.7
14	glyphosate	0.96		76.7	98.3	98.3	98.3	100	100
15	sulfosate	0.96		80.0	98.3	99.0	99.3	100	100
16	paraquat+diuron	0.40 + 0.15	17	89.3	93.3	92.7	83.3	70.0	78.3
17	glyphosate	0.96	96	78.3	97.3	97.3	98.3	100	98.3
18	sulfosate	0.96		78.3	97.7	98.3	99.3	100	100
19	paraquat+diuron	0.40 + 0.15	17	96.7	96.0	95.0	86.7	76.7	85.0
20	glyphosate	0.96	96	94.3	98.3	99.3	100	100	100
21	sulfosate	0.96		93.3	99.3	100	100	100	100
22	Control	-		0	0	0	0	0	0
Treatments				67.24	361.73	91.62	94.67	76.67	47.57
C.V./(%)				5.02	2.04	4.15	4.21	5.13	6.05
DMS Tukey 5 %				12.992	5.878	11.945	11.882	14.14	16.917

Table 4. Second year. Percentage of control of *Panicum maximum* after first application of the herrbicides at 7, 14, 21, 28. 35. 55. 70 and 90 DAC and after application of herbicides at 7, 14, 21, 43 and 60 DAT, with the respective intervals from mechanical cultivation and application - Bariri, SP, Brazil - 1996/97 seasons

Treatments		Dose		% control - First application								
			DAC	7	14	21	28	35	55	70	90
1	Gl	0.96	8	71.7	81.7	91.7	66.7	93.3	93.3	100	43.3
2	Sulf	0.96		63.3	81.7	91.7	66.7	95.0	93.3	100	40.0
3	Gl	0.96	18		70.0	66.7	76.7	83.3	85.0	83.3	43.3
4	Sulf	0.96			70.0	66.7	78.3	83.3	85.0	80.0	40.0
5	Gl	0.96	22		50.0	53.3	75.0	83.3	86.7	76.7	63.3
6	Sulf	0.96			63.3	63.3	80.0	85.0	88.3	76.7	65.0
7	Gl	0.96	28		3.3	66.7	80.0	86.7	88.3	83.3	76.7
8	Sulf	0.96			13.3	66.7	83.3	88.3	88.3	85.0	78.3
9	Gl	0.96	31			36.7	60.0	75.0	80.0	81.7	81.7
10	Sulf	0.96				35.7	66.7	75.0	78.3	78.3	78.3
11	Gl	0.96	37				10.0	63.3	75.0	73.3	75.0
12	Sulf	0.96					13.3	65.0	78.3	73.3	75.0
13	Gl	2.40	43	0				95.0	96.3	97.0	98.7
14	Sulf	2.40						93.3	96.0	97.0	97.7
15	Control				0	0	0	0	0	0	0
Treatments					31.33	29.03	6.55	79.67	51.44	102.89	69.7
C.V./(%)					21.52	14.50	34.47	5.92	6.96	5.14	8.5
DMS Tukey 5%					29.678	24.63	59.559	13.821	16.927	12.223	16.31

Treatments		Dose		% control - Second application				
			DAC	7	14	21	45	60
1	Glyphosate	0.96	30	95.0	100	95.0	95.0	90.0
2	Sulfosate	0.96		95.0	100	95.0	96.7	91.7
3	Glyphosate	0.96	30	95.0	100	95.0	96.7	91.7
4	Sulfosate	0.96		95.0	100	95.0	98.3	93.3
5	Glyphosate	0.96	30	95.0	100	95.0	97.7	91.7
6	Sulfosate	0.96		95.0	100	95.0	97.3	91.7
7	Glyphosate	0.96	132	90.0	100	76.7	76.7	63.3
8	Sulfosate	0.96		88.3	100	76.7	78.3	68.3
9	Glyphosate	0.96	132	83.3	100	76.7	88.3	78.3
10	Sulfosate	0.96		81.0	100	73.3	76.7	63.3
11	Glyphosate	0.96	132	85.0	98.7	70.0	76.7	66.7
12	Sulfosate	0.96		83.3	99.3	70.0	78.3	63.3
13	Glyphosate	0.96	132	100	100	99.3	99.3	96.7
14	Sulfosate	0.96		100	100	99.7	98.3	96.7
15	Control			80.0	70.0	60.0	0	0
Treatments				24.19	1005.21	21.71	15.45	13.99
C.V./(%)				2.60	0.43	5.40	13.17	15.14
DMS Tukey 5%				7.089	1.268	13.875	33.136	34.805

RESULTS AND DISCUSSION

The results are summarized in Tables 3 and 4. The control data for the main weed - *Panicum maximum* - occurring in the rows are shown in Table 3 for the first year and in Table 4 for the second year. The results for the first year show a short period of control, with consistent results for application as from the 12° day after cutting. The applications with paraquat+diuron showed low efficacy. The results for the second application (first year) generally show good efficacy, although this was lower for the mixture of paraquat+diuron. It must be mentioned that for the treatments with glyphosate and sulfosate (after 16 and 24 DAC of the first application) the mechanical cultivator was not used (for the second application) and the control results remained at an excellent level. For the second year, the treatment with paraquat+diuron was not made because of its low performance in the first year. As only glyphosate and sulphosate were used, the intervals after mechanical cultivation were increased. At the last season (43 DAC) recommended dose - 2,40 kg a.i./há - was used. The results showed a good level of control until 70 DAT. At 90 DAT only the treatments made after 22 DAC were shown to be acceptable. After the second mechanical cutting (30 DAC), the mixture paraquat+diuron was applied in all treatments. This application was designed to control *P. maximum* and *Commelina*. The results showed a good level of control where the second cutting was made. Economically, it was better where the herbicides were applied without the second cutting. These data show that it is possible to use the combination of mechanical cultivation, with application of sulfosate and glyphosate at low doses where *P. maximum* presents a low stand (from 16 to 30 days after cutting) with two applications per year.

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