Inter- and Cross-row Cultivation, Atrazine Application and Band Spraying Effects on 'Grasslands Maku' Lotus (*Lotus uliginosus* Schk.) Seed Production

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ABSTRACT

Trials with treatments of atrazine, broadcast or band sprayed, and inter-row and cross-row cultivation were imposed on established 'Grasslands Maku' lotus (*Lotus uliginosus* Schk. syn. *L. pedunculatus* Cav.) seed stands over four seasons between 1984 and 1990.

Broadcast spraying of atrazine (2.0 kg ai ha^{-1} in split applications, 1.5 and 0.5 kg ai ha^{-1}) three weeks apart significantly increased seed yields by 119% above control treatments in the first trial, but in the second trial similar and lower atrazine applications which were not split, decreased seed yields.

Cross-row cultivation in spring and early summer increased seed yields by 176% above that of uncultivated controls in the third trial. In other trials inter-row cultivation had no effect on seed yields. However, when plots had both inter-row and cross-row cultivation, seed yields fell by 33% below that of control plots.

The herbicide chlorimuron desiccated Maku lotus in the spring, but after stems regrew in early summer and a dry period occurred during the seed development phase in late summer, seed yields of 950 kg ha^{-1} were produced. The implications of site selection and spring desiccation of the seed crop are discussed.

***Additional index words:* atrazine, chlorimuron, cultivation, herbicide desiccation, umbel density.**

INTRODUCTION

In perennial pasture legumes there is a close negative relationship between plant density and subsequent seed yields. Low plant densities of between 20 and 30 plants m^{-2} have given the highest seed yields in *Trifolium pratense* (Clifford, 1974), *Medicago sativa* (Kowithayakorn and Hill, 1982), *Lotus corniculatus* (McGraw, Beuselinck and Ingram, 1986) and *L. uliginosus* (Hare, 1984).

Grasslands Maku lotus (*L. uliginosus*) is a rhizomatous legume which will produce a very dense stand over the five years it is allowed within New Zealand Seed Certification (Anon, 1985). Some farmers believe the rhizomatous stems should be encouraged to grow, as it is these stems which become the main seed bearing stems (Neal, 1983). However, if Maku lotus seed stands produce too many stems, many of them either remain vegetative or fail to branch and then produce few umbels per unit area (Hare, 1984). Usually Maku lotus seed stands have decreased in seed yields from year two to year five and it is believed that one of the main reasons has been an overly dense stand.

To reduce tiller populations in mature grass seed stands of cocksfoot (*Dactylis glomerata* L.) mechanical gapping at 24 cm intervals with a hoe increased seed yields (Lambert, 1963). This 'gapping' technique also significantly increased flower numbers by 70% in white clover seed crops when [2]glyphosate and creasote were applied to remove excess stolons; the most successful technique being cross gapping leaving 25 x 25 cm squares (Lewis, James and Evans, 1983). But further work with ethofumesate and 2,3,6-tricholorobenzoic acid (TBA) with dicamba, MCPA and mecoprop, did not increase seed yields (Marshall and James, 1986). Mechanically gapping 8 cm and leaving 30 cm of plants, either cross cut both ways or one way only, improved seed yields of white clover cv. Kent by between 23 and 26% (Lewis, James and Marshall, 1984). Cross-gapping wide-spaced rows of lucerne has improved seed yields by 11% (Jones and Pomeroy, 1962).

Inter-row cultivation or thinning of lucerne has also produced seed crops that are shorter, lodge less, are less susceptible to frost injury, flower earlier, have more upright growth allowing bees greater access to flowers, and have increased nectar secretion and concentration resulting in better pollination (Pedersen, Bohart, Levin, Nye, Taylor and Haddock, 1959; Pedersen and Nye, 1962; Pedersen, Bohart, Marble and Klostermeyer, 1972). Also, thinned plants of lucerne have high root carbohydrate reserves and produce more seeds, more pods per stem and seeds per pod than non-thinned plants with reduced concentrations of carbohydrates (Dobrenz and Massengale, 1966).

The objective of the following trials was to reduce stem populations in mature Maku lotus seed stands, either with herbicides or by mechanical methods. It was hypothesised that Maku lotus at low stem densities would give higher seed yields by branching and producing more umbels per unit area than at high stem densities.

MATERIALS AND METHODS

The trials were conducted over four seasons between 1984 and 1990 at the DSIR Grasslands farm 'Aorangi', Manawatu, New Zealand (latitude 40° south), on a weakly leached, slow accumulating, recent gley soil from poorly drained quartzo-feldspathic silty alluvium (Kairanga silt loam). Rainfall was measured at a meteorological station, 500-1000 m from the trial sites. Details of field and trial management are given in Table 1.

[1] DSIR Grasslands, Private Bag, Palmerston North, New Zealand. Received for publication 8 August 1991.
[2] Common names of herbicides are those given by the Weed Science Society of America.

Table 1. Details of field and experimental management.

	Trial			
	1	2	3	4
Year of harvest	**1985**	**1986**	**1989**	**1990**
Month sown	Oct 1980	Oct 1980	Oct 1986	Mar 1987
Seed rate (kg ha^{-1})	2 kg	2 kg	2 kg	2 kg
Row space	60 cm	60 cm	45 cm	60 cm
Plot size	10 x 3 m	8 x 3 m	20 x 6 m	10 x 6 m
Herbicides in year of trial only	24 Sept 1984 2,4-DB (1.2 kg ai ha^{-1}) ethofumesate (2 kg ai ha^{-1}) ioxynil (500 g ai ha^{-1})	30 May 1985 asulam (1.2 kg ai ha^{-1}) paraquat (1.2 kg ai ha^{-1}) atrazine (1.5 kg ai ha^{-1})	28 Nov 1988 haloxyfop (200 g ai ha^{-1}) 2,4-DB (1.6 kg ai ha^{-1}) ethofumesate (2 kg ai ha^{-1})	20 Jul 1989 chlorimuron (30 g ai ha^{-1}) haloxyfop (200 g ai ha^{-1})
Insecticides in year of trial only	11 Dec and 16 Jan 1984 dichlorvos (200 ml ai ha^{-1})	-	1 Feb 1989 cyhalothin (10 g ai ha^{-1})	-
Date sheep last grazed	15 Jul 1984	1 Sept 1985	15 Sept 1988	15 Jul 1989
Harvest date	8 Feb 1985 26 Feb 1985 High atrazine plots only	10 Feb 1986	27 Feb 1989	16 Feb 1990

Trial 1 (1984-1985)

This experiment was laid out in a complete randomised block design with four treatments each with six replications. The treatments which were applied on July 19, 1984 were atrazine at 0.5 kg ai ha^{-1}, broadcast sprayed; atrazine at 2 kg ai ha^{-1} (split application 1.5 kg on July 19 and 0.5 kg on August 9), broadcast sprayed; inter-row cultivation, 40 cm cultivated, 20 cm of Maku lotus row left intact; and a control which was not cultivated or sprayed.

At harvest, 1 m^2 areas were cut from each plot for seed yield, and the cut material air dried, threshed and cleaned. Seed yields and one thousand seed weight (TSW) were corrected to 12% seed moisture content. Immediately adjacent to the area harvested for seed yield a 50 x 30 cm quadrat was cut on the same day for seed yield component analysis; reproductive stems, vegetative stems and mature umbel numbers were counted from the whole sample and pods per umbel were counted from 50 mature umbels.

Trial 2 (1985-1986)

In this complete randomised block designed trial, six treatments each with four replications were laid out on 9 September 1985. The treatments were atrazine at 1.0, 1.5 and 2.0 kg ai ha^{-1}, all broadcast sprayed, an inter-row cultivation of 40 cm to leave 60 cm rows of Maku lotus intact, an inter- and cross-row cultivation of 40 cm to leave 60 x 60 cm of Maku lotus squares intact and a control. At harvest, 2 x 1 m^2 areas were cut for seed yield from each plot and a 50 x 30 cm adjacent area cut for seed yield component analysis as described in Trial 1.

Trial 3 (1988-1989)

In this complete randomised block designed trial there were two treatments each replicated 16 times; a cross-row cultivation of 47 cm to leave 13 cm of row intact - cultivation took place on 17 August 1988 and 1 November 1988, and control plots left uncultivated. At harvest, 4 x 0.25 m areas were cut from each plot. Seed yield components were not measured.

Trial 4 (1989-1990)

Five treatments were replicated four times in a complete randomised block design. Treatments which were laid out on 28 July 1989 were inter-row cultivation of 47 cm down the row to leave 13 cm of row intact, inter- and cross-row cultivation of 47 cm to leave 13 cm squares of Maku lotus intact, atrazine at 2.0 kg ai ha^{-1} band sprayed down the row (50 cm width) to leave 10 cm wide rows intact and atrazine at the above rates cross sprayed down and across the rows (50 cm width) to leave 10 cm squares intact. At

harvest 4 x 0.25 m areas were cut from each plot for seed yield and a 0.25 m^2 area taken for seed yield component analysis.

RESULTS

Rainfall data

Rainfall for the summer growing period (October to February) varied between seasons (Table 2). The first trial (1984/85) had good rainfall through the growing-flowering phase (October-June), with a dry main pod maturing period (late January to February). In the next season (Trial 2), rainfall was higher than normal from November to February. The 1988/89 season saw a very dry December (18 mm rain during the main flowering period), followed by adequate rainfall in January and February. The final trial (1989/90) had good rainfall from October to early January followed by a very dry February.

Table 2. Total monthly rainfall for the summer period of the trials.

	Rainfall (mm)			
	1984/85	1985/86	1988/89	1989/90
October	57	32	77	125
November	86	101	80	33
December	79	112	18	57
January	171	137	62	103
February	44	125	77	12

Seed yield

Atrazine at 2.0 kg ai ha^{-1} (split application) increased seed yields by 119% over control treatments in Trial 1 (Table 3). In Trial 2 all treatments produced lower seed yields than the control treatment, particularly atrazine treatments. These treatments lowered seed yields by up to 43%. Cultivation did not significantly affect seed yields in both Trial 1 and 2. In Trial 3 seed yields were increased by 176% above control treatments by cross-row cultivation. However, in Trial 4 inter- and cross-row cultivation decreased seed yields by over 300 kg ha^{-1}. Band spraying had no effect on seed yields in Trial 4. Seed yields in Trial 4 were eight to nine times greater than seed yields recorded in previous trials.

Seed yield components

Atrazine at 2.0 kg ai ha^{-1} (split application) in Trial 1 increased reproductive stems m^2 by more than 400 over control treatments, and over 300 over the lower rates of atrazine (Table 4). Reproductive stems in trials 2 and 4 were not increased significantly by any treatments; inter- and cross-row cultivation lowered reproductive stems by 35% compared to control plots in Trial 4.

Table 3. Effect of row cultivation and atrazine on Maku lotus seed yields.

	Seed Yield (kg ha^{-1})			
Treatments	Trial 1	Trial 2	Trial 3	Trial 4
Control	151	101	64	937
Inter-row cultivation	181	91	-	990
Cross-row cultivation	-	-	177	-
Inter- and cross-row cultivation	-	90		627
Atrazine 0.5 kg ai ha^{-1}	223	-	-	-
Atrazine 1.0 kg ai ha^{-1}	-	60	-	-
Atrazine 1.5 kg ai ha^{-1}	-	57	-	-
Atrazine 2.0 kg ai ha^{-1}	332	65	-	-
Band spraying down the row	-	-	-	942
Band spraying down and across the row	-	-	-	948
LSD ($P < 0.05$)	87	43	47	270

DISCUSSION

These trials have illustrated the difficulty of managing Maku lotus seed stands and, in particular, trying to manipulate management practices to increase seed yield. In the first trial the application of 2 kg ai ha^{-1} of atrazine was split, three weeks apart. There was an almost total desiccation of all above-ground leaves and stems in August, and stems did not start to regrow until late October, yet the highest seed yields in this trial were from this treatment.

In Trial 2 there was no above ground desiccation even though the last grazing was in early September, and green shoots and leaves were present in all treatments. No treatments increased seed yields.

Table 4. Effect of row cultivation and atrazine on Maku lotus seed yield components.

	Reproductive stems m^{-2}	Umbels m^{-2}	Pods per umbel	TSW[1] (g)
Trial 1				
Control	330	908	6.9	0.81
Inter-row cultivation	428	1470	6.4	0.80
Atrazine 0.5 kg ai ha^{-1}	377	1259	6.9	0.83
Atrazine 2 kg ai ha^{-1}	742	2210	6.5	0.83
LSD ($P < 0.05$)	155	535	n.s[2]	n.s
Trial 2				
Control	203	343	7.1	0.76
Inter-row cultivation	168	336	7.2	0.80
Inter- and cross-row cultivation	243	281	6.7	0.77
Atrazine 1 kg ai ha^{-1}	173	244	6.4	0.75
Atrazine 1.5 kg ai ha^{-1}	294	525	7.6	0.76
Atrazine 2.0 kg ai ha^{-1}	262	301	6.4	0.75
LSD ($P < 0.05$)	104	200	1.0	n.s
Trial 4				
Control	493	3315	10.1	0.78
Inter-row cultivation	428	3172	9.0	0.77
Inter- and cross-row cultivation	316	2381	9.4	0.76
Band spraying down row	447	3119	8.8	0.76
Band spraying down and across the row	447	3369	8.9	0.74
LSD ($P < 0.05$)	146	975	n.s	n.s

[1] One thousand seed weight
[2] Not significant

In Trial 3 the last cross-row cultivation on November 1 effectively removed most of the stems and shoots from between the cross-rows, and in the process clipped back the intact Maku lotus to 5 cm above ground level. New shoots grew from the intact row during November and December. Seed yield from this treatment was nearly three times the control treatment.

In Trial 4 chlorimuron was applied on 20 July to control white clover (Hare and Rolston, 1990). Chlorimuron completely desiccated all above ground stems and leaves. New shoots which did not start to regrow until mid - late October came from the plant crowns only, and not from the rhizomes. All treatments, except for the severely cultivated treatment, were equally affected and, as such, gave similar seed yields. Stem numbers in this latter treatment were reduced severely by both cultivation and chlorimuron in early spring, and reproductive stems that did regrow in November produced far fewer umbels than other treatments.

Seed yields in Trial 4 were the highest yet reported for a Maku lotus seed crop. Umbel numbers which averaged 3000 m^{-2} were ten times the number in Trial 2 (the lowest yielding seed season). The high numbers of umbels were probably related to two factors, field management and rainfall. In field management of the crop in Trial 4, chlorimuron desiccated the stand until late October. The stems then grew vigorously from the main crown and not from rhizomes further out in the 60 cm spaced rows. Previous studies in *Lotus corniculatus* have shown that shoots produced in October, November and December produced the most inflorescences (Li and Hill, 1988) and that seed yield in *L. corniculatus* is determined by number of umbels (Stephenson, 1984). In these studies it appears that if management delays shoot or stem production until late October, more reproductive stems will appear. In Trial 1 the high rate of atrazine (2.0 kg ai ha^{-1} as a split application) also delayed new shoot formation until late October, resulting in the formation of a very high number of umbels.

The second factor which affected Maku lotus seed yields was summer rainfall. Trials sites were on a heavy moisture retentive soil. Stems produced in trial 4 grew under good rainfall from October to January. Peak flowering occurs in the middle of December for Maku lotus in New Zealand (Hare, 1984). Pods in Trial 4 which ripened under dry conditions in late January and February, still had sufficient soil moisture to enhance pod and seed fill. Lack of February rainfall prevented growth of vegetative stems which can compete with reproductive stems, or cover developing pods, and prevent adequate ripening.

The lower seed yields from Trial 2 were probably due to the wet summer which allowed vegetative stems to develop and cover the flowers, causing many of them to either abort or rot. Umbels m^{-2} for that season were extremely low, as were the seed yields. The better seed yields of Trial 1 were produced when November to early January rainfall was good, allowing reproductive stems to grow and develop without moisture stress, followed by a dry period in late January and February.

Low December rainfall in Trial 3 (1988/89) probably resulted in low flower bud formation. Even though rainfall did increase in January and February these months did not have the day lengths required for maximum flowering in Maku lotus (Hare, 1984).

Maku lotus remains a most difficult legume from which to produce consistently high seed yields. These trials attempted to develop some agronomic management practices which may produce more consistent seed yields. Firstly, it appears that spring desiccation of the crop is necessary to prevent spring rhizome stem formation and encourage October, November and December crown stem development without interference from earlier formed vegetative rhizome stems. Secondly, on heavy moisture retentive soils, heavy rainfall after the period of maximum flowering and seed pod formation and development, hinders reproductive development. Choosing the right site with suitable soils and a reliable dry January-February, without excessive heat to cause pod shattering (Hare and Lucas, 1984), may go a long way in helping to produce good seed yields of Maku lotus. Management then could be used to manipulate this site advantage, and make Maku lotus seed production a viable cash crop proposition in most years.

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