Weed control in *Leucaena leucocephala* (Lam.) de Wit and associated toxicity effects of some pre-emergence herbicides

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Summary

Seven pre-emergence herbicides were evaluated alone and in combination in newly sown stands of leucaena *(Leucaena leucocephala)* in south-eastern Queensland. Reduction in leucaena emergence and survival were observed with atrazine, diuron and prometryne applied at 2 to 4 kg ha^{-1} and with 2,4-D applied at 2 to 8 kg ha^{-1}. Pelleting leucaena seed with either lime or activated carbon before sowing failed to prevent these effects. Chlorthal at 8 to 12 kg ha^{-1} and nitralin at 1 to 3 kg ha^{-1} were acceptable from the point of view of toxicity to leucaena, but did not give consistently improved yields of leucaena over unweeded controls in five separate trials. Diphenamid at 4 to 8 kg ha^{-1} had no apparent toxic effects on leucaena, and resulted in yields equivalent to hand-weeded controls in the two trials in which it was evaluated. Similar results were obtained whether herbicides were applied before or after rainfall or irrigating, and there was no effect of a delay of up to 30 days between applying the herbicides and the first rainfall. Lack of persistence of the herbicides in the soil following rainfall or irrigating was a problem, allowing later germinating weeds to establish and compete with leucaena.

Introduction

Leucaena (*Leucaena leucocephala* (Lam.) de Wit cv. Peru) has the potential to provide a high quality protein supplement for cattle grazing native pastures dominated by forest blue grass (*Bothriochloa bladhii* (Retz.) S.T.Blake) and black spear grass (*Heteropogon contortus* (L.) Roem. and Schult) in south-eastern Queensland (Addison, 1974; Shaw and Bisset, 1955). However, growth rate of leucaena is slow during the first few months and weed growth can quickly smother young leucaena plants (Takahashi and Ripperton, 1949). The small leucaena plants are difficult to see among the weeds and are easy to damage, making mechanical inter-row cultivation difficult.

The preferred time for leucaena planting is in spring when 23% of the mean annual rainfall is received, so that leucaena can grow during summer (45% of mean annual rainfall) and be established to survive the winter frosts (34 mean annual grass frosts).

This paper considers the possibility of effecting weed control using pre-emergence herbicides applied immediately following sowing. The herbicide efficiency was investigated when applied before or after irrigation and when sprayed on to dry soil to await rainfall. Leucaena seed was pelleted to protect it from the more toxic herbicides.

Materials and methods

The trials were conducted at 'Brian Pastures' Pasture Research Station, Gayndah (25°39′ S, 151°47′ E; altitude 130 m; mean annual rainfall 735 mm). The brown clay soil had a moderately self-mulching surface with a clay content of 67% and 1.7% organic carbon in the surface 10 cm, and was classified as a Ug 5.32 (Northcote, 1971). The soil was heavily infested with grass and broad-leaf weeds, dominated by liverseed grass *(Urochloa panicoides* Beauv.), black pigweed *(Trianthema portulacastrum* L.) and common sida *(Sida rhombifolia* L.).

Prior to sowing, leucaena seed was treated in hot water, soaked in water at room temperature, and then dried for optimum germination and speedy emergence (Cooksley, 1979) and inoculated with Rhizobium CB 81. Except for Trial 4 which relied on rainfall for germination, the soil was irrigated and wet to a depth of more than 15 cm at sowing. Seed was sown by hand at a depth of 2.5 cm in Trials 1 and 2, and with a cone planter (Fletcher, 1970) at a depth of 4 to 6 cm in Trials 3 to 5.

Herbicides were applied in water at 500 L ha^{-1} after the leucaena seed was sown. Numbers of leucaena seedlings were assessed following emergence, and number and yield (oven dry weight) of both leucaena and weeds were obtained from later destructive harvests of above-ground material.

Trial 1 Timing of sowing and herbicide application in relation to time of irrigation was examined. Five pre-emergence herbicides, 2,4-D, chlorthal, nitralin, diuron and prometryne were used at rates recommended by the manufacturers for controlling the weeds present (Table 1), and applied following sowing either before or after irrigating. Weeded and unweeded controls were included giving a 7 × 2 factorial experiment. Individual treatment plots measuring 1.0 m × 1.0 m were laid out in a randomized block design with three replicates. Leucaena seed was sown and herbicides applied as a surface spray during the morning of 4 October 1971, and irrigated the following morning. The other half of the

Table 1 Effects of the five pre-emergence herbicides used in Trial 1 on leucaena and accompanying weeds

Treatments	Rate (kg ha^{-1})	Leucaena			Weeds			
		Survival[1] (%)	Dry weight (g m^{-2})	Dry weight (g plant^{-1})	Number (m^{-2}) grass[2]	Number (m^{-2}) broad-leaf	Dry weight (g m^{-2}) grass	Dry weight (g m^{-2}) broad-leaf
2,4-D	2	78c[3]	5.9a	0.30a	68c	40c	42b	5a
chlorthal	8	94d	9.8b	0.42b	2a	48c	3a	5a
nitralin	0.8	88cd	9.8b	0.44b	12ab	48c	9a	18b
diuron	2	58b	6.3a	0.44b	22b	12b	20a	3a
prometryne	2	3a	0.5[4]	0.62[4]	2a	1a	5a	3a
weeded control	–	91cd	12.4c	0.56c	–	–	–	–
unweeded control	–	93cd	5.5a	0.24a	72c	79d	79c	10ab

[1] Inverse sine transformations were used in the data analysis
[2] $\sqrt{x + ½}$ transformations were used in the data analysis
[3] Means in the same column and followed by a common letter are not significantly (P > 0.05) different
[4] Omitted from the analysis

trial was sown into moist soil and herbicides applied on 6 October 1971. A total of 62 mm of rain fell between 12 and 19 October. Harvests of all above-ground material were taken from a 1.0 m × 0.8 m quadrat located in the centre of each plot on 17 and 18 November 1971.

Trial 2 The herbicides of Trial 1 were evaluated at reduced or increased rates of application based on the results of that trial (Table 2). Weeded and unweeded controls were included, thus giving a total of 15 treatments. Individual treatment plots measuring 2.0 m × 1.0 m were laid out in a randomized block design with three replicates. Leucaena seed was sown into dry soil, herbicides applied, and the whole trial irrigated on 20 and 21 September 1972. Between 26 September and 2 October 41 mm of rain fell, and a further 108 mm fell between 17 October and 1 November. Harvests were taken as in Trial 1 from a quadrat of 0.9 m × 0.9 m randomly located on each plot on 11 October and 1 November 1972.

Trial 3 As none of the herbicides in the preceding trials offered a satisfactory combination of control of the major weeds without suppressing leucaena growth, a third trial was undertaken to evaluate their effects in combination. Chlorthal (8 and 12 kg ha^{-1}), nitralin (1 and 2 kg ha^{-1}), and 2,4-D (2 and 4 kg ha^{-1}) were applied singly and in all possible combinations of two herbicides. Diuron and prometryne were not included as, apart from failing to provide satisfactory weed control, these had proved to be somewhat toxic to leucaena even at quite low doses.

Weeded and unweeded controls were included with the six individual herbicides and 12 combination herbicides, thus giving a total of 20 treatments. Individual treatment plots measuring 2.0 m × 1.24 m were laid out in a randomized block design with three replicates. Leucaena seed was sown into moist soil and herbicides applied on 9 November 1973. A total of 221 mm of rain fell between 5 and 23 December. Harvests were taken, as in earlier trials, from 1.0 m × 0.5 m quadrats located randomly on each plot on 27 December 1973.

Trial 4 This trial examined the effect of a delay after sowing and applying herbicides before rainfall caused germination of leucaena and weeds. 2,4-D, chlorthal, nitralin and diphenamid were used in this trial (Table 3). Ten sowings were made between 17 September and 30 December 1974 on occasions when the soil was too dry to cause germination, so that germination was dependent upon subsequent rain-

Table 2 Effects of the five pre-emergence herbicides used at two or three rates in Trial 2 on leucaena and accompanying weeds

Treatments	Rate (kg ha^{-1})	Leucaena				Weeds			
		Emergence[1] (%)	Survival[1] (%)	Dry weight (g m^{-2})	Dry weight (g plant^{-1})	Number (m^{-2}) grass[2]	Number (m^{-2}) broad-leaf[1]	Dry weight (g m^{-2}) grass	Dry weight (g m^{-2}) broad-leaf[3]
2,4-D	4	61b[4]	50bc	2.2ab	0.23abc	50a	4bcde	27	1
	6	44a	42ab	1.8a	0.20ab	115abc	4bcde	40	0
	8	33a	26a	1.8a	0.36cd	60ab	5bcde	16	0
chlorthal	8	83c	80e	2.7ab	0.18ab	152abc	3bcd	57	0
	12	78bc	70cde	5.4cd	0.39de	37a	6cde	55	1
	16	70bc	57bcde	3.1ab	0.27bcd	41a	2bcd	53	0
nitraline	1	79bc	66cde	1.7a	0.13a	328cd	11e	58	1
	2	61b	54bcd	2.8ab	0.26abcd	152abc	1bc	50	0
	3	78bc	76de	3.7bc	0.25abcd	92ab	3bcde	52	1
diuron	1	81c	68cde	1.7a	0.13a	275bcd	9de	109	1
	1.5	81c	71cde	2.0ab	0.13a	354cd	3bcd	56	1
prometryne	1	78bc	64cdc	2.5ab	0.18ab	143abc	0ab	94	1
	1.5	74bc	61bcde	1.6a	0.13a	359cd	0a	52	0
weeded control	—	72bc	65cde	6.7d	0.52e	-	-	-	-
unweeded control	—	81c	73de	1.9ab	0.13a	1178d	58f	51	1

[1] $\sqrt{x + ½}$ transformations were used in the data analysis
[2] log transformations were used in the data analysis
[3] Insufficient material for analysis
[4] Means in the same column and followed by a common letter are not significantly (P>0.05) different. When letters are not used in a column, means are not significantly (P>0.05) different.

Table 3 Effects of four pre-emergence herbicides applied at ten plantings in Trial 4 on leucaena and accompanying weeds

Treatments	Rate (kg ha^{-1})	Leucaena			Weeds			
		Survival (%)	Dry weight (g m^{-2})	Dry weight (g plant^{-1})	Number (m^{-2}) grass	Number (m^{-2}) broad-leaf	Dry weight (g m^{-2}) grass	Dry weight (g m^{-2}) broad-leaf
2,4-D	4	27[1]	27b[2]	1.6d	6b	10a	6a	22a
chlorthal	12	26	15a	0.9ab	6b	28c	14a	33ab
nitralin	2	29	22b	1.1bc	7b	20b	9a	31ab
diphenamid	5.5	27	22b	1.4cd	2a	29c	8a	41b
weeded control	-	30	26b	1.4cd	-	-	-	-
unweeded control	-	30	14a	0.7a	21c	35c	26b	38ab

[1] When letters are not used in a column, means are not significantly (P>0.05) different.
[2] Means in the same column and followed by a common letter are not significantly (P>0.05) different.

fall. The herbicides were applied after sowing. Weeded and unweeded controls were included on each occasion. The trial was laid out in a split plot design with the ten sowing times as the main plots, and the four herbicide treatments plus controls as the subplots; four replicates were used. Individual treatment plots measured 2.5 m × 1.07 m. Harvests were taken, as in earlier trials, from 1.0 m × 0.5 m quadrats located randomly on each plot approximately 11 weeks after planting, although harvesting was delayed in some treatments to permit a minimum period of 8 weeks growth.

Trial 5 The effects on herbicide toxicity of pelleting leucaena seed with either lime or activated carbon were examined. All the six herbicides used previously, plus atrazine, were tested at two rates of application (Table 4). Weeded and unweeded controls were included giving a 16 × 3 factorial experiment. Individual treatment plots measuring 2.0 m × 1.24 m were laid out in a randomized block design with three replicates. Leucaena seed was sown into dry soil, the herbicides applied and the trial irrigated on 12 and 13 November 1974. A total of 72 mm of rain fell between 14 and 18 November, 1974. Harvests were taken, as in earlier trials, from 1.24 m × 0.5 m quadrats located randomly on each plot on 20 December 1974.

Results

Trial 1 All main treatment effects suppressed leucaena yield below that of the weed-free control. Sowing before irrigation significantly increased leucaena yield (9.1 g m^{-2} compared with 7.5 g m^{-2}), but otherwise time of irrigation had no significant effect on weed growth or any of the interactions, so its effects have been bulked in Table 1.

Almost no leucaena survived spraying with prometryne although emergence was unaffected, while 2,4-D suppressed emergence to 78% from a mean of 91% for the other treatments. Survival at harvest was also significantly suppressed in plots sprayed with diuron compared with the unweeded control. All herbicides gave leucaena growth inferior to that obtained with hand weeding, and only chlorthal and nitralin offered a significant improvement over no weeding at all.

All herbicides offered a high degree of control of weeds germinating in response to irrigation at planting except that 2,4-D had little effect on grass weeds. In all herbicide treatments, herbicide effect and/or competition from the surviving weeds from the initial planting and of the second flush after rain was enough to depress leucaena yield relative to the hand-weeded control plots.

Trial 2 Increased rates of 2,4-D suppressed leucaena emergence and subsequent survival, while the decreased rates of diuron and prometryne did not suppress leucaena survival. Leucaena yields per plant were all significantly lower than those of the hand-weeded control, while three of the 2,4-D and chlorthal treatments resulted in leucaena yields significantly heavier than the unweeded control (Table 2).

All herbicide treatments reduced weed numbers compared with the unweeded control. The only treatment in which grass weed numbers increased substantially between 11 October and 1 November 1972 was 2,4-D. Numbers increased from 20 m^{-2} to 75 m^{-2} with no difference between rates. Mean grass weed number was 197 m^{-2} for the remaining herbicide treatments and 790 m^{-2} for the unweeded control on 11 October.

Only 2,4-D and chlorthal suppressed grass weed dry weight at 10 October (to 0.0 g m^{-2} and 1.6 g m^{-2} respectively) compared with the unweeded control of 10.0 g m^{-2}. Broad-leaf weed and leucaena yields were unaffected by treatment on 10 October. At 1 November, total weed biomass was not suppressed by herbicide treatment.

Trial 3 Results for herbicides applied singly were similar to those of Trials 1 and 2. No benefit was apparent from applying herbicides in combination when compared with each herbicide being applied alone. Weed numbers and biomass were reduced by about half in the treated plots when compared with the unweeded control.

Trial 4 Germination occurred in response to subsequent rain which caused delays of 2 to 30 days (average of 9 days) in duration between the time of planting and the germinating falls of rain. However, such delays had no effect on the efficacy of the herbicides so the results for each herbicide have been bulked for all sowing dates in Table 3.

Leucaena survival was unaffected by herbicide but overall was reduced relative to other trials, possibly by breakdown and death of seed in dry soil. The lowest survival level was 17% after the longest period of 30 days in dry soil. All four herbicides gave significant and substantial reductions in the number and biomass of grass weeds, although a lesser degree of control was apparent

Table 4 Effect of seven pre-emergence herbicides applied at two rates in Trial 5 on leucaena and accompanying weeds

Treatments	Rate ($kg\ ha^{-1}$)	Leucaena Dry weight		Weeds Number (m^{-2})		Weeds Dry weight (g m^{-2})	
		(g m^{-2})	(g $plant^{-1}$)	grass	broad-leaf	grass	broad-leaf
2,4-D	4	12c[1]	0.20bcd	8abc	6a	14ab	23c
	8	8b	0.17b	9abc	4a	29abcd	15abc
chlorthal	10	20defg	0.24defg	12abc	11a	41bcde	8abc
	20	22efg	0.27ef	3abc	3a	5ab	2ab
nitralin	1.5	22efg	0.26def	20abcd	6a	12ab	6ab
	3	25g	0.29f	4ab	2a	0a	3ab
diphenamid	4	23fg	0.26def	6ab	9a	8ab	17bc
	8	25g	0.28ef	0a	1a	0a	0a
diuron	2	16cd	0.19bc	29cd	5a	72efg	12abc
	4	18cdef	0.20bcd	25bcd	5a	81fgh	14abc
prometryne	2	17cde	0.24cdef	22abcd	1a	68defg	4ab
	4	13bc	0.22bcde	11abc	7a	38abcde	11abc
atrazine	2	1a	0.04a	41d	0a	105gh	0a
	4	0a	0.05a	18abc	0a	56cdef	0a
weeded control	–	19def	0.23bcdef	–	–	–	–
unweeded control	–	8b	0.10a	64e	90b	114h	70d

[1] Mean in the same column and followed by a common letter are not significantly ($P > 0.05$) different

in the broad-leaf weeds which increased in number and yield during the ten plantings.

Leucaena yields from herbicide treatments were comparable with those from weeded controls except chlorthal which was not significantly different from the unweeded control.

Trial 5 Seed pelleting failed to protect the leucaena seedling from damage, so the pelleting results have been bulked. All herbicides gave a significant measure of weed control except atrazine (2 kg ha^{-1}) and diuron (4 kg ha^{-1}) which did not significantly reduce grass yield. Atrazine almost completely destroyed the leucaena. With all other herbicide treatments, leucaena yield per plant was not significantly different from the weeded control.

General results

Leucaena emergence and survival were suppressed by 2,4-D, diuron, prometryne and atrazine. 2,4-D did not suppress leucaena emergence in Trial 5 yet it still gave weed suppression where the 2,4-D remained on dry soil until rain fell. Diuron and prometryne only suppressed leucaena survival in Trial 1 at a rate of 2 kg ha^{-1}. High application rates of chlorthal, nitralin and diphenamid were not suppressive to leucaena survival when compared to recommended rates.

Only in Trial 2 were there two falls of rain following herbicide incorporation into the soil. The second rainfall produced a four-fold increase in grass weeds in the 2,4-D treated plots but only small changes in the other treatment plots.

Discussion

The herbicides investigated can be placed in three groups. Atrazine, diuron, and prometryne are broad-spectrum pre-emergence residual herbicides of limited selectivity. Chlorthal, diphenamid, and nitralin are similar but more selective. 2,4-D is selective and normally used in a post-emergence role although it has been used successfully as a pre-emergence herbicide in peanuts (Rawson, 1962), and the data in this paper indicate that it may find a similar role with leucaena.

None of the herbicides examined gave consistently both satisfactory weed control and leucaena growth comparable with that in the hand-weeded plots. The failure to do so was related to the number and dry matter yield of remaining weeds which either survived the herbicide spray or emerged after subsequent falls of rain. When weed seedlings are killed by cultivation at planting, then no pre-emergence herbicide is required. The herbicide is required only if rain falls after planting and causes further weeds to emerge. Rain fell within a week of herbicide application in Trials 1, 2 and 5, thus preventing the separate identification of weeds which germinated at planting and subsequently. In Trial 2 a second fall of rain induced a separate flush of weeds only in the 2,4-D treated plots, yet in Trial 4 2,4-D remained active on the dry soil surface for periods of up to 4 weeks. The loss of 2,4-D activity in Trial 2 may have been caused by the leaching of 2,4-D below the weed seed zone (Wilson and Cheng, 1976).

Herbicides applied under dry conditions retained their efficacy and were as effective as when applied to moist soil or to dry soil and irrigated. However, until such time as reliable and suitably selective herbicides with greater weed control capacities become available, the application of herbicides at planting may not be warranted.

A seed pelleting technique was investigated in which the herbicide could be neutralized in a small zone around the leucaena seed. Jones (1975) achieved only limited success by spraying a narrow band of activated carbon on the ground above the leucaena seed after planting using specialized equipment. However, a simple technique of pelleting wheat seed with activated carbon was successfully used (Shubert, 1967) but pelleting failed on leucaena. Lime pelleting also failed to protect the leucaena seedling.

Atrazine had little effect on grass weeds, but almost completely destroyed both leucaena and broad-leaf weeds. Jones (1975) also observed that atrazine killed leucaena, while Nicholls *et al.* (1973) found that leucaena was tolerant to atrazine at 1.1 and 4.5 kg ha^{-1}. All other herbicides gave a significant measure of control of both types of weeds. This was reflected in growth of individual leucaena plants which was comparable to that of plants in the hand-weeded plots, although leucaena yield (when expressed per unit area) was not always correspondingly high as some treatments prejudiced leucaena survival.

A 93% reduction in grass weed numbers in herbicide treatments in Trial 2 produced no reduction in grass weed dry weight per square metre and only a small increase in leucaena dry weight yield. In other trials in which there were lower numbers of weed seedlings to control, similar proportions of grass weeds were killed which resulted in increases in leucaena yield.

Thus to obtain weed suppression and leucaena yields similar to weed-free leucaena, areas low in weed seed population need to be chosen and newly-germinated weeds removed at planting. Further flushes of weed seed germination could probably be controlled most effectively by mechanical inter-row cultivation.

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