CONTROL OPTIONS FOR *ACACIA BLAKELYI* IN REVEGETATION SITES

for

Iluka Resources, Eneabba, Western Australia

Environmental Services Unit, Greening Australia (WA)

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Environmental Services Unit
Greening Australia WA Ltd.
10-12 The Terrace
Fremantle WA 6160
Australia
Tel: +61 8 9335 8933
Fax: +61 8 9335 9203
Web: www.gawa.org.au

Author: Andrew Franks

INTRODUCTION

At the Iluka Resources mineral sand mining operations at Eneabba (Figure 1), *Acacia blakelyi* has historically been used to stabilise topsoil stockpiles. This has resulted in a large accumulation of *A. blakelyi* seed in the topsoil seed bank. The topsoil has since been used in some rehabilitation of areas where mining has occurred. *A. blakelyi* has also been included in the direct seeding mix in the revegetation process. This has resulted in *A. blakelyi* dominating the rehabilitation areas and out-competing other desirable native species.

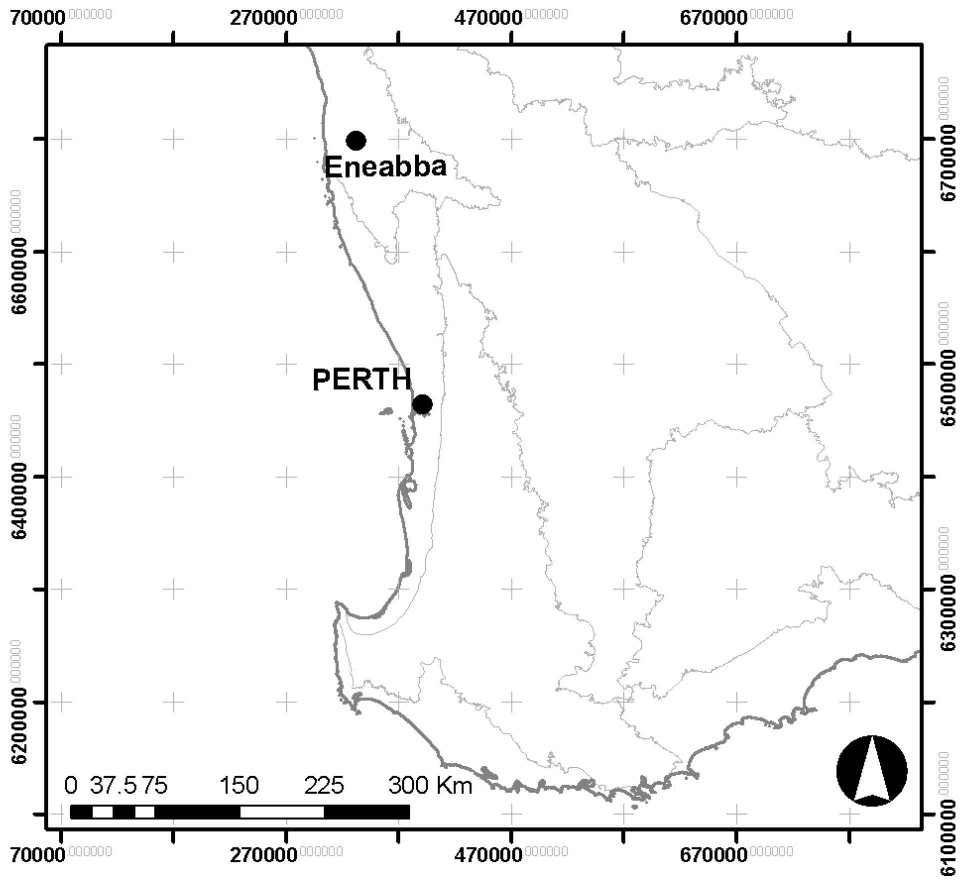

Figure 1. Location of Eneabba indicating IBRA 6.1 subregional boundaries. IBRA (version 6.1) data supplied by the Australian Government Department of the Environment and Heritage.

In August 2004, Iluka Resources requested Greening Australia Western Australia's Environmental Services Unit (ESU) to conduct herbicide application trials for the control of *A. blakelyi* in rehabilitation areas. *A. blakelyi* is an endemic species to the local Kwongan heath vegetation. However it has the potential to dominate areas that have been vacant or bare for prolonged periods. This is particularly so in areas of disturbance where *A. blakelyi* seed has accumulated in the seed bank.

The objective of these on-going herbicide trials is to determine the most effective treatment for control of *A. blakelyi*, while minimising the effect of these treatments upon the health of other native species within the sites.

During 2004, the ESU established a broadacre herbicide trial in an attempt to determine a method of control for *Acacia blakelyi* in rehabilitation areas. The trials were carried out on three year old rehabilitation sites (by 2006 these sites were at the five year mark). Based on the finding of the first year of monitoring of this site, it was found that the combination of mechanised slashing and the application of the herbicide Lontrel™ 240 appeared to be the most successful method for control of density of *Acacia blakelyi* without significantly impacting on the native species richness of this site (Branigan, 2005).

Based on these results, Iluka Resources approached ESU to complete monitoring of the existing trials and conduct further trials in new rehabilitation sites. This report documents the results of the 2006 monitoring of the trials established in 2004.

METHODOLOGY

Survey Methods

Spraying/slashing treatments of three-year old sites

The methodology used to determine the success or otherwise of the various treatments used in August 2004, is outlined below. Treatments to be assessed include:

- Eight slashing/spraying treatments, plus control, originally performed on three-year old revegetation sites.
- Broad acre spraying within the 2004 revegetation to remove new germinants of *Acacia blakelyi*.

Original spraying/slashing treatments conducted on the three-year old revegetation sites are outlined in Table 1.

Table 1. Original treatments performed on three-year old sites in 2004.

Label	Treatment	Location
1 – AB	Lontrel @ 320g per hectare plus wetting agent (BS-1000).	29° 55.53S 115° 16.61E
2 – AB	Garlon 600 @ 560ml per hectare plus wetting agent (BS-1000).	29° 55.53S 115° 16.57E
3 – AB	Grazon DS @ 1225ml per hectare plus wetting agent (BS-1000).	29° 55.53S 115° 16.54E
4 – AB	Lontrel @ 240g per hectare plus wetting agent (BS-1000).	29° 55.53S 115° 16.52E
5 – AB	Mechanical slash carried out by Iluka staff followed up with 4 – AB treatment.	29° 55.52S 115° 16.50E
6 – AB	Mechanical slash carried out by Iluka staff followed up with 3 – AB treatment.	29° 55.52S 115° 16.48E
7 – AB	Mechanical slash carried out by Iluka staff followed up	29° 55.51S 115° 16.47E

Label	Treatment	Location
	with 2 – AB treatment.	
8 – AB	Mechanical slash carried out by Iluka staff followed up with 1 – AB treatment.	29° 55.51S 115° 16.46E

Within each treated area, three quadrats of 4m x 4m were established at least 5m from the edge of the treated area (to ensure areas of accidental overlap of treatments are not sampled). Plots were located otherwise randomly. Features recorded within each plot are detailed in Table 2, along with the purpose.

Table 2. Vegetation features to be noted in each 4 m by 4 m plot during the 2006 assessment.

Feature	Description	Purpose
Density of *A. blakelyi*	Number of plants per plot (if discrete plants can be identified), or stems per plot.	To assess *A. blakelyi* abundance.
Foliage projective cover of *A. blakelyi*	Percent of plot area.	To assess *A. blakelyi* abundance/growth.
List of plant families present	Within plot area. Feasibility of noting number of species per family will be assessed on-site.	Taxonomic richness.
Seedling density for each plant family present	Number of plants per plot.	To assess growth of species other than *A. blakelyi*.
Health of each plant family present	For each family present, rate as: 1) unaffected by herbicide, 2) affected or 3) dead.	Potentially provides data to indicate differential impacts/benefits of spraying on different plant families.

The experimental design for the three year old revegetation site lends itself to analysis via a two-factor analysis of variance (ANOVA), using the factors slashing (two treatments: slashed and unslashed), and spraying (four treatments). The ANOVA statistical analysis enables the detection of significant differences between the treatments as a whole, with a 5% chance of the conclusion being wrong ($p=0.05$). Therefore if the "P value" is below 0.05, then the data suggests that there is a significant difference.

Notably, "success" in regeneration of desirable species is seen as a function of the slash/spray treatment as well as the initial method of seed supply to the site.

The results are discussed in the order of the vegetation features analysed (see Table 2).

The recommendations are derived through a combination of methods:

- During the 2006 monitoring process visual observations and data were recorded for each treatment, treatment comparisons and trial site differences.
- Recommendations are based on analysis of data and visual observations and provide advice on the effectiveness of each treatment.

There are some limitations to the trials, which may affect the results discussed and the recommendations outlined.

I. Initially no base line data was collected from the trial site before the spray treatments were applied. This data could have been compared to the first year data results. Although, this is nullified to a certain extent, with the inclusion of a "control" in the experimental design.

II. In the slash treatments, spraying occurred directly after slashing had occurred. There is a possibility that the control of the *A. blakelyi* may have been even more effective if foliage regeneration, post slashing was permitted.

III. If further trials are deemed necessary in the one year old revegetation site, it would be advisable to include a "slash control". This control could assess the effectiveness of just slashing (not spraying) and provide further base line data.

Spraying of newly-germinated A. blakelyi *within 2004 revegetation*

Within the 6m wide treated strip, and within an adjacent (equivalent) untreated area, three square monitoring plots were established. Plot size of 1 m x 1 m was used with plots located in the approximate centre of the strip to ensure that herbicide treatment was indeed received in the plot. These plots are spaced randomly lengthwise to cover the centre and each end of the sprayed and untreated strips. The features noted are the same as for trial 1, as detailed in Table 2. Foliage projective cover of *A. blakelyi* was not assessed, since density alone will provide an adequate index of growth. The analysis of the data for this experiment lends itself to a t-test (Two-Sample Assuming Equal Variances). The *t*-test compares the actual difference between two means in relation to the variation in the data. This variation is expressed as the standard deviation of the difference between the means.

Field surveys were undertaken in late November 2006. Nomenclature used in this study follows Paczkowska & Chapman (2000) and botanical binomials presently accepted by the WA Herbarium (Western Australian Herbarium 1998).

RESULTS & DISCUSSION

Spraying/slashing treatments of five-year old revegetation sites

Density of Acacia blakelyi *in five-year old revegetation sites*

Data was collected on the density of *A. blakelyi* post treatment for each of the plots. Density was defined as the number of *A. blakelyi* saplings per plot. Figure 1 displays the density of *A. blakelyi* for each of the different treatment applications.

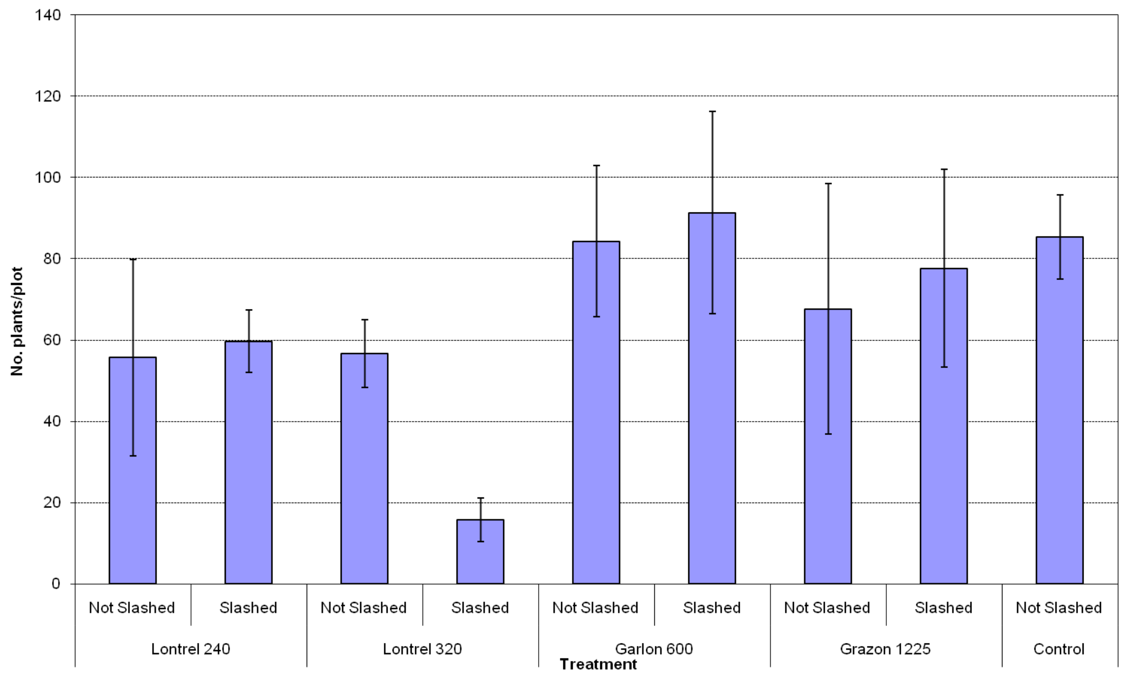

Figure 1. Density of *Acacia blakelyi* in each of the experimental treatments.

The trend indicated in Figure 1 is very similar to the findings in the 2005 assessment. To differentiate between the effectiveness of each treatment, slashed and sprayed results will be presented separately in the following sections.

Sprayed versus Density

Table 3. *Acacia blakelyi* densities for each spray treatment for both monitoring periods.

	2006			2005		
Treatment	**Mean**	**N**	**Std. Deviation**	**Mean**	**N**	**Std. Deviation**
Lontrel 320	36.16	6	24.98	49.33	6	41.515
Garlon 600	87.83	6	34.30	103.00	6	45.374
Grazon 1225	72.67	6	43.25	72.17	6	42.381
Lontrel 240	57.67	6	27.91	66.17	6	30.222
Control	85.33	3	18.03	116.67	3	20.744
Total	66.00	27	35.57	77.56	27	42.754

The density of *Acacia blakelyi* in the unsprayed control plot has decreased between field assessments from 116.67 in 2005 to 85.33 individual per 16m² plot in 2006. This may indicate some self thinning of the population over time. The density in all other treatments has also decreased, except for Grazon 115 which have remained similar (Table 3). Lontrel 320 still records the lowest average density (Table 3).

To determine whether these differences are statistically significant, a one-way ANOVA was used. The first analyses presented below (Table 4) will determine whether there were overall differences when comparing all groups.

Table 4. ANOVA summary of density of *Acacia blakelyi* versus spray treatments.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10005	4	2501.250	2.402843	0.080596	2.816708
Within Groups	22901	22	1040.955			
Total	32906	26				

The ANOVA summary presented in Table 4 indicates that there is no significant difference in the density of *Acacia blakelyi* between the different spry treatments (df = 4, F = 2.5, P = 0.08). Although no significant difference was recorded, spray treatments are individually compared to the unsprayed control plots to determine whether or not there are significant differences.

Lontrel 320

Table 5. Mean density of *Acacia blakelyi* between Lontrel 320 and the control plots.

Treatment	Mean	N	Std. Deviation
Lontrel 320	36.167	6	24.97
Control	85.333	3	18.03

The result indicates that there is a significant difference in density of *Acacia blakelyi* between plots sprayed with Lontrel 320 and the control plots (df = 1, $F = 8.978$, $P = 0.02$).

Garlon 600

Table 6. Mean density of *Acacia blakelyi* between Garlon 600 and the control plots.

Treatment	Mean	N	Std. Deviation
Garlon 600	87.83	6	34.295
Control	85.333	3	18.03

The result indicates that there is no significant difference in density of *Acacia blakelyi* between plots sprayed with Garlon 600 and the control plots (df = 1, $F = 0.013$, $P = 0.911$).

Grazon 1225

Table 7. Mean density of *Acacia blakelyi* between Grazon 1225 and the control plots.

Treatment	Mean	N	Std. Deviation
Grazon 1225	72.66	6	43.256
Control	85.333	3	18.03

The result indicates that there is no significant difference in density of *Acacia blakelyi* between plots sprayed with Grazon 1225 and the control plots (df = 1, $F = 0.224$, $P = 0.65$).

Lontrel 240

Table 8. Mean density of *Acacia blakelyi* between Lontrel 240 and the control plots.

Treatment	Mean	N	Std. Deviation
Lontrel 240	57.67	6	27.91
Control	85.333	3	18.03

The result indicates that there is no significant difference in density of *Acacia blakelyi* between plots sprayed with Lontrel 240 and the control plots (df = 1, F = 2.357, P = 0.168).

Slashed versus Density

This section examines the effect of slashing on *Acacia blakelyi* density. From the data presented in Table 9 it can be seen that slashed plots have a lower average density than the non-slashed plots however this is not a significantly different result (df = 1, F = 0.403, P = 0.531).

Table 9. Mean density of *Acacia blakelyi* for slashed and non-slashed plots.

Treatment	Mean	N	Std. Deviation
Slashed	61.08	12	39.92
Non-slashed	69.93	15	32.56

Cover of Acacia blakelyi in five-year old revegetation sites

The foliage projective cover (FPC) per plot was recorded to assess the abundance and vigour of *Acacia blakelyi* and is graphically represented in Figure 2.

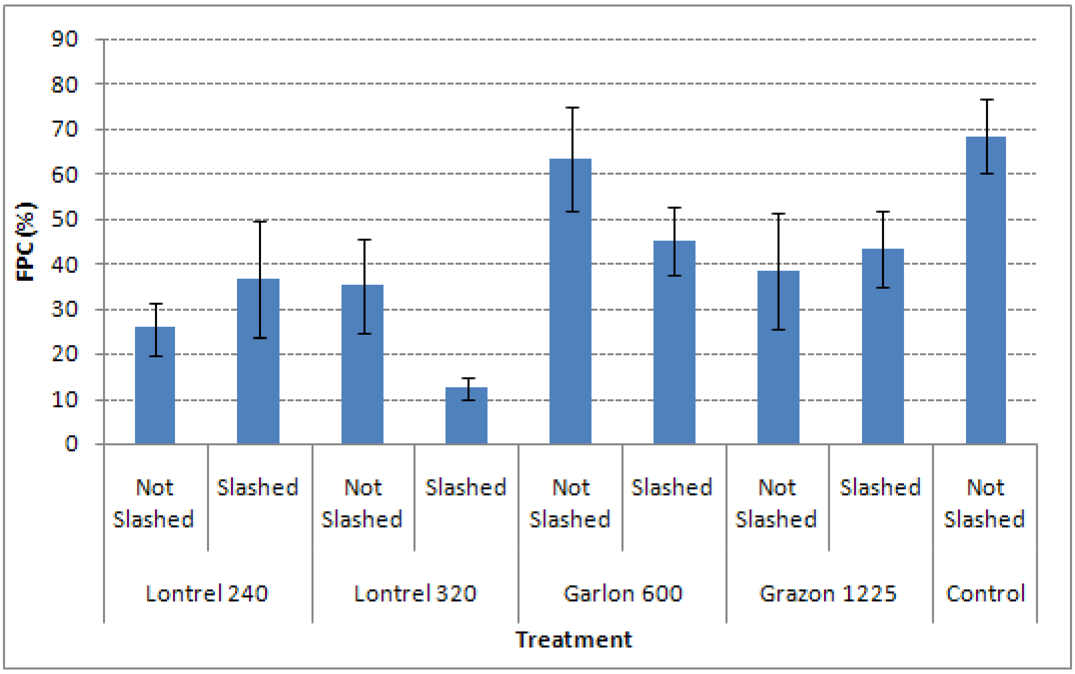

Figure 2. Average foliage projective cover of *Acacia blakelyi* in all treatments.

As indicated in Figure 2, the foliage projective cover of *Acacia blakelyi* still differs between the various treatments and has naturally increased since the previous assessment undertaken in 2005. To differentiate between the effectiveness of each treatment, slashed and sprayed results will be presented separately in the following sections.

Sprayed versus Density

Table 10. *Acacia blakelyi* foliage projective cover for each spray treatment.

	2006			**2005**		
Treatment	**Mean**	**N**	**Std. Deviation**	**Mean**	**N**	**Std. Deviation**
Lontrel 320	23.75	6	17.01	8.83	6	11.62
Garlon 600	54.16	6	18.28	25.00	6	22.84
Grazon 1225	40.83	6	17.15	12.17	6	13.79
Lontrel 240	31.16	6	16.74	7.00	6	6.69
Control	68.33	3	14.43	55.00	3	5.00
Total	40.91	27	21.53	17.89	27	19.95

Both Lontrel 240 and Lontrel 320 once again have the lowest FPC than other treatments with the control plots still having the greatest amount of FPC.

To determine whether these differences are statistically significant, a one-way ANOVA was used. The first analyses presented below (Table 11) will determine whether there were overall differences in FPC when comparing all groups.

Table 11. ANOVA summary of FPC of *Acacia blakelyi* versus spray treatments.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5646.97	4	1411.744	4.848	0.0058	2.816708
Within Groups	6406.04	22	291.184			
Total	12053.02	26				

The results indicate that there are significant differences in the FPC between the five treatments (df = 4, F = 4.848, P = 0.005). Each treatment is compared with the control to determine which spray treatment has FPC which differs significantly from the unsprayed control.

Lontrel 320

Table 12. Mean FPC of *Acacia blakelyi* between Lontrel 320 and the control plots.

Treatment	Mean	N	Std. Deviation
Lontrel 320	23.75	6	17.01
Control	68.33	3	14.43

The result indicates that there is a significant difference in the FPC of *Acacia blakelyi* between plots sprayed with Lontrel 320 and the control plots (df = 1, F = 14.93, P = 0.006). This is consistent with the density analysis presented in the previous section.

Garlon 600

Table 13. Mean FPC of *Acacia blakelyi* between Garlon 600 and the control plots.

Treatment	Mean	N	Std. Deviation
Lontrel 320	54.16	6	18.28
Control	68.33	3	14.43

The result indicates that there is no significant difference in the FPC of *Acacia blakelyi* between plots sprayed with Garlon 600 and the control plots (df = 1, F = 1.346, P = 0.284).

Grazon 1225

Table 14. Mean FPC of *Acacia blakelyi* between Grazon 1225 and the control plots.

Treatment	Mean	N	Std. Deviation
Grazon 1225	40.83	6	17.15
Control	68.33	3	14.43

The result indicates that there is a significant difference in the FPC of *Acacia blakelyi* between plots sprayed with Grazon 1225 and the control plots (df = 1, F = 5.61, P = 0.049).

Lontrel 240

Table 15. Mean FPC of *Acacia blakelyi* between Lontrel 240 and the control plots.

Treatment	Mean	N	Std. Deviation
Lontrel 240	31.16	6	16.74
Control	68.33	3	14.43

The result indicates that there is a significant difference in the FPC of *Acacia blakelyi* between plots sprayed with Lontrel 240 and the control plots (df = 1, F = 10.64, P = 0.013).

Lontrel 320, Grazon 1225 and Lontrel 240 all showed a significantly lower FPC than the control plot.

Slashed Treatments versus FPC

This section examines the effect of slashing on the FPC of *Acacia blakelyi*. From the data presented in Table 16 it can be seen that slashed plots have a lower average FPC than the non-slashed plots however this is not a significantly different result (df = 1, F = 2.07, P = 0.162).

Table 16. Mean FPC of *Acacia blakelyi* for slashed and non-slashed plots.

Treatment	Mean	N	Std. Deviation
Slashed	34.38	12	18.71
Non-slashed	46.13	15	22.80

Number of plant families in five-year old revegetation sites

The number of families represented per plot was counted to assess the taxonomic richness within each treatment. Again, sprayed and slashed treatments are assessed separately.

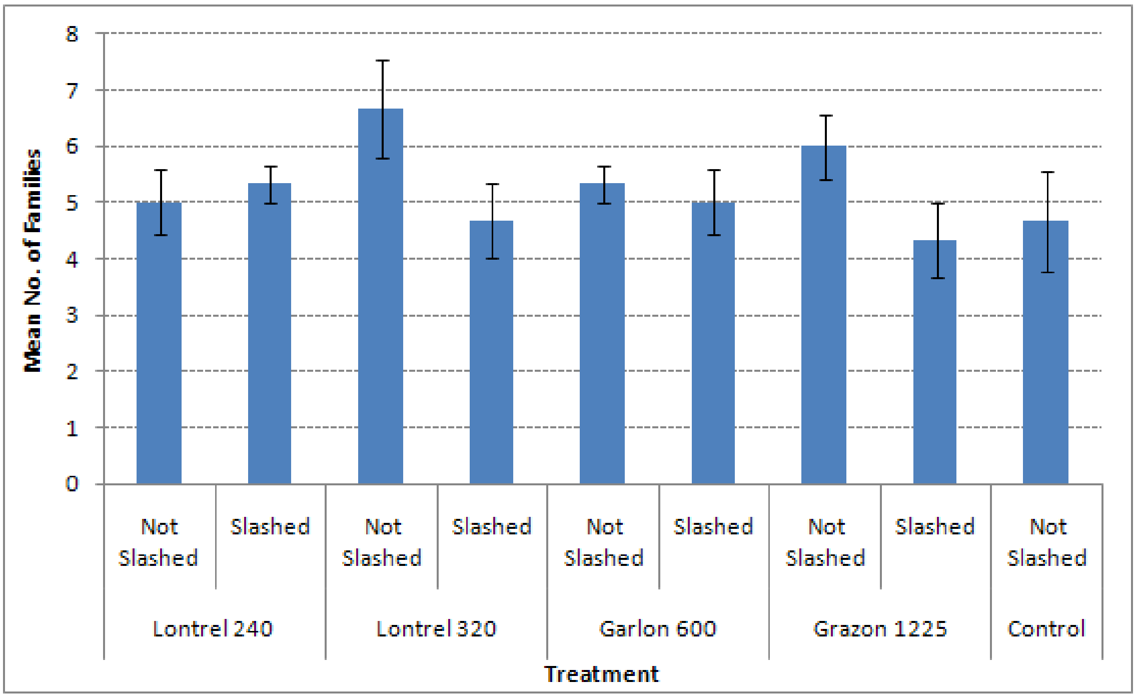

Figure 3. Average number of families per plot for each control treatment of *Acacia blakelyi*.

The average number of families per plot between all treatments and the control appear to differ only slightly as indicated in Figure 3. This will be assessed statistically in the following section to determine if there are any significant differences in the number of families per treatment.

Sprayed Treatment versus Average Number of Plant Families

Table 17. Average number of plant families for each spray treatment.

	2006			**2005**		
Treatment	**Mean**	**N**	**Std. Deviation**	**Mean**	**N**	**Std. Deviation**
Lontrel 320	5.66	6	1.63	5.50	6	1.64
Garlon 600	5.16	6	0.75	6.83	6	1.47
Grazon 1225	5.16	6	1.33	5.83	6	1.72
Lontrel 240	5.16	6	0.75	6.17	6	1.47
Control	4.66	3	1.53	5.33	3	1.15
Total	5.22	27	1.15	6.00	27	1.52

The results presented here indicate that there is no significant difference in the average number of families among the different spray treatments and the control plot (df = 4, F = 0.366, P = 0.829). This original conclusion that the different spray treatments have a minimal effect on the average number of plant families still holds true.

Slash Treatment versus Average Number of Plant Families

Table 16. Average number of plant families for slashed and non-slashed plots.

Treatment	**Mean**	**N**	**Std. Deviation**
Slashed	4.83	12	0.94
Non-slashed	5.53	15	1.25

The results indicate that there is no significant difference between the number of plant families between the slashed and non-slashed plots (df = 1, $F = 2.6$, $P = 0.119$).

Spot spraying of Acacia blakelyi *within 2004 revegetation sites*

Within the 2004 revegetation site, a trial was conducted using Lontrel 240 as the spray treatment to assess the effectiveness of this herbicide in controlling *Acacia blakelyi*. The average number of plant families was measured as a surrogate of taxonomic richness in the trial. A control plot was established in the same area to effectively assess the effectiveness of this treatment.

Density of Acacia blakelyi

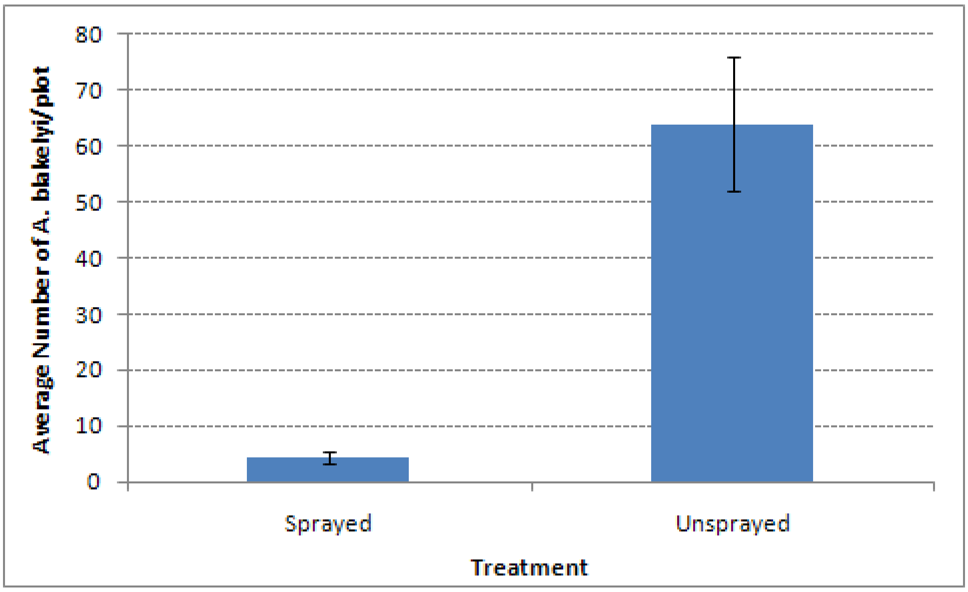

Figure 4. The average number of *Acacia blakelyi* plants per plot between the Lontrel 240 sprayed treatment and the neighbouring control plot.

There is still a significantly lower average number of *Acacia blakelyi* individuals in the Lontrel 240 sprayed treatment than in the neighbouring control plots (df = 4, P = 0.007; Figure 4).

Average Number of Plant Families

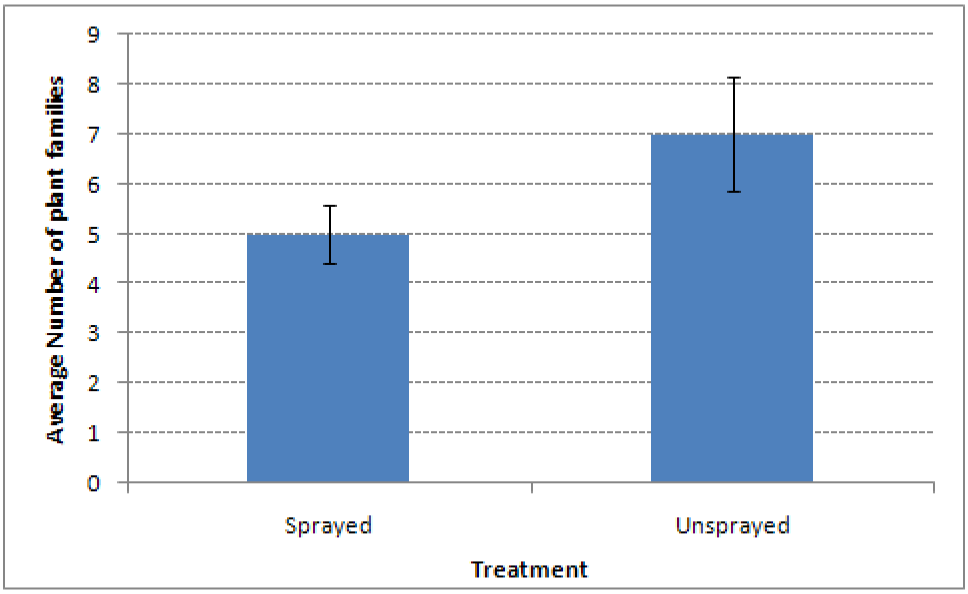

Figure 5. The average number of plant families per plot between the Lontrel 240 sprayed treatment and the neighbouring control plot.

The results indicate that there is no significant difference between the average number of plant families present in the sprayed to those present in the unsprayed plots (df = 4, P = 0.196). This is also indicated in Figure 10.

CONCLUSIONS

- Analysis of the data gained in this most recent survey indicates that Lontrel 320 is the only herbicide to record a significant effect on the density of *Acacia blakelyi*. All herbicide treatments did have an effect on the density of *Acacia blakelyi* but the majority of these were not statistically significant.

- Similarly, the foliage projective cover of *Acacia blakelyi* has been significantly reduced with the application of Lontrel 240, Lontrel 320 and Grazon 1225.

- Although slashing did have a significant effect on the seedling density of *Acacia blakelyi* one year after treatment, there is no significant difference in density or foliage projective cover in this assessment.

- Analyses suggest that there is still no significant difference among all treatments on the average number of plant families in each plot.

- The spraying of newly germinated *Acacia blakelyi* within the 2004 revegetation site with Lontrel 240 still significantly controls the density of this species while not significantly affecting the average number of plant families per plot.

- Overall, based on the findings of this most recent assessment, including on-ground visual assessments, slashing followed by Lontrel 320 or 240 applications appears to be the most efficient treatment for the control of *Acacia blakelyi*.

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