THE SUPPRESSION OF *ACACIA* SPP. THROUGH EXCLUSION BY HERBACEOUS PLANTS

HONOURS ECOLOGY PROJECT

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ABSTRACT

The recruitment potential of alien invasive acacias after a fire was observed to be reduced by the presence of herbaceous plants at Hagelkraal, Gansbaai. This pattern indicated that competition or inhibition could be an important factor in limiting the distribution of *Acacia cyclops* and *A. saligna*, two important invasive plants within the Cape fynbos. To test whether this was the case, a field experiment was undertaken at Melkbos. Seedling height, mortality and germination rates were monitored for seedlings under herb covers and for seedlings with herb covers removed. As laboratory experiments, *Acacia cyclops* was tested for its performance grown with two different densities of barley, a herbaceous crop plant; and for its performance when germinated at the same time, two weeks after barley germinated and four weeks after barley germinated. It was found that herbs may inhibit germination of the seeds of *Acacia cyclops* and that the seedlings of both *Acacia cyclops* and *A. saligna* suffer huge losses in biomass through growth with herbs. The results could be extrapolated to a management programme.

INTRODUCTION

Most studies concerning the control of invasive woody species have concentrated on seed bank dynamics since their reproductive capacities are enormous (Milton and Hall 1981). For this reason, the control measures recommended or attempted often involve pre- or post dispersal predation, frequently with much success. However, by the very fact that these woody alien plants have enormous reproductive capacities means that control measures aimed at the depletion of seed banks (which are soil-stored) cannot ensure total success. This study focuses the exclusion of *Acacia cyclops* Cunn. ex G. Don. and *A. saligna* (Labill.) H. Wendl. at the seedling stage from nutrient poor soils by herbaceous plants (referred to as herbs below).

Rationale

Recent studies have shown that the extent of invasion by alien species is limited through competition with indigenous species. Weiss and Noble (1984) found that *Chrysanthemoides monilifera*, introduced from South Africa into Australia, was displacing the naturally occurring *Acacia longifolia* in coastal dune communities. They reasoned that in uninvaded areas it would be expected that *Acacia* populations would be replenished by seedlings. In invaded areas however, *Acacia* seedlings would encounter interspecific competition with *C. monilifera* seedlings. Snaydon and Howe (1986) also found that in England, the invasion of grass species into established ryegrass swards was curbed by competition with the ryegrass. Here in South Africa, *Acacia cyclops* seedling recruitment at Hagelkraal Farm, Gansbaai, was observed to be markedly poor after a fire where dense mats of herbaceous plants occurred. This was considered unusual since the parent population was so dense. It seemed possible that these seedlings were being outcompeted by the herbaceous plants and that this phenomenon could be used to combat the invasiveness of acacias at the seedling stage. The idea seemed even more reasonable since if dormancy of the seeds is broken (chiefly by fire) the plants are in an irreversible phase of growth. If mortality occurs at this stage then, the seedlings would be irreplaceable. Holmes *et al.*(1987) have shown that no matter which treatment (felling, piling and burning) is used in order to clear *Acacia* thickets, enough seeds always remain in the soil to regenerate new *Acacia* stands. It is therefore important to concentrate on seedling mortality as a control measure for *Acacia* spp.

To find out whether this approach towards the management of *Acacia* is possible, I ask the questions (a) whether the herbs retard the recruitment of *Acacia* seedlings through inhibiting the germination of its seeds; (b) whether the performance of the seedlings is in any way affected through competitive effects; and (c) whether this approach can be applied through the use of an herbaceous crop plant.

MATERIALS AND METHODS

Study sites

Two areas served as field sites for data collection. The first site, Hagelkraal Farm is situated on the Agulhas Plain near Gansbaai in the southwestern Cape. This area is where the pattern responsible for the initiation of this project was first observed. The soil at Hagelkraal is sandy and acidic and the area is characterised by lowland fynbos which has been heavily infested by *Acacia cyclops* in places. The study site in question was a dense *A. cyclops* stand burnt in February 1989. The second area, Melkbosplaas (fig. 1.), served as a field experimental site and was chosen because of the similar coastal situation that it shared with

Figure 1. The study site at Melkbos. The mixed *Acacia* stand was burnt in February 1990. Herb growth (*Geranium molle* and *Fumaria officinalis*) can be seen covering the ground.

Hagelkraal. Melkbos is situated on the west coast within the southwestern Cape. It is typical coastal dune area characterised by strandveld. The area in which the experiment took place was a mixed stand of *A. cyclops* and *A. saligna* burnt in February 1990.

Field experiment

The pattern at Hagelkraal was so visible but needed to be quantified. Transects were laid out in the *Acacia cyclops* stand burnt in February 1989. The numbers of seedlings and the percentage cover of the herbaceous plants were recorded every four paces in a 1x1m plot. The herbs involved in this study were: *Callumia* sp., two species of *Pelargonium* and *Centella* sp. Care was taken to record seedling numbers only in areas where the parent trees were dense so that the source of propagules remained constant for each recording.

The field experiment which was undertaken at Melkbos involved two herbs: ***Fumaria officinalis*** and ***Geranium molle***. Both are introduced plants but were only chosen for their growth forms. The experiment was initiated on the 7 July and for the purposes of this project, ended on the 1 October. Seedlings were not harvested because it was intended that the experiment continue through the next summer where moisture stress would play an important role, and when the herbaceous plants would die back.

For the treatment, 0.2x0.2m plots were chosen for presence of one of the herbs mentioned above. *Acacia* seedlings under the herb cover were mapped onto graph paper and measured for their height and canopy diameter. The crown cover of the herb was outlined as well. For the control, the above procedure was repeated within 1m of the treatment except the herb was carefully removed from the plot. This was replicated 11 times for *Geranium molle* and 10 times for *Fumaria*.

The plots were monitored twice over a period of three months for turnover. Those seedlings that died were marked with an X on the maps and those seedlings that had just germinated were mapped and measured for height and crown diameter. This gave an idea of growth, mortality and germination rates in each of the plots. Problems arose when plots could not be found owing to the spring growth of the herbaceous plants. A few of the controls were swamped with herb growth and had to be recleared. However, this was not considered a great problem since any difference that would be found in the analysis would be even more conclusive.

To get an idea of the relative biomasses of *Acacia cyclops* seedlings, seedlings in a 0.2x0.2m plot under herb cover were harvested as well as those in a same-sized plot in the open. The open plots were not more than 1m away from their respective cover plots. The seedlings were oven dried at 75°C and their above- and below-ground biomasses weighed. The design of this study involved two factors, namely cover and plot.

Laboratory experiments

Two experiments were run simultaneously using barley as a representative herbaceous crop plant. Barley was also chosen because should the experiment prove successful, the seed of barley is cheap and easily acquired by anyone attempting to eliminate *A. cyclops* with the recommendations of this project.

Each replicate mentioned below represents a 12" pot with barley plants planted in a circle on the periphery, and with one of three planted *A. cyclops* seedlings in the centre. The seeds of *Acacia cyclops* were collected from a single population which surrounded the reservoir dam at the University of Cape Town to avoid genotypical complications in the experiment. The plants were watered twice-weekly so that moisture was not a limiting factor.

Experiment I. A time delay experiment was run. Here, barley was germinated at the same time in all treatments. For the first treatment, the seeds of *A. cyclops* were germinated simultaneously with the barley. Germination of *Acacia cyclops* seeds in all treatments was induced through micropylar chipping. For the second treatment, *A. cyclops* seeds were germinated 2 weeks after barley germinated and for the third treatment, *A. cyclops* seeds were germinated four weeks after barley germinated. For the controls, *Acacia cyclops* sedlings were germinated without barley at the same times as their respective treatments. Each treatment and control was replicated five times and consisted of 6 barley plants in the pot and 1 *A. cyclops* seedling. The design of this experiment involved two factors: cover and time of germination.

Experiment II. A density experiment was run to determine whether *Acacia cyclops* suffered more under higher densities of barley. *Acacia cyclops* seedlings were germinated without barley, with low densities of barley, and with high densities of barley. Each treatment was replicated six times. Low densities of barley were 3 plants in a pot and high densities of barley were 6 plants in a pot. The densities used were slightly unrealistic for practical purposes. Under cultivation in the field, densities of barley are likely to be higher. The design of this experiment involved only one factor which was density.

One and a half months into the running of the experiments, many of the control replicates and a few of the treatment replicates were destroyed by rats. In some replicates, *A. cyclops* seedlings were only partly eaten. The damage was assessed and the experiments were transferred from a glasshouse to a rat-proof growth chamber where conditions were a lot more regulated. The only part of the experiment that was left entirely without a control was the two-week germination delay in experiment I. A new control was therefore planted to give some idea of the relative growth rates of the *A. cyclops* seedlings grown with and without barley.

At the end of the experiment, the barley and *Acacia cyclops* seedlings were harvested, oven dried at 75°C and their above- and below-ground biomasses weighed. For the staggered germination experiment, the harvesting was staggered accordingly every two weeks over a period of four weeks.

Data analysis

The analysis of data either involved a one- or two-way analysis of variance , depending on how many factors were involved; or simple two-sample analyses such as T- or Range Tests. Log or square-root transformations were made where necessary to conform to the assumptions of normality (Zar 1984).

RESULTS

Field results

On an observational basis, there was a quantifiable pattern at Hagelkraal since considerably fewer Acacia seedlings were found under high herb covers than under low herb covers (Table 1.).

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Table 1. **The numbers of *Acacia cyclops* seedlings occurring under high and low herb covers in plots along a transect at Hagelkraal**

Treatment	High cover	Low cover
No. of plots	15	15
No. of seedlings	3	45

per plot ?
per m^2

In terms of actual biomass, seedlings occurring under herb covers at Melkbos were much smaller than those occurring naturally in the open (Table 2a.) This difference was highly significant and the effect of cover was uniform for all plots since there was no inter-level interaction (Table 2b.). Those seedlings occurring in the open were observed to develop phyllodes (flattened stems resembling leaves) sooner than those seedlings shaded by herbs (figures 2a and 2b.).

When the effect of herb cover was controlled for in the field experiment (herb covers removed), however, there is still a significant difference in *Acacia* seedling performance (seedling height) after three months, but the difference is not that marked (Table 3.).

During the time that the experiment was run, total mortality was more frequent in those plots that were left covered by the herbs than those that were cleared of herbs (Table 4.). However, for the treatment, the number of plots which showed 100% mortality, equalled the number which showed some survivorship (Table 4.).

Taken as a proportion of initial seedling density, mortality seemed to be higher in covered plots than in the control (Table 5.). Germination on the other hand (not as a proportion), showed a six-fold increase in the control (Table 6.)

Laboratory results

For the density experiment, the biomass of *Acacia cyclops* seedlings was markedly lower for those seedlings grown with low and high densities of barley than those in the cintrol (Table 7a). However, although the variance between the groups was significantly different from that within the groups (Table 7b.), a Range Test showed that ~~in actual fact~~, there was no significant difference between those seedlings

Table 2a. The biomasses (mean mass (g)) of *Acacia cyclops* seedlings in covered and open plots at Melkbos. Data were log-transformed.

Plot		Covered	Cleared
1	mean (g)	0.02	0.03
	log mean (g)	-4.12	-3.53
	S.D.	0.07	0.10
2	mean (g)	0.04	0.03
	log mean (g)	-3.26	-3.35
	S.D.	0.14	0.13
3	mean (g)	0.07	0.11
	log mean (g)	-2.70	-2.22
	S.D. 0.44	0.48	0.40
4	mean (g)	0.03	0.06
	log mean (g)	-3.82	-2.79
	S.D.	0.22	0.25
5	mean (g)	0.02	0.02
	log mean (g)	-3.75	-3.86
	S.D.	0.36	0.02
6	mean (g)	0.03	0.07
	log mean (g)	-3.54	-2.66
	S.D.	0.17	0.44
7	mean (g)	0.03	0.05
	log mean (g)	-3.57	-3.01
	S.D.	0.11	0.17
8	mean (g)	0.02	0.04
	log mean (g)	-3.88	-3.32
	S.D. 0.32	0.23	0.28
9	mean (g)	0.02	0.07
	log mean (g)	-3.82	-2.72
	S.D.	0.20	0.11
10	mean (g)	0.02	0.08
	log mean (g)	-4.01	-2.53
	S.D.	0.33	0.31

Table 2b. Two-way analysis of variance on biomasses of *Acacia* seedlings in open plots and herb-covered plots.

Source	df	SS	F	P
cover	1	12.66	27.24	0.001
plot	9	20.73	4.96	0.001
c x p	9	7.30	1.75	0.082

Table 3. The difference between sizes of *Acacia* seedlings in herb-covered and -cleared plots at Melkbos. Analysis was conducted on square-root transformed data. (T = 2.20; P <0.05)

Treatment	covered	cleared
mean seedling height (mm)	35.30	41.99
S.D.	20.20	14.86
N	31	46

Table 4. The frequency of herb-covered and -cleared plots in which all *Acacia* seedlings had died at Melkbos. Fisher's Exact test was used (P<0.001).

Treatment	100% dead	<100% dead
covered	9	8
cleared	16	0

Figure 2a. *Acacia* seedlings germinating in the open. The seedlings are large and already have well-developed phyllodes (P).

Figure 2b. *Acacia* seedlings germinating under the canopy of *Fumaria officinalis* (herb has been pulled back). The number of seedlings found under herb cover is low and the seedlings still have their compound leaves (c).

Table 5. Proportion of mortality of *Acacia* seedlings in herb-covered and -cleared plots at Melkbos.

Treatment	covered	cleared
N	11	11
proportion mortality	Ø.68	Ø.4Ø
S.D.	Ø.28	Ø.23
T	2.51*	
Pairs	2.2364*	

*P<Ø.Ø5

Table 6. The difference between germination success (mean number of seedlings germinated over a three month period) in herb-covered and cleared plots in Melkbos

Treatment	covered	cleared
N	11	11
Germination rate	1.73	6.36
S.D.	2.69	3.35
T	3.58*	
Pairs	2.86*	

*P<Ø.Ø5

Table 7a. The effects of barley density on the growth of *Acacia* cyclops. Analysis was conducted on log-transformed data. Values with similar symbols (a,b) indicate no significant difference.

Treatment	control	low density	high density
mean seedling mass (g)	1.82	0.13	0.09
log mean mass (g)	0.60	-2.04	-2.46
S.D.	0.14	0.13	0.31
Range test	a	b	b

what was barley LAI? Did it vary with density?

Table 7b. One way analysis of variance performed on the biomasses of *Acacia cyclops* seedlings grown at low, high and no densities of barley.

Source of variation	df	SS	F	P
Between groups	2	24.89	44.197	0.001
Within groups	13	0.28		

grown with high densities of barley and those grown with low densities of barley (Table 7a).

For the germination delay experiment, there ~~is~~ was once again a difference in *A. cyclops* seedling biomass between those grown with barley and those grown without barley (Table 8a.) However, there does not seem to be any significant germination delay effect (Table 8b). Figure 3. shows how those seedlings grown in the control had both their roots and shoots much more highly developed than those seedlings grown with barley. The seedlings in the control developed their phyllodes much earlier than those grown with barley. Interestingly, mean seedling biomass seemed to peak for the two-week germination delay and then decrease slightly for the four-week germination delay (Table 8a.). This pattern showed an inverse effect in the control with a trough in mean seedling biomass occurring in the two-week germination delay. Obviously, much of this pattern can be attributed to the effect that the rats had on the experiment. The control for the two-week germination delay was replanted and so the seedlings in the treatment had an effective one month more in which to grow. That there is any difference at all between the treatment and the control for the two-week germination delay is therefore interesting. This explains why, when compared with the other controls, mean seedling biomass for the two-week germination delay was lower. Barring the effects of the rats, however, a general increase in mean seedling biomass can be seen in both the treatment and the control. This effect may be attributed to the transferral of the experiment from the glasshouse to regulated growth chambers. From all of this, it can be seen that firstly, despite the apparent pattern, the data show no reliable difference in seedling biomass between the treatment and the control with regards the germination delay. Secondly, it can be seen that even given an extra month in which to grow, the *Acacia* seedlings in the two-week germination delay

Table 8a. The performance of *Acacia cyclops* seedlings grown with and without barley at the same time (T0), two weeks after barley emerged (T2), and four weeks after barley emerged (T4). Data were log-transformed.

	Barley			No barley		
Time	T0	T2	T4	T0	T2	T4
mean~~s~~ mass (g)	0.06	0.10	0.08	1.82	1.26	2.66
log mean(g)	-2.80	-2.32	-2.53	0.60	0.23	0.98
S.D.	0.31	0.29	0.23	0.15	0.08	0.17

Table 8b. Two-way analysis of variance on log transformed data of the biomasses of *Acacia cyclops* seedlings grown with and without barley at the same time, two weeks after barley emerged and four weeks after barley emerged.

Source of variation	df	SS	F
cover	1	64.94	350.32*
time	2	0.70	1.89+
cover x time	2	1.09	2.95+

*P<0.001
+P>0.05

treatment, still show a thirteen-fold decrease in biomass compared with that of the control. Interestingly, the treatments of the no germination delay and the four-week germination delay both show around a thirty-fold decrease in biomass compared with that of their respective controls.

DISCUSSION

At Hagelkraal, the *Acacia* seedlings had been through one summer during which the herbs involved in the study had died back. Most of them regrew from root stocks the following spring. The fact that more seedlings were found under low herb covers than under high herb covers indicates that the herbs somehow created disadvantages for the seedlings growing beneath their canopies so that they were incapable of withstanding the summer drought. Alternatively, the herb cover had a negative effect on the germination of the *Acacia* seeds.

Inhibition

From the results of the experiment at Melkbos, it would seem that the presence of herbs did have an inhibitory effect on the germination of *Acacia* seeds since germination rates were much higher in cleared plots than in the covered plots. This is supported by the fact that removal of herb covers subsequent to germination does not seem to benefit the *Acacia* seedlings much more than those left under herb covers. Those seedlings germinating in the open to begin with were much larger and phyllodal than those germinating under covers since they had an advantage in germinating sooner. Early seedling size has been shown to be important in determining ultimate fitness of a plant (Harper 1977; Goldberg and Werner 1983). Those *Acacia* seedlings germinating in the open, therefore, are most likely to be able to withstand the impending summer drought to give rise to a

Figure 3. Comparative sizes of *Acacia cyclops* seedlings grown without barley (A), and with barley (B). The seedling grown with barley had an extra month in which to grow.

similar pattern to that observed at Hagelkraal after the summer.

Jeffrey *et al.* (1987) found that *A. cyclops* seeds may respond to moderate fluctuating soil temperatures heated by sunlight during the day. The results of this study suggest that the seeds of both *A. cyclops* and *A. saligna* are light-sensitive, needing the correct quality of light in order to germinate. The advantage in this is that it it enables seeds to germinate when they are at or near the soil surface and provides a mechanism for maintaining a bank of dormant seeds within the soil (Frankland 1980). This explains why even after felling, piling and burning treatments of *Acacia*, enough seed reserves remain in the soil for future regeneration (Holmes *et al.* 1987).

Competition between growth forms

Although the herbs seem to have a strong inhibitory effect on the germination of *Acacia* seedlings, competition for resources also seems to be a powerful process in determining the distribution of *Acacias*. The results of the laboratory experiment clearly show how *Acacia* seedlings are impacted when grown with barley, a herbaceous grass. Interestingly, Vlok (1988) found that alien annuals may suppress the re-establishment of perennial indigenous shrubs in the fynbos and observed this to be the case in the Karoo as well.

How do herbs outcompete perennial seedlings? The etiolation of *Acacia* seedlings grown with barley and the dramatic reduction in their root systems compared with those of the control would seem to suggest that competition for light is important. Further, doubling the biomass of barley in the density experiment did not have an inverse effect on the biomasses of *Acacia* seedlings which would be expected if nutrients played an important role in competition. Legumes are able to fix nitrogen in their root nodules and so may be able to compensate for nutrient limitation imposed by barley.

Herbs have much higher growth rates than perennial plants and so may shade out their seedlings in a post-fire environment leading to a reduction in the seedling's fitness (Bond, 1987 Ph.D Thesis:43). Competition for light reduces photosynthetic activity and therefore shoot and root growth which in turn increases risk of death from drought (Bond Ph.D Thesis: 43). For an *Acacia* seedling germinating with or under a barley canopy, therefore, the probability of surviving the summer drought is low.

Implications for management

The results of this project suggest that ~~the use of~~ easily sown crop plants may be used as an efficient tool for management of *Acacia* spp. If, after a fire has swept through an *Acacia* stand, barley should be sown in and around the stand the negative effects on the recruitment of *Acacia* should be two-fold. Firstly the number of seeds germinating would be reduced. The advantage in this is that the first batch to germinate would be easier to control and that those seeds remaining in the soil would still be susceptible to granivores and pathogens. Holmes (1988) showed that the seed banks of *Acacia cyclops* are prone to alydid bug attack (*Zalubius acaciaphagus*) in the first year after felling treatment. The seed banks of *Acacia saligna* however, retain a high percentage of viability for many years owing to their hard seed coats (Holmes 1988) and are therefore unlikely to be depleted by granivores. Secondly, for those *Acacia* seedlings that do germinate, barley has the ability to retard their development. If an *Acacia* stand is burnt in autumn, barley, being a herbaceous plant, will show enhanced growth in spring after the winter rains. This should ensure that *Acacia* seedlings growing beneath barley canopies would be impacted to the extent that they are less likely to

adversely influenced

survive any moisture stress in summer. Any survivors could be easily hand-pulled from the soil.

The densities of barley used should perhaps be high, but need not necessarily create a lawn. What this study shows is that even low densities of barley have just as severe an impact on the growth of *Acacia* seedlings than do high densities. This result may have been obtained because unrealistic densities of barley were used in the experiment but it clearly shows that acacias essentially need large open gaps for successful recruitment of fit individuals. Barley also seems to have a consistently negative effect on the performance of *Acacia* seedlings irrespective of when *Acacia* germinates after a fire. This is important in the case of *Acacia cyclops*, the seeds of which may germinate between fires in response to high soil temperatures (Holmes 1988), or, according to this study, to the correct quality of light. Therefore, for *A. cyclops* barley should probably be sown at regular intervals following a fire so that most of the seedling generation experience a recruitment bottleneck. The seeds of *Acacia saligna* on the other hand, are highly dormant and therefore germinate mostly in response to a single heat treatment, namely fire. In such a case it would be important to germinate barley immediately after a fire.

CONCLUSION

Herbaceous plants have the competitive and inhibitive ability to exclude *Acacia* spp. from sites through limiting and altering the light received by *Acacia* seedlings. This phenomenon can be used as an important management tool to control the recruitment potential of acacias through the use of a crop plant, namely barley.

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