THE EFFECT OF DRY HEAT ON THE SEED GERMINATION OF TWO INDIGENOUS AND TWO ALIEN LEGUME SPECIES IN SOUTH AFRICA

SYNECOLOGY HONOURS PROJECT

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ABSTRACT:

Seed germination of two indigenous legumes (Podalyria calyptrata and Virgilia oroboides) and two alien legumes (Acacia cyclops and Acacia saligna), was tested following different dry heat treatments.

Podalyria calyptrata and A. saligna responded significantly to dry heat whereas A. cyclops and V. oroboides did not.

In the control experiments, where seeds were not heat treated very little germination occurred in all four species. Following micropylar chipping however, all species showed high percentage germination (≥85%).

A.saligna had a faster germination rate than the other species tested, whilst A.cyclops germination over the first thirty days was minimal and its germination rate was not calculated.

The indigenous species had lower lethal temperatures than the alien Acacia spp.

INTRODUCTION:

In South Africa *Acacia cyclops* and *Acacia saligna* are ranked in the top three most important invasive species in the fynbos biome according to the extent of their current infestation (Macdonald and Jarman 1984). Fire plays a major role in controlling the South African fynbos flora and *Acacia* spp. often tend to become dominant after fire (Cavanagh 1980).

The species used in this study are small leguminous trees or shrubs with hard coated, impermeable seeds. Hard seed coats permit extension of life to many seeds so that they are distributed in time as well as in space (Rolston 1978). This poses a major problem in the control of invasive species of this type as their seeds may remain dormant in the seed bank for many years. When treatments are applied to these seeds it is thought that they soften or damage the seed coat allowing water penetration and then germination to occur (Cavanagh 1980). Pieterse and Cairns (1986) suggest some ways of breaking the dormancy of these hard coated seeds : hot water, dry heat, freezing, organic solvents, acid scarification, mechanical scarification and microwave energy. All the weedy Australian acacias at the Cape produce seed prolifically (Milton and Hall 1981) and it is usually assumed that the heat from the fire breaks the dormancy of the seeds and allows them to germinate (Cavanagh 1980). Temperature readings taken during a fire in an A. cyclops stand at Walker Bay near Hermanus (Van Wilgen and Holmes 1986) show that the soil temperature varies with depth as well as with treatment applied (ie: whether the vegetation was burnt standing live, felled and piled, or just felled).

This study aims to determine the effect of dry heat treatments on A. cyclops seed germination as well as the minimum temperatures required to kill A.cyclops seeds (lethal temperature). Concurrently the effects of temperature on the germination of A.saligna and two indigenous species, Podalyria calyptrata and Virgilia oroboides, were also tested. The effects of fires of different intensities on seed banks of these species at different depths in the soil can therefore be implicated

A. saligna occurs on a wide variety of substratas wherever water is available (Milton and Hall 1981). P. calyptrata occurs in kloofs and moist hillsides (Jackson 1982). Both of these species therefore prefer moist areas. V. oroboides is a forest precursor (Jackson 1982). A. cyclops occurs on leached, saline or lime-rich sand and has extended its range in the Cape onto sandstone derived, rocky soils of the coastal fold mountains (Milton and Hall 1981).

METHODS

Fresh seeds, collected no more than one year previously, were used. Acacia cyclops seeds were collected at Walker Bay and A. saligna seeds were collected in the Muizenberg mountains above Sandvlei. The P. calyptrata and V. oroboides seeds were obtained from the Kirstenbosch National Botanic Gardens.

For each treatment and subsequent germination test four replicates of 25 seeds each (totalling 100 seeds of each species) were used (Pieterse and Cairns 1986). Treatments consisted of exposing seeds to dry heat, in preheated ovens, at a range of different temperatures each with a different duration. The temperatures used were 60°C, 80°C, 100°C, 150°C and 215°C, and the exposure durations were 1 min, 2.5 min, 5 min, 10 min, 30 min and 60 min.

Following heat treatments the seeds were removed from the oven, allowed to cool and then placed in 9mm sterile plastic petri dishes containing two 9mm filter paper circles. The filter paper was moistened with 6 ml of benomyl at a concentration of 0,022% (m/v) active ingredient (Clemens et al 1977). Seeds were germinated in a controlled environment alternating 12 hours light at 25°C with 12 hours darkness at 20°C. Every two days the germinated seeds, those with the radicle emerging 1-2mm beyond the seed coat (Pieterse and Cairns 1986) were counted and removed from

the dishes up to a cut off time of 30 days. Because the germination of A. cyclops was very low in all treatments (except chipping) the cut off point was extended from 30 to 60 days to see if any further germination would occur. At the same time distilled water was added to maintain the moist environment.
The rate of germination was calculated as the time taken (in days) for 90% germination of the total number of seeds that had germinated after 30 days. Germination rates of the different species were then compared.

For each species a control (ie. no heat treatment) and a viability trial were also set up. For the latter, seeds were manually chipped at the micropylar end to break dormancy and then the normal germination procedure was followed.

A series of t-tests were used to compare the germination averages with those of the control for A.saligna, P.calyptrata and V. oroboides. The effects of the treatments on the different species with respect to germination, germination rate and viability of the seeds were compared using contour diagrams and three dimensional graphs as well as tables.

RESULTS:

Average Germination

Virgilia oroboides:

Viability of V. oroboides seeds was high (89%) whilst percentage germination of the control seeds was low (16%) (Table 1). Furthermore, maximum percentage germination obtained from the different treatments was not very high (36%). Heat treatments resulting in significantly increased germination were 80°C for 30 minutes and 60 minutes ($P \leq 0{,}05$ in both cases). Optimal temperature/time combinations are illustrated in Figures 1a and b. Germination ceased for temperature durations exceeding 10 mins at 100°C, 2.5 mins at 150°C and 1 min at 215°C.

Podalyria calyptrata:

Viability of P. calyptrata seeds was 85% and only 9% of control seeds germinated (Table 1). In all exposure durations at 60°C and 80°C as well as at 100°C, until the duration exceeded 10 minutes the germination rates were significantly enhanced ($P \leq 0{,}01$ in all comparisons) (Table 1, Figures 2a and b). At 100°C for 30 minutes and longer and for all the treatments at 150°C and 215°C no germination occurred, except at 150°C for 2.5 minutes where an average of one seed per replicate germinated . Seeds exposed to these treatments were killed.

At 60°C for 5 minutes exposure time and longer and at 80°C and 100°C at all exposure times up to 10 minutes, the average number of seeds germinating per replicate was 21 or greater ($\geq$84%)

TABLE 1. The effect of different treatments (temp/time combinations) on the % germination, of four legume species, at 30 days (germination percentage of <u>A. cyclops</u> is given at 30 & 60 days because of its low germination rate).

(Significantly different to control, t-test, * $P \leq 0,05$; ** $P \leq 0,01$)

TEMP	TIME (MIN.)	A.SALIGNA 30 DAYS	P.CALYPTRATA 30 DAYS	V.OROBOIDES 30 DAYS	A.CYCLOPS 30 DAYS	A.CYCLOPS 60 DAYS
CONTROL		3	9	16	4	52
CHIPPED		98	85	89	100	
60° C	1	0	72 **	8	3	25
	2.5	11 **	76 **	11	3	29
	5	12 **	92 **	18	3	39
	10	21 **	84 **	12	3	35
	30	37 **	87 **	9	4	25
	60	29 **	84 **	7	5	16
80° C	1	72 **	85 **	21	4	38
	2.5	31 **	88 **	8	0	14
	5	62 **	90 **	23	3	6
	10	60 **	83 **	21	1	23
	30	81 **	66 **	35 *	1	18
	60	69 **	49 **	34 *	0	16
100° C	1	52 **	93 **	7	2	16
	2.5	30 **	84 **	11	0	14
	5	26 **	83 **	9	1	9
	10	67 **	91 **	11	1	11
	30	88 **	0	0	0	2
	60	23 **	0	0	0	0
150° C	1	70 **	0	31	1	30
	2.5	88 **	5	27	0	24
	5	6	0	0	0	1
	10	3	0	0	0	0
	30	0	0	0	0	0
	60	0	0	0	0	0
215° C	1	61 **	0	20	0	14
	2.5	0	0	0	0	1
	5	0	0	0	0	0
	10	0	0	0	0	0
	30	0	0	0	0	0
	60	0	0	0	0	0

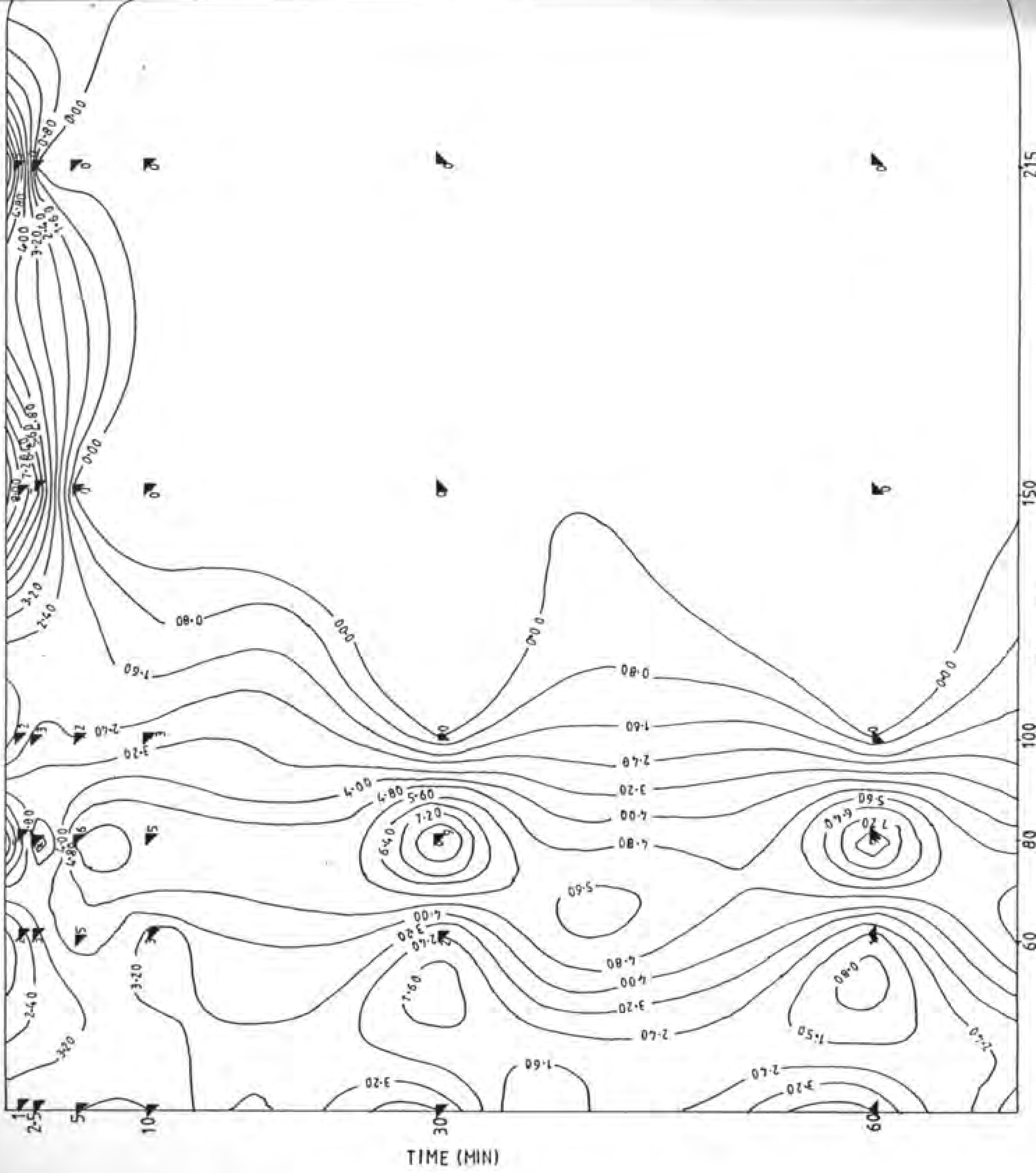

Figure 1a. The average germination (of four replicates of 25 seeds each) of V. oroboides at each temp/time combination.

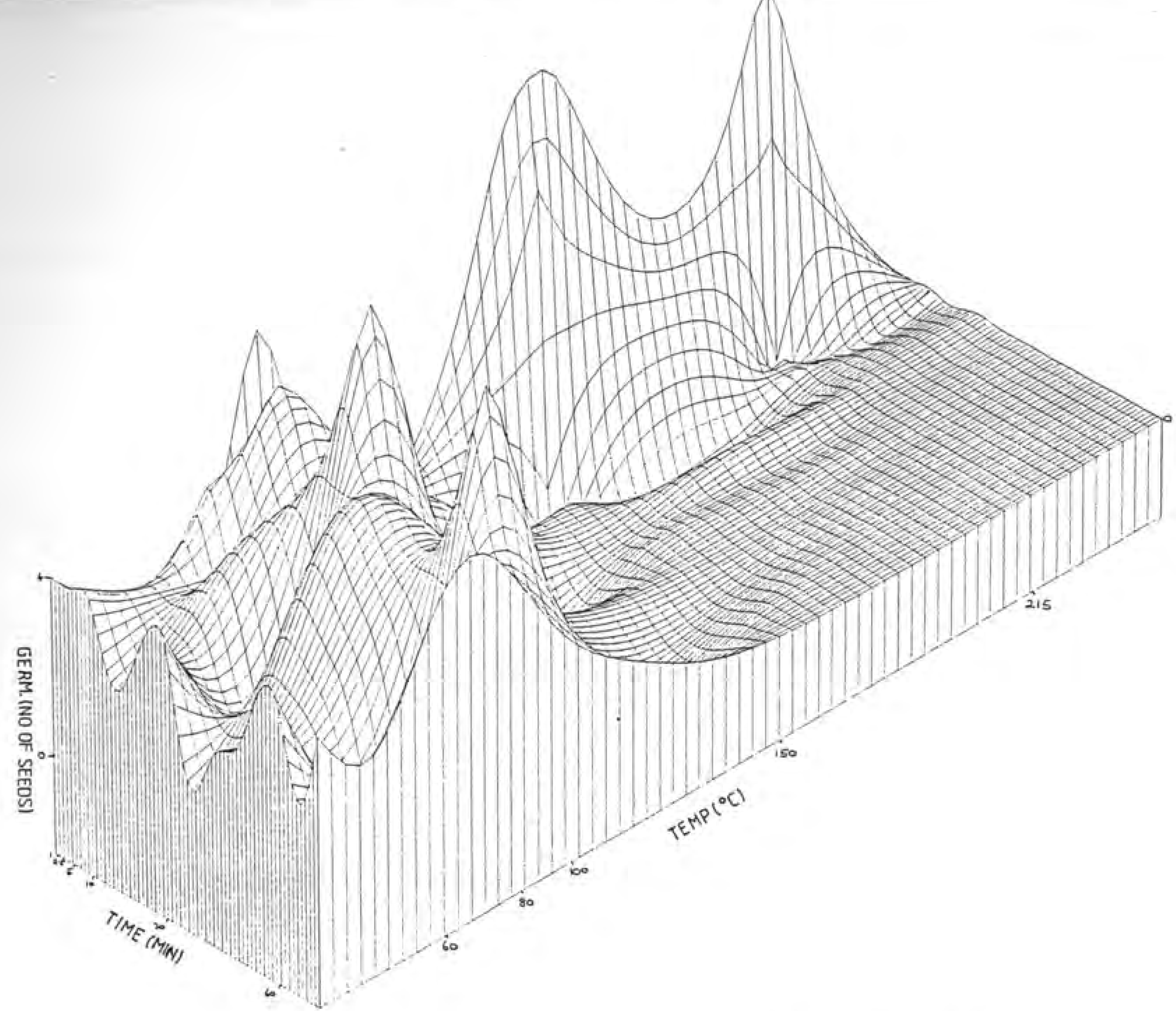

Figure 1b. A 3-dimensional graph of the average germination (of four replicates of 25 seeds each) of V. oroboides at each temp/time combination.

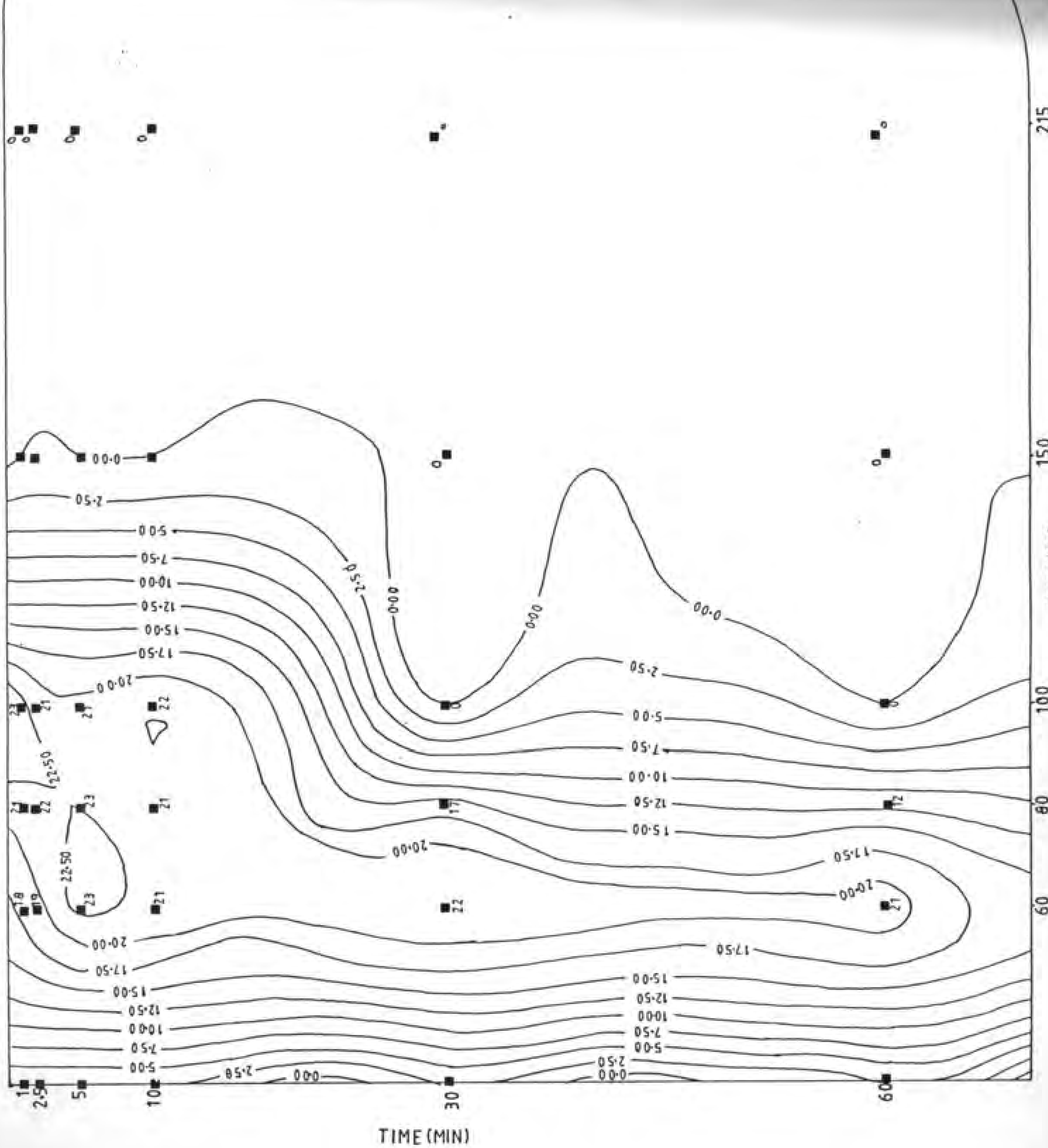

Figure 2a. The average germination (of four replicates of 25 seeds each) of P. calyptrata at each temp/time combination.

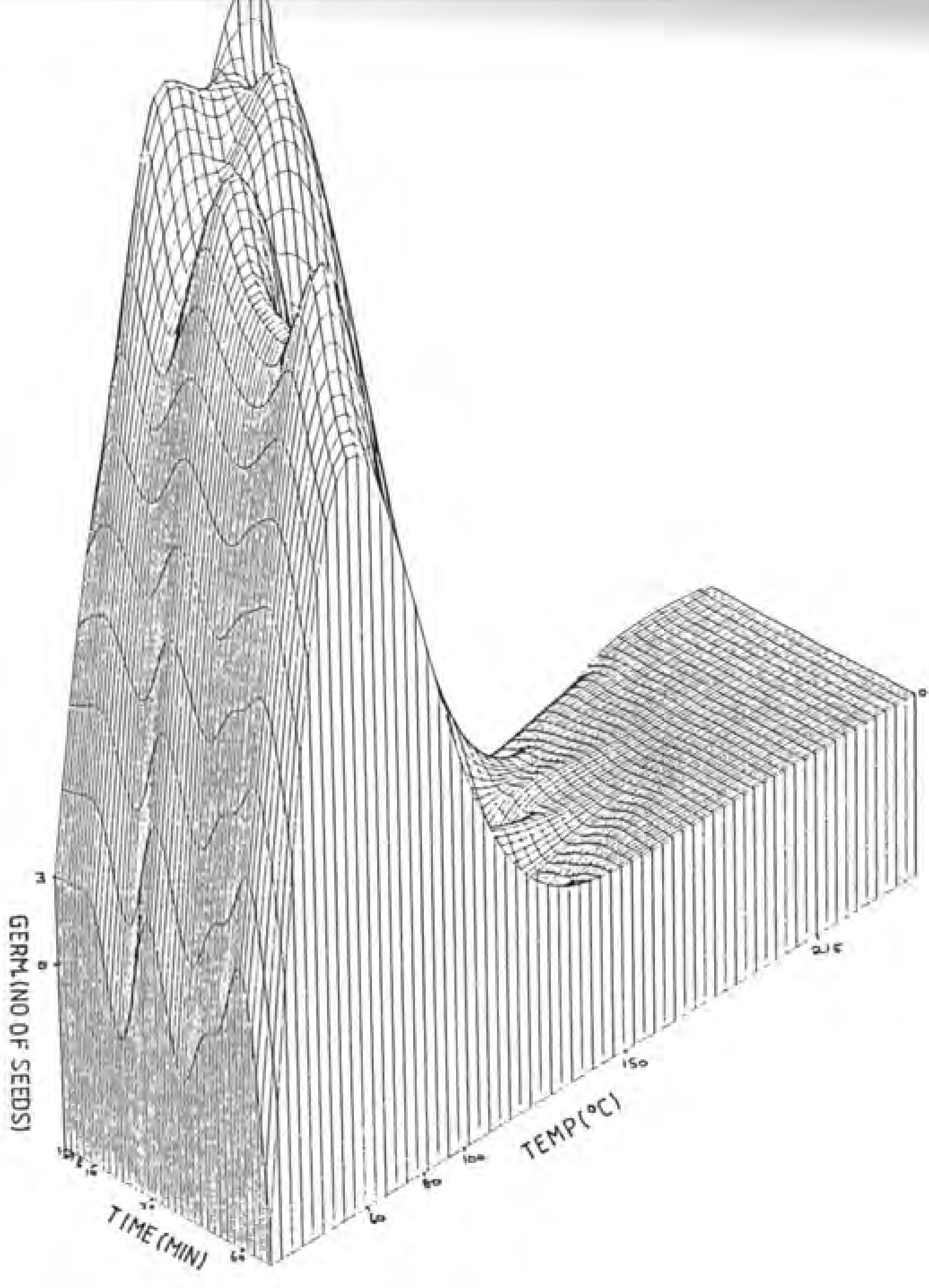

Figure 2b. A 3-dimensional graph of the average germination (of four replicates of 25 seeds each) of **P. calyptrata** at each temp/time combination.

Acacia saligna:

Whilst 98% of the A. saligna seeds were viable, only 3% germinated in the control (Table 1). Maximum germination following treatment occurred at 100°C with an exposure time of 30 minutes and at 150°C with an exposure time of 2.5 minutes (22 seeds each or 88%) (figures 3a and b, Table 1). The only other treatment to induce an average germination percentage ≥80% was 80°C for 30 minutes. At 60°C the average number of seeds germinating per replicate at all exposure times was low. Germination averages significantly greater than those of the control ($P \leq 0{,}01$), were induced by treatments at 60°C for 2.5 minutes and longer, all treatments at 80°C and 100°C, treatments at 150°C of 1 minute and 2.5 minutes and treatment of 215°C for 1 minute. At 150°C for 30 minutes and longer and 215°C for 2.5 minutes and longer no germination occurred.

Acacia cyclops:

Whilst 100% of the A. cyclops seeds were viable only 4% germinated in the control (Table 1). Very little germination occurred in any of the treatments in the first 30 days (Table 1, Figures 4a and b). A maximum germination of 5% occurred at 60°C with 60 minutes exposure. After 60 days, however, more germination had occurred but only a maximum of 39% germination was acheived at a treatment of 60°C with 5 minutes exposure time which was not significantly different from the control. At 150°C with an exposure time of 30 minutes and longer and 215°C with an exposure time of 5 minutes and longer no germination occurred.

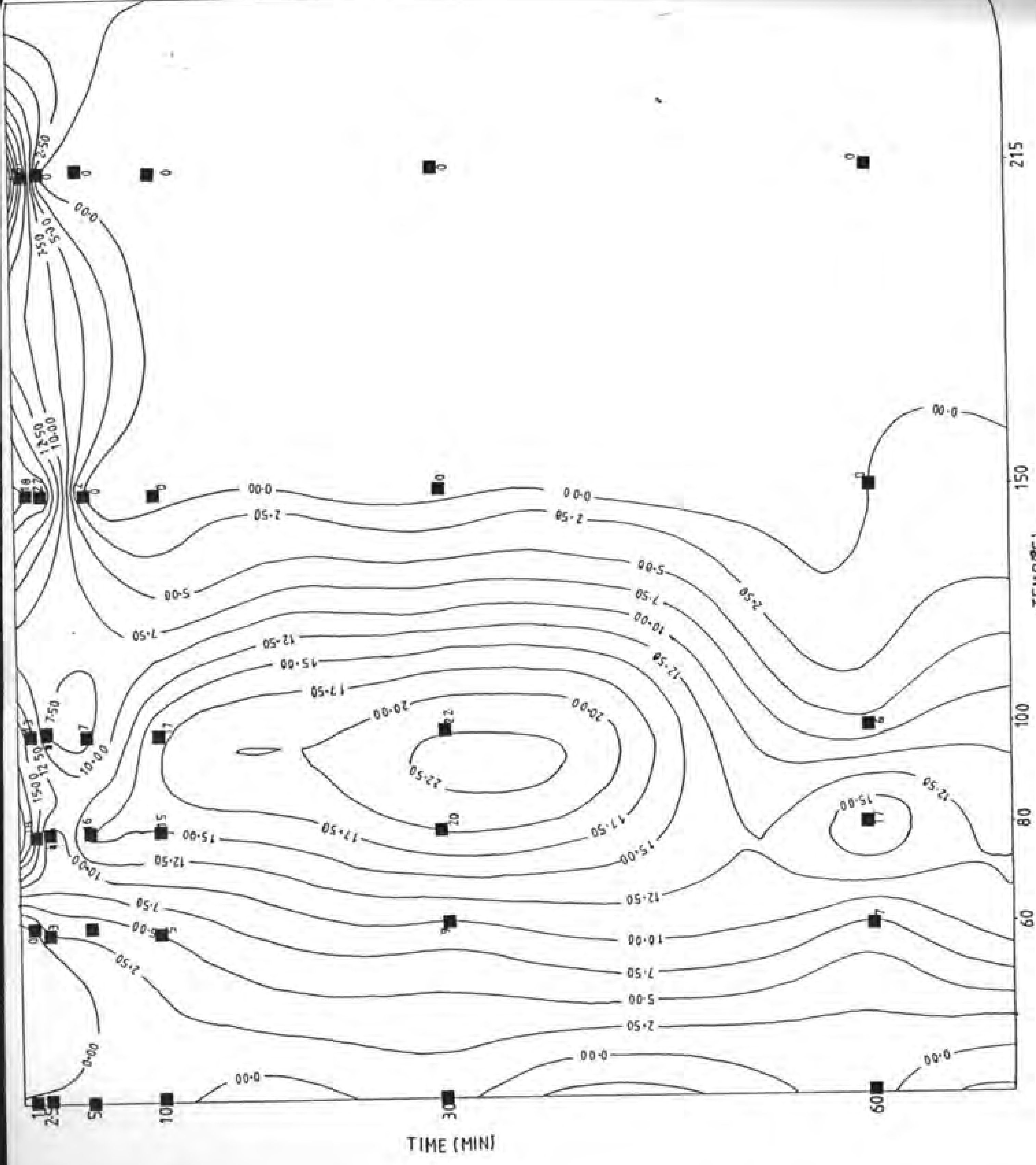

Figure 3a. The average germination (of four replicates of 25 seeds each) of A. saligna at each temp/time combination.

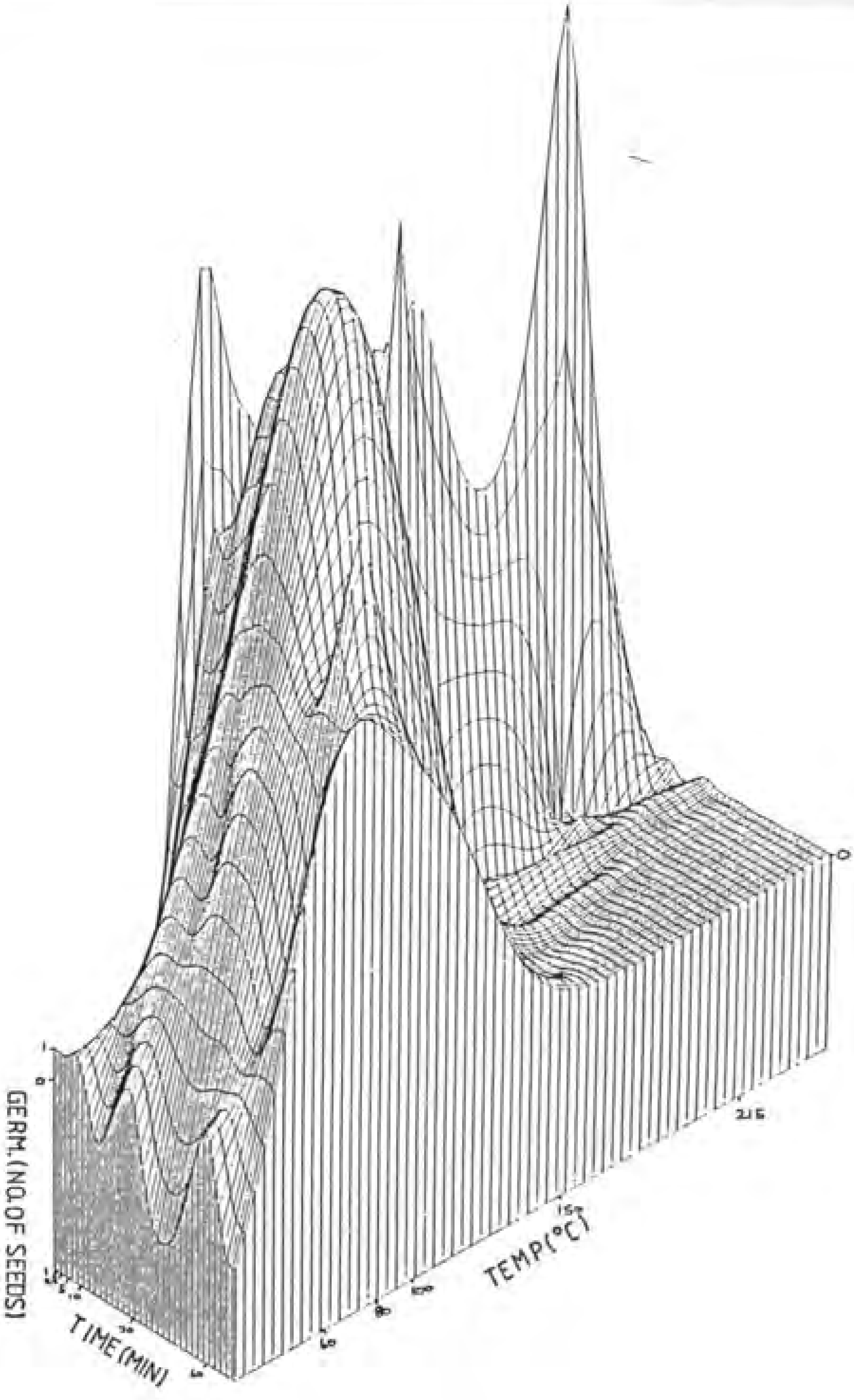

Figure 3b. A 3-dimensional graph of the average germination (of four replicates of 25 seeds each) of A. saligna at each temp/time combination.

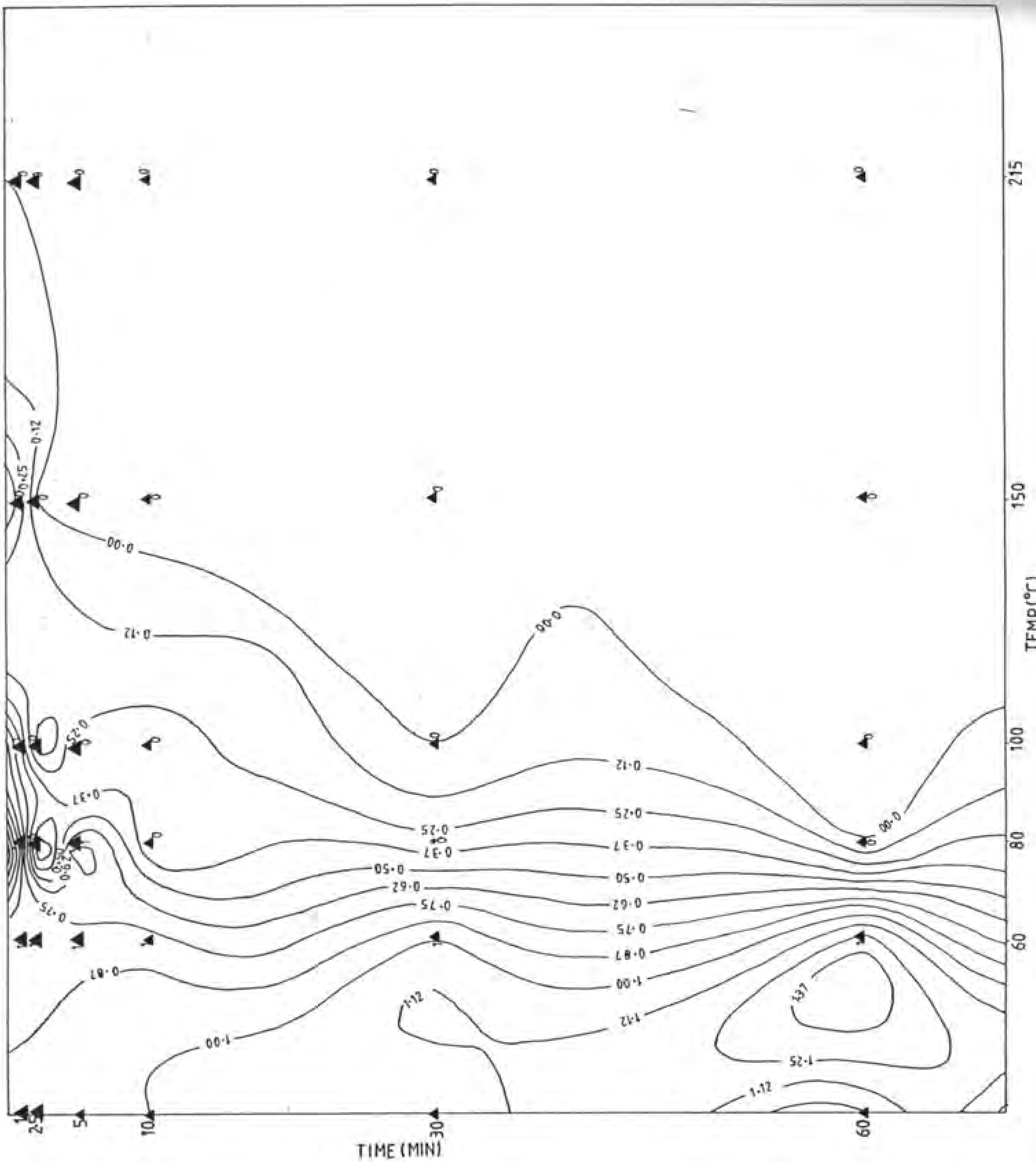

Figure 4a. The average germination (of four replicates of 25 seeds each) of A. cyclops at each temp/time combination.

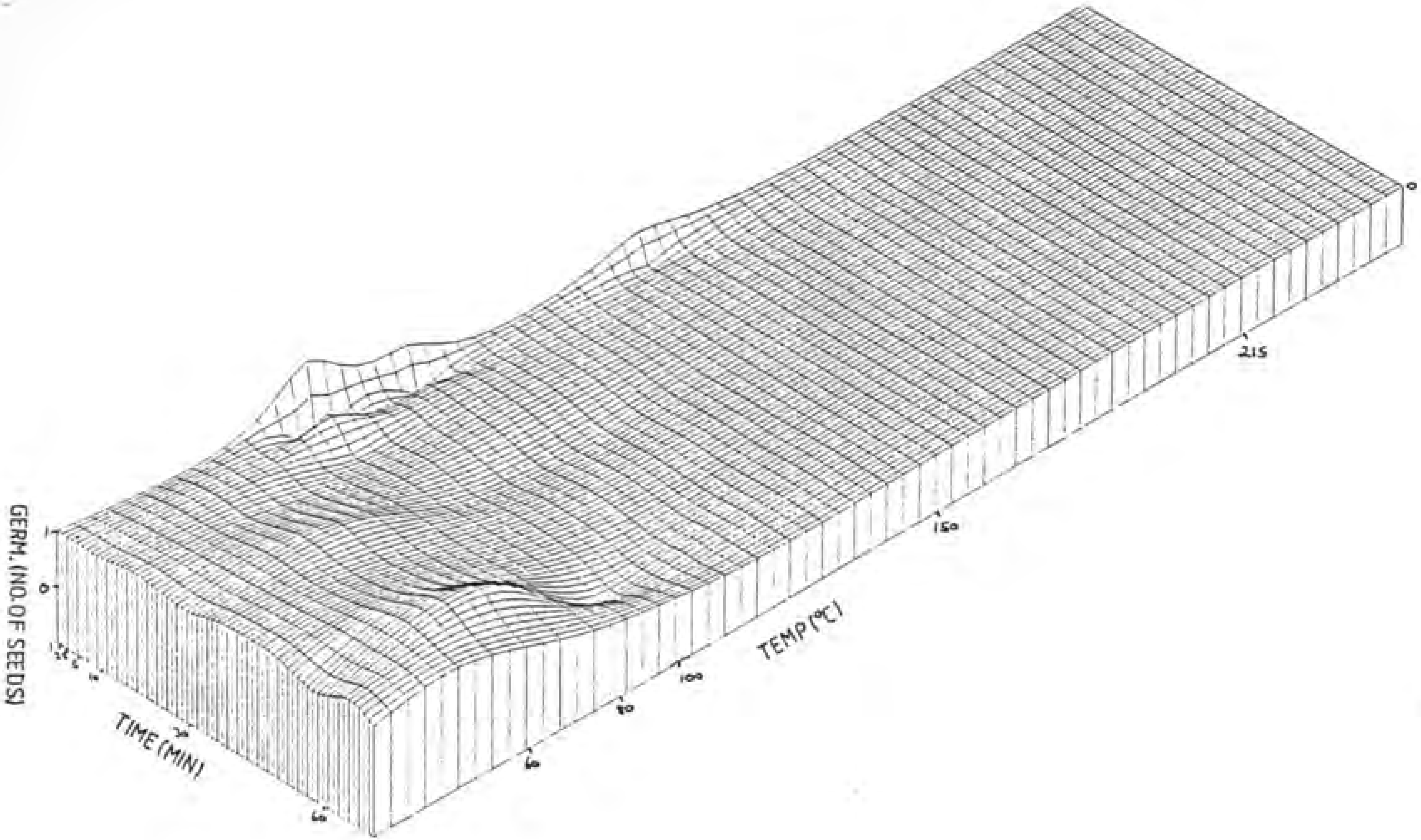

Figure 4b. A 3-dimensional graph of the average germination (of four replicates of 25 seeds each) of <u>A. cyclops</u> at each temp/time combination.

Germination Rates

The germination rates of V. oroboides (Table 2) range between 14 days (60°C for 5 minutes) and 29 days (60°C for 1 minute)(Control germination rate = 22 days)

P. calyptra had a minimum germination rate of 14 days (150°C for 2.5 minutes) and a maximum rate of 22 days (80°C for 30 minutes) (Table 2). (Control germination rate = 22 days)

Except for two treatments where the rates were 20 and 21 days (60°C for 10 minutes and 80°C for 2.5 minutes respectively), A. saligna had germination rates of no higher than 12 days with a minimum rate of 5 days (100°C for 1 minute) (Table 2). (Only 3% of the seeds germinated in the control experiment and so no rate was calculated)

The germination rate of A. cyclops was not calculated because of its very low total germination.

TABLE 2. The effect of different treatments (temp/time combinations) on the germination rates of <u>A.saligna</u>, <u>P.calyptrata</u> and <u>V.oroboides</u> seeds

(Rates given in days)

TEMP	TIME(MIN)	A.SALIGNA	V.OROBOIDES	P.CALYPTRATA
60 C	1	-	29	19
	2.5	12	16	19
	5	14	14	17
	10	20	12	18
	30	9	22	20
	60	8	18	21
80 C	1	6	26	21
	2.5	21	25	16
	5	7	27	18
	10	8	22	18
	30	7	22	22
	60	8	17	20
100 C	1	5	23	21
	2.5	6	26	20
	5	6	28	18
	10	7	22	21
	30	8	-	-
	60	12	-	-
150 C	1	8	18	-
	2.5	6	19	14
	5	8	-	-
	10	8	-	-
	30	-	-	-
	60	-	-	-
215 C	1	11	20	-
	2.5	-	-	-
	5	-	-	-
	10	-	-	-
	30	-	-	-
	60	-	-	-
CONTROL		-	22	22

DISCUSSION:

Virgilia oroboides showed a very marginal response to heat when related to its total viability (36% vs 89%). As V. oroboides is a forest precursor species its seeds would be more likely to respond to scarification than to heat treatment. It is possible that V. oroboides does germinate after fire but that in fact fire is not the primary mechanism stimulating germination. The fire will expose the soil surface which will expose the V.oroboides seeds to diurnal temperature changes over many days. This long duration at low maximum temperatures could be the primary mechanism needed to stimulate germination. At 100C the germination percentage fell below 12% at all durations indicating that this temperature was adversely affecting the seeds. The germination rates of V.oroboides seeds were low and this, coupled with the insignificant differences of all but two treatments to the control, supports the fact that this species is not adated to heat stimulated germination.

P.calyptrata responded significantly to dry heat and in many treatments the percentage germination equalled or exceeded that of the total viability of the seeds indicating that the dormancy of all the seeds had been broken.
Treatments at 80°C for 30 and 60 minutes caused slightly reduced germination. This shows that long durations at this temperature has an adverse affect on the seed viability.

Although _A. saligna_ seed had a viability of 98%, only a maximum germination of 88% was attained following dry heat treatments. However, all treatments below lethal temperature duration (except the lowest temperature duration at 60°C) caused a significatly greater germination average than the control. It can therefore be said that _A. saligna_ is adapted to heat stimulated seed germination.

Acacia saligna has a much faster germination rate after treatment than either of the indigenous species. This fast germination rate may help to account for its ability to suppress indigenous species in the field; the seedlings would be the first to establish themselves after a disturbance which would give them a competitive advantage over other species with slower germination rates. Its ability to withstand higher temperature durations than the indigenous species tested, suggests that it has a competitive advantage following intense fire.

Acacia cyclops did not respond to heat treatment and this may be because in Australia it is rarely subject to fire. In many localities the species is associated with human disturbance, for example along commonly travelled roads (Gill 1985). However, temperature treatments of 60°C for 8 days or repeated half day exposures of 15°C followed by 60°C over 8 days gave germination response of 42% and 21% respectively (Gill 1985). This treatment was thought to simulate conditions which seeds lying exposed to the sun would be subjected to.

A. cyclops seeds are dispersed by birds in both South Africa and Australia (Glyphis et al. 1981). It was found that the passage of A. cyclops seed through the gut of a bird results in 30% germination, compared to 9% spontaneous germination (Glyphis et al. 1981). It is probable that heat alone does not break A.cyclops seeds dormancy. Glyphis et al. (1981) suggest that a combination of bird digestion of the seed and heat would possibly stimulate the germination of these seeds. The heat requirement is more likely to be that from the sun over extended periods than intense heat from fire.

Cavanagh (1980) found that whilst Acacia seeds can withstand prolonged periods of exposure to dry heat, they are more adversely affected by moist heat. Milton and Hall (1981) found that A.cyclops seeds with a spontaneous germination of 9.2% yielded an 87% germination following hot water treatments. Soil is seldom completely dry and so when it is heated as a result of fire seeds in the soil are possibly exposed to some degree to moist heat rather than dry heat. This could have two implications with respect to the results of this project.

1. The finding that A. cyclops and V. orobroides seeds do not respond to dry heat does not necessarily mean that they will not respond to moist heat. Moist heat may well bring in another scarification factor which could stimulate their germination.

2. The fact that Acacia seeds are more adversely affected by moist heat than dry heat may well mean that the lethal temperatures may be even lower when the seeds are exposed to moist heat.

An average-sized mature Australian _Acacia_ in the South-Western Cape is capable of producing $9,5 \times 10^3$ to $4,8 \times 10^4$ seeds yr. of which a large proportion remains dormant in the seed bank (Milton and Hall 1981). One method of reducing this seed bank is by burning the area. A fairly intense fire reduced the seed bank density of _A.longifolia_ by 92.8%,as a result of killing the seeds and stimulating them to germinate (Pieterse and Cairns 1986).The same clearing treatment could be used for _A.saligna_ because, as shown by the results, it is also stimulated to germinate after fire.

Conversely seed banks of _A.cyclops_ would not be reduced to the same extent by fire as this species does not germinate in response to dry heat and the seed bank would therefore only be reduced by the number of seeds killed.

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REFERENCES:

Cavanagh, A.K. (1980). A review of some aspects of the germination of acacias. Proc.Roy.Soc.Vic 91(161-180)

Clemens, J., Jones, P.G. and Gilbert N.H. (1977) Effect of Seed Treatments on Germination of Acacia. Aust J. Bot 25: 269-76

Gill, A.M. (1985) Acacia cyclops G. Don (Leguminosae - Mimosaceae) in Australia : Distribution and Dispersal. J.Roy.Soc.W.Aust. 67(2)(59-65)

Glyphis, J.P., Milton, S.J. and Siegfriend, W.R. (1981) Dispersal of Acacia cyclops by Birds. Oecologia (Berl) 48: 138-141

Jackson, W.P.U. (1982). Wild Flowers of Table Mountain. Howard Timmins Publishers. Cape Town.

Macdonald, I.A.W. and Jarman, M.L. (1984) Invasive Alien Organisms in the Terrestrial Ecosystems of the Fynbos Biome, South Africa. South African National Scientific Programmes Report No.85

Milton, S.J. and Hall, A.V. (1981) Reproductive Biology of Australian Acacias in the South Western Cape Province, South Africa. Trans. Roy.Soc.SAfr 44(3)

Pieterse, P.J. and Carns, A.L.P. (1986) The effect of fire on Acacia longifolia seed banks in the South Western Cape. S.A.J.Bot 52(233-236)

Pieterse, P.J. and Cairns, A.L.P. (1986). An effective technique for breaking the seed dormancy of <u>Acacia longifolia.</u> (in Press)

van Wilgen, B.W. and Holmes, P.M. (1986). Fire Behavior and Soil Temperatures in <u>Acacia cyclops</u> at Walker Bay State Forest. Report No. J6/86. Jonkershoek Forestry Research Centre.