

**FIRE AND THE PERSISTENCE OF TUART WOODLANDS**

**by**

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**This thesis is presented for the degree of Doctor of Philosophy of Murdoch  
University 2006**

**I declare that the work in this thesis is my own account of my research and contains as its main content work that has not been submitted for a degree at any tertiary education institution.**

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# 1 EXAMPLES OF TUART CANOPY HEALTH ASSESSMENTS



**Figure 1.1:** Examples of ratings for canopy area (CA) and canopy health (CH) for tuart trees in this study adapted from Grimes (1978): **a)** CA = 3, CH = 5 **b)** CA = 7 for a tree recovering after fire (CH was not assessed for trees recovering after fire), **c)** CA = 4, CH = 8, **d)** same tree as in c one year after fire causing 35 % canopy scorch CA = 4, **e)** two trees rated immediately following 100 % scorch: CA = 4, CH = 9 (left) and CA = 8, CH = 13.5 (right) and **f)** same trees as in previous one year after fire: CA = 1.5 (left) and CA = 7 (right). Note, the tree on the left in f may have lost some leaves due to incineration and thus pre-fire health may have been underestimated. Similar cases were believed to comprise a minority of the sample of trees assessed post-fire only (and rated for assumed pre-fire health).

## 2 *SPYRIDIUM GLOBULOSUM*: FIRE RESPONSE AND EFFECT ON FIRE BEHAVIOUR

### 2.1 INTRODUCTION

As with peppermint, the shrub *Spyridium globulosum* may be proliferating in long-unburnt areas. Chapter 3 indicated that the cover of the shrub has increased in parts of the National Park (section 3.3.3). Further, it is apparent that the shrub has a tendency to grow directly under tuart trees and that it does not readily burn when in the path of low-intensity fire (Figure 2.1). If these observations reflect reality, implications arise for community dynamics, including tuart health and regeneration. Therefore, the following hypotheses were tested:

- There is a significant association between the presence of *S. globulosum* and the presence of tuart.
- *S. globulosum* does not resprout after fire.
- The probability of a point remaining unburnt is higher where *S. globulosum* is present.



**Figure 2.1:** **a)** A declining tuart tree (↓) encircled by *Spyridium globulosum* shrubs (←) within an *Acacia* spp. shrubland on near-coastal dunes west of Yalgorup National Park. **b)** *S. globulosum* under a tuart tree at site Y1 one year after 2004 controlled burn. Note that the foreground area was burnt up to the outer edge of the shrub (↑) only.

### 2.2 METHODS

#### 2.2.1 The association between *S. globulosum* and tuart

A total of 44 plots (each 4 x 4 m) were established across sites Y1 to Y3 in a gridded pattern. These correspond to the seedling regeneration plots outlined in Chapter 3 with

the exception that two additional main plots, accounting for a further 8 regeneration plots in total, were located at site Y1. Projected cover by species within each plot was estimated visually for each shrub and tree species between September and November 2003. The existence of a relationship between the presence of tuart and *S. globulosum* was tested for using  $\chi^2$  analysis in MINITAB Version 13 (Minitab Inc. 2000) with significance ( $\alpha$ ) set to 0.05.

### **2.2.2 The fire response of *S. globulosum* in comparison to other shrub species**

In January 2005, one month after the controlled burn, the proportion of each plot area that was burnt was estimated. Only seven plots had been burnt such that 95 % of the shrub layer had been consumed or scorched. Therefore, only these plots were examined further. In January 2006, cover by species was again assessed. As some species were regenerating by seed and it was difficult to find and estimate cover for small seedlings in the 16 m<sup>2</sup> plot, cover for seedlings of a species was only estimated when it exceeded approximately 1 % of the plot area. The seedling cover scores were added to the total cover scores. The effect of burning on shrub species was determined by comparing the ranked means of cover by species before the fire, and approximately one year after.

### **2.2.3 The association between the distribution of *S. globulosum* and burn pattern**

A point-interception survey of the presence or absence of shrub species was conducted throughout the six primary 50 x 50 m monitoring plots within site Y2 (Chapter 3), approximately three months before the controlled burn. This was carried out originally with a view to assessing elevated fuel distribution across the site. Points were laid out evenly on a grid 10 m apart such that there were 25 sampling points within each of the six plots. A species was recorded as present if any part of the plant touched a pole (approximately 1 cm diameter) held vertically. In the post-fire survey, the same points were surveyed and the immediate area surrounding the point (approximately 0.5 m radius) was rated as burnt or unburnt. A  $\chi^2$  test of association between unburnt patches and the presence of the shrub was performed in MINITAB Version 13 (Minitab Inc. 2000) with significance ( $\alpha$ ) set to 0.05. The gridded nature of the sampling potentially invalidated the results of the analysis by violating the assumption of independence. Therefore the pattern of burnt and unburnt points overlaid with the presence of *S. globulosum* was examined visually to judge whether a lack of independence could have affected the results.

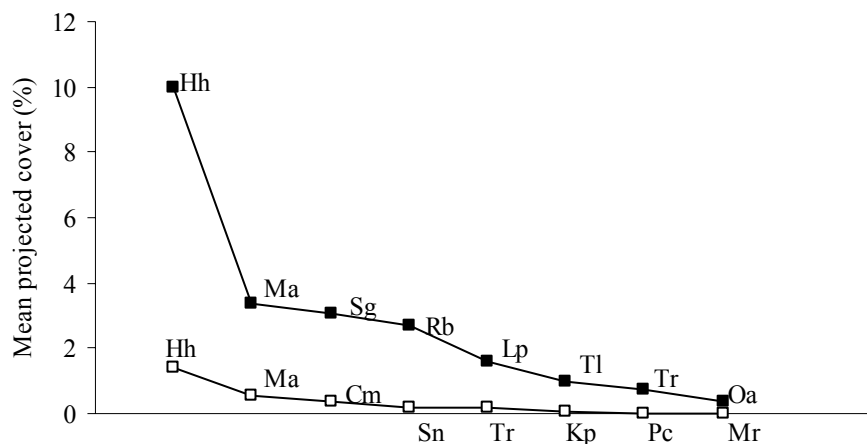
## 2.3 RESULTS

### 2.3.1 The association between *S. globulosum* and tuart

Analysis of the presence-absence data for the two species in the understorey monitoring plots at Y1, Y2 and Y3 ( $n = 44$ ) indicated a positive association:  $\chi^2_{(1)} = 13.391$ ,  $P < 0.001$ . While the shrub was recorded on occasions without tuart cover ( $n = 12$ ), every plot with tuart cover also had *S. globulosum* present.

### 2.3.2 The fire response of *S. globulosum* in comparison to other shrub species

Observations revealed burnt *S. globulosum* shrubs did not resprout. Consequently, the proportion of cover for this species declined relative to other resprouting shrub species or those such as *Solanum nigrum* that developed vigorously from seed (Figure 2.2). However, *S. globulosum* seedling regeneration was observed within the burnt plots.

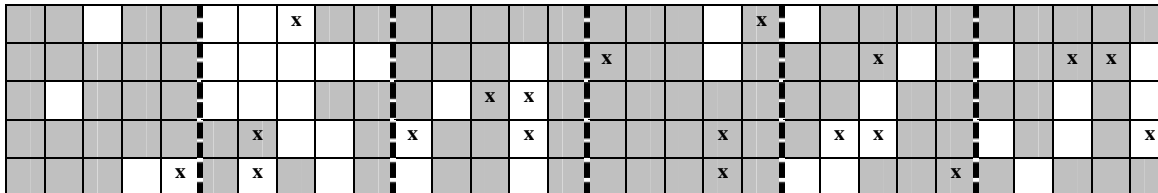


**Figure 2.2:** Rank-order of shrub and vine species (rank 1 to 8 only) for mean projected cover in seven 4 x 4 m plots at site Y1 before fire (■) and one-year post-fire (□). At least 95 % of each plot area was burnt. Full species names: Cm (*Clematis microphylla*), Hh (*Hibbertia hypericoides*), Kp (*Kennedia prostrata*), Lp (*Leucopogon parviflorus*), Mr (*Macrozamia riedlei*), Ma (*Melaleuca acerosa*), Oa (*Olearia axillaris*), Pc (*Phyllanthus calycinus*), Sg (*Spyridium globulosum*), Sn (*Solanum nigrum*), Tr (*Templetonia retusa*), Tl (*Trymalium ledifolium*).

### 2.3.3 The association between the distribution of *S. globulosum* and burn pattern

A survey of the burn patterns across the six main plots following the fire, revealed a significant association between unburnt patches and the presence of *S. globulosum*:  $\chi^2_{(1)} = 8.942$ ,  $P = 0.003$ ,  $n = 150$ . As the survey involved systematic sampling, the possibility

of non-independence invalidating the result existed. However, plotting the spatial distribution of the shrubs sampled indicated a reasonable level of dispersion (Figure 2.3). There were two instances where two shrubs located at adjacent sampling points were unburnt. However, when weighed against the level of significance ( $P < 0.01$ ), it is still reasonable to infer that a significant relationship existed.



**Figure 2.3:** Representation of the sampling results for the presence of *Spyridium globulosum* (x) as determined by interception of foliage with a pole, and unburnt (□) and burnt patches (■) at each sampling point. Sampling occurred on a 10 x 10 m grid, that is, the centre of each small square represented was sampled. Each main plot was separated by at least 25 m. Inter-plot boundaries are represented by the dashed line.

## 2.4 DISCUSSION

If the expansion and development of *S globulosum* at sites within the park continues, reintroducing frequent, low-intensity fire will be difficult. This study observed that the shrub burned and was killed when exposed to fire of sufficient intensity. However, by nature of its dense canopy which restricts air-flow and casts considerable shade, and/or its leaf chemistry, *S globulosum* appears to impede the passage of low-intensity fire. As with forest patches within fynbos this fire-dampening effect allows fire-sensitive adults to survive fires once established, particularly if thickets are eventually formed (van Wilgen *et al.* 1990). This point receives little recognition in debates regarding the coexistence of frequent fire and the persistence of fire-sensitive seeder species in the landscape (for example, Enright *et al.* 2005).

As the shrub grows preferentially under tuart trees, the area surrounding the trees would have an increased chance of remaining unburnt in low-intensity fire. Therefore, the opportunity for trees to benefit from an increased availability of soil nutrients, or for the establishment of tree seedlings to occur on burnt ground around the tree, would be limited. Alternatively, where fire does penetrate vegetation dominated by *S. globulosum*, it is likely to be of high intensity. With the tendency for the shrub to proliferate at the base of tuart trees, the probability of tuart bole and canopy damage in



such fires would be further increased, particularly as the shrub would act as a “fuel trap”, accumulating elevated dead fuels that fall from the tree stem and crown above.

Where *S. globulosum* becomes an increasingly dominant component of the understorey, it also has the potential to alter fire regimes at site scale. Sufficient wind speed or warm dry conditions are likely to be necessary before fire would be carried through such vegetation, as is the case generally for heathland in the Yalgorup area (S. Dutton, Department of Conservation and Land Management [DCLM], pers. comm.). Therefore, reintroducing frequent, low intensity fire will be difficult in areas such as in Figure 3.11 (Chapter 3). Before the declaration of the National Park, graziers regularly burnt the borders of shrublands so as to gradually expand the area of suitable grazing ground (S. Dutton, DCLM, pers. comm.). Frequent fire is likely to limit the spread of *S. globulosum*, as seedlings or small shrubs of this species would be destroyed by low intensity fire. The long absence of fire in parts of the Park may now be allowing shrubland to recolonize, or even expand beyond areas that it once occupied. From a biodiversity perspective, it may not be desirable for a single shrub species to dominate an expanding shrub layer across extensive areas.

## **3 RESPROUTING OF TUART SEEDLINGS AT TWO YEARS OF AGE**

### **3.1 INTRODUCTION**

The results in Chapter 4 cast some doubt over the capacity of two-year-old tuart seedlings to resprout when seedling stems were decapitated within 1 cm of the stem-root junction. A further experiment indicated the capacity for resprouting when stems were cut 5 cm above the root-stem junction, but only four seedlings were studied. Therefore, the following hypothesis was tested using an additional and larger sample:

- At two years of age, tuart seedlings resprout after above-ground stem decapitation.

Season and plant-size factors can also affect resprouting patterns (Bond and van Wilgen 1996). Consequently, in order to provide some level of generality, a range of seedling sizes and two times of decapitation were incorporated into the experiment. This also enabled the following hypotheses to be tested for two-year-old tuart seedlings:

- Resprouting capacity varies with season of defoliation.
- Resprouting capacity varies with seedling size.

### **3.2 METHODS**

#### **3.2.1 Sites, treatments and measurements**

A selection of planted tuart seedlings growing in the field experiment at site Y1 (see Chapter 6 for the location, design and set-up of this experiment) had their stems severed approximately 5 cm above the soil surface. Seedlings were approximately two years of age at the time of the treatment. Two seedlings were randomly selected from each ashbed and each non-ashbed soil replicate (where sufficient seedlings remained to do so), measured for height and then cut; this occurred in both December 2005 ( $n = 43$ ) and in March 2006 ( $n = 48$ ). The presence of living resprouts was assessed two months after each cut. Uncut seedlings were also monitored for survival over the period to assess background levels of mortality. While 132 uncut seedlings were available for monitoring following the first cut, only 62 were available following the second. In addition, most of the latter were located off the ashbed soil treatment, further detracting somewhat from their value as controls.

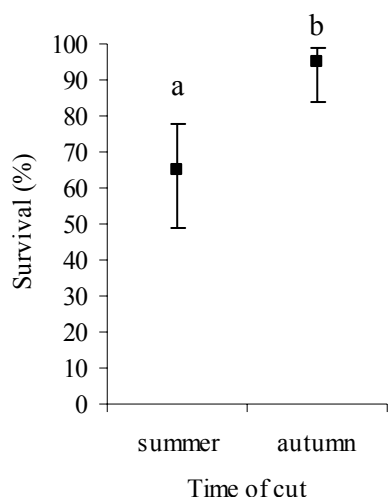
### 3.2.2 Statistical analyses

MINITAB Release 13 (Minitab Inc. 2000) was used for all tests and significance ( $\alpha$ ) was set to 0.05. Survival proportions were compared between cutting dates using the  $z$ -test. In order to test if seedling size was a potentially confounding factor,  $t$ -tests were performed on the height data. Assumptions of constant variance and normality were checked prior to the analyses and data was transformed where necessary. The relationship between seedling height and the presence of resprouts was tested using logistic regression. Regression models were checked for Pearson, Deviance and Hosmer-Lemeshow Goodness of fit test results as provided by the MINITAB output.

### 3.3 RESULTS

The majority of the seedlings survived the decapitation treatment (Figure 4.1). There was a marked increase in survival rate in the autumn (95 %) over the summer cut (65 %):  $z = -4.04$ ,  $P < 0.001$ ,  $n = 43$  and  $48$ , respectively. In contrast, survival of the uncut seedlings ( $n = 132$ ) over the period of the first to the second cut was higher (92 %) than for the cut seedlings:  $z = -3.83$ ,  $P < 0.001$ . However, for the autumn period, the opposite occurred with only 82 % of the uncut surviving ( $n = 62$ ) compared with 95 % for the cut, but this difference was not significant:  $z = -1.37$ ,  $P = 0.172$ . Due to the sampling scheme, there was a higher proportion of seedlings left uncut off ashbed soils during the autumn period. Thus, the validity of any comparison of the survival of uncut seedlings between the two times is questionable.

There was a positive and significant relationship between seedling height and survival following the summer decapitation (Table 3.1). Such a relationship was also apparent for the autumn cut data. When the initial heights of the 43 autumn-cut seedlings were ranked from tallest to shortest, the two non-surviving individuals were ranked as the shortest and the third shortest. This height-survival relationship potentially compromised any comparison between survival times as a result of growth in the intervening period. However, when the heights of the seedlings from the two sample times were compared, the means were almost identical:  $71 \text{ cm} \pm 6.4 \text{ SE}$  (summer cut) versus  $70 \text{ cm} \pm 5.3 \text{ SE}$  (autumn cut),  $t_{(89)} = -0.56$ ,  $P = 0.575$  (log-transformed data).



**Figure 3.1:** Survival of two-year-old tuart seedlings following the decapitation of the stems 5 cm above ground-level. Seedlings were planted at five months of age in the field experiment at site Y1. Cutting occurred in summer (December 14 2005,  $n = 48$ ) and in autumn (March 31 2006,  $n = 43$ ). Survival (determined as the presence of living resprouts) was assessed at two months after the decapitation treatment. Different letters denote significant differences between proportions following  $z$ -tests. 95 % confidence interval bars are indicated.

**Table 3.1:** Logistic regression results for survival (dependent variable) versus height of two-year-old tuart seedlings ( $n = 48$ ) following the decapitation of stems 5 cm above ground-level in December 2006. Seedlings were planted at five-months of age in the field experiment at site Y1. Survival (determined as the presence of living resprouts) was assessed two months after the decapitation treatment. The regression was significant:  $G_{(1)} = 11.261$ ,  $P = 0.001$ .

Variable	Coefficient				Odds ratio	95 % CI	
		SE	Z	P		Lower	Upper
Constant	-1.40	0.748	-1.87	0.061			
Height (cm)	0.032	0.012	2.65	<b>0.008</b>	1.03	1.01	1.06

### 3.4 DISCUSSION

The results confirmed the strong capacity for two-year old tuarts to resprout when damage occurs above ground-level on the stem, although seedling size and season of defoliation affected this capacity. Presumably, seedling size was inversely related to past vigour, current non-structural carbohydrate (NSC) stores and possibly physiological condition. This may account for the lower survival rates of the smaller seedlings. When the survival rates of the uncut seedlings were considered, poorer survival in the summer cutting treatment did not appear to be linked to factors unrelated to the cutting treatment. Further, the seedlings were similar in height between the cutting times, so size could also be ruled out as factor in the difference. In resprouters

such as mallees, the similarity in survival rates between seasons of defoliation for well-established plants has been attributed to the accumulation of a large pool of NSC reserves (Wildy and Pate 2000). In contrast, young seedlings may have limited reserves, and hence defoliation earlier in the growth season may be detrimental (Bond and van Wilgen 1996). Replication of season would be required to confirm the significance of any seasonal effect on the resprouting tuart seedlings. If very frequent fire was to be restored to some tuart woodlands, season of fire could be selected to promote or prevent seedling/sapling survival. However, intensity and variability in intensity as determined by season and frequency would likely be more influential factors in determining the fate of seedlings/saplings.

## **4 A PRELIMINARY STUDY OF THE ALLELOPATHIC POTENTIAL OF PEPPERMINT**

### **4.1 INTRODUCTION**

Ward (2000) suggested the allelopathic potential of peppermint should be investigated. However, none of the results in Chapter 6 demonstrated a negative effect of the presence of peppermint trees on tuart seedling growth or survival. Nevertheless the findings that peppermint leaves suffer much less chewing damage than tuart, even though they have a larger specific leaf area, hints that peppermint may contain a high concentration of secondary chemicals (Chapter 6). If this is the case, peppermint may have the potential to affect tuart through allelopathy due to the leaching of these chemicals from peppermint leaves and leaf litter into the soil. Therefore, the aim here was to test if tuart germination and seedling health and growth were affected when the seeds or seedlings were in contact with soil collected from under peppermint canopies.

### **4.2 METHODS**

#### **4.2.1 Background**

As a preliminary investigation of the existence of an ecologically significant effect of allelopathy originating from peppermint, the simulation of realistic conditions over bioassay-type experiments was favoured. Thus, relatively undisturbed field soils and tuart seed and seedlings were used. There were two experiments: the first examined germination and the second, early seedling growth and health. The germination experiment took place in a controlled-temperature room while the seedling experiment occurred in an evaporatively-cooled glasshouse. A fertilizer treatment was imposed to ensure that any negative effect on germination or growth was not due to nutrient differences between the soil from under and outside peppermint canopies. Experiment 2 used the soils from Experiment 1.

## 4.2.2 Hypotheses

- Tuart germination rates are greater when seeds are placed on soil collected from outside rather than under peppermint canopies.
- For tuart germination rates, there is an interaction between nutrient availability and whether soil originates from under or outside peppermint canopies.
- The health and growth rates of tuart seedlings grown in soil collected from outside peppermint canopies are superior to when the seedlings are grown in soils collected from under peppermint canopies.
- For the health and growth rate of tuart seedlings, there is an interaction between nutrient availability and whether soil originates from under or outside peppermint canopies.

## 4.2.3 Experimental design

There were nine replicates for each soil collection position: outside or under peppermint canopy (Table 4.1). Within each soil type there were three replicates of three fertilizer treatments: control (no addition), low and high. For the germination experiment there were 40 seeds for each soil core. For the seedling experiment there were five seedlings planted in each core. The cores were set out in a completely randomized design with re-randomizations occurring every week.

**Table 4.1:** Treatments and replicates for glasshouse experiments testing the effect of soils collected from under and outside peppermint tree canopies on the germination of tuart seed, and the growth and health of tuart seedlings.

Soil	Treatments and replicates		
	High (1 g L <sup>-1</sup> )	Low (0.5 g L <sup>-1</sup> )	None (0 g L <sup>-1</sup> )
Under peppermint canopy <sup>1</sup>	3	3	3
Outside peppermint canopy	3	3	3

1. One replicate for the no fertilizer treatment in the germination experiment was excluded due to uncertainty with the count of germinants at one measurement time.

## 4.2.4 Soil collection

The soil was obtained along one transect at site Y1 and one transect at site Y2 in November 2004 (see section 3.2.1 in Chapter 3 for site details and Appendix 5 for transect coordinates). The transects extended in a south-east (site Y2) and a north-east (site Y1) direction. The collections outside the canopy were made at the approximate

centre of canopy gaps along transects. PVC pipes 20 cm in length and 8.8 cm diameter were used to extract and then support the soil collected as relatively undisturbed cores. A layer of fine-mesh shade cloth was secured to the bottom of the pipe in order to hold the soil in place. At site Y2, there were six soil samples collected from under peppermint canopies, and six from outside. At site Y1, three of each position-type were collected. The identity of the replicates by site was not preserved for the remainder of the experiment: that is, site was not considered as a factor.

#### **4.2.5 Seed**

The seed for the germination experiment was sourced from the Lake Clifton, Lake Preston and Ludlow areas in the ratio of 6:1:1, while the seed used for the seedling experiment originated from the Lake Clifton area.

#### **4.2.6 Fertilizer addition**

Three replicates of a fertilizer treatment (Thrive®, Arthur Yates and Co. Ltd. Australia: 27 % nitrogen, 5.5 % phosphorus, 9.0 % potassium plus trace elements) per soil treatment were applied to the cores immediately prior to adding the seeds. These treatments consisted of a high rate ( $1 \text{ g L}^{-1}$ ), a low rate ( $0.5 \text{ g L}^{-1}$ ) and no addition applied as a 40ml solution with DI water. One further addition was made during the germination experiment (see below).

#### **4.2.7 Experiment conditions and measurements: Germination**

The experiment began in the glasshouse. Temperature in the glasshouse ranged from 11 to 31°C and irrigation was provided twice daily by a sprinkler system. By day 10, there had been no germination, possibly due to higher than optimum temperatures. Consequently, the cores were relocated into a constant temperature room (21°C) for the duration of the experiment. A further 20 ml of solution as per the fertiliser treatments were applied at this time. Light was provided 12 hours day<sup>-1</sup> by metal-halide lamps. Moisture was maintained by placing the cores in trays of water and sealing the top of the pipes with plastic film. Germination was monitored periodically until day 20 by which time the germination rate had peaked. Upon germination, germinants were removed. One replicate for the under-canopy no-fertilizer treatment in the germination experiment was excluded due to uncertainty with the count of the germinants at one measurement time.



#### **4.2.8 Experiment conditions and measurements: Seedling growth**

Within one week of the completion of the germination experiment, the cores were removed from the trays of water and placed back in the glasshouse in a randomized layout. Five new germinants were placed in the soil cores. These germinants had germinated on filter paper soaked with DI water during the previous day. Water was supplied twice daily by sprinkler irrigation and temperatures in the glasshouse ranged from 15 to 38°C during the experimental period. After four weeks the seedlings were harvested and shoot length was measured and leaf number (including cotyledons) was counted. Leaf area of scanned images of the leaves was measured using ASSESS software (American Phytopathological Society 2002). Additionally, the program was used to distinguish green leaf-area from leaf area of another colour.

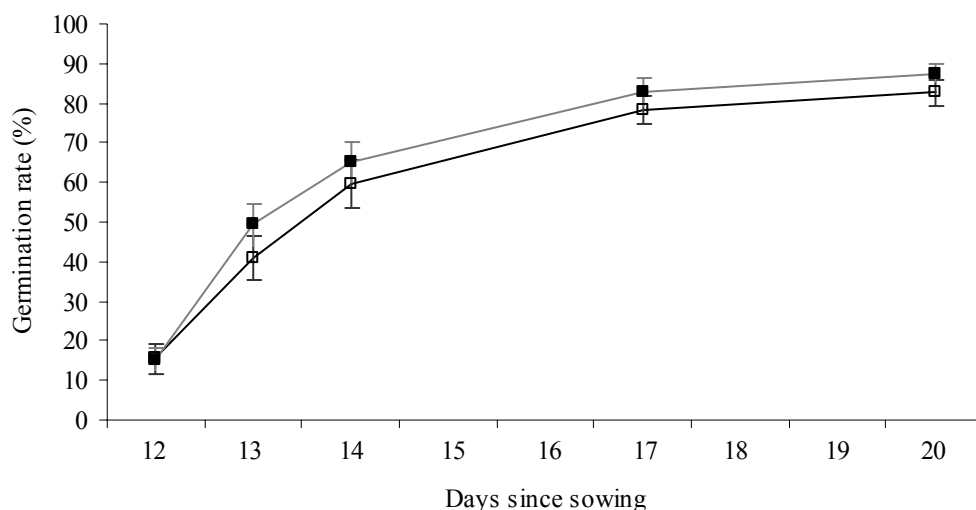
#### **4.2.9 Statistical analyses**

MINITAB Release 13 (Minitab Inc. 2000) was used for all statistical tests. Significance ( $\alpha$ ) was set to 0.05 unless otherwise stated. Multiple responses (time series or different attributes) were tested using MANOVA. The residual plots for the MANOVA models were diagnosed for departures from the assumptions of independence, constant variance and normality. Data transformations were made where necessary. *P* values from Pillai's trace were reported for MANOVA given that this measure is less affected by departures from normality and constant variance compared to the others (Townend 2002). Regardless, in instances where departures from model assumptions could not be rectified, adjustment of  $\alpha$  to 0.01 was made to reduce the probability of Type 1 errors (Tabachnik and Fidell 1996).

### **4.3 RESULTS**

#### **4.3.1 The effect of soil collected from under peppermint trees on tuart germination**

The germination rate of tuart seed on undisturbed soil cores collected from under and outside peppermint canopy was little different (Figure 4.1). The greatest difference in the means occurred on day 13, where the germination rate on the soil collected from under canopy was higher (49 %) than on soil from outside (41 %). However, there was no significant difference between the germination percentages on the different soils or under the different rates of fertilizer addition (Table 4.2).



**Figure 4.1:** Germination rate (%) of tuart seed on undisturbed soil cores collected from under peppermint canopy (■, n = 8) and outside peppermint canopy (□, n = 9). The experiment was carried out under glasshouse conditions until day 10 and then in a controlled-temperature room at 21°C. There were no significant differences between the treatments (Table 4.2). Standard error bars are indicated.

**Table 4.2:** MANOVA results for five measurements over time for the germination rate (arcsine transformed) of tuart seed on undisturbed soil cores collected from under peppermint (Pep.) canopy and outside peppermint canopy, with fertilizer treatments applied to the soil: none, low (0.5 g L<sup>-1</sup>) and high (1.0 g L<sup>-1</sup>). The experiment was carried out under glasshouse conditions until day 10 (by when germination had not yet commenced) and then in a controlled-temperature room at 21°C.

Effect		<i>P</i>
Pep.	$F_{(5, 7)} = 0.396$	0.837
Fertilizer	$F_{(10, 16)} = 0.810$	0.624
Soil x fertilizer	$F_{(10, 16)} = 0.215$	0.991

### 4.3.2 The effect of soil collected from under peppermint trees on tuart seedling growth

There was little variation in the basic morphology of newly emerged tuart seedlings grown for one month on undisturbed soil cores collected from under and outside peppermint canopy (Table 4.3). The proportion of leaf area exhibiting discolouration was also similar between the treatments. No significant differences were detected for soil type or the interaction between soil type and the fertilizer treatment (Table 4.4).

**Table 4.3:** Height and leaf characteristics of tuart seedlings grown in undisturbed soil cores collected from under peppermint (pep.) canopy (n = 9) and outside peppermint canopy (n = 9). The experiment was carried out under glasshouse conditions for four weeks. LA = leaf area..

Attribute	Soil under pep. canopy			Soil outside pep. canopy		
	Mean	±	SE	Mean	±	SE
Height (cm)	4.6	±	0.3	4.3	±	0.5
LA (cm <sup>2</sup> )	6.8	±	1.6	7.6	±	1.0
LA not green (%)	17	±	3	20	±	2
No. leaves	7.8	±	0.4	8.4	±	0.4

**Table 4.4:** MANOVA results for height, leaf area, proportion of leaf area not green and the number of leaves for tuart seedlings grown in undisturbed soil cores collected from under peppermint (Pep.) canopy and outside peppermint canopy, and with fertilizer treatments applied to the soil: none, low (0.5 g L<sup>-1</sup>) and high (1.0 g L<sup>-1</sup>). The experiment was carried out under glasshouse conditions for four weeks. Due to violations of MANOVA model assumptions,  $\alpha = 0.01$ .

Effect	<i>P</i>		
Pep.	$F_{(4, 9)}$	= 4.808	0.024
Fertilizer	$F_{(8, 20)}$	= 2.463	0.049
Pep. x fertilizer	$F_{(8, 20)}$	= 1.722	0.154

#### 4.4 DISCUSSION

There was no evidence for an allelopathic effect of peppermint on tuart via the soil. With spring as the season of soil collection and the frequent irrigation in the seedling experiment, it was possible that any allelochemicals were leached from the soil prior to, or following, collection. A similar experiment with greater statistical power, and with soil collections made at different times of the year, may be more revealing. However, it should be considered that great effort and possibly endless experimentation would be necessary to demonstrate conclusively the absence of allelopathy (Harper 1977). The effect of peppermint litter on mycorrhizae and nutrient cycling may not only be a more important ecological issue than direct allelopathy, it may also be a more profitable area of research. This point was taken up in the discussion in Chapter 6.

## 5 COORDINATES FOR STUDY AREAS

**Table 5.1:** Coordinates (UTM zone 50S) for study areas in this thesis.

Thesis section	Site	Feature (plot ID)	Easting	Northing	Location relates to:	
Chapter 3	Y1	Main plot (1)	372582	6383234	NW corner	
		Main plot (2)	372513	6383145	NW corner	
		Main plot (3)	372567	6382813	NW corner	
		Main plot (4)	372564	6382726	NW corner	
		Main plot (5)	372574	6382612	NW corner	
		Main plot (6)	372607	6382520	NW corner	
	Y2	Main Plot (1)	372671	6382241	NW corner	
		Main Plot (2)	372772	6382263	NW corner	
		1976/77 circular plot (138)	372746	6382096	Plot centre	
		1976/77 circular plot (139)	372852	6382086	Plot centre	
		1976/77 circular plot (140)	372950	6382064	Plot centre	
		1976/77 circular plot (141)	372576	6380773	Plot centre	
	Y3	Y4	1976/77 circular plot (143)	372700	6380930	Plot centre
			Main Plot	372438	6383306	NW corner
	Y5	Plotless sampling transects		377821	6368492	Approx. N boundary
				377811	6368340	Approx. W boundary
				378169	6367925	Approx. S boundary
				378169	6367925	Approx. E boundary
				378547	6366670	Approx. N boundary
				378547	6366670	Approx. W boundary
	Y6	Plotless sampling transects		379441	6365970	Approx. S boundary
				379441	6365970	Approx. E boundary
				375118	6364952	Approx. N boundary
	Y7	Plotless sampling transects		374969	6364924	Approx. W boundary
				375081	6364650	Approx. S boundary
				375130	6364764	Approx. E boundary
				377475	6357960	Approx. N boundary
	Y8	Plotless sampling transects		377120	6358192	Approx. W boundary
				376929	6357797	Approx. S boundary
				377144	6357605	Approx. E boundary
				381196	6352211	Approx. N boundary
	Y9	Plotless sampling transects		381128	6352187	Approx. W boundary
				381798	6350323	Approx. S boundary
				381798	6350323	Approx. E boundary
				381966	6345596	Approx. N boundary
	Y10	1976/77 circular plot (51)		381966	6345596	Approx. W boundary
				382093	6345304	Approx. S boundary
				382809	6345379	Approx. E boundary
				373831	6366198	Plot centre
	Y11	1976/77 circular plot (52)		373828	6366128	Plot centre
				375743	6362581	Plot centre
	Y11	1976/77 circular plot (36)		375870	6362594	Plot centre
				376016	6362613	Plot centre
				376247	6362588	Plot centre
				376350	6362600	Plot centre
	GB	Main plot 1 (SE)		385401	6413116	NW corner
				385342	6413119	NW corner
			385336	6413200	NW corner	
			385394	6413221	NW corner	
Ya1	Nearest track intersection		372872	6512367	Feature close to plots <sup>1</sup>	
			As above	As above	As above	
Chapter 4	Ya2	As above	As above	As above	As above	
						Ya3
	Ya4	Transect	375734	6506770	Start of transect	
						Y1
	Y1	Area of higher intensity fire	372558	6382772	Approx. centre of area	

Table continues over the page

Table 5.1 continued from previous page

Thesis section	Site	Feature (plot ID)	Easting	Northing	Location relates to:
Chapter 5	Y1	Main plot 7	372513	6383145	NW corner
	Y1	Main plot 8	372540	6383050	NW corner
Chapter 6	Y1	Seedling experiment plot 1	372539	6382461	NW corner
	Y1	Seedling experiment plot 2	372531	6382892	NW corner
	Y1	Seedling experiment plot 3	372556	6382530	NW corner
	Y1	Seedling experiment plot 4	372539	6382461	NW corner
Appendix 4	Y1	Transect	372568	6382334	Transect origin
	Y2	Transect	372593	6382293	Transect origin

1. The plots are located approximately 20 m from the edge of the track that runs south from this point. Ya1 plots are to the west and Ya 2 plots are to the east with each plot separated by approximately 25 m.