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Economic impact of a post-hail outbreak of dieback induced by *Sphaeropsis sapinea*

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Abstract

Following a hail storm in the southern Cape Province of South Africa, about 2000 ha of pine plantations were infected by *Sphaeropsis sapinea*. The timber loss due to *S. sapinea* infection in compartments prematurely clearfelled was about 28 % of volume and 55 % of value of potential production. Total predicted volume of timber lost in compartments not felled prematurely was an average of 11.4 %. Percentage volume lost increased with age, with the greatest losses being recorded on good quality sites.

1 Introduction

Infection of *Pinus* spp. by *Sphaeropsis sapinea* (Fr.) Dyko and Sutton has been reported from many different countries (PUNITHALINGAM and WATERSTON 1970; PETERSON 1978; GIBSON 1979; BROWN et al. 1981; VAN DAM and DE KAM 1984; DE KAM 1985; SWART, KNOX-DAVIES and WINGFIELD 1987). The pathogen is particularly notorious for the devastation it has caused in plantations of *Pinus radiata* D. Don and *P. patula* Sch. et Cham. after hailstorms in the summer rainfall areas of South Africa (LAUGHTON 1937; LÜCKHOFF 1964; GIBSON 1979). These outbreaks have restricted the cultivation of *P. radiata* and other susceptible pine species to the south-western and southern Cape Province where the occurrence of hail is rare (LAUGHTON 1937; LÜCKHOFF 1964; POYNTON 1979). However, even in these areas *S. sapinea* infection continues to be a problem after occasional hail storms.

Damage caused by *S. sapinea* can be both direct and indirect. Direct losses are usually in the form of increment loss due to defoliation and death of leading shoots and branches. Indirect losses are associated with exploiting diseased trees and stands before they reach maturity and attain maximum value, and timber degradation due to bluestain (LÜCKHOFF 1964).

Impact studies of *S. sapinea*-associated losses are scarce. The economic importance of *S. sapinea* was evaluated by WRIGHT and MARKS (1970) in Australia and CURRIE and TOES (1978) in New Zealand, and maximum reduction in timber increment and potential merchantable volume was assessed at 40% and 60%, respectively. An assessment of the amount of timber damaged or lost in outbreaks of *S. sapinea* infection following hail damage in South Africa has never been made (GREY 1987; LUNDQUIST 1987a).

The intensity in relation to site conditions of an outbreak of *S. sapinea*-induced dieback following a hail storm in the southern Cape Province, was previously reported by ZWOLINSKI et al. (1990). In the present paper, the extent of losses attributed to this outbreak are evaluated and associated timber and financial losses are calculated.

2 Methods

The total area affected following the hail storm in February 1986 was calculated after observations had been made in the field. Personal communication with forest managers as well as foresters' reports served as supplementary information.

The study area was located in a 191.5 ha block of plantations in which the following pine species were planted: *P. radiata* (80.3%), *P. elliottii* Engelm. et Vasey (12.2%), *P. pinaster* Ait. (6.7%), and *P. taeda* L. (0.8%). Production potentials for these species in the region range from an average minimum of 12 m³/ha/yr for *P. pinaster* and a maximum of 26 m³/ha/yr for *P. radiata*. Characteristics of the *P. radiata* stands are shown separately for each compartment in Table 1.

Table 1. Characteristics of *Pinus radiata* stands in the study area located at Kruisfontein State Forest

Compt no.	Area (ha)	Age (yr)	Site Index ¹
6	9.7	11	26
10 b	5.8	25	17
10 d	1.1	21	23
11 a	21.0	16	19
13 a	5.2	10	16
13 b	7.0	11	22
14 b	5.5	10	29
14 c	10.8	10	30
15 a	9.3	10	9
16 a	16.0	13	11
16 e	8.0	19	20
17 a	10.8	25	15
17 c	2.5	27	20
18 a	8.8	9	10
18 b	11.7	9	9
19	18.0	10	10
20 c	2.6	28	28

¹ mean height at 20 years of age

Three square plots of 0.25 ha each were established in a 13-year-old stand of *P. radiata* for a detailed study of the effect of post-hail *S. sapinea* infection on tree growth. The plots were spaced approximately 50 m apart. Trees in the compartment had been planted 2.7 m apart and pruned to 5 m height in 1983. Number of trees, basal area, mean height (HT) and predicted site index were recorded for each plot (Table 2). The differences in mean height and diameters at 1.3 m height (DBH) between the stands were statistically significant ($P < 0.01$).

Total volume of stems was calculated according to a locally developed formula. The volume of depreciated timber was summarized as total volume of dead trees and volume of dead tops of infected trees. Diameter of the thicker part of a dead section (at the "green height") was calculated after taper was calculated separately for each tree. Dead trees and

Table 2. Number of trees, basal area, mean height, and predicted site index of experimental plots

Plot no.	No. of trees	Basal Area (m ² /ha)	Mean height (m)	Predicted site index (m)
1	206	5.257	7.796	10.8
2	174	18.899	16.394	22.5
3	177	11.873	13.388	18.5

trees with the shortest living stems were selected for the second and third thinning. Trees with the highest living stems were selected for the final harvesting. Thinning of the stands was planned as recommended by WESSELS (1987) except for plot 1 which was overstocked at the time of the first assessment. Percentage volume loss at the third thinning and at clearfelling was estimated assuming that (i) timber formed from the tops of live stems of trees with killed leaders could not be utilized due to forks, crooks and other faults, and (ii) the growth rate of trees had recovered fully, 18 months after the hail storm. Mean DBHs and HTs of the trees were predicted from growth curves published by MARSH (1978), and then predicted diameters at the end of utilizable parts of the stems were calculated.

In the study area, compartments 6, 11a, 13a, 13b, 14c, 15a, 16a, 16e, 17a, and 20c were clearfelled due to extensive damage, and replanted with *P. radiata*. The total volume utilized was classified as sawlogs, poles, pulp (blockboards), and spar material (Table 5). Potential yields of the replanted stands were predicted for the number of years needed to complete the previous rotation at the age of 30 years. The total of the achieved yield at the felling stage, and the potential yield predicted for the reestablished stands, was then compared to the potential yield of the stands. It was assumed that these stands would have been harvested at the age of 30 years had they not been disturbed by hail damage and *S. sapinea* infection. Financial loss associated with age and site index of the clearfelled stands was estimated. The predicted volumes are based on the most recent assessments in the compartments and standardized calculations processed for management purposes. Further division of the predicted yields into product classes is based on the estimates made by local foresters. The average unit prices of the timber sold at Kruisfontein were lower than the normal prices of timber sold in the Forest Region because of the emergency of the situation and blueing of the timber.

The SAS statistical package was used to summarize and analyze the data (SAS Institute Inc., 1985). Tukey's Studentized range test of the general linear models procedure was used to compare differences between the mean DBHs and HTs of trees in each plot. Multivariate regression was employed to investigate the relationships between value loss of the timber harvested from the clear-felled compartments and age, and site index of the stands.

3 Results

The hail storm on 3 February 1986 comprised intermittent, very heavy bouts of hail and sleet with high winds over a period of 10–15 minutes in the late afternoon (J. Verdoucq, Kruisfontein State Forest, pers. comm. 1986). Within one week there was widespread mortality of one-year-old *P. pinaster* and about 25% needle loss in three- to five-year-old *P. elliotii* (V. Luyt, Kruisfontein State Forest, pers. comm. 1986). During the third week after the hail storm, discolouration of needles, shoot blight and dieback of tops developed in 13- to 20-year-old *P. radiata* trees (F. Gonzales, Kruisfontein State Forest, pers. comm. 1986). All the commercial pine species in the area showed symptoms of infection but *P. radiata* stands were the most heavily affected. The total area affected was more than 1930 ha. Approximately one quarter of this area was evaluated as being so heavily damaged that thinning or even clearfelling was necessary to eliminate dead and malformed trees.

In the sample plots, percentage of timber volume lost differed between the plots and was almost entirely confined to trees selected for the second thinning (Table 3). In this group of trees, the greatest damage to timber occurred in plot 3, where 12.5 m³/ha, i. e. 16.6% of the stand or 53% of the second thinnings were depreciated. In plot 1, more than 8% of the stand or 62% of the second thinnings were depreciated but volume of the dead trees was low due to small total volume in the plot. The percentage of volume lost in plot 2 was the smallest and exceeded only 2% of the stand or 8% of the second thinnings. On average, timber loss was 27.1% at the first thinning. Predicted volume loss among the

Table 3. Depreciation of timber of trees left standing and trees selected for the second thinning in experimental plots

Plot No.		Stems/ha (m ³ /ha)	Total volume (m ³ /ha)	Lost volume	% Loss
1	2nd thinning	324	2.91	1.816	62.28
	left standing	500	19.00	0.028	0.15
	Total	824	21.91	1.844	8.41
2	2nd thinning	296	38.18	3.145	8.24
	left standing	400	108.00	0.046	0.04
	Total	696	146.18	3.191	2.18
3	2nd thinning	308	23.40	12.508	53.44
	left standing	400	52.40	0.043	0.08
	Total	708	75.808	12.551	16.56

Table 4. Predicted volume lost among trees selected for the third thinning (at 18 years of age) and trees to be utilized at 30 years in the experimental plots

Plot no.	Tree Group	Stems/ha	Vol. of depreciated timber (%)
1	felled at 3rd thinning	200	3.1
	felled at clearfelling	300	13.4
2	felled at 3rd thinning	150	3.7
	felled at clearfelling	250	10.1
3	felled at 3rd thinning	150	4.1
	felled at clearfelling	250	10.5

trees selected for the third thinning and those to be utilized at the final clearfelling at the age of 30 years is shown in Table 4.

Most of the timber depreciated was confined to the uppermost part of the stems which is usually not sold, or sold at lower prices. Percentage volume lost increased with age, with the greatest losses being recorded on good quality sites (Fig. 1). Total predicted volume of timber lost in compartments not felled was an average of 11.4%.

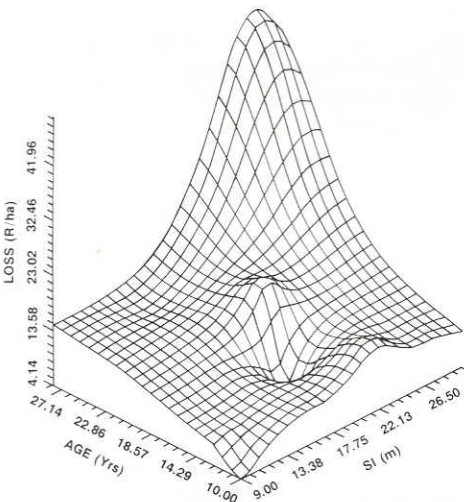


Fig. 1. The effect of site index (SI) and age of stands on the loss of value of timber utilized from *P. radiata* stands prematurely clearfelled due to *Sphaeropsis sapinea* infection at Kruisfontein State Forest

Table 5. Loss of volume and value of timber due to premature harvesting in *Pinus radiata* compartments at Kruisfontein State Forest

Timber class	Rotation						Disturbed				Loss	
	Undisturbed			Sold			Value (R)		Predicted		Volume (m ³)	Value (R) ¹
	Volume (m ³)	Unit price (R/m ³)	Value (R)	Volume (m ³)	Unit price	Value (R)	Volume (m ³)	Value (R)	Unit (R/m ³)	Value (R)		
Spar mat.	836	7.05	5894	1409	9.05	12752	2548	17963	7.05	17963	-3121	-24821
Blockboard	4238	10.58	44838	2794	3.08	8606	6307	66728	10.58	66728	-4863	-30496
Poles	702	15.90	11162	1122	20.62	23136	515	8189	15.90	8189	-935	-20163
Sawlogs B	14891	19.98	297522	-	-	-	9362	187053	19.98	187053	5529	110469
Sawlogs C	13568	27.38	371492	-	-	-	1140	31213	27.38	31213	12428	340279
Sawlogs D	5418	33.08	179227	-	-	-	14	463	33.08	463	5404	178764
Sawlogs avg.	-	-	-	3406	17.00	57902	-	-	-	-	-3406	-57902
Total	39653	-	910135	8731	-	102396	19886	311609	-	311609	11036	496130

1 R 1.00 = DM 0.67

The loss of volume and value of timber in the clearfelled compartments is shown in Table 5. In total, 8731 m³ of the timber valued at R 102 396 (R 1.00 = DM 0.67) had to be prematurely harvested on 100.4 ha of the block because of extensive tree mortality. Had clearfelled stands not been disturbed, they would have produced approximately 39653 m³ of timber in the 30 years needed to complete the rotation. The amount of timber harvested prematurely, plus that predicted for reestablished stands during the same time period, was 72.2% of the volume and 45.5% of the value of the potential production, i. e. production not disrupted by hail associated *S. sapinea* infection. The timber loss due to *S. sapinea* infection in compartments prematurely clearfelled was therefore 27.8% of volume and 54.5% of value.

The effect of site quality, expressed by site index, and age of stand on financial loss due to premature clearfelling can be expressed by use of the following multivariate linear regression model:

$$Y = a + bX_1 + cX_2 + E$$

where: Y = financial loss (Rand/ha)

X₁ = site index [height (m) at 20 yrs of age]

X₂ = age of a stand (years)

E = error

a = -5547.51 (constant)

b = 273.13 (constant)

c = 420.91 (constant)

This multivariate regression model explains 72.3% of the variation in the financial loss of the ten prematurely clearfelled stands of *P. radiata* at Kruisfontein State Forest. The model is statistically significant ($P < 0.01$). Using this model, the effect of site index and age of trees on the financial loss could be assessed (Fig. 1).

4 Discussion

An economic evaluation of the impact of *S. sapinea* infection of pines after hail is difficult. The accuracy of such an evaluation will be negatively influenced by dynamic trends in the local timber market, the emergency of the situation, and estimations made with respect to the potential quality and production of

timber. Losses which increase with age and site index could reflect, (i) a decrease in the value of highly priced timber assortments due to discolouration by *S. sapinea*, (ii) the effect of "plunder harvesting" in which only the best logs are utilized by a limited market, and (iii) the disadvantages of emergency timber sales. Further damage to forest stands will probably be determined by factors such as stand accessibility, marketing trends, and available man-power. Costs of "premature" reestablishment, i. e. site preparation, planting and weeding, will add to the total financial loss in prematurely harvested compartments. The calculated loss of approximately R 4961/ha and the regression model presented, therefore, does not have universal application.

The decision to clearfell stands infected by *S. sapinea* is difficult because potential mortality cannot be reliably predicted at the time that hail damage occurs. The decision should not be influenced by extensive foliage discolouration soon after the occurrence of hail because foliage can regenerate after a year (ZWOLINSKI et al. 1990). A more reliable indicator of disease development is the amount of timber discolouration. A small number of hail damaged trees could be felled periodically and examined for discolouration of the cambium, wood and pith during the first six months after symptoms appear. Consideration should first be given to removing infected trees in commercial thinnings when discolouration spreads to the lower crowns below the minimum utilizable stem length. Stands should only be clearfelled when infected trees are too numerous to be eliminated by thinning.

Assuming that 25 % of the total area affected in this outbreak was clear-felled prematurely because of *Sphaeropsis*-dieback, then the economic loss for the region could be estimated as R 2.5 million (2000 ha \times 0.25 \times 5000 R/ha). Twenty five outbreaks of dieback after hail have been recorded during the years 1923–1983. This would be approximately 0.4 outbreaks/yr (LUNDQUIST 1987b). Assuming that the magnitude of the outbreak in this study was double the average, this would mean that the forest industry in the Southern Cape is losing about R 500 000 per year. Extrapolation of this result to all the pine plantations in South Africa would be an average loss of R 9.5 million/yr due to *S. sapinea*.

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Summary

An assessment was made of the amount of timber damaged or lost in an extensive outbreak of *S. sapinea*-induced dieback of pines following a hail storm in the Southern Cape Province of South Africa. The timber loss due to *S. sapinea* infection in compartments prematurely clearfelled was about 28 % of volume and 55 % of value of potential production. Total predicted volume of timber lost in compartments not felled prematurely was an average of 11.4 %. Percentage volume lost increased with age, with the greatest losses being recorded on good quality sites.

Résumé

Importance économique d'une attaque de Sphaeropsis sapinea après des dégâts de grêle

Une évaluation a été faite du nombre de tiges perdues ou endommagées par une épidémie de *S. sapinea* chez des pins à la suite d'une chute de grêle dans le sud de la province du Cap (Afrique du Sud). Dans les placeaux prématurément exploités la perte était de 28 % du volume et 55 % de la valeur potentielle. Le volume total de pertes dans les autres placeaux était estimé à 11,4 % en moyenne. Le volume perdu augmentait avec l'âge, les plus grandes pertes étant enregistrées dans les sites de bonne qualité.

Zusammenfassung

Wirtschaftliche Auswirkungen eines durch Hagelschlag ausgelösten *Sphaeropsis sapinea*-Triebsterbens

Das Ausmaß an Holzschäden und Holzverlusten in der Folge eines auf einen Hagelschlag folgenden intensiven *Sphaeropsis sapinea*-Befalls in der südlichen Kapprovinz Südafrikas wurde eingeschätzt. Der Holzverlust auf Grund der *S. sapinea*-Infektion in Bereichen, in denen die Bestände vorzeitig abgetrieben werden mußten, betrug 28 % des Volumens und 55 % des Wertes der potentiellen Produktion. In Bereichen, in denen nicht vorzeitig abgetrieben wurde, beträgt der vorhersehbare Holzverlust im Durchschnitt 11,4 %. Der Anteil verlorener Holzmasse steigt mit dem Alter der Bestände. Die größten Verluste sind auf guten Standorten zu verzeichnen.

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