Chapter 5

Inhibition of *Pinus patula* seedling growth by *Cyperus esculentus*, and other weed species in the field

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1. Introduction

According to Noble & Schumann (1993) the forestry industry is progressively acquiring land that was previously used for agricultural purposes. These land areas are typically a mixture of natural vegetation (afforested soil) and old agronomical sites (oldland soil). Smith & Van Huyssteen (1992) reported that oldland soils may differ from afforested soils with respect to pathogens, weed spectrum and soil nutrition. Reinhardt, Khalil, Labuschagne, Claasens, & Bezuidenhout (1996) concluded that the weed community on oldlands consists virtually exclusively of annuals that commonly occur in annual crops, e.g. *Cyperus esculentus* (yellow nutsedge), *Bidens pilosa* (common blackjack) and *Conyza albida* (tall fleabane). On adjacent afforested soil, grass species dominate .

Where pine seedlings have been established on old agronomical sites, growth and development abnormalities were encountered. According to Linde, Kemp & Wingfield (1994) mortality of the seedlings was greater than 95% in most cases in the North eastern Cape province in South Africa. The pine seedlings on oldlands died approximately 4-5 months after they were established in the field. It was reported by Smith & Van Huyssteen (1992) and Schumann & Noble (1993) that the symptoms

of poor seedling performance involved a minimally developed root systems, stunting, lack of apical dominance, chlorosis and necrosis of fascicles, and necrosis of the growth tips. Various attempts to solve or amend the problem were launched which included soil and pathogen studies (Smith & Van Huyssteen, 1992; Schumann & Noble, 1993 and Viljoen, Wingfield & Marasas, 1994).

Interfering vegetation decreases the growth of pine seedlings (Nelson, Pedersen, Autry, Dudley & Wellstead, 1981; Bacon & Zedaker, 1985; Knowe, Gjerstad, Glover, Nelson, Zutter, Minogue & Dukes, 1985; Zutter, Gjerstad & Glover, 1986). Height, stem diameter and biomass of pine seedlings increased when competing vegetation was removed. Zutter *et al.*, (1986) reported that interfering vegetation had a significant effect on biomass, fascicle type distribution, fascicle morphology and leaf area of loblolly pine seedlings. Miller, Zutter, Zedaker, Edwards, Haywood & Newbold (1991) investigated the influence of woody and herbaceous competition on early loblolly pine growth. After five years, the tree volume was increased by an average of 67% with woody control while with herbaceous control volume increased by 171%.

2. Aim

The main objective was to determine the effect of *C .esculentus* and naturally occurring broadleaf and grass weeds on the height and stem diameter growth of pine seedlings growing on an oldland site.

3. Materials and Methods

Site description

A field trial was established in October 1998 at the Giant's Castle Estate of Mondi Forest (Pty) Ltd. at Mooi River KwaZulu-Natal. The site was previously under agronomic production and the soil is classified as a clay loam with: pH (H_2O) 5.71 and exchangeable Ca, Mg, K and Na content of 685; 261; 430 and 59 mg kg^{-1} respectively. Herbaceous vegetation on the site was dominated by the weeds *C. esculentus, B. pilosa, C. albida* and *Tagetes minuta* (kaki weed).

Experimental design

The trial consisted of three weed treatments: (1) only *C. esculentus* present, (2) only broadleaf species present, and (3) a mixture of both broadleaf spp., grass spp. and *C. esculentus*. No weeds were present at the control treatment. These different weed infestations were obtained by spraying herbicides before seedling establishment. The control treatment was sprayed with atrazine, 2,4-D and glyphosate at the manufacture's recommended rates. It was kept weed-free for the duration of the trial by hoeing. For the treatment consisting of only *C. esculentus*, 2,4-D was sprayed and all other weed species were removed by hand. For only broadleaves to be present, (treatment 2), alachlor was sprayed and hoeing was used for the duration to control the grasses. No herbicides were sprayed at treatment (3) for all the weed species to flourish. Standard silviculture procedures for soil preparation were followed with trial initiation. *P. patula* seedlings were transplanted by staff of Mondi Forests (Pty) Ltd. At transplant, each seedling received 2 L tap water and solid fertilizer in the form of 2:3:2 at a equivalent rate of 200 kg/ha. Seedlings were planted 1.5 m in and between rows. Due to frost damage, it was necessary to replant seedlings in January

1999. Each plot consisted of seven rows, 50 m in length. Due to replant problems, initial measurements of randomly selected seedlings were made in September 1999. Measurements included height growth from the stem base to the apical growth point, and stem diameter measured at 50 mm above the soil surface.

Statistical analysis

A block design was used and the four treatments were assigned to six blocks. Analysis of variance was done to determine the effect of the different weed treatments on the height and stem diameter growth of seedlings. Differences between means were identified by the Least Significant Difference test at P=0.05.

4. Results and Discussion

The presence of weeds caused significant reductions in both pine seedling height and stem diameter compared to the control (Figure 1 and 2).The height inhibition caused by the presence of *C. esculentus,* was significantly greater than the reduction by only broadleaf spp. (Figure 1). Although height reductions by the mixture of weed species were significantly greater compared to the control, it was not significantly different from the reductions caused by *C. esculentus.*

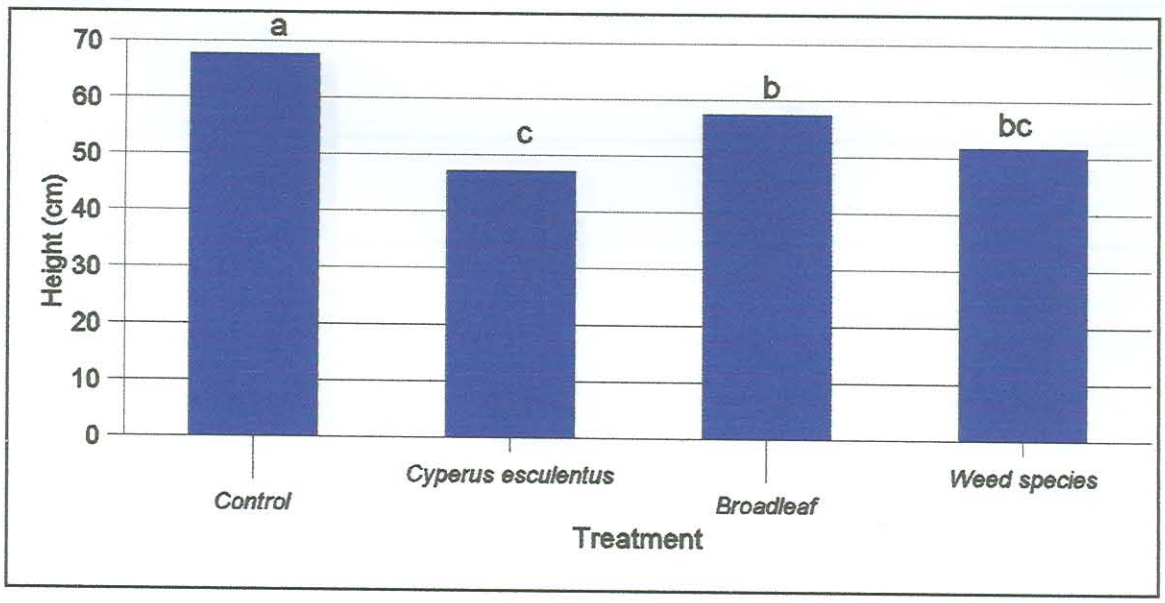

Figure 1 The influence of different weed treatments on the height growth of *Pinus patula* seedlings. Means followed by the same letter are not significantly different at P=0.05. (ANOVA appears in Table 1 in Appendix D)

All three weed treatments caused a significant seedling stem diameter reduction compared to the control (Figure 2). *C. esculentus* and the weed species treatment, caused a greater reduction in stem diameter than the treatment with only broadleaf species.

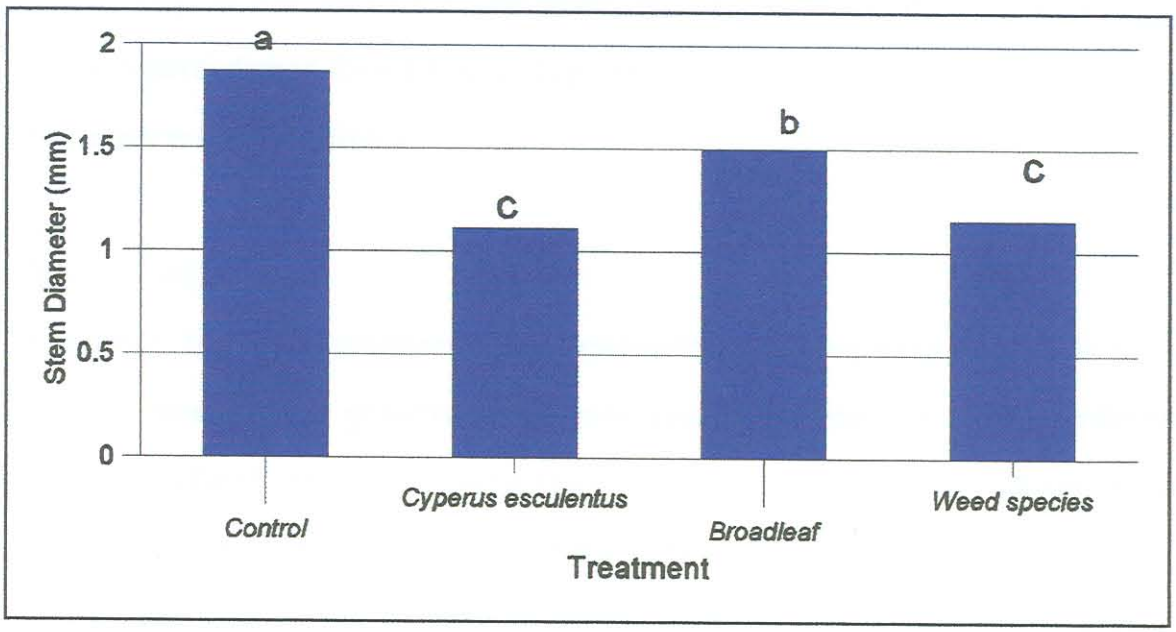

Figure 2 The influence of different weed treatments on the stem diameter growth of *Pinus patula* seedlings. Means followed by the same letter are not significantly different at P=0.05. (ANOVA appears in Table 2 in Appendix D)

Results obtained from the trial are in accordance with those from research done by Keeley & Thullen (1975), Stoller, Wax & Slife (1979), Drost & Doll (1980), Patterson, Buchanan, Street & Crowley (1980) and Keeley (1987). All of the above described the reduction in crop growth due to the interference effect of *C. esculentus*. Allelopathic interactions have been demonstrated to play a crucial role in natural and man made forests. Fisher & Adrian (1981) noticed a strong effect of *Paspalum notatum* (Bahia grass) on *P. elliottii* (slash pine). As the percentage of grass covered ground increased, the height growth decreased markedly. Gilmore (1985) noticed the erratic establishment of *P. taeda* (loblolly pine) on old fields covered with *Setaria faberii*

(giant foxtail). Water extracts inhibited germination and radicle elongation of seedlings in petri dishes. Dried foxtail tops were the most inhibitory while fresh tops and roots were less inhibitory.

5. Conclusions

It is evident that the presence of *C. esculentus* growing with *P. patula* can be deleterious towards the growth of the pine seedlings. However, the interference effect of broadleaf- and grass species with the pine seedlings also reduced growth significantly. It is concluded from the preliminary results that weeds, especially *C. esculentus*, are responsible for the poor growth and development of *P. patula* seedlings on oldland sites due to competition and allelopathy. When weed interference are minimized, seedlings should grow and develop normally on oldland sites.

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Appendix D

1. Height

Table 1 Analysis of variance of the percentage height increase of *Pinus patula* seedlings at different weed treatments

Source	DF	Sum of Squares	Mean Square	F	Pr > F
Treatment	8	1532.081	191.510	5.58	0.0021
Error	15	515.239	34.349		
Total	23	2047.320			

$R^2 = 0.0600$

2. Diameter

Table 2 Analysis of variance of the percentage stem diameter increase of *Pinus patula* seedlings at different *Cyperus esculentus* treatments

Source	DF	Sum of Squares	Mean Square	F	Pr > F
Treatment	8	2.363	0.295	19.37	0.001
Error	15	0.229	0.015		
Total	23	2.592			

$R^2 = 0.1679$

Summary

The forestry industry in South Africa is dependent on acquiring new land to meet the growing demand for timber. Mondi Forests (Pty) Ltd. in KwaZulu-Natal , bought land that was previously used for agronomic production (hereafter referred to as oldlands). After establishing *Pinus patula* (patula pine) seedlings on oldlands, seedlings exhibited abnormal growth symptoms. These include an inadequately developed root system, stunting, lack of apical dominance, chlorosis and necrosis of the fascicles and necrosis of the growth tips. These symptoms were noticed only on seedlings planted on oldlands. Seedlings established on sites previously used for grazing only did not show these symptoms.

Various soil and pathogen studies were conducted, with no conclusive answers to what is known as the "oldland syndrome". Certain pathogens, *Fusarium subglutinans* f.sp. *pini, F. oxysporum* and *Pythium irregulare* were identified on seedling roots in the nursery. It was concluded that infected seedlings were transplanted to oldland sites. Soil studies in the north eastern Cape revealed ploughpans and poor drainage, which limited the root development of pine seedlings. Soil analysis of problematic oldland sites at the Giant's Castle Estate in KwaZulu-Natal did not reveal the foregoing characteristics. Soils were well drained with adequate nutrition. Weed control on the oldland sites was however judged to be inadequate. The dominant weed species at a site selected for study were *Bidens pilosa* (common blackjack), *Conyza albida* (tall fleabane), *Cyperus esculentus* (yellow nutsedge), *Helichrysum* spp. and *Tagetes minuta* (khaki bos). Of these, *C. esculentus* was the most dominant, especially early in the growing season. New tubers are formed each season thereby enlarging the weed population. The weed residues are ploughed in

when seedbed preparation is done for new pine seedlings, or left on the soil surface. The rodent *Tatera* spp. (gerbilles) line their nests with the *C. esculentus* residues, thereby creating favourable conditions decomposition and release of allelochemicals in the root sone of the pine seedlings. Without adequate weed control methods, pine seedlings are exposed to competition and possible allelochemicals excreted by the weeds.

Prior to the present study, no research had been done on the influence of herbaceous weeds on the growth of the *P. patula* seedlings. Applying agronomic principles for crop-weed interactions, could probably aid in resolving most of the pine seedling establishment problems. These interactions involved both competition for natural resources and the allelopathic potential of the weeds present. Therefore, symptoms of seedling establishment failure could be the manifestation of both competition and allelopathy.

The first experiment initiated, investigated the effect of incorporated residues of *B. pilosa, C. albida* and *C. esculentus* on the height and stem diameter growth of *P. patula* seedlings, as these species were the most prominent on the field trial site at the Giant's Castle Estate of Mondi Forest. Results from incorporated *B. pilosa* and *C. albida* were inconclusive, and therefore, it was decided to continue working with only *C. esculentus*.

Pine seedling height and stem diameter growth were more inhibited by leachate obtained from actively growing *C. esculentus* than from incorporation of mature *C. esculentus* leaf material. Allelochemicals released from the actively growing plants were continuously applied to pine seedlings, while no addition of new leaf residues

was made to the soil. The incorporated weed material therefore probably released only a limited quantity of allelochemicals. Associated mycorrhizae growth on the roots of the pine seedlings were inhibited by both applied root leachate and incorporated leaf residues. This finding suggests that *C. esculentus* could have an indirect influence on the growth of the trees. Mycorrhizae are critical for the health and growth of the pine seedlings. Any inhibition of these fungi will have an impact on the host. As competition for light, space, nutrients and water was limited, it is concluded that *C. esculentus* was potentially more allelopathic than competitive towards pine seedling growth.

To have confirmation of the foregoing allelopathy-related hypothesis, seed germination and ectomycorrhizae studies were initiated. *Lactuca sativa* (lettuce) and *Zea mays* (maize) were used as test species in the germination experiments. Lettuce is considered a very sensitive plant and is often used in herbicide bioassays. Maize was included as it is an important crop in South Africa. Aqueous extracts of *C. esculentus* tubers, immature plant parts and mature plant parts were prepared and tested against growth of the ectomycorrhizal fungus *Boletus maxamaria*, *L. sativa* germination, and seedling growth and emergence of *Z. mays*.

Results of the ectomycorrhizae experiment confirmed results previously obtained with the incorporation into soil of *C. esculentus* leaf material which inhibited growth of the ectomycorrhizal fungus *Boletus maxamaria*. The occurrence of growth inhibition by the weed on the pine seedlings, associated with the symbiont, could be pivotal in explaining the establishment problems of new pine seedlings on former crop sites infested with *C. esculentus*.

Although mature weed extract had a greater inhibitory effect on the mycorrhizal growth than the other extracts, it was not confirmed where lettuce was used as an indicator species. It could be that test species' responses to allelochemicals differ, and this possibility should therefore be considered in explaining results. With the elimination of soil as a factor in the hydroponics experiment, it was evident that allelochemicals released from *C. esculentus* had an inhibitory effect on the growth of *L. sativa*. Emergence of maize, planted to soil in which *C. esculentus* were grown for three weeks, was retarded and it is thus conceivable that, under conditions favouring the production and release of allelochemicals in high concentrations by *C. esculentus*, maize seedlings would be placed under chemical stress that might weaken their resistance to other environmental stress factors. Although anomalies were found in work done with the allelopathic compounds identified in growth media of *C. esculentus*, there were indications of germination inhibition. This confirms the results from the germination work done with the extracts.

The significant negative growth response of pine seedlings in the presence of *C. esculentus* confirmed earlier results and reports by other researchers of the allelopathic characteristics of the weed. Boron deficiency was eliminated as a possible cause for seedling establishment failure on oldland soils, as none of the symptoms of deficiency was observed. Addition of boron did not prevent poor growth of seedlings exposed to *C. esculentus*. As *C. esculentus* was actively growing during the first period of seedling growth, allelochemicals were probably continuously released. This phenomenon is reflected in the significant growth differences among seedlings growing in the presence of the weed and those not. Partial recovery from the inhibition effects of these compounds was observed

during the winter, when no weeds were present. When *C. esculentus* was removed or suppressed by a groundcover, the growth was significantly higher than seedlings still exposed to the weed.

Results obtained from experiments done in the greenhouse were confirmed by the field trial. Seedlings growing without weeds present had a significantly higher growth increase than those growing in the presence of weeds. *C. esculentus* had a more detrimental effect on growth than broadleaved species. Seedlings continuously exposed to *C. esculentus* had to be replanted twice.

In conclusion, *P. patula* seedlings exposed to *C. esculentus* show growth inhibition. As the mycorrhizae that are associated with *P. patula* are affected negatively also, seedlings are likely to be more vulnerable to pathogens and adverse environmental conditions. It is clear from the results that pine seedlings could be successfully established on oldlands, provided that an effective weed control programme is followed, in particular a strategy that prevents the establishment of *C. esculentus.*