GROWTH OF SECOND ROTATION *PINUS PATULA* STANDS: EFFECT OF INTERCROPPING WITH *LEUCAENA DIVERSIFORLIA* LEGUME AT SHUME FOREST PLANTATIONS PROJECT, TANZANIA

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ABSTRACT

This study was carried out to investigate the effect of *Leucaena diversifolia* on the growth of second rotation Pinus patula stands as one of the options for increasing growth and yield. The trial was conducted at Shume Forest Plantations Project, Lushoto, Tanga, Tanzania. Site preparation was done through clearing of the harvested first rotation stands, burning of the logging slash, followed by complete cultivation. Nursery raised potted seedlings of the Pinus patula were planted in 1997 at a spacing of 3 m × 3 m within each plot, while those of *Leucaena diversifolia* were interplanted in alternating rows in 1998, followed by complete weeding twice a year. A Completely Randomized Block Design (CRBD) with three replications was adapted. Total tree height and diameter at breast height (dbh) were measured in 1999, 2000, 2001 and 2002 and analyzed for growth. Within the limits of the present study, the results on the cumulative growth performance of the second rotation pine plantations in their pure stands were, generally superior to those recorded in the mixtures with Leucaena trees - mainly resulting from the underground competition for limited nutrient resources. The mean cumulative heights were 3.67, 4.82, 5.58 and 7.77 m in pure stands and 3.64, 4.71, 5.55 and 7.60 m in the mixtures while the corresponding diameters were 4.74, 6.95, 9.78, 12.39 cm and 4.65, 6.69, 8.64, 11.41 cm for the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} years of assessment respectively. The corresponding 1^{st}, 2^{nd} and 3^{rd} annual height increments were 1.15, 0.76, 2.19 m and 1.07, 0.84, 2.05 m with annual diameter increments being 2.21, 2.83, 2.61 cm and 2.04, 1.95, 2.77 cm respectively. Although, within the time limits of the present study, the anticipated beneficial effects of the Leucaena legumes in promoting the growth of none leguminous plantation trees were not indicated in terms of cumulative growth, they were clearly manifested in the fourth year of annual increment trends. These results should, therefore, be treated as preliminary and an extended monitoring protocol is recommended to give room for the observed emergence of favorable effects, through the annual increment trends, to translate into positive cumulative growth expected to manifest within the first half of the pine's 25-30 years rotation age.

Key words: Growth, intercropping, annual-increment, mixtures, pure stands

INTRODUCTION

Pinus patula is one of the most important forest plantation species in East and Southern Africa due to its good timber qualities for lumber, particle board, wood wool, pulp and paper manufacture (Wormald, 1975). In Tanzania, in particular, pines are grown in the Southern and Northern Highlands and around Lake Victoria at saw log rotations of 25-35 years. To date, plantation forests of various tree species cover over 150,000 ha and are the only source which can plug the growing gap between wood demand and supply in the country (Mtuy, 1996).

Annual yields of *P. patula* during the first rotation, varied from 25–35 m^3ha^{-1} (Ahlback, 1988). These yields though modest, were considered acceptable under less intensive silviculture, outbreak of forest fires, pests and diseases attributed to shortage of funds (Chamshama and Philip, 1980; Okama and Chamshama, 1988; Nsolomo and Venn, 1994; Lulandala *et al.*, 1995). Planting of appropriate tree species properly selected from earlier introduced trials and use of good quality sites, were the reasons for these good yields (Zobel and Talbert, 1984).

After more than 40 years of industrial plantation forestry in Tanzania, most of the *P. patula* plantations are in the second rotation. The growth and yields of these stands have not been measured although results of some studies elsewhere are contradictory. Keeves (1968) reported lower yields while Evans (1983) higher yields. Where lower yields were reported, they were attributable to poor site preparation and tending techniques; emergence of new pests and diseases; use of unimproved low yielding and poorly adapted genotypes and leaving large areas of harvested plantations for long periods without any attempt to regenerate them effectively (Lundgren, 1978; Evans, 1984; Zobel and Talbert, 1984).

It has been found, however, that few forest soils can provide optimal amount of nutrients for plant growth. Marked deficiencies exist, either due to improper land management associated with increased harvest removals, soil erosion and leaching (Maliondo and Chamshama, 1996) or inherent low natural soil fertility (Schonou and Herbert, 1989). Deficiency in boron, phosphorous and nitrogen in our plantations was also reported during the first rotation (Waring, 1982; Cannon, 1985; Tangwa *et al.*, 1988; Mhando *et al.*, 1993).

Where the inherent soil fertility status was not sufficient, use of fertility enhancing plants such as *Crotalaria grandibracteata, Gliricidia sepium, Leucaena diversifolia, Leucaena leucocephala, Sesbania sesban, Senna siamea, Alchornea cordifolia, Alnus nepalensis* and *Robinia pseudoacacia* was recommended, elsewhere, based on various site conditions, either in combination or in rotation with the target crops. Results from several studies have revealed that, tree species mixtures in forest plantations gave higher yields than pure stands (Wu and Rin, 1976; Willy and Manley, 1983; De Bell *et al.*, 1989; FAO, 1992).

Since information on growth rates of *P. patula* trees and related soil conditions in the second rotation plantations in Tanzania are yet to be sufficiently and confidently established, there is urgent need of integrating protocols for monitoring site productivity trends in their management routines. The information gained would help to indicate whether the soil fertility conditions have changed significantly between the two rotations or not and whether the intermixing of plantation trees with leguminous plants results into soil fertility improvement and hence increased tree growth and wood yield rates in the second and subsequent rotations.

The broad objective of the present study, therefore, was to confirm the indicated potential of improving the yields of second and subsequent rotations of *P. patula* plantation stands through site amelioration. The specific objective being to determine the growth pattern of 5-years old second rotation stands of *P. patula (Pine)* under the influence of intermixed leguminous plants, *Leucaena diversifolia (Leucaena).*

MATERIALS AND METHODS

Study site

The study was carried out at the Shume Forest Plantation Project (4° 38′ and 4° 44′ S and 38° 11′ and 38° 17′ E) located in Lushoto District, Tanga Region, Tanzania. According to Lundgren (1978), the topography of the area is described as broken and undulating with altitudinal range between 1200 m and 1800 m above sea level. There are two rain seasons; the main rain season occurring in the period from March to May and the minor one in November to December. Distinct gradients in rainfall from south to north, have been observed ranging from 1090 mm to 1270 mm per year. Mists are frequent in the area especially in the cool months of June to September. The dry period is between June and October. Temperatures range from 5^{0}C to 27^{0}C with a mean of 17-18°C. The soils vary from sandy-loam to clays. In the wetter parts of the area the soils are strongly acid with pH values around 3.4 - 4.0. In the rain shadow areas the soils are weakly acid to neutral with pH values of 5.8-7.1. Topsoil colors are usually dark due to high organic matter and sub-soils are red, yellowish-red or yellow, indicating high iron and aluminum oxide content. The original vegetation was montane rainforest, which varied in species composition and diversity as one moved up from the valley bottoms. A large part of the natural vegetation has been cleared and replaced with the plantations of various exotic tree species. To date the dominant exotic species are various pines, *Cupressus lusitanica* and *Juniperus procera*

Data collection

Data collection for growth of the second rotation *P. patula* was done in the permanent sample plots, which were laid out when the trial was being established in 1997 in a newly cleared and burnt first rotation *P. patula* plantation area. There are three blocks each with two plots such that, one plot was planted with the *Pine* alone and the other plot, the *Pine* was inter-planted with *Leucaena. Leucaena* seedlings were inter-planted in alternating rows in 1998, one year after planting the *P. patula* crop. Each plot contains 72 *P. patula* trees at a 3 m × 3 m spacing. Data were collected on tree height and diameter at breast height (dbh), for *P. patula* alone, for the years 1999, 2000 2001 and 2002.

Data analysis

The obtained data on cumulative tree growth in height and diameter were summarized into means and analyzed for variance by using the Completely Randomized Block Design (CRBD) statistical model with the Least Significant Difference (LSD) test being used to separate the differing means (Snedecor & Cochran, 1967). Graphic presentations were used to indicate the corresponding annual increment trends in tree growth.

RESULTS

Height growth

The results on the height growth of *Pine* trees in the two management systems are presented in Table 1 and the increment trends in Figure 1. It should be noted that the *P. patula* trees in the pure stands grew slightly faster than those in the *Leucaena* mixtures and becoming significantly taller ($p<0.05$) by the age of 5 years (i.e. fourth year of assessment). The differences in the mean height increments were insignificant and their trends in the two management systems were similar – initially falling to their respective minima (i.e. 0.76 m in the pure stands and 0.84 m in the mixtures) before leveling out in the fourth year and subsequently, by the fifth year of the stands' development, the increments in the pure stands surpassing those in the mixtures.

Table 1. The mean height growth of *Pinus patula* in the pure stands and in mixtures with *Leuceana diversifolia,* during the period 1999 to 2002, at Shume Forest Plantations Project, Lushoto, Tanzania

Mean height (m)				
Management System	1999	2000	2001	2002
Pine stand	3.67a	4.82a	5.58a	7.77a
Mixtures	3.64a	4.71a	5.55a	7.60 b

NB: Values within the same column with the same letter do not differ significantly ($p<0.05$).

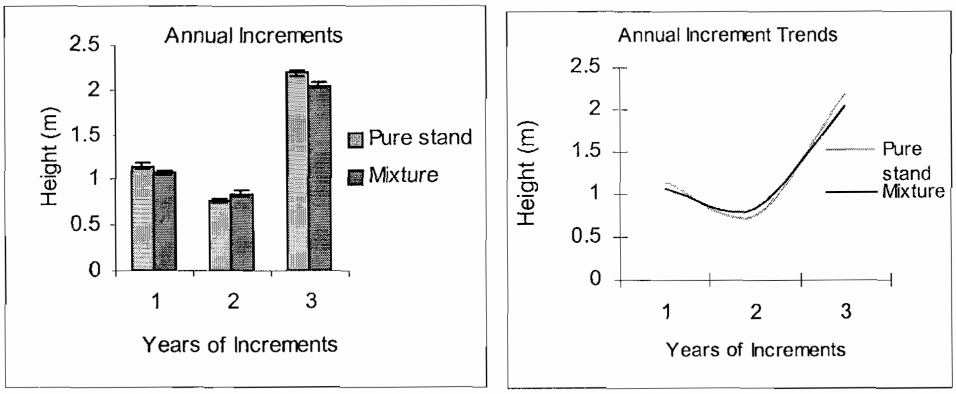

Figure 1: The mean annual height increment trends of *Pinus patula* when growing in pure stands and in mixtures with *Leacaena diversifolia,* durind the period 1999 to 2002, at the Shume Forest Plantations Project, Lushoto, Tanzania

Diameter growth

The results on the diameter growth of *Pine* trees in two management systems are presented in Table 2 and the annual increments and increment trends in Figure 2. The pure stands seemed to have provided a better diameter growth environment for the *Pine* trees than the mixtures with *Leucaena* trees with the mean cumulative diameter growth being significantly superior (P<0.05) in all the years of assessment except the first one. The annual increments were, similarly, significantly different (P<0.05) in all the three years of growth. Initially, the growth rate of the plants in the pure pine stands increased to a maximum at the second year of increment (fourth year growth) and subsequently declined. That in the mixtures, on the other hand, initially fell to a minimum in the fourth year of growth and henceforth increasing to supercede that in the pure stands at the fifth year (third year of assessed increment).

Table 2 Mean diameter growths of *P. patula* trees in pure stands and in mixtures with *Leacaena diversifolia,* during the period 1999 to 2002, at the Shume Forest Plantations Project, Lushoto, Tanzania

Diameter growth (cm)				
Managem ent System	**1999**	**2000**	**2001**	**2002**
Pure stand	4.74a	6.95a	9.78a	12.3 9a
Mixtures	4.65a	6.69 b	8.64 b	11.4 1b

NB: Values within the same column with the same letter do not differ significantly (P < 0.05).

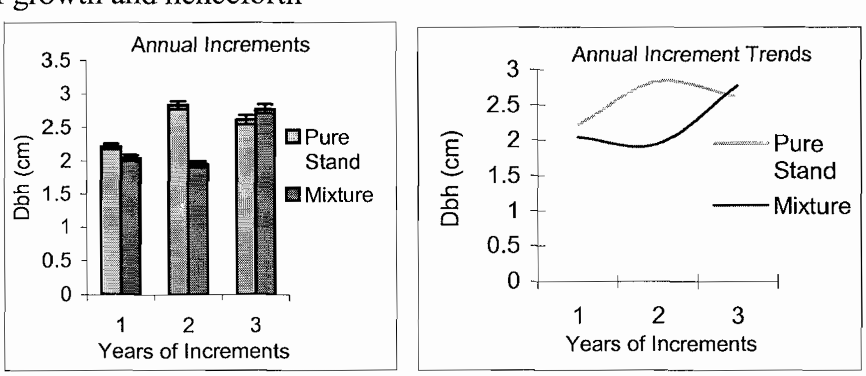

Figure 2 The mean annual diameter increments and increment trends of *Pinus patula* when growing in pure stands and in mixtures with *Leacaena diversifolia* during the period 1999 to 2002 at the Shume Forest Plantations Project, Lushoto, Tanzania

DISCUSSION

The better cumulative height and diameter growth performance of the *Pines* in the pure stands compared to those in the mixtures with *Leucaena* (Tab. 1 and 2) seems to more generally reflect a low soil fertility problem of the site resulting in the competition for the limited amounts of nutrients between the plants of larger plant populations in the mixture stands. The direct relation of both height and diameter growth with tree spacing of this tree species and other conifers, has been widely reported (Evert, 1971; Hamilton & Christie, 1974; Mishra & Gupta, 1993; Iddi *et al.*

1996). The effect of sharing the limited nutrient resources on the height growth of pine plants was more explicitly demonstrated by the initially falling annual height increments (Fig. 1) with the fall being higher in the pure stands. Lundgren (1978), Waring (1982), Cannon (1985), Tangwa *et al.* (1988) and Mhando *et al.* (1993) demonstrated that deficiencies in boron, phosphorous and nitrogen were the leading problems facing most forest plantation projects in Tanzania even during the first rotation. The Shume Forest Plantations Project, in particular, was reported to be very deficient in nitrogen (Lundgren, 1978). In Swaziland, Morris (1984) observed a net decline in the forest floor potassium from the first to the second rotation of the same species. The effect of low soil fertility was further indicated by the initially higher annual diameter increment in the pure stands during the initial four years of pine establishment (Figure 2).

The slight depression in the annual height increment of the *Pine* plants in the mixtures relative to that of the plants in the pure stands observed at the ages greater than four years (Fig. 1), on the other hand, most probably reflects the set in shading effect by the *Leucaena* trees in the mixture.

Various researchers (Malimbwi *et al.* 1992a, b; Mishra & Gupta, 1993; Iddi *et al.* 1996) have clearly shown that mean height of stands of this species and most other conifers, increase with tree spacing (i.e. smaller tree populations per unit area) since they are light demanders. The beneficial effect of the leguminous *Leucaena* plants, although currently not clearly detectable from the cumulative growth figures, is well demonstrated by the trends in the annual increment rates. The reversed trends in annual diameter increments at the plants ages older than four years, with that in the pure stands falling while that in the mixtures increase to a higher rate in the fifth year, could be influenced by the improvements in soil nutrient availability resulting from biologically fixed and recycled nitrogen by the now well established legume plants. The legume, especially its low altitude sister species, *L. leucocephala,* have been credited with some of the highest nitrogen-fixation rates (up to 600 $Kgha^{-1}year^{-1}$) (Guevarra, 1976; Hogberg & Kvarnstrom, 1982; Lulandala & Hall, 1986) with up to 35% of the fixed nitrogen being directly made available, in various ways including sap leaks and biomass turnover, to the associated crops. Improvements in the soil nitrogen availability also increases the availability of the other nutrient elements for plant growth (NAS, 1977). The favourable influence of the various *Leucaena* plant species, especially *L. leucocephala* and *L. diversifolia,* in promoting the growth of other forest trees in their associations, have been widely reported (Wu and Rin, 1976; Willy and Manley, 1983; De Bell *et al.*, 1989; FAO, 1992; Kumar *et al.* 1998). If the same conditions of management are maintained, it should be expected that the indicated higher annual diameter increment trends of the *Pine* trees in the intermixed stands should translate into higher cumulative diameter and volume growth within the first half of the species' rotation period.

While there is an indicated favorable potential of *L. diversifolia* in effectively contributing to the initial and medium establishment and growth of *P. patula* at Shume, it is still not certain, at this stage, how this response is going to translate in the later part and subsequent plantation rotations. Despite the high fixation capacity and ability to absorb and recycle other mineral elements including Phosphorus and Potassium from the deep soil layers (NAS, 1977) when properly matched with site conditions and climate, the extent of the legume's influence will, also, depend on other factors such as soil pH, type, moisture, temperature (FAO, 1983) and management strategies (Kumar *et al.* 1998). Similarly, the duration of the responses of the pines, will depend on the quantity of N fixed and released from organic materials. Pines, however, grow in acid soils where the ammonification is probably the dominant conversion of available nitrogen materials (Barnes and Ralston, 1955). *Leucaena diversifolia* being tolerant to acid soils and frost (Wu and Rin, 1976; FAO, 1992) with the soil pH at Shume varying around 3.4 to 4.0 (Lundgren, 1978), it is expected to do well at Shume and other pine plantation areas with similar conditions.

CONCLUSIONS AND RECOMMENDATIONS

From the results of the present study and preceding discussion, the following conclusions are drawn:

Within the period of the present study, *P. patula* trees in the monocultural (pure) stands had better cumulative growth performance than those in the mixtures.

Although the expected beneficial effect of using *L. diversifolia* to enhance early growth and yield of second rotation *P. patula* at Shume Forest Plantation Project was not detectable from the cumulative growth figures, it was well demonstrated by the trends in the annual increment rates. These should translate into higher cumulative diameter and volume growth within the first half of the species' rotation period.

Since this study only covered the initial five years (four years after intercropping *L. diversifolia)* of the 25-30 years *P. patula* plantation rotation age, the present results should be treated as very preliminary and await a longer monitoring period to ascertain the cumulated effects of the observed increment trends to manifest.

It is, therefore, recommended that the indicated favourable influence of *L. diversifolia* on the annual diameter increment of *P. patula*, should be closely monitored to determine the time when it translates into positive cumulative growth and subsequent growth patterns.

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