EFFECT OF POST-HARVEST *CUPRESSUS LUSITANICA* SLASH MANAGEMENT ON EARLY GROWTH OF *PINUS PATULA* AT SHUME, LUSHOTO, TANZANIA

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ABSTRACT

Sustainable forest productivity requires nutrient retention and protection of soil surface to ensure long-term soil fertility. This study was carried out in a second rotation forest plantation in Tanzania to provide insights on post-harvest slash and litter management practices for maintenance or increased productivity of subsequent rotations of forest crops. A randomized complete block design with four replications was used. Management treatments were: (a) control (litter left intact), (b) slash and litter removed, and (c) slash and litter burned. Periodic data were collected on root collar diameter (RCD), breast height diameter (DBH) and height. A final assessment was done at 36 months of age and the control treatment was slightly superior compared to other treatments. This could be due to the enhanced physical and chemical properties of soils from slash and litter layers. Although assessment for longer period is required, the preliminary findings revealed that after clear felling and removal of merchantable wood and branches, the remaining slash and litter should be retained on the site to induce better tree growth and maintain the nutrient capital.

Keywords: *Pinus patula*; *Cupressus lusitanica*; post-harvest; slash and litter management, site productivity.

INTRODUCTION

Pinus patula is the main species grown for production of lumber, pulp and paper, particle board and wood-wool manufacture (Wormald 1975). In Tanzania, plantation areas are characterized by soils with a high level of leaching, low nutrient content, low cation exchange capacity and moderate to strong acidity (Mugasha 1996). Poor tree growth attributed to nutrient deficiency has been reported by *inter alia*, Lundgren (1978) at Shume Forest Plantation Project. According to the author, the plantation also is characterized by annual removals of 40, 4, 23, 25 and 6 kg ha^{-1} of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) respectively. Unless judicious measures are adopted to rectify these nutrient losses, the loss will likely become even more serious during subsequent rotations. Nutrients are depleted through consecutive harvesting and subsequently during the taungya phase of stand establishment (Mtui *et al.* 2005).

Moreover, forest management practices are the main reasons for the declining productivity of industrial plantations of exotic tree species such as *Pinus patula* and *Cupresssus lusitanica* by accelerating the loss of nutrient reserves from sites (O'Hehir and Nambiar 2010). However, a central goal of sustainable plantation forest management should be to ensure that the trends in productivity are non-declining or remain positive over successive rotations and harvests, while maintaining and enhancing the quality of the soil resources base (Nambiar 1996). Little is known about the sustainability of *Pinus patula* plantations with respect to long-term production and maintenance of site quality in Tanzania (Maliondo *et al.* 2001). The knowledge is particularly relevant in soils with low nutrient capital in form of primary minerals, organic reserves or available nutrients (Laclau *et al.* 2000).

Historically, Tanzania's industrial exotic plantations were mainly introduced in highland areas with favourable climatic conditions and involved clearing of natural forests (Mugasha 1996). As a consequence, yields of the first rotation pines and cypress plantations were high ranging from 25 to 35m^3/ha/yr (Ahlback 1988). At present, the country has industrial forest plantations which are in the second rotation. Studies in other countries have shown the productivity of second rotation crops to decline at a scale that threatens its sustainability (Cossalter and Pye-Smith 2003; O'Hehir and Nambiar 2010). The decline is serious and wide spread, amounting to about 25-65% in wood volume in about 85% of the second rotation areas (Woods 1991). This problem of yield decline on second and subsequent rotations continues to receive international attention (Powers 1999).

There are different ways to deal with post-harvest residues. When slash and litter from the previous crop is left on site it can act as long term source of nutrients through mineralization (Schafer and Krieger 1994; Johnson 1995; Tiessen *et al.* 1994). There is common practice of taungya system in forest plantations in which slash and litter are burned and sites planted with food crops prior to tree planting. Burning may be a useful tool for site preparation and weed control but it may also result in rapid nutrient release, increased leaching losses, volatilization of some nutrients, and enhanced nitrogen mineralization (Raison *et al.* 1990).

Moreover, burning can alter physical and hydrological soil properties, affecting subsequent site productivity (Rab 1996). In other countries, slash and litter are completely removed from site. This is also likely to exacerbate nutrient loss and the risk of erosion and reduce subsequent tree growth. This study investigated the effect of post-harvest slash and litter management on early growth of *Pinus patula* at Shume Forest Plantation, Tanzania. It is aimed to promote sustainable industrial forest plantations management through understanding productivity levels in slash and litter retention as comparable to those removal or burned practices. This also provides insight on the importance of slash and litter management as a source or sink of nutrients for current and subsequent rotations.

MATERIALS AND METHODS

Study site

The trial was established at Shume Forest Plantation Project (4^o 38$'$ and 4^o 44'S and 38^o 17' E) in West Usambara Mountains, Lushoto, District, Tanzania. According to Lundgren (1978), the topography of the area is described as broken and undulating with altitudinal range between 1200m and 1800 m above sea level. The mean rainfall ranges from 1500 to 2000 mm per year and is distributed in two rain seasons, long rains in March-May and short rains in November-December. The maximum and minimum mean temperatures of the year are 7^o and 27^{o}C respectively (Luoga *et al.* 1994). Soils are dominated by clay with varying amounts of sand and the soil reaction is generally neutral or acidic (Lundgren 1978). The original vegetation of the area was characterized by dry montane forest with *Juniperus procera* as the main species with a fairly thick under-storey. Prior to establishment of this experiment, the site was occupied by a 24 year old *Cupressus lusitanica* stand, which was clear-felled in November 1997.

Experimental design and treatments

A randomized complete block design with four replications was used. After clear-felling the following treatment were imposed:

(a) Control: After removal of merchantable wood and branches >3 cm diameter, the remaining slash (branches and litter) were redistributed over the plots manually;

(b) Slash and litter removed: After removal of merchantable wood and branches >3 cm diameter, the remaining slash (branches and litter) was completely scarified off exposing mineral soil; and

(c) Slash and litter burned: After removal of merchantable wood and branches >3 cm diameter, the remaining slash (branches and litter) was completely burned.

Experimental establishment and management

Removal or burning of slash was done in early March 1998. Six-month old potted seedlings of *Pinus patula* raised using standard nursery cultural techniques (Forest Division 1982) were planted in late March 1998 at a spacing of 3 x 3 m. Each plot was made up of 5 x 5 rows i.e. 25 seedlings. All plots were clean weeded twice during the rain season and once during the dry season.

Data collection and analysis

For each plot, the inner plot (excluding the outer row) was the assessment unit. Measurements of sapling root collar-diameter (RCD) i.e. diameter at 10 cm aboveground and tree height were assessed at ages 6, 12, 18, 30 and 36 months, while breast height diameter (DBH) was assessed at 30 and 36 months. Root collar-diameter and DBH were measured to the nearest 0.01 cm using a micro caliper. Height was measured to the nearest 0.01 m using graduated pole. At 36 months after planting, foliar samples were taken and analyzed for N and P concentrations as described by Mgangamundo (2000).

Individual tree volume was calculated using the following formula: $V = h \times g \times f$

Where:

V= individual tree volume (m^3)

h= tree height (m)

g=tree basal area (m^2)

f= stem form factor of 0.45 (Malimbwi pers. Comm.).

Statistical analyses were carried out using the GLM procedure of SAS (Statistical Analysis Systems Institute Inc., 1987). Each tree variable i.e. RCD, DBH, height, basal area and volume were subjected to analysis of variance (ANOVA) using plot means and significant different means were separated using the Duncan's Multiple Range test (Steel and Torrie 1980). For each treatment plot, individual tree basal areas and volumes were summed up to get plot basal area and volume, which were later expressed on a hectare (ha) basis.

RESULTS AND DISCUSSION

The effect of slash management treatments on RCD, DBH, height, basal area and volume were significantly ($P<0.05$) different at all assessment occasions (Tables 1, 2 and 3). In all cases, the control treatment had the highest values followed by treatment where slash was removed while the one where the slash was burned gave the least values. Differences in performance of these parameters indicate different alteration in physical and chemical properties of soils due to treatments. Slash and litter management account partly for the differences in tree growth observed. This observation indicates that burning of slash and litter after harvesting leads to losses of organic matter which are sources of N, P and S (Kooreyaar *et al.* 1983). Burning of slash may lead to some direct loss of nutrients contained in the fuel to the atmosphere by volatilization (N, P and S) and increase leaching of nutrients in the ash. Other effects include changes or breakdown in soil structure, reduction in moisture retention and infiltration capacity, development of water repellency, changes in nutrient cycling rates and fluxes, off site erosion losses, loss of forest floor organic matter, reduction or loss of invertebrates and partial elimination of plant roots (Deka and Mishra 1983; Neary *et al.* 1999; Ballard 2000).

Treatment	**RCD (cm)**					**DBH (cm)**	
	Age (Months) 6	12	18	30	36	30	36
Control	2.71a	5.28a	7.84a	12.15a	13.77a	8.72a	9.38a
Slash removed	2.24b	4.89b	7.30b	11.14b	13.23ab	7.87b	9.06ab
Slash burned	2.06c	4.50c	7.11b	10.77b	12.75b	7.65b	8.66b
Pr>f	0.0002	0.0052	0.0135	0.0124	0.0137	0.0009	0.032
MSE	0.0996	0.0424	0.0607	0.205	0.1101	0.0461	0.0813
CV (%)	4.275	4.2108	3.322	3.989	2.5051	2.659	3.1591

Table 1: Effect of post- harvest slash management on mean root collar diameter (RCD) and diameter at breast height (DBH) of *Pinus patula* at Shume in Lushoto, Tanzania

Table 2: Effect of post harvest slash management on mean height (m) of *Pinus patula* at Shume in Lushoto, Tanzania

	Age (months)				
Treatment	6	12	18	30	36
Control	1.44a	2.41a	3.48a	5.64a	6.81a
Slash removed	1.21b	2.14b	3.19b	5.28ab	6.54b
Slash burned	1.21b	2.04b	3.11b	5.04b	6.22c
Pr>f	0.0047	0.0067	0.0026	0.029	0.0014
MSE	0.0047	0.0112	0.0079	0.0544	0.0145
CV (%)	5.337	4.812	2.736	4.383	1.8489

Table 3: Effect of post harvest slash management on basal area and stand volume of *Pinus patula* at Shume in Lushoto, Tanzania.

Treatment	Stand basal area (m^2/ha)		Stand volume (m^3/ha)	
Age (months)	30	36	30	36
Control	6.64a	7.68a	16.86a	23.68a
Slash removed	5.41b	7.17b	12.85b	21.09b
Slash burned	5.12b	6.56b	11.53c	18.39c
Pr>f	0.0007	0.049	0.0001	0.0055
MSE	0.0845	0.1912	0.444	1.982
CV (%)	5.079	6.128	4.848	6.689

In contrast, burning can sharply increase the amount of nutrients at the soil surface at planting. According to Mendham *et al.* (2003), burning increased early tree growth in eucalyptus plantations in Australia. This is the most common responses found in forest stands due to increased availability of N and P to plant after burning of organic residues. However, these effects tend to be of relatively short duration (Ludwig *et al.*, 1998; O'Connel *et al.* 1999).

Moreover, interesting results were observed at 36 months in which differenc+es in RCD and DBH were only significant between the control and slash burned treatments. This can be attributed to improved N availability in control treatment when slash and litter are not removed or burnt. The Shume Forest Plantation Project was reported to be very deficient in N (Lundgren 1978). A positive effect of residual slash and litter on tree growth was also found for *Pinus radiata* (Farell *et al.* 1981) and for *Pinus elliottii* Engelm (Simpson *et al.* 1999). In Spain and Portugal, growth of *Eucalyptus globulus* was lower when residues were removed compared to when the residue incorporated in the soil (Jones *et al.* 1999). The observation is also in consistent with results reported elsewhere (Ballard and Will 1981; Morris *et al.* 1983; Hopmans *et al.* 1993; Smith *et al.* 1994; Ballard 2000).

It has been shown that the removal of litter or forest floor organic matter from forest sites normally affects forest productivity through reduced nutrient status (Ballard 2000). Clear cutting and subsequent slash and litter removal or burning would alter soil temperature and soil water content and significantly increase the rate of decomposition of remaining organic matter, mineralization and leaching of N from the top soil (Smith *et al.* 1994).

The findings in these treatments for slash and litter removal or burned could also be associated with unavailable moisture and soil temperature conditions within the root zone from the loss of the mulch layer. According to Piatek and Allen (2001), soil temperature and moisture conditions have explained most of the differences in site productivity because these factors are expected to influence slash and litter decomposition and nutrient dynamics, thus the nutritional status of the stand as whole. Moreover, soil biota may also be strongly influenced by forest floor displacement too, by virtual removal of food source and other habitat changes (Ballard 2000).

In this study the effect of slash removal on early performance of *P. patula* was generally less adverse compared to that of slash burning (Table 1). This was expected because removal of slash from the forest site does not result in negative impacts noted above for slash burning. Nutrient accumulation in slash and litter materials acts as source or sink of nutrients (Piatek and Allen 2001) for current and subsequent rotations of *P. patula* stands. Nutrient cycling studies have shown that slash and litter mineralizes and also retains nutrients through immobilization (Piatek and Allen 2001). Overall slash and litter management is an important issue in plantation forest sustainability, from both moisture and temperature regulation to maintenance of soil fertility. This may influence the availability of nutrients in the soil and thus productivity of subsequent forest crops.

CONCLUSION AND RECOMMENDATION

Maintenance of productive capacity of the subsequent rotation of forest crop such as *P. patula* is influenced considerably by slash and litter management practices, some of which can cause positive or negative effects on productivity at a site. The early results from this study revealed that after clear felling and removal of merchantable wood and branches, the remaining slash and litter should be retained on the site to induce better tree growth and maintain the nutrient capital. This therefore supports the conclusions of most studies that post-harvest slash and litter management without burning or retaining harvest residues on site are required for sustainable productivity of these fast growing-growing plantations. The management practices that encourage slash burning or removals, commonly used by taungya farmers for site preparation should be discouraged. The post harvest slash and litter burning or removal if applied would seriously jeopardize long term production of subsequent forest rotations. Conversely, practices that foster conservation of post-harvest slash and litter resources would enable not only maintenance but also increase productivity of subsequent rotations of forest crops.

ACKNOWLEDGEMENTS

We wish to thank Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, Shume Forest Plantation, Tanzania for allowing us to carry this experiment. The successful completeion of this study would not have possible without the commitment of the late Prof. A.G. Mugasha whose spirit will always be an asset.

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