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PINE RESIN PRODUCTIVITY AT SAO HILL FOREST PLANTATION, SOUTHERN TANZANIA

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ABSTRACT

A study on resin productivity from *Pinus patula* and *P. elliottii* was carried out at Sao Hill Forest Plantation. Four and three compartments for *Pinus patula* and *P. elliottii,* respectively covering age between 5 and 25 years were selected. In each compartment, three plots (12m × 12m) were systematically established. All trees in each plot were measured for diameter at breast height (Dbh) and three trees (smallest, medium and largest in diameter) measured for total height and crown diameter. All trees in treatment plots were tapped for resin. Weighing and re-wounding of tapped trees was done after every ten days in ten sessions. The findings show that annual resin yield ranged from 0.56kg $tree^{-1}$ to 1.32kg $tree^{-1}$ and from 0.47kg $tree^{-1}$ to 1.98kg $tree^{-1}$ for *P. patula P. elliottii*, respectively. The Dbh and crown diameter were important predictors resin production. Over 31% of annual resin production was explained by stand level variables. It was recommended that integration of resin tapping into the current schemes of timber will improve the contribution of the forest sector in economic growth. Further, introduction of resin tapping may be an attractive option for early income generation while waiting trees to attain the rotation age.

Keywords: Resin productivity, trees, *Pinus patula*, *Pinus elliottii.*

INTRODUCTION

Forest plantations of Tanzania are stocked with both soft and hardwood tree species. MNRT (2015) estimated that the country has 554,500 ha of forest plantations planted with pines (*Pinus patula*, *Pinus elliottii* and *Pinus caribaea*), cypress, eucalyptus and teak. Pines are the dominant tree species in most plantations occupying about 78% of the total planted area and the remaining 22% is shared by hardwoods and other softwood species (Ngaga 2011). The main use of pines, among others, is to provide raw material to wood industries for pulp and timber production. Forest plantations are also important sources of numerous useful products, including non-wood products used by the chemical, food, and pharmaceutical industries, as well as for bio refineries (Rodrigues *et al.* 2007). Pine resin is one of the valuable plant extracts which is tapped from different pine tree species around the world (Coppen and Hone 1995). Resins are described as sticky, liquid, organic substances that harden upon exposure to air into brittle, amorphous solids (Ciesla 1998).

Recently, Tanzania has embarked on pilot commercial resin tapping from pine trees at Sao Hill Forest Plantation (SHFP). Introduction of resin tapping in commercial plantations is an innovative venture that has direct bearing with improvement of sector's capacity to provide goods and services through revenue collection and provision of employment. Since August 2017 to date about 1500 tons of resin worth 1.3 billion TZS have been collected and exported to China for processing (TFS 2019).

Quantity and quality of resin are important aspects of commercial resin tapping (Makupa 1995, Coppen 1995). These are determined by a number of factors ranging from biological and environmental factors; to those induced by a tapper during resin extraction (Neels 2000). So far there are no adequate information on the factors that affect resin productivity at Sao Hill. Knowledge of the factors that influence resin productivity is important since it is the management of those factors that can enhance resin yield in pine stands. Evidence exists in Australia and South Africa that biotic and abiotic factors that affect oleoresin production can be manipulated genetically or through management practices so as to improve both wood production as well as enhance resin yield from pine trees (Coppen and Hone 1995, Rodrigues-Correa *et al*. 2013). How these factors affect resin productivity varies from one site to another depending on the local growth conditions (Neis *et al*. 2018). It is therefore imperative that these factors are examined at local levels.

It is against this background that a study was carried out in SHFP with main objective of understanding the factors related to pine resin productivity. The specific objectives were to: 1) assess productivity (yield per hectare) of pine resin; and 2) assess tree level and stand level factors that influence pine resin yield.

METHODOLOGY

Description of the study area

This study was conducted at SHFP located between latitude 8°18' and 8°33' South and longitude 35°6' and 35°20' East (Figure 1). The area is elevated from 1700 to 2000 m above sea level. The SHFP is a state-owned forest plantation with its larger part falling under Mufindi District in Iringa region in the southern highlands of Tanzania, and a small portion is found in Kilombero District, in Morogoro region. The plantation receives annual rainfall between 600 mm and 1300 mm (Mgeni 1986). Temperatures are fairly cool, reaching close to freezing point between June and August. The mean monthly minima and maxima temperatures are 10°C and 23°C, respectively. Soils are relatively homogenous and are mainly dystricnitosols (Ngegba 1998). SHFP is the largest of all forest plantations in the country, having planted area of about 59,520 ha out of total gazetted area of 135,903 ha.

Study design

Two-stage sampling technique (Shiver and Borders, 1996) was employed. The first stage was selection of four representative compartments of age difference of 5 years; 5, 10, 15 and 20 years among *P. patula* stands. Only three *P. elliottii* compartments of age 10, 12 and 25 years were purposively adopted because current plantation composition could not support adequate age classes to make pairs with the those of *P. patula*. The second stage was establishment of three sample plots of dimensions 12 × 12 m for each age class which were systematically selected. The first resin plot was established at least 50 m from the compartment border and subsequent plots located 50 m apart. Four compartments of *P. patula* and three compartments of *P. elliottii* all together gave 7 × 3 = 21 treatments. Each plot is surrounded by several rows of trees to control edge effect on the measured trees. Each tree was given a number written on the trunk for easy identification during monitoring sessions. Table 1 shows the allocation of the plots in the selected compartments.

Data collection

Single trees parameters

Single tree parameters were measured using standard tree measurement principles presented in Malimbwi (1997). Single tree parameters measured were Dbh, total tree height, and crown height. In each plot, all trees were measured for Dbh. For total tree height, three trees, i.e., smallest, medium and the largest were identified within a plot and their heights measured using Suunto Hypsometer. In addition, to these three sample trees, height to the first live branches (m) referred as stem height was measured using Suunto hypsometer. Crown diameter (m) of each of the three selected trees was estimated by measuring and averaging the widest and the narrowest diameter of the crown using a tape measure at ground level.

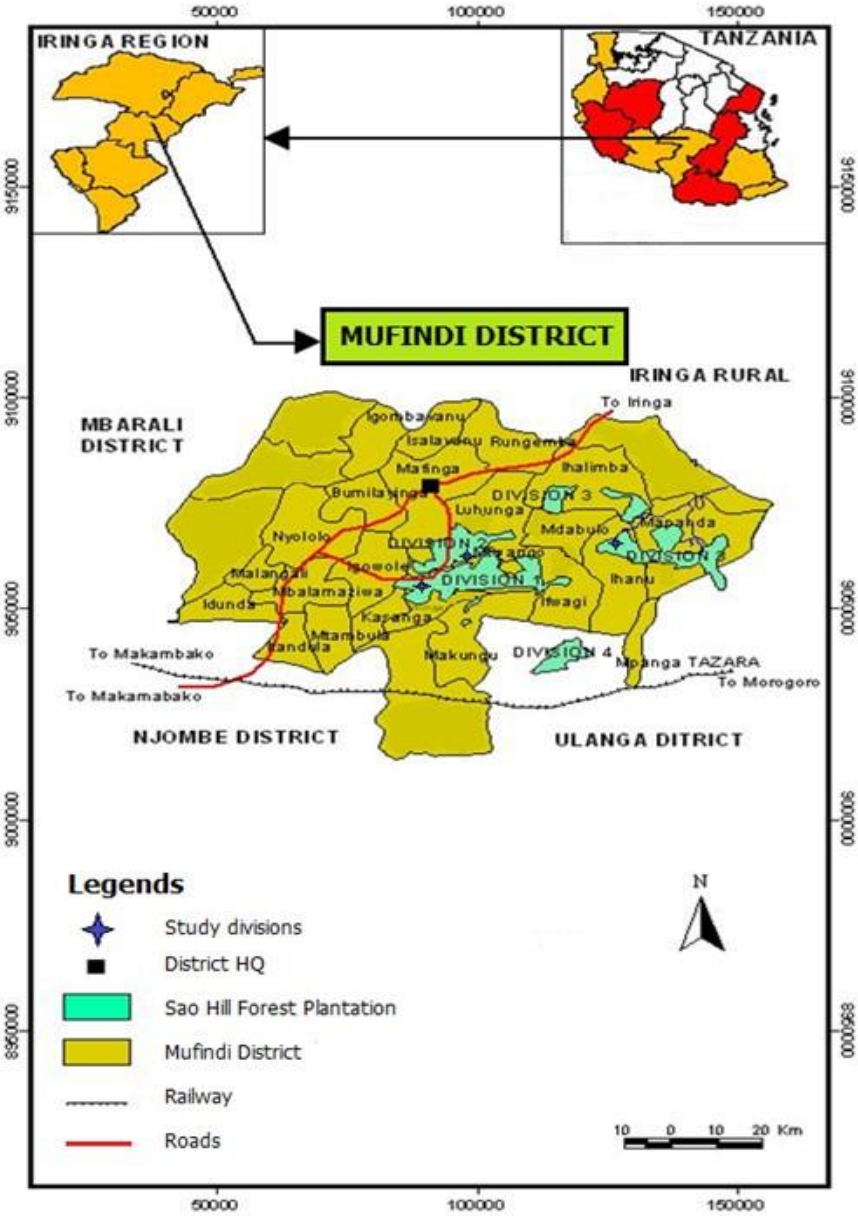

Figure 1: **Location of study area in Mufindi district showing study sites: Division 1, 2 and 3 of Sao Hill Forest Plantation**

Table 1: Distribution of Plots in Divisions within the Study Area

S/N	Range	Species	Age (years)	Plots	Division
1	Ruaha	*P. patula*	15	3T, 3C	Div I – Irundi
2	Irundi	*P. patula*	20	3T, 3C	Div I – Irundi
3	Nundwe	*P. elliottii*	10	3T, 3C	Div III- Ihalimba
4	Irundi	*P. elliottii*	25	3T, C3	Div I – Irundi
5	Makalala	*P. patula*	5	3T, 3C	Div II – Ihefu
6	Saohill	*P. elliottii*	12	3T, 3C	Div II – Ihefu
7	Matanana	*P. patula*	10	3T, 3C	Div II – Ihefu

Key: T - Treatment, C – Control

Resin yield

Chinese method of resin tapping was used where "V-shaped" grooves were cut, deep enough to reach the secondary xylem. The first groove was cut about 1.2 m above the ground, and subsequent grooves were cut below it. The groove reached roughly halfway (50% tapping intensity) around tree's circumference. Dilute Sulphuric acid (40%) was sprayed on wounded part to stimulate and maintain resin flow for a longer period (Coppen and Hone 1995, Spanos *et al*. 2010). This was purposely done to avoid shorter wounding frequencies which are costly and tedious.

Weight (in grams) data of resin was recorded using a data sheet between October 2018 and January 2019. There were ten collection sessions and material from different plots and species were stored separately. Re-wounding and resin collection were carried out every 10 days throughout the experiment period except the 9th session in which resin collection was prolonged to three weeks to honour the request of research assistants who went for end of the year festivals.

Data analysis

Quantitative methods of data analysis were employed where yield data were analyzed using descriptive statistics. Significance of selected set of factors (tree and stand level) was analyzed using simple and multiple regression methods. Data on stocking, age, Dbh, basal area, tree height, tree volume, crown size and resin weight were summarized in order to estimate various plot and stand variables. To ascertain the effect of factors at tree level (Dbh, tree height, and crown diameter) and stand level (basal area per ha, volume per ha, stocking, age, and average height), the regression equations were fitted. Data preparation and computation of different tree and stand level variables are described below.

Stand density

Stand density in this case encompasses the number of trees and the basal area per ha. The average number of stems and basal area per hectare was obtained by counting and estimating cross-sectional area, respectively in 3 representative plots of area size 0.0144 ha. The computation was carried out by applying the standard method for estimation of stem density and basal area as shown in equation 1 and 2.

$$N = {}^{1}/_{m} \sum \left(\frac{n_i}{a_i}\right) \qquad (1)$$

Where:

N = Number of stems per hectare;
m = number of sample plots;
n_i = number of trees per plot and
a_i = plot area (0.0144 m^2)

$$G = {}^{1}/_{m} \sum \left(\frac{g_i}{a_i}\right) \qquad (2)$$

Where:

G = basal are per ha; (m^2/ha)
g_i = tree cross-sectional area ($gi = \pi \times Dbh^2$).

Tree height (Ht)

Height of trees that were measured for Dbh alone was estimated using height equation by Malimbwi *et al*. (2016).

$$Ht = 1.3 + \frac{dbh^2}{13.63898 + 0.026482 \times dbh^2} \qquad (3)$$

Where:

Ht = estimated tree height (m);
Dbh = Measured diameter at breast height (cm).

Stand volume

Single tree volume was estimated using single tree volume model for SHFP developed by Malimbwi *et al.* (2016).

$$V = \exp(-9.04925 + 1.14781 \times \ln(\mathrm{Ht}) + 1.5496 \times \ln \mathrm{Dbh} \qquad (4)$$

Where:
V = tree volume (m^3);
Ht = tree total height (m);
Dbh = tree diameter measured at breast height (cm).
Stand volume (m^3/ha) was estimated in similar way as the basal area per ha.

Crown size

Average crown diameter was obtained by calculating average of wider and shorter diameter of crown base by ensuring that the two measurement are made at a right angle.

Resin yield (kg/ha)

The per hectare yield for each age class for 102 days of the study period was obtained using the following general formula:

$$y = {}^{1}\!/_{m} \sum \left(\frac{y_i}{a_i}\right) \qquad (5)$$

Where:
y = yield per hectare;
m = number of sample plots;
y_i = yield per plot and
a_i = plot area.

For annual resin yield determination, number of tapping days per year were assumed to be 365. We consider 102 days are adequate to represent annual resin productivity. Therefore, the annual resin yield (kg/ha/year) was obtained by multiplying y (from equation 5) by ${}^{365}\!/_{102}$.

RESULTS AND DISCUSSION

Resin yields

Figures 2 and 3 show the trends of resin flow in *P. elliottii* and *P. patula* for different age compartments. The labels indicate compartment number; and its age (the last two digits). Resin flow time series in both tree species indicate cyclic fluctuation in resin yield from session to session over the study period. The possible cause of yield fluctuations and yield drop could not be established although it is suspected to be due to delay between cause-and-effect relation in resin formation after re-wounding, and evaporation of water from resin in the resin bag due to prolonged exposure to dry weather, respectively. *P. patula* consistently commenced with sharp decrease in yield from first to the second session which was followed by increase in resin flow close to initial readings in all four age classes

The results also indicated variation in yield between trees, within species, between species and between age classes as shown in Table 2 and Table 3 for *P. elliottii* and *P. patula*, respectively. The resin production decreased and increased with age for *P. elliottii* and *P. patula*, respectively

Table 2: Resin yield for *P. elliottii*

Compt.	Age (years)	Yield per tree (kg) for 102 days	Confidence limit at 95%	Annual yield (kg/tree)	Stocking (Stems/ha)	Annual Yield (kg/ha)
NU1_3A	10	0.37	0.05	1.32	1644	2170.08
S15B_20	12	0.33	0.06	1.19	996	1185.24
R6E	25	0.15	0.02	0.56	1505	842.80

Table 3: Resin yield for *P. patula*

Compt.	Age (years)	Yield per tree in 102 days (kg)	Confidence Limit at 95%	Annual yield (kg/tree)	Stocking (stems/ha)	Annual yield (kg/ha)
2MK-1	5	0.13	0.02	0.47	1 366	642.02
MT1_13	10	0.13	0.03	0.47	926	435.22
I/R16C/37	15	0.34	0.07	1.23	695	854.85
IR_12ai/2	20	0.55	0.11	1.98	625	1 237.50

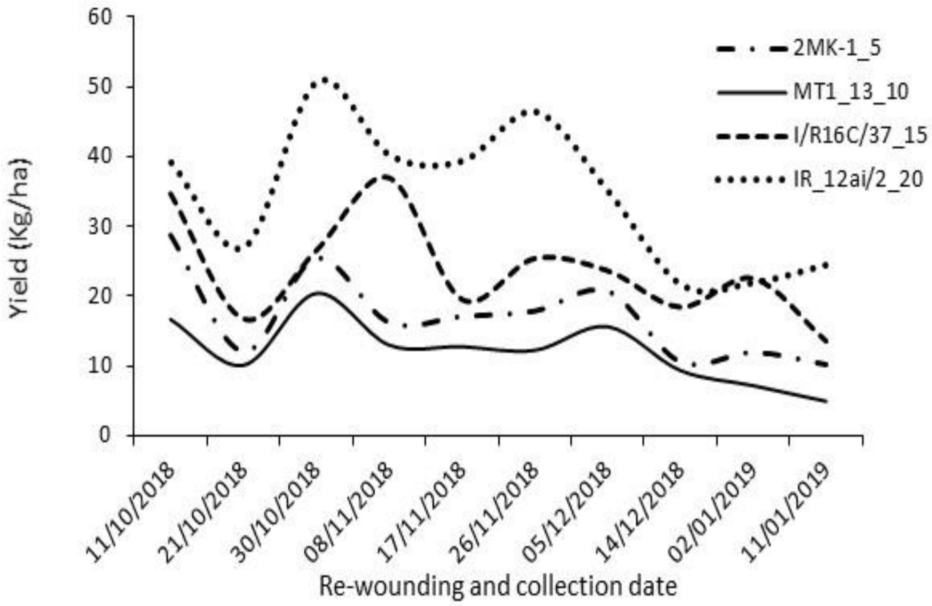

Figure 2: Temporal variation of resin flow in *P. elliottii* during 102 days of study period

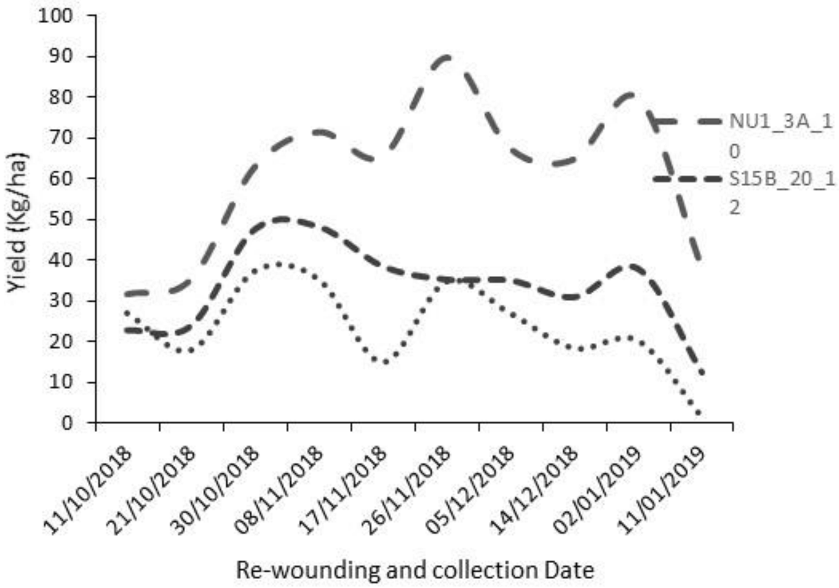

Figure 3: Temporal variation of resin flow in *P. patula* during the 102 days of study period.

The exact reason for antagonistic trend in yield with regard to age of the two species could not be established but a complex play of multiple factors such as differences in genetics, silvicultural treatments, site conditions and location, are the main suspected. Generally, results from this study indicated that both *P. elliotii* and *P. patula* grown at SHFP have the potential to produce resin.

The maximum yield per trees for each compartment is shown in Table 4. Assuming a tapping season of 365 days, descriptive statistics of plot level yield at 95% confidence level indicated that annual resin yield may raise to better levels.

Table 4: Annual resin production for maximum yield trees of *P. elliottii* and *P. patula*

Compt. Name	Spp	Trees level max. resin yield for 102 days (kg)	Annual trees level max. resin yield (kg)
NU1_3A	*P. elliotii*	0.41	1.47
S15B_20	*P. elliotii*	0.39	1.40
RE6	*P. elliotii*	0.17	0.61
2MK_1	*P. patula*	0.15	0.54
MT1_13	*P. patula*	0.16	0.57
1/R16c/37	*P. patula*	0.41	1.47
IR_12ai/2	*P. patula*	0.67	2.39

Table 5: Stocking level (Sph) in the study area

Compt. name	Spp.	Age (Years)	Scheduled stock (Sph)	Actual stock (Sph)	Over (+) or Under (-) stocked
2MK_1	Pp	5	1111	1 366	+255
MT1-13	Pp	10	650	926	+276
1/R16c/37	Pp	15	400	695	+295
IR_12ai/2	Pp	20	490	625	+135
NU1_3A	Pe	10	650	1 644	+994
S15B_20	Pe	12	650	996	+346
6RE	Pe	25	490	1 505	+1 015

Resin yields from the study area are slightly lower than yield reported in different studies. The reasons could be differences in tree growing conditions and or research methodology. Makupa (1995) reported an average annual resin yield of 2.1 kg/tree and 1.8 kg/tree for *P. elliottii* and *P. patula*, respectively

Characterization of the forest stands

Technical order No.1 of 2003 sets standards for forest stand establishment where initial spacing for conifers is 2.44 x 2.44 m and spacing of 3.0 x 3.0 m for trees planted before and after year 2003, respectively. Results presented in Table 5 indicate deviations from scheduled stocking levels where trees in all the studied compartments exceeded the required number of stems per hectare.

MNRT (2018) reported overstocking in most compartments in 15 studied plantations, including SHFP where this study was conducted. Studies by McConchie (1997, 2003) in the spacing trials revealed that the incidence of resin ducts formation, hence resin accumulation, increases when stocking rates are lower. Study by Coppen and Hone (1995) established that the greater the diameter of the tree tapped and the bigger the proportion of open live crown, the higher the resin yields. Other studies (Orallo and Veracion 1984, Low and Abdul Razak 1985, Gonzales *et al.* 1986, Ella and Tongacan 1987, Halimahton and Morris 1989, Chaudhari *et al.* 1992) concluded that suitable species grown under favorable conditions of site and forest management could result into larger diameter trees with large crown size which give higher yields of resin. Coppen & Hone (1995) estimated that species grown under favourable conditions can yield 3-4 kg of resin per tree annually, with *P. elliottii* having the highest yield of 4-6 kg. These studies conclusively suggest that resin production per tree in this study could have improved if the compartment were thinned as required.

Factors influencing resin yield

Tree level

Diameter at breast height

Results showed relatively satisfactory positive correlation for both tree species between resin yield and Dbh (Table 6, 7). In all the compartments and species, the Dbh coefficient was positive and highly significant (p-value < 0.05). Since Dbh is highly correlated with crown diameter (essential tree part for food production through photosynthesis), the observed pattern is quite logical (Drobyshev *et al*. 2007). This implies that tree diameter is a good indicator of resin yield and therefore, the larger the Dbh the higher is the resin productivity (Rodríguez-García *et al*. 2014).

Tree height

Similarly, tree height indicated strong positive contribution to resin yield in both tree species. The coefficient describing the slope of the regression was positive and significant in all tree species (p-value < 0.05). The correlation between height and resin yield increased with age in both tree species (Table 6, 7). This indicate that taller trees produce more resin than shorter trees. Total tree height is known to be a good indicator of site quality (the taller the tree the better is the local site quality) (Malimbwi *et al.* 2016). With this finding, it implies that compartments with good site quality are expected to yield more resin than poor sites (Rodríguez-García *et al*. 2014).

Crown diameter

Results indicated slightly high to low coefficients of determination but positive in both tree species. Influence of crown diameter in resin yield was higher in *P. elliottii* than *P. patula* (Table 6, 7). Nevertheless, these findings suggest that large crown indicates large surface area for photosynthesis processes and therefore effectiveness in manufacturing food resources including resin (e.g., Samanta *et al*. 2012).

Influence stand level parameters on resin productivity

P. elliotii

Coefficients of linear relationship relating resin productivity with each of stand variables (age, stems/ha, basal area (m^2/ha); and volume (m^3/ha)) in *P. elliottii* are presented in Table 8. The patten of the relationship is shown in Figure 4. The coefficients of determination (R^2) ranged from 36% to 95%. The findings show that resin yield decrease with age and increases with number of stems, basal area and volume (Table 8; Figure 4).

Table 6: Regression coefficients of tree variables with resin yield in *P. elliottii*

Compartment	Equation	R^2	SE	P - value
S15B_20 (12 yrs)	$y = 0.0786 \times \mathrm{Dbh} - \mathbf{0.2332}$	0.36	0.53	< 0.0001
	$y = 0.0560 \times \mathrm{Ht} + \mathbf{0.3518}$	0.14	0.61	0.0119
	$y = 0.5322 \times \mathrm{CrD} - \mathbf{0.2277}$	0.55	0.66	0.0363
R6E (25 yrs)	$y = 0.0271 \times \mathrm{Dbh}\ \mathbf{0.0666}$	0.21	0.29	<0.0001
	$y = 0.0388 \times \mathrm{Ht} - \mathbf{0.2101}$	0.25	0.28	<0.0001
	$y = 0.1212 \times \mathrm{Ht} + \mathbf{0.0502}$	0.46	0.17	0.0219
NU1_3A (10 yrs)	$y = 0.0861 \times \mathrm{Dbh} - \mathbf{0.0557}$	0.28	0.56	<0.0001
	$y = 0.0724 \times \mathrm{Ht} + \mathbf{0.3412}$	0.20	0.60	0.0001
	$y = \mathbf{0.4112} \times \mathrm{CrD} + \mathbf{0.2191}$	0.15	0.70	0.3031

y is weight in kg/year; *Dbh* in cm; *Crd*, ht in m; bold coefficients are non-significant

Table 7: Regression coefficients of tree variables with resin yield in *P. patula*

Compartment	Equation	R^2	SE	P value
MT1_13 (10 year)	$y = 0.0441 \times \mathrm{Dbh} - \mathbf{0.174}$	0.46	0.21	<0.0001
	$y = 0.0458 \times \mathrm{Ht} - \mathbf{0.0892}$	0.32	0.64	0.0001
	$y = \mathbf{0.1037} \times \mathrm{CrD} + \mathbf{0.2601}$	0.15	0.38	0.3506
IR_12ai-2 (20 years)	$y = 0.098 \times \mathrm{Dbh} - \mathbf{2.324}$	0.43	0.78	0.0002
	$y = 0.196 \times \mathrm{Ht} - \mathbf{6.368}$	0.59	0.66	<0.0001
	$y = 0.4107 \times \mathrm{CrD} - \mathbf{0.6354}$	0.84	0.33	0.0005

IR16C_37 (15 years)	$y = 0.094 \times Dbh - \mathbf{0.919}$	0.41	0.51	0.0001
	$y = 0.1087 \times Ht - \mathbf{0.935}$	0.25	0.57	0.0050
	$y = \mathbf{0.2289} \times CrD + \mathbf{0.3584}$	0.12	0.83	0.3647
2MK-1(5 years)	$y = 0.0340 \times Dbh - \mathbf{0.0648}$	0.21	0.20	0.0003
	$y = 0.0324 \times Ht + \mathbf{0.0338}$	0.17	0.21	0.0010
	$y = \mathbf{0.1545} \times CrD - \mathbf{0.007}$	0.30	0.25	0.1239

y is weight in kg/year; *Dbh* in cm; *Crd*, ht in m; bold coefficients are non-significant

This is contrary to what is expected since it is anticipated that with the increase in age, stand parameters are expected to increase. Such discrepancies are assumed to be caused by poor site stand quality of old compartments of *P. elliottii* emerged from natural regeneration which were not tended properly (average of 1505 stems/ha for compartment 6RE at age of 25 years (Table 5). Therefore, it should be noted that with similar crop quality, the resin yield is expected to increase with age. An equation combining all the stand variables described a significant number of variations of resin productivity.

P. patula

Coefficients of equations relating resin productivity with a set of variables in *P. patula* stands are presented in Table 9 while Figure 5 shows the pattern of the relationship. Except for stems per ha, the findings show that age, basal area per ha, stand volume had positive and significant influence (p-value < 0.05) on resin yield in *P. patula*. Coefficient of determination (R^2) values indicate that the contribution of individual stand variables in explaining variability in resin yield in the studied *P. patula* stands ranged from 31% to 97%. The decrease of resin with the increase in stems per ha is expected since lower number of stems imply increased individual tree Dbh and crown diameter and therefore increased resin yield as we have seen in Table 6 and Table 7. An equation combining all the stand variables described a significant number of variations of resin productivity

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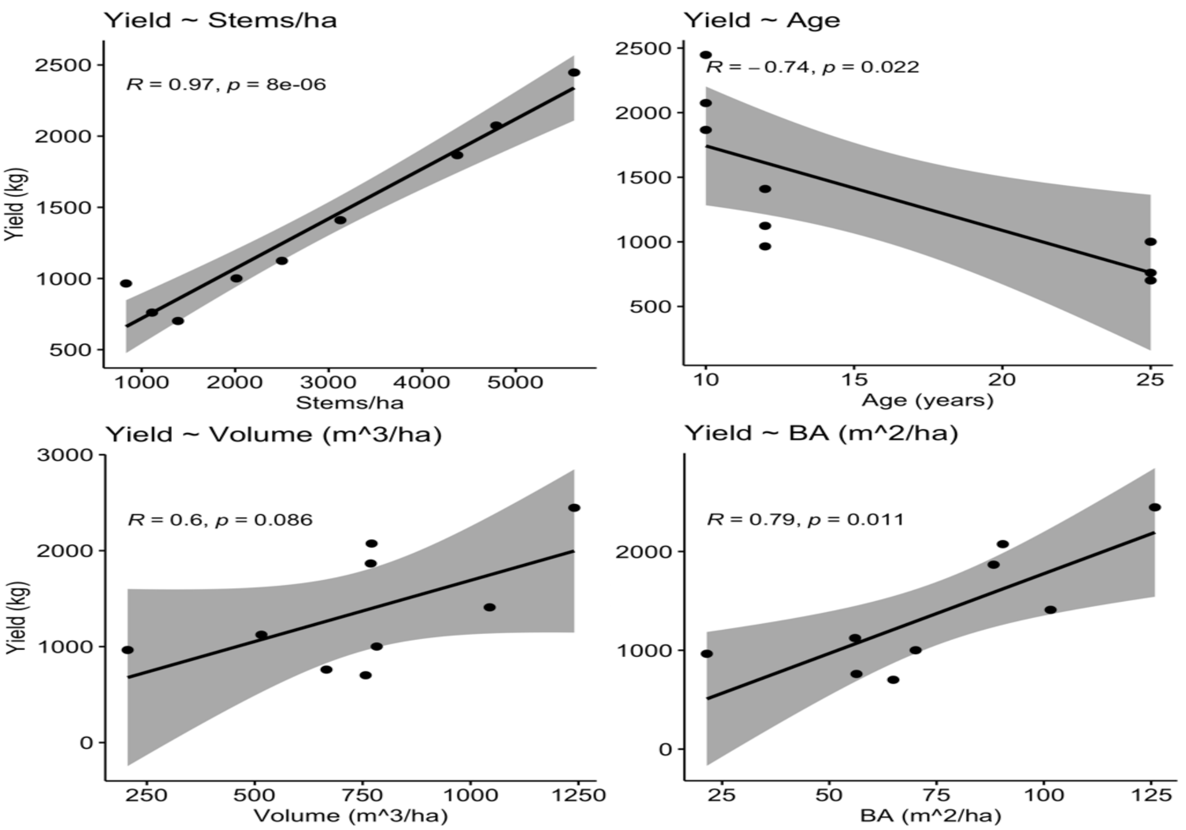

Figure 4: The relationship between stand level variables and annual resin production.

Table 8: Regression of individual stand variables with resin yield in *P. elliottii* stands

Equation	SE	R^2	*p*-value
$y = \mathbf{2397.07} - 65.43 \times \text{Age}$	444	0.55	0.02
$y = 369.9 + 0.350 \times \text{N}$	147	0.95	<0.0001
$y = \mathbf{162.01} + 16.135 \times \text{G}$	405	0.63	0.0111
$y = \mathbf{415.9} + 1.274 \times \text{V}$	530	0.36	0.086
$\text{Y} = 932.4 + 0.580 \times \text{N} - \mathbf{22.04} \times \text{age} - \mathbf{43.3} \times \text{G} + \mathbf{3.162} \times \text{V}$	124.6	0.98	0.001

y is weight in kg/year; *Age* in years; *N* is stems per ha; *G* in basal area per ha (m^2/ha); and *V* is volume per ha (m^3/ha); bold coefficients are non-significant.

Table 9: Regression of individual stand variables with resin yield in P. patula stands

Equation	SE	R^2	p-value
$y = \mathbf{205.3} + 45.08 \times \text{Age}$	191.2	0.67	0.0010
$y = 1274.9 - 0.560 \times \text{N}$	279	0.31	0.0606
$y = \mathbf{-186.64} + 35.885 \times \text{G}$	94.3	0.92	<0.0001
$y = 91.807 + 2.417 \times \text{V}$	62.5	0.97	<0.0001
$\text{Y} = -303.89 + \mathbf{22.352} \times \text{N} + \mathbf{0.2614} \times \text{age} + \mathbf{1.0136} \times \text{G} + \mathbf{1.8937} \times \text{V}$	65.7	0.97	<0.0001

y is weight in kg/year; *Age* in years; *N* is stems per ha; *G* in basal area per ha (m^2/ha); and *V* is volume per ha (m^3/ha), bold coefficients are non-significant.

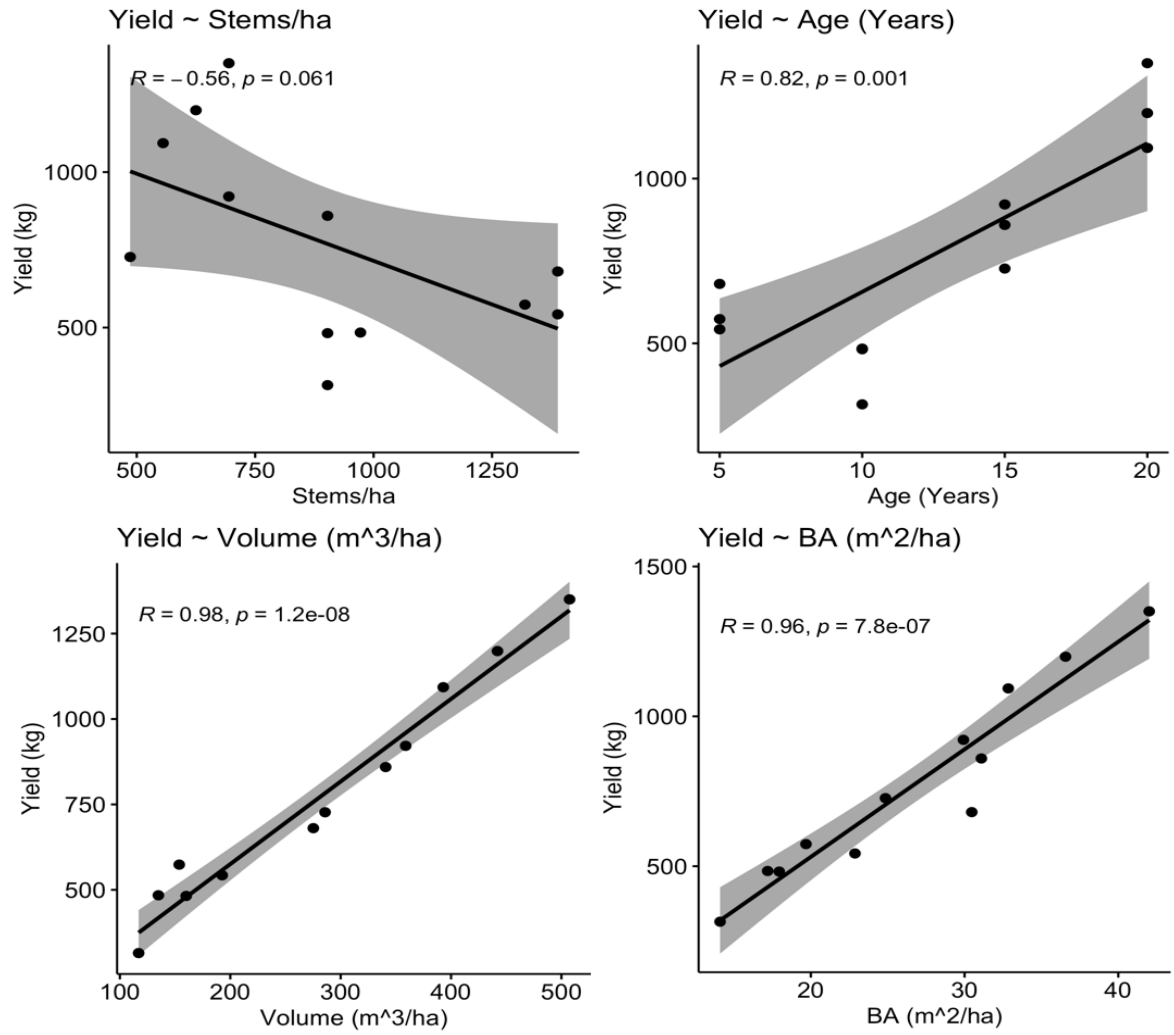

Figure 5: The relationship between stand level variables and annual resin production.

Results from this study indicated that the factors that most significantly influenced resin yield are similar to those in previous research works but differs in the magnitude of influence depending on the biological and environmental conditions of the forest stand. Of all variables assessed at SHFP at tree level, Dbh was found to be a good predictor of resin yield, followed by crown diameter. Although this study applied a different methodology where a tree was a sampling unit, Makupa (1995) reported almost similar trend. Chaudhari *et al.* (1992) in their study that determined the relationship between Dbh and resin yield established that larger diameter trees give higher yields of resin. According to Coppen and Honne (1995), influence of crown size on resin yield lies on the fact that large, healthy crowns are associated with increased bio synthetic capacity to produce the metabolites which are the precursors of resin. Other studies such as Papajiannopoulos (2002) and Spanos (2010) suggested that photosynthetic and other physiological processes affect resin accumulation.

On the other hands, correct spacing plays an important role in tree growth (Zobel *et al.* 1987; Evans, 1992), cited by Chamshama (2011), leading to increment in tree girth, height and crown size, the factors that are important in resin production. This means that for better resin yield, intra and inter tree relationships controlled by the current management regime targeted to improve stand wood volume for timber production are very essential in enhancing resin yield.

CONCLUSION AND RECOMMENDATIONS

This study intended to explore some factors affecting pine resin productivity. It was established that despite the poor stand conditions at the study area, both *P. elliottii* and *P. patula* produce significant amount of resin. The findings revealed that tree and stand variables such as Dbh, crown size, age, tree height, spacing, basal area and volume per hectare are important predictor of resin yield in pine trees. In viewpoint of forest resources assessment, this is an added value since similar variables (Dbh and height) are important predictor of other important tree parameters such as biomass and volume. Although this study was confined to a small area of SHFP, integration of resin tapping into the current schemes of timber and pulp wood may be a smart decision not only for improving the contribution of the forest sector in economic growth but also in improving forest management practices for healthier forest resources. Further, introduction of resin tapping activities may be an attractive option for early income generation before trees attain the rotation age. In addition, resin tapping activities will create jobs to communities surrounding pine plantations. Results of this study provide reasonably enough information that may trigger resin tapping and processing business in the country. In addition, the study justifies a need for more detailed resource assessment for sustainable development of this new forest practice in the country. Further, to enhance resin productivity and create conducive environment for resin businee, the following is recommended: 1) adherence to improved forest stand establishment and management practices such as use of good planting material, site selection, timely planting, pruning and thinning; 2) carrying out studies with wider spatial and temporal coverage to capture the effect of more variables such as weather, seasonality and altitude on resin productivity; 3) since *P. elliottii* has shown resin productivity potential, advocating planting of *P. elliottii* should be insisted in the study area and all other areas in the country where it can perform better; 5) exploration of the real value of pine resin in the country should be established through a separate pricing mechanism.

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