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Research Article

Correlation and Regression Studies on Estimation of Resin Yield in *Pinus roxburghii*

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ABSTRACT

Different characteristics of Pinus roxburghii were recorded from randomly selected 80 trees to establish the relationship between resin yield with diameter at breast height, tree height, bole height, bark thickness, crown width, number of branches, needle length, needle thickness, leaf area index, transmission coefficient and mean leaf angle. Resin yield was positively and significantly correlated with all tree morphological parameters except number of branches. Quadratic model can be used to predict resin yield with the height.

Keywords: *Pinus roxburghii, Correlation, Regression.*

INTRODUCTION

Pinus roxburghii is one of the most important species among the six Himalayan pines which is extensively used for the extraction of resin yield. Although, resin can be extracted from diverse species but, quantity wise, *Pinus roxburghii* is the most preferred species in the Himalayas for resin extraction. In India, *Pinus roxburghii* grows between 450m to 2400m above mean sea level, covering the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, parts of Sikkim, West Bengal and Arunachal Pradesh. In Himachal Pradesh, it is found in Shimla, Kunihar, Solan, Rajgarh, Chopal, Nahan, Dalhousie, Bilaspur, Hamirpur, Palampur, Una, Dharamshala and Nurpur forest divisions. The species has a wide adaptability compared to other conifers. Resins occupy a prime place among Non-wood Forest Produce. The oleoresin production is important not only to oleoresin based industries but it also has an immense potential to generate employment for rural people. For commercial purposes, resin is obtained by tapping standing pine trees i.e. by making a cut which exposes the surface of the wood. Resin canals are large and irregularly distributed in chir pine. The yield of the oleoresin is affected by number of factors such as diameter, tree height, needle diameter, needle length, time of tapping, and various anatomical characters (Nimkar & Sharma, 2006). Therefore, the study was conducted to establish the relationship between resin yield and various characteristics of *Pinus roxburghii*.

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MATERIALS AND METHODS

The field of the Department of Forest Products, Dr Y S Parmar University of Horticulture & Forestry, Nauni, Solan Himachal Pradesh was selected at the experimental site. The area is located in the mid hill zone of Himachal Pradesh with the elevation of about 900-1300 m amsl. The data were collected on various characteristics of *Pinus roxburghii.* Karl Pearson's correlation coefficient between resin and various tree growth parameters (diameter at breast height (X_1), tree height (X_2), bole height (X_3), bark thickness (X_4), crown width (X_5), number of branches (X_6), needle length (X_7), needle thickness (X_8), leaf area index (X_9), transmission coefficient (X_{10}) and mean leaf angle (X_{11}) was worked out and tested for its statistical significance. Various regression functions linear and non linear (logarithmic, S curve, exponential, quadratic, compound, growth, cubic, inverse and power) were fitted for resin yield with diameter at breast height, tree height, bole height, bark thickness, crown width, number of branches, needle length, needle thickness, leaf area index, transmission coefficient and mean leaf angle. Further multi-linear regression equations were also developed for tree growth characteristics on resin yield of *Pinus roxburghii*. Finally Adj R^2 (i. e $\overline{R}^2$) was used to gauge the best fitted regression function.

RESULTS AND DISCUSSION

Correlation Studies: Karl Pearson's correlation coefficient was worked out for different growth parameters viz., diameter at breast height (DBH), tree height, bole height, bark thickness, crown width, number of branches, needle length, needle thickness, leaf area index, transmission coefficient and mean leaf angle, to get estimates of relationship among various growth characters, the results of which have been are presented in Table 1. The results reveal that resin yield was positively and significantly correlated with all tree morphological characters except number of branches. It is also evident from the table that resin yield showed a highly significant correlation with tree height (0.483) and DBH (0.482) followed by crown width (0.415) and bark thickness (0.410). Maximum correlation of 0.884 was found between diameter and bark thickness, followed of correlation of 0.776 between diameter and height.

Table 1: Correlation matrix for various morphological characters and resin yield in *Pinus roxburghii*

Characters	DBH (cm)	Height (m)	Bole Height (m)	Bark Thickness (cm)	Crown Width (m)	Number of Branches	Needle Length (cm)	Needle Thickness (mm)	Leaf Area Index	Transmission coefficient	Mean leaf angle	Resin Yield (gm)
DBH (cm)	1	0.776**	0.459**	0.884**	0.774**	-0.023	0.647**	0.580**	0.546**	0.341**	0.114	0.482**
Height (m)		1	0.457**	0.764**	0.665**	0.042	0.614**	0.488**	0.476**	0.297**	0.177	0.483**
Bole Height (m)			1	0.384**	0.292**	0.11	0.261*	0.269*	0.313**	0.265*	0.117	0.287**
Bark Thickness (cm)				1	0.632**	-0.003	0.709**	0.639**	0.573**	0.233*	0.153	0.410**
Crown Width (m)					1	-0.06	0.420**	0.365**	0.398**	0.221*	0.106	0.415**
Number of Branches						1	0.059	0.025	0.014	0.138	0.225*	0.144
Needle Length (cm)							1	0.522**	0.553**	0.162	0.064	0.326**
Needle Thickness (mm)								1	0.436**	0.158	-0.214	0.267*
Leaf Area Index									1	0.096	-0.051	0.306**
Transmission coefficient										1	0.328**	0.346**
Mean leaf angle											1	0.354**

******significant at 1% level of significance

*****significant at 5% level of significance

Table 2: Linear and non-linear functions for estimation of resin yield.

Characters	Model	Resin Yield	SE of estimate	Adj R^2
DBH (cm)	Linear	$Y = -1081.40 + 59.98X_1$	12.35	0.222
Height (m)	Quadratic	$Y = 2143.434 + 6.928 X_2 - 178.546 X_2^2$	197.858, 4.548	0.236
Bole Height (m)	Growth	$Y = e^{6.42 + 0.09X_3}$	0.029	0.088
Bark Thickness (cm)	Linear	$Y = -1162.07 + 441.109 X_4$	111.120	0.157
Crown Width (m)	Quadratic	$Y = 3860.45 - 674.49 X_5 + 43.55 X_5^2$	444.20, 21.122	0.195
Needle Length (cm)	Growth	$Y = e^{6.25 + 0.05X_7}$	0.014	0.107
Needle Thickness (mm)	Logarithmic	$Y = 1652.16 + 1529.98 \ln X_8$	621.330	0.060
Leaf Area Index	Cubic	$Y = 12134.90 - 66542.10X_9 + 125540.20 X_9^2 - 71806.30 X_9^3$	28398.485, 54155.913, 32973.964	0.140
Transmission coefficient	Growth	$Y = e^{5.88 + 1.96X_{10}}$	0.471	0.171
Mean leaf angle	Cubic	$Y = 1553.02 - 67.67 X_{11} + 2.76 X_{11}^2 - 0.02 X_{11}^3$	60.257, 1.529, 0.011	0.173

Regression Studies: Various linear (straight line) and non-linear (logarithmic, inverse, quadratic, cubic, compound, power, S curve, growth curve and exponential) functions have been tried on various tree growth characteristics *viz.,* diameter at breast height (DBH), tree height, bole height, bark thickness, crown width, number of branches, needle length, needle thickness, leaf area index, transmission coefficient and mean leaf angle to estimate resin yield by taking one character at a time as independent variable and results are given in table 2. Adj. R^2 and standard error of estimate are also presented along with the respective fitted functions. Table 2 reveals that, the linear function can be used for predicting resin yield on the basis of DBH with maximum Adj. R^2 value of 0.222. Quadratic function can be used to predict resin yield on the basis of tree height with maximum Adj. R^2 value of 0.236. While using bole height as independent variable, growth function had Adj. R^2 value of 0.088. Prediction of resin yield on basis of bark thickness can be made by using linear function with Adj R^2 value of 0.157. For crown width, quadratic function can be used to predict the resin yield with Adj R^2 value of 0. 195. Linear and non-linear regression models were fitted taking the number of branches as an independent variable, and it was found that none of the fitted models could be used to predict resin yield. While using needle length as an independent variable, growth function had Adj. R^2 value of 0.107. Considering needle thickness as an independent variable, logarithmic function with Adj. R^2 value of 0.060 can be used to predict resin yield. For leaf area index cubic had highest Adj. R^2 value of 0.140.While using transmission coefficient as an independent variable, growth had Adj. R^2 value of 0.171. Cubic function can be used to predict resin yield on the basis of mean leaf angle with Adj. R^2 value of 0.173.

Multiple linear regression equations for resin yield: Multiple linear regression was carried out by keeping resin yield (Y) as the dependent variable and all other recorded morphological characters as independent variable by using stepwise regression analysis. It was found that only two morphological characters i.e. height and mean leaf angle significantly affected the prediction of resin yield and the rest of the morphological characters had non- significant effect on resin yield estimation. Thus resin yield of *Pinus roxburghii* can be estimated by

$Y = -1169.116 + 108.24X_2 + 14.12X_{11}$

(24.062) (4.916)

(Values in parentheses are standard errors of estimated regression coefficient)

Values of R^2 and Adj. R^2 were found to be 0.320 and 0.289 respectively. Thus 32 per cent of the variation in estimation of resin yield is being explained by fitted above multiple linear regression equation. The model also shows that for a unit increase in the value of height, there is 108.24 gm increase in the value of resin yield and for a unit increase in value of mean leaf angle, there is 14.12 gm increase in the resin yield. Lohani reported a marked correlation of resin yield with diameter from chir pine tree varying from 30 cm to 60 cm diameter tapped by cup and lip method. Chaudhary et al. (1992) while studying the correlation between diameter and resin yield by Rill Method of tapping observed that the resin yield increased up to 45 cm and then decreased afterwards. Based on this, they described a model for forecasting the resin yield from the trees having diameter between 35-55 cm. Singhal (1996) reported a positive and significant correlation of oleoresin yield with diameter and height. Lekha et al. (2002) demonstrated that height, needle colour, needle length and bark thickness showed significant correlation with oleoresin yield in *Pinus roxburghii*. Nimkar et al. (2002) reported that diameter, needle colour, needle length and bark thickness showed significant variation with oleoresin yield. Nimkar and Sharma (2007) obtained highly significant and positive correlation coefficients between oleoresin yield and other traits, i.e. needle length vs needle thickness.

CONCLUSION

Correlation between different characters was carried out and their significance was tested using t-test. Regression analysis was performed to predict the resin yield of *Pinus roxburghii* trees on the basis of various morphological parameters recorded. Different models *viz.* linear, logarithmic, inverse, quadratic, cubic, compound, power, S curve, Growth, and exponential were fitted and their validity was tested by using coefficient of determination (R^2) and root mean square error (RMSE) method. Stepwise multiple linear regression was carried out keeping resin yield as the dependent variable and all other morphological characters as independent variable. Resin yield was positively and significantly correlated with all tree morphological parameters except number of branches. Quadratic model can be used to predict resin yield with the character height.

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