Growth and Resin Production Structure of *Pinus merkusii* Under Different Environment Condition (Case study in Perum Perhutani Seedling Seed Orchard)

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Abstract. *Pinus merkusii* was famous wood and resin producer trees in Indonesia. Previously, pine wood became one of major material for pulp and paper, later along the changes in forestry paradigm, resin product as non wood forest product became more prospective to develop.. Pine as resin-producing tree requires suitable condition for Producing high amount and good quality of resin. The objective of our study was to determine environment factor that influence growth and resin production structure in three Seedling Seed Orchard (SSO) Perum Perhutani, those were Baturaden (Central Java), Cijambu (West Java) and Sempolan (East Java). Data for this research obtained from secondary and primary data in three Perum Perhutani SSO through direct observation and measurement. Result showed that Cijambu SSO has the highest resin production (101.4 g/tree/3days) compared to Baturaden SSO (88.72 g/tree/3days) and Jember SSO (64.4 g/tree/3days), *right-skewness* resin production distribution structure and wider resin production interval. Pearson correlation test and multiple linear regression for 14 growth characters out of 35 characters were tested. Stem diameter, branching number, bark thickness and crown had moderate correlation with resin yield (r: 0.75). It is concluded that resin production was affected by genetic and enviromental factors. Although resin production was affected by genetic and environmental factor, therefore appropriate stand management (silviculture treatment) must also be implemented because potential genetic expression would be maximized if environmental conditions is well managed.

1. Introduction

Pinus merkusii was potential wood and resin producer trees in Indonesia. There were 3 strains of *P. merkusii* growing naturally in Indonesia namely, Aceh, Tapanuli and Kerinci with different characteristics [1]. In considering with its economical value, since 1920 this species was introduced to Java Island from Aceh population by Perum Perhutani and become second priority species after teak. With the increasing value of pine timber at that time, in 1976 selection activity was conducted to obtain plus trees with good stem and growth character [2] and followed by establisment of Seedling Seed Orchard (SSO) in Sumedang (West Java), Baturaden (Central Java) and Jember (East Java).

Along with the change of paradigm in pine management from wood-oriented to non-timber products, since 2006 the pine breeding program in Perum Perhutani not only focused on timber but also on its resin. Gum rosin is one of high valueable non timber forest products in international market and contibuted about US $ 50 million every year of Indonesian devisen [3]. Therefore, since 2006 until now tree breeding activity of Perum Perhutani focusing on high resin production, considering in previously research some high resin yielder candidate trees was founded.

Information about growth and resin production structure in Perum Perhutani SSO is still not determined yet, although this information is very important for characterization and stand management activities. Information of resin production structure may describe the distribution of resin for each resin yielder pine in Perum Perhutani SSO. In addition, for breeding activities with focused on resin production, *right-skewness* resin production distribution structure and wider resin production interval was needed [4]. Therefore, our research was conducted to get information about growth structure and resin production structure of resin yielder at Perum Perhutani SSO as basic data for the next breeding activity.

2. Material and Methods

Growth and resin production structure observation was conducted on high resin yielder pine stand planted in year 1978-1983 at Cijambu, Baturaden and Jember SSO. In 2006 a preliminary selection on high resin yielder pine found 110 trees plus (Cijambu), 90 plus trees (Jember) and 75 plus trees (Baturaden) that produce higher resin compared to others and hereinafter refered as normal. (more than 21 g/3 day/ tree). To get information about growth structure and its relationship with resin production, material from Cijambu SSO was choosed.

Research on resin production structure in 3 SSO was conducted through data stratification and statistical analysis using secondary data of resin production owned by Perum Perhutani. Growth structure and relationship between growth characters was done through direct observation in Cijambu SSO using 35 growth and ecological characters. The observed growth characters include: height, diameter, canopy, branching, bark thickness and severity of pest attack. Measurement methods for 35 growth and ecological characters refered to previous research procedures on forest trees. The results of direct measurements then processed using statistical software to determine the mean value, standard deviation, coefficient of variant, correlation and multiple linear regression with refers to [5]. Standardization of data was done to obtained Principal Component Analysis (PCA).

3. Result and Discussion

3.1. Growth Structure

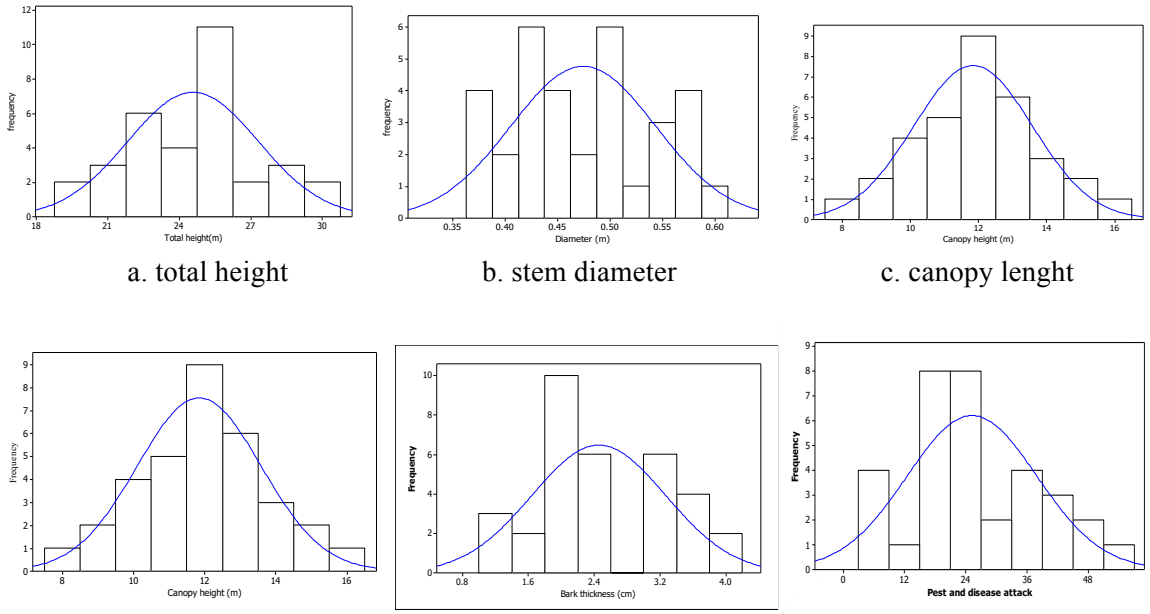
The forest stand condition is ifluenced by growth conditions, silvicultural treatment, tree age and genetic properties of tree, interaction of each individual tree with habitat, and interaction between individual trees. The growth structure is able to reflect the influence of these factors through the growth output and yield [6] one of which is the resin production.

Generally, the structure of stem diameter, free branch height, total height, volume, canopy and branching on Perum Perhutani SSO following a common pattern on platation forest. The growth structure of pine stands in Cijambu SSO based on total height, stem diameter, canopy lenght and width, bark thickness and saverity of pest and disease presented in figure 1.

Tree height on a stand is one of the most important variables in forest management because it is able to reflect the total volume of trees for commercial purposes, reflecting the quality of growth location and describes vertical structure of a stand [7]. Height structure on Cijambu are generally at 15-30 m intervals with the highest number at an average interval of 24.5 m (Figure 1.a), whereas the diameter distribution has an interval between 0.35-0.66 m, with an average of 0.47 m (1.b).

The canopy condition is an important component in growth structure study because it described wood quality, stand competition level, tree vigor, mechanical stability of trees and microclimate [8]. The variables are represent by crown height, crown length and crown area [9]. The canopy length in Cijambu has an interval of 8-16 m and an average of 11.85 m (Fig. 1.c), for the crown width having an interval value of 100-600 m^2 with an average of 361 m^2 (Fig. 1.d).

Bark thickness is generally used to predict the volume of wood and correction of actual tree diameter. The bark thickness in Cijambu at the interval of 0.8-4.0 cm with the highest number being on the average thickness of 2.45 cm (Figure 1.e), while for the level of severity pest and disease at the interval of 0-48% and the highest number of trees located at 25.44% level.



a. total height b. stem diameter c. canopy lenght

d. canopy width e. bark thickness f. pest and disease

Figure 1. Growth structure of pine stand in Cijambu SSO, (a) total height, (b) stem diameter, (c) canopy lenght, (d) canopy width, (e) bark thickness, (f) pest and disease.

3.2. Resin production structure

Resin production structure in three of Perum Perhutani SSO (Figure 2) shows the same pattern of distribution as found in other plantation forest with an average production value of 85.9 g / tree /3 days. The largest resin production frequency was at intervals of 80-100 g / tree / 3 day (154 trees) and the smallest frequency was at intervals of ≥150 g / tree / 3 days (14 trees). Cijambu SSO has the highest average (101.4 g / tree / 3 days) followed by Baturaden (88.72 g / tree / 3 day) and Jember (64.4 g / tree / 3 day). Resin production structure of Cijambu SSO was right skewness, it indicated that individual trees in Cijambu SSO produce higher resin compared to normal.

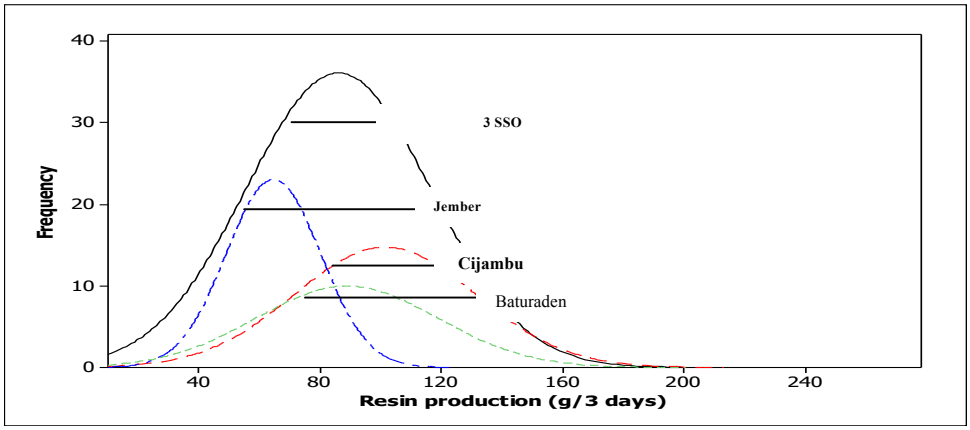


Figure 2. Resin production structure at all seed orchard, Cijambu, Baturaden and Jember

Resin production in each SSO shows different structures. Previous studies have found the role of soil conditions, climate, chemical usage, age, silvicultural techniques (environmental factors) and

plant genetic factors in determining the quantity of resin production [10]. The results of the research on resin yielder pines in the temperate regions found the role of dominan genetic factors in determining the character of resin production [11]. But both of factors together support character expression, because phenotype of resin production is a result of interaction betwen genetic and environmental factors.

Based on its history, establishment of Cijambu, Baturaden and Jember SSO was carried out gradually in 1978-1983 with the same genetic material source [2] with focused on stem straightness characters. Result on data stratification from 3 SSO found that trees from the same family produce different resin quantity when planted on 3 different SSO. The inconsistency of the rankings is also due to the genetic material for planting in Perum Perhutani derived from half-sib descendants who are still segregated.

The environmental conditions support genetic expression of resin production character. This reason in accordance with [12] who states that environmental variations will limit the genetic gain of a population because the expression of genetic potential will be maximized if supported by appropriate environmental conditions. The growing site conditions that include geographical position, altitude, rainfall, soil type and slopes of each SSO are presented in Table 1.

Table 1. Habitat characteristic of Cijambu, Baturaden and Jember SSO.

Variable	Cijambu	Baturaden	Jember
Geographic location	107°45' BT 6 °.52'LS	108°.73'BT 6°.79'LS	113°.52'BT 7 °.67'LS
Altitude (m.asl)	1290	725	600
Average precipitation (mm/year)	2520	3500	2400
Soil type	Andosol	Andosol	Regosol
Slope (%)	11-62%	10	0

Based on Table 1, SSO altitude of location and slope becomes the difference between Cijambu with two other SSO. Altitute of growing location affect the smooth flow of resin because higher place will produce clot resin and blocked the resin flow due to low air temperature and sunlight intensity [13]. Soil type also affects plant growth. Andosol soils (Cijambu and Baturaden) are characterized by a black-brown, andik, light texture, derived from volcanic material or volcanic eruptions and deep and relatively fertile. The regosol (Jember) is characterized by a shallow, alkaline or near-neutral solum and is commonly found in limestone areas and kars in East Java, Central Java, Madura, Nusa Tenggara and South Maluku. Andosol soils with light texture and deep and sour soluble are more suitable for pine growth with the purpose of resin production, as indicated by Cijambu and Baturaden that produced higher resin compared than Jember.

The interaction of genetic and environmental factors leads to differences in trees genotype when planted in different environments condition [14]. The existence of GxE interactions requires intensive management activities based on the suitability of the growing location of each family. This is because the environmental conditions will determine the fitness of the family. The difference of resin yield of 3 SSO and GxE interaction resulted in further resin yielder improvement strategy. Individual families that produced concistent resin in each SSO reflect good adaptability, so that can be used as a source of material at different sites plantation. In contrast, individuals from families that produce a fluctuating and inconsistent resin indicate that the individual is only adaptive at a particular location, then can only be used as a source of local localized planting material.

3.3. Growth characters and its relation with resin production

The correlation between growth and ecological character with resin production was conducted through correlation test of 35 characters. Initial correlation results found 14 growth characters (total height, branch free height, diameter, bark thickness, number of branches, crown length, canopy width, first

branch angle, branch free volume, total volume, pest and disease severity, skin roughness) that has corelation with resin production (value of correlatio than 0.1), while the other characters have a correlation coefficient smaller than 0.1. To obtain a character that can represent both of correlation, further testing for 14 characters was conducted. For this purpose, the Principal Component Analysis (PCA) testing procedure and group analysis (dendrogram) were selected.

Table 2. *Eigenvalue* of the variability of growth character

Faktor	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalue	3.9866	2.8008	2.2262	1.3276	1.2650	1.0225
Varian	0.266	0.188	0.148	0.089	0.084	0.068
cumulative	26.57%	45.32%	60.17%	68.99	77.43%	84.24%
				%		
Resin production (g/tree/ 3 days)	0.179	-0.202	-0.405	-0.024	0.101	-0.515
Total Height (m)	0.401	-0.048	0.207	0.075	-0.274	-0.122
Clear bole (m)	0.195	-0.050	0.445	0.040	0.244	-0.469
Stem diameter (m)	0.181	0.316	-0.449	-0.152	-0.004	0.057
Bark thickness (cm)	0.242	0.103	-0.389	0.264	0.196	-0.050
Number of brancing (n)	-0.001	-0.248	0.109	0.548	-0.449	0.036
Branching angle (^{o})	-0.180	-0.059	-0.082	-0.094	-0.486	-0.586
Canopy lenght (m)	0.378	-0.288	-0.115	-0.097	0.027	0.171
Canopy height (m)	0.344	-0.102	0.221	0.239	-0.196	0.168
Stem straighness	0.098	-0.455	-0.007	0.031	0.027	0.094
Pest and disease	0.091	0.219	0.367	-0.394	0.233	0.007
Clear bole volume (m^3)	0.301	0.391	0.116	-0.195	0.015	-0.208
Total volume (m^3)	0.283	0.424	-0.110	-0.160	-0.205	0.112
Canopy width	0.440	-0.243	-0.017	-0.057	-0.071	0.082

Components 1 and component 2 on PCA test (Table 2) are the results of observed variable reduction, so that the number of characters is fewer without reducing the objectivity. Component 1 has a diversity value of 26.57% with an eigenvalue of 3.964 and component 2 has a diversity of 18.75% with an eigenvalue of 2,811. The sum of two main components (components 1 and 2) is able to explain 45.32% data diversity so that data can explain of the growth character of 45.32%. Component 1 is supported by 13 characters positively while component 2 is supported by 1 positive character (number of branches) and 1 negative character (first branch angle).

Based on the Pearson correlation value between growth characters, it is known that resin production is positively correlated with stem diameter, bark thickness, and canopy length, whereas gum production is negatively correlated with the number of branches and levels of pest and disease attack. Positive correlation between resin production and tree diameter was 0.364, 0.423 with bark thickness, 0.417 with crown length and 0.405 with a crown area. Negative correlation value between resin production with the number of branches is equal to -0.317, with a pest attack rate of -0.356. The positive correlation indicates that resin production will be increased with higher values of the characters. Negative correlation indicates that resin production will decrease with the high value of the character.

Large-diameter trees have a wide growing increment, so assumed that it number of resin duct was higher and able to produce large amount of resin. Spacing and fertilization with carbon fertilizer can be done to increase diameter [15]. Spacing management allows trees to obtain greater sunlight input for photosynthesis, resulting in more photosynthat, which will be used for growth in diameter. Carbon fertilizer also able to stimulate cell structural development and physiological processes of plants to obtain a wide diameter [16]. Cijambu has a spacing of 3m x 4m capable of producing a higher resin

compared to other. Thus it can be concluded that the spacing of 3 x 4 meters in Cijambu has been appropriate to support the resin production.

Resin production has a positive correlation with canopy conditions. It is related to light absorption for photosynthesis process. The high resin yielder is characterized by a wide of growth ring, flat or full canopy, cone-shaped, and has a crown height of half of tree height [17]. Large canopy allow tree to receive more sunlight and resulting smoother resin flow. Bark thickness has a positive correlation with resin production. Although there is no reference explained this correlation, it is assumed with tree protection mechanisms against external mechanical disturbances such as wind to resin duct form. Bark is a suitable protector for trees from mechanical disturbance stress and pressure from outside tree environment and usually increases with the increase in tree diameter [18]. The presence of bark will reduce the resin duct damage due to wind breaking. The number of branches is negatively correlated with resin production. These results in accordance with [10] research on *P. halepensis* that found trees with more open canopies (fewer branch numbers) capable of producing higher resin, it related to photosynthesis and other physiological processes associated with resin accumulation.

The results of this study found a correlation between resin production with tree diameter, bark thickness, crown area and number of branches although with a moderate level of tightness. The results are also consistent with previous studies on other pines in the temperate region that found a correlation between resin production with tree height character [20], canopy characters [21], number of branches [10] and stem diameter [22]. A moderate correlation between resin production and growth character is in accordance with previous research with the value of r: 0.799 [21] and with a value of r: 0.76 on *P. eliotii* [23].

Although some previous studies have found genetic factors to influence more sap production characteristics, the proper application of silvicultural techniques will also maintain genetic expression of resin production. Tree maintenance is also necessary to create environmental conditions that support the genetic expression of a character [24]. In this study, the spacing to widen diameter and extend the canopy, as well as pruning technique of branches to reduce unproductive branches is highly recommended to supports resin production.

4. Conclussion

The growth and resin structure of pine stand in Perum Perhutani showed normal pattern as those in other plantation forest. Resin production of 3 Perum Perhutani SSO average was 85.9 g / tree / 3 days. Cijambu SSO produced the highest resin (101.4 g / tree / 3 days), followed by Baturaden (88.72 g / tree / 3 day) and Jember (64.4 g / tree / 3 day). The results of resin production structure found Cijambu SSO has right skewness and wider interval of resin production, so that tis location is prospective for further breeding for resin yielder pine.

The resin production character in Cijambu SSO is positively correlated with tree diameter, barkthickness and crown width, but negatively correlated with number of branches. To support the expression of gum production reflected in growth characteristics, the technique of spacing arrangement through thinning and branch pruning is necessary because it encourages the openness of canopy for photosynthesis, diameter growth and crown growth

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