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Research Article

Identification of Pine Species Based on Their Morphology in the Parsingguran Protected Forest, North Sumatra, Indonesia

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Abstract

Background and Objective: Pine trees belong to the Pinaceae family and have a wide distribution starting from Earth's Northern to Southern hemispheres and include nearly 120 species. Tropical pine, is known by the name Tusam, is the only type of pine that is distributed in Southeast Asia, such as Thailand, Vietnam, Malaysia and Indonesia. This research was conducted to identify the morphology of pine (*Pinus merkusii*) found in the Parsingguran Village Protected Forest, Pollung District, Humbang Hasundutan County.

Materials and Methods: This research was conducted in one area. The protected forest, managed by a forest farmer group, covers an area of 172 ha and consists of 110 ha pine stands and 60 ha of degraded land. This research used the plotted line method with a construction plot measuring 20×20 m, which is a combination of the lane and double plot methods. The intensity of the sampling used in this research was 5%. The determination of sample plots is carried out randomly, intentionally (purposive sampling).

Results: In this study, 401 Aceh strain pine trees and 233 pines were found to be Tapanuli strain. Based on morphological analysis, the Aceh strain of pine has a rougher bark structure, deep grooves, longer leaves and shorter fruit than the Tapanuli pine strain. Pine strain Tapanuli has a taller, slimmer and straighter trunk shape than the Aceh pine strain. The condition of Pine health in the Parsingguran Protected Forest is in class 2 and 3, which is included in unhealthy canopy characteristics. **Conclusion:** Aceh strain pine has a higher tolerance to the environment compared to the Tapanuli strain pine. This may be due to its larger, rougher and shorter morphological form and a longer leaf shape. This morphological adaptability has been proven to be able to develop rapidly in a wider range of climate differences.

Key words: *Pinus merkusii*, morphological analysis, Aceh strain, Tapanuli strain, protected forest, purposive sampling

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Data Availability: All relevant data are within the paper and its supporting information files.

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Pines that grow natively in Sumatra are divided into three strains, namely Aceh, Kerinci and Tapanuli. This Sumatran pine was first discovered by a German botanist in the area Sipirok in South Tapanuli in 1841², often referred to as the 'Tusam' tree in Indonesian. Of the three strains in Sumatra, the Aceh strain is known to have the largest population of the three. *Pinus merkusii* is the only genus of pine that has needle-shaped leaves; there are a pair of them, arranged in a spiral. Pine can grow from lowland to regional areas and mountains up to a height of 2,000 m above sea level³.

Pines are one of the main types of trees that are motivated to be planted in technical plantation schemes agroforestry because of its characteristics, benefits and

Tropical forests contain high biodiversity. Apart from pines, the vegetation is covering this area with many broad-leaved trees such as frankincense and this is not uncommon large trees that are decades old to grow in it. Research on *P. merkusii* many studies have been carried out from various aspects, but there is a need for research on pine morphology analysis and its diversity in an area, especially in its original place of growth or natural distribution, is very necessary considered considering the large distribution of other strains of pine as an effort to preserve pine which can threaten the population of native species in the area⁵.

MATERIALS AND METHODS

Study area: This research was carried out in February-July 2024 in Parsingguran Village, Pollung District, Humbang Hasundutan County, Province North Sumatra. This research location is one of the forest areas managed by the community in under the supervision of government forest agencies (Fig. 1).



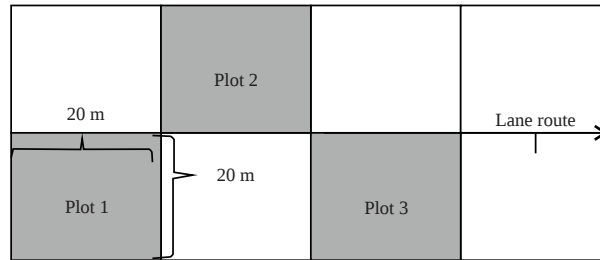


Fig. 2: Research plot design

The tools used in this research are GPS, camera for documentation, price altimeter to measure the height of a tree, a fiband to measure the diameter of a tree, a ruler to measure length of leaves, pine fruit and flowers, timestamp application for sample documentation, meter used to measure the length of the plot being made, a machete is used to pave the way in making the plot, raffia rope is used to make plots. Documentation is carried out on each comparison sample, the pine morphological characters. The materials used in this research were as many stakes as needed as poles or stakes from plots made, maps of research locations and journals about *P. merkusii*. Results data research obtained in the field is written in a tally sheet.

Procedure: The research object is pine in the Parsingguran Village Protected Forest area, Pollung District, Humbang Hasundutan County. In this research, to determine the number of samples, the number of sample plots was determined using the following formula: The research object is pine in the Parsingguran Village Protected Forest area, Pollung District, Humbang Hasundutan County. For forests with an area of 1,000 ha or more, the sampling intensity used is preferably 2%; meanwhile, if it is less than 1,000 ha, then the sampling intensity should be 5-10%⁶. In this research, to determine the number of samples, the following formula is used⁷:

$$n = \frac{IS \times N}{Lpc}$$

$$n = \frac{5\% \times 110}{0.04}$$

$$n = \frac{5.5}{0.04}$$

$$n = 130 \text{ plot}$$

Where:

N = Area of whole research location (ha)

n = Number of sample plots

IS = Sampling intensity

Lpc = Area of sample plot ($20 \times 20 = 400 \text{ m}^2 / 0.04 \text{ ha}$)

Data collection technique: The method used in this research was the grid line method, which is a combination of the strip and double grid methods. Determined the path deliberately (purposive sampling). The plots in this grid line method can be rectangular, square or circular⁸. In this research, the sampling intensity used was 5%. There were 130 observation plots used with observation plots in the form of square plots measuring $20 \times 20 \text{ m}$, which is the plot size for observations at tree level. The research plot design can be seen in Fig. 2:

- Then, measure the height and diameter of the pine trees in each plot using a fiband and Haga altimeter and record them on a tally sheet
- Taking the coordinates using the Global Positioning System (GPS) of each pine tree found in each plot and record them on a tally sheet
- Analyze morphological criteria, individual types of pine and assess the health of each pine tree found based on the condition of the crown, straightness of the trunk, roundness of the trunk and branch angles of the pine found in each plot and recorded on a tally sheet
- Data collection on environmental conditions was carried out to measure physical data on the environment around *P. merkusii*. The physical environmental data measured includes:
 - Temperature is measured with a thermometer
 - Air humidity is measured with a hygrometer
 - Height of the place is measured by GPS
- The samples obtained were identified using morphological analysis, namely identification by matching the morphological characteristics of the organs with the pine morphology literature

Data analysis: Data analysis was carried out qualitatively and quantitatively. The qualitative analysis observed included stem shape (trunk straightness, stem roundness, bark shape), branching angles, crown condition of each pine tree in the protected forest of Parsingguran Village, Pollung District, Humbang Hasundutan County, North Sumatra Province by presenting tables and graphs and sample documentation.

Quantitative analysis observed included measuring total height, free branch height, stem diameter, leaf length, fruit (fruit length and fruit diameter) and flower length (male flowers and female flowers) as a comparison of the morphological characters of each pine tree, measuring the height of the place, coordinates, temperature, humidity in each planting plot and determining the interval for measuring the height and diameter of pine in the protected forest of Parsingguran Village, Pollung District, Humbang Hasundutan County, North Sumatra Province. The measurement interval in the data is grouped and can be calculated by the formula⁸:

$$\text{Range (R)} = \text{Maximum value} - \text{Minimum value}$$

$$\text{Many classes (B)} = 1 + 3.3 \log (n)$$

$$\text{Class length (P)} = \frac{R}{B}$$

RESULTS AND DISCUSSION

The Parsingguran Village Protected Forest is one of the forest areas managed by the community through the formation of farmer groups to utilize Non-Timber Forest Products (NTFPs). The research location is in one of the areas managed by Panorama forest farming group with an area containing pine stands covering an area of ± 110 and ± 62 ha of the area is degraded land due to illegal logging. The sampling intensity used in this research was 5%. In 130 plots placed on 5 observation lines. In each observation plot, 7-15 *P. merkusii* species were found, consisting of the Aceh strain pine and the Tapanuli strain pine⁹.

Measurement of height and diameter of *P. merkusii* in Parsingguran Protected Forest tree height and diameter measurements were carried out to compare the morphological characteristics of *P. merkusii* trunks in the Parsingguran Protected Forest area. In 5 lines consisting of 130 observation plots, 653 *P. merkusii* individuals were found. Comparative data on the results of measurements of the height and diameter of *P. merkusii* in the Parsingguran Protected Forest area at each measurement interval can be seen in Table 1. Data analysis can be carried out by compiling

data systematically¹⁰. Class intervals can be calculated by determining the range and number of classes in data.

The *P. merkusii* species in the Parsingguran Protected Forest (Table 1) has a total height of 24-40 m, with an average total height of 33.60 m. Based on the results of Tbc measurements, pines in the Parsingguran Protected Forest have a branch-free height of 12-32 m, with an average of 25.62 m and a diameter of 40-95 cm, with an average diameter of 72.55 cm. Stand density is one of the factors that can influence tree height and diameter. The denser the stands in an area, the taller the trees tend to be due to competition for light as an element that plays a role in the process of plant photosynthesis. When planting pine in the Parsingguran Protected Forest area, the planting distance used is 2×5 m. Controlling plant spacing has an impact on the availability of nutrients and the intensity of light that plants require¹¹. In contrast, the closer the planting distance, the more trees there are and the more intense the competition; the wider the planting spacing, the more light there is and the more nutrients are available for each plant because there are fewer trees.

Based on the comparison diagram of the number of individuals in each pine height measurement interval (Fig. 3a-b), the highest number of individuals was in the measurement interval with a height of 34-35 m, with a total of 212 trees. In the tree diameter measurement interval, the largest number of trees was in the diameter measurement interval of 70-74 cm, with a total of 473 trees. Based on the data, it can be seen that the pines in the Parsingguran Protected Forest have an average height of 34-35 m with a diameter of 70-74 cm. Plant age is one of the factors that greatly influences the increase in tree height and diameter. This is by the statement of the local community, which states that the Parsingguran Protected Forest area was the result of planting by the forestry authorities in the 1970s with the help of the local community¹².

In research analysing the morphology of *P. merkusii* in the Parsingguran Village Protected Forest, 2 strains of *P. merkusii* were found, namely the Aceh strain pine and the Tapanuli strain pine. *P. merkusii* has different morphological characters. Differences in morphological characters in tree species can be caused by genetics and external factors such as light, temperature and altitude. The determination of the strain of individual pines in the protected forest of Parsingguran village was carried out based on observations of the physical form of each sample recorded. The Aceh strain of pine has morphological characteristics with thicker bark and deep grooves compared to the Tapanuli strain of pine, which has thin bark (Fig. 3a-b)¹³.

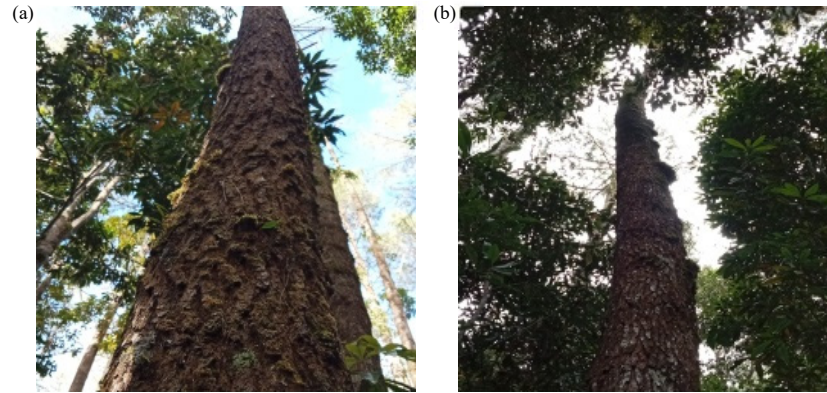


Fig. 3(a-b): Shape of the trunk, (a) Aceh strain pine and (b) Tapanuli strain pine

Table 1: Measurement of total height, free branch height and diameter of *Pinus merkusii* in Parsingguran Protected Forest

Parameter	Minimum	Maximum	Average	Interval of measurement	Total
Total height (m)	24.00	40.00	33.60	24-25	1
				26-27	15
				28-29	31
				30-31	88
				32-33	139
				34-35	212
				36-37	108
				38-39	34
				40-41	6
Free branch height (m)	12.00	32.00	25.62	12-13	1
				14-15	1
				16-17	0
				18-19	4
				20-21	26
				22-23	87
				24-25	184
				26-27	191
				28-29	106
				30-31	29
				32-33	5
Trunk diameter (cm)	40.79	94.90	72.55	40-44	2
				45-49	1
				50-54	0
				55-59	20
				60-64	25
				65-69	69
				70-74	293
				75-79	166
				80-84	42
				85-89	10
				90-95	6

Apart from genetic factors, the level of tree bark thickness can be influenced by water availability in the area where the tree grows. The level of water availability in an area can affect the network of transport beams in each tree. The cortex parenchyma cells in plants that experience drought stress shrink so that the cells become smaller and the stem bark tends to be thinner¹⁴. The thickness of the cortex layer is related to water storage capacity and an increase in the number of cells in the cortex

tissue can increase plant tolerance to conditions of water availability.

Based on field sampling data, 634 *P. merkusii* individuals consisted of 401 Aceh strain pines and 233 Tapanuli strain pines, which were determined based on the suitability of the pine bark morphology (Fig. 4). The Aceh and Tapanuli strains of pine have different heights and diameters. The results of measuring the height and diameter of the Aceh strain and Tapanuli strain pine can be seen in Table 2.



Fig. 4(a-b): (a) Tapanuli strain pine and (b) Aceh strain pine leaves

Table 2: Measurement of height, diameter and free height of branches

Parameter	Strain	
	Aceh	Tapanuli
Total height	24-37	29-40
Height average	32.51	35.47
Free branch height	12-32	14-32
Average free branch height	25.57	25.70
Number of tree	401	233
Diameter	40.76-94.90	46.18-90.76
Average diameter	73.74	70.51

Based on field measurements (Table 2), the Aceh strain pine has an average height and diameter of 33 m and 73.74 cm, while the Tapanuli strain pine has an average height and diameter of 35 m and 70.51 cm. The tallest Aceh strain pine tree is 37 m, with the largest diameter of 298 cm and the highest Tapanuli strain pine tree is 40 m, with the largest diameter of 285 cm. Based on the results of free branch height measurements, the Aceh strain of pine has 12-32 m with an average free branch height of 25.57 m, while the Tapanuli strain of pine has 14-32 m.

Based on the diagram of the results of measurements of total height, free branch height and average diameter of *P. merkusii* in the Parsingguran Protected Forest area, it can be seen that the stems of the Tapanuli strain pine tend to be taller and slimmer than the stems of the Aceh strain pine. The stem morphology of the Tapanuli strain pine is more similar to that of the Tapanuli strain pine. Kerinci tends to be straighter and taller and has slimmer trunks compared to the Aceh strain of pine¹⁵. The total height of pines in the Parsingguran Protected Forest area does not show significant differences, This is because the Parsingguran pine forest is a plantation forest area without any insertion or replanting so that the age of each pine is fairly the same and the tree canopy is uniform.

Morphological characteristics of *Pinus merkusii* leaves and fruit: Morphological characters are one of the comparative aspects of the types of a species. Sampling to measure leaf

length, fruit and fruit diameter to compare the morphological characters of each pine strain was carried out in 27 observation plots with the selection of 5-6 observation plots on each route¹⁶. In 27 observation plots, measurements were carried out on 4 tree samples in each plot consisting of Aceh strain pine and Tapanuli strain pine. The results of measuring leaf length, fruit and fruit diameter can be seen in Table 3.

Based on measurements of the length of pine leaves and cones in the Parsingguran Protected Forest Area (Table 3), the Aceh pine strain has leaves with an average length of 16.55 cm with a leaf length of 15.10-20.1 cm, while the average length of pine leaves the Tapanuli strain is 12.16 cm with leaf length 10.1-13.6 cm. Based on a comparison of the morphological characters of the pines, it was found that the Aceh strain of pine has longer leaves than the Tapanuli strain of pine. *Pinus merkusii* has long, needle-shaped leaves. Environmental conditions can influence the structure and morphology of a species. Changes in the anatomical structure of Agarwood (*Aquilaria malaccensis* Lam.) leaves occurred after experiencing drought stress. The more stressed, the length of the upper and lower epidermal cells of the leaf becomes smaller, but the thickness of the leaf increases¹⁷. The shape of the pine leaves of the Aceh strain and Tapanuli strain can be seen in Fig. 4a-b.

The morphological characteristics of the fruit in each pine strain have significant differences. Pines have cone-shaped fruit with a scale-like texture (Fig. 5a-b). Based on data from

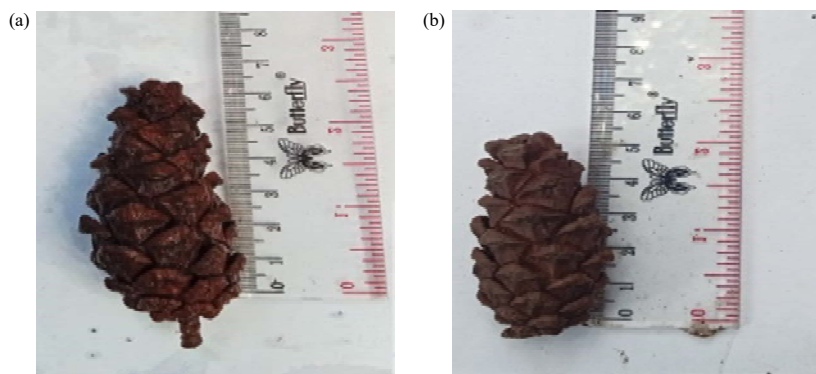


Fig. 5(a-b): (a) Tapanuli strain pine and (b) Aceh strain pine fruit

Table 3: Measurement of leaf length, fruit and fruit diameter

Parameter	Strain of pine	
	Aceh	Tapanuli
Leaf length (cm)	15.1-20.1	10.1-13.6
Average (cm)	16.55	12.16
Fruit length (cm)	4-6.9	6.5-9.1
Average (cm)	5.46	7.78
Fruit diameter (cm)	2.7-3.4	2.6-3.4
Average (cm)	3.04	3

measurements of fruit length and diameter (Table 3), the Aceh strain of pine has fruit with an average length and diameter of 5.49 and 3.04 cm, while the Tapanuli strain of pine has fruit with an average length and diameter of 7.78 and 3 cm.

Based on the graph of the results of measurements of leaf length, fruit and fruit diameter of *P. merkusii* in the Parsingguran Protected Forest area, the Aceh strain of pine has longer leaf shapes than the leaves of the Tapanuli strain of pine. The Tapanuli strain of pine fruit is longer than the Aceh strain of pine fruit. Meanwhile, based on fruit diameter measurements, the Aceh pine strain did not show a significant difference¹⁸.

Results of previous research in the Dolok Tusam area, Pangaribuan District, which is at an altitude of 1000-1400 m above sea level. Based on morphological analysis of *P. merkusii* in the area using the cluster method with a radius of 17.95 m at an altitude of 1000-1400 m above sea level, the Aceh strain of pine has leaves with an average length of 18.7 cm while the Tapanuli strain of pine has an average leaf length of 16.7 cm¹⁹. The fruits of the Aceh strain pine have an average length of 5.72 cm, while the Tapanuli strain pine has an average fruit length of 6.6 cm and based on fruit diameter measurements, there is no significant difference. The Aceh and Tapanuli strains of pine have an average fruit diameter of 3.9 cm.

Classification of the condition of *Pinus merkusii* in the Parsingguran Protected Forest area: An analysis of the

condition of *P. merkusii* was carried out to assess the condition of pine stands in the Parsingguran Protected Forest area. Tree health is an important aspect that greatly influences the sustainability of a forest stand. Identification of the condition of *P. merkusii* in the Parsingguran Protected Forest can be seen in Table 4.

The canopy condition of *P. merkusii* in the Parsingguran Protected Forest is in canopy classes 2, 3, 4 and 5. Based on the canopy class, canopy classification 0 and 1 are included in unhealthy characteristics, canopy class 2 and 3 are included in unhealthy canopy characteristics and canopy class 4 and 5 are included in healthy and balanced canopy characteristics²⁰. Based on the data (Table 4), trees with class 2 canopy conditions numbered 179 trees consisting of 105 Aceh strain pines and 74 Tapanuli strain pines, class 3 canopy conditions numbered 288 trees consisting of 184 Aceh strain pines and 104 Tapanuli strain pines, class 4 numbered 108 trees consisting of 66 Aceh strain pines and 42 Tapanuli strain pines and class 5 numbered 59 trees consisting of 42 Aceh strain pines and 17 Tapanuli strain pines. Based on the data, it can be seen that the condition of the pine crown at the research location is, on average, at crown condition 2 and 3 (less healthy crown characteristics)²¹. The health condition of the pine in the Parsingguran Protected Forest can be seen in Fig. 6a-b.

The pine forest in the Parsingguran area is one of the protected forest areas that has been managed by local communities for generations to utilize non-timber forest

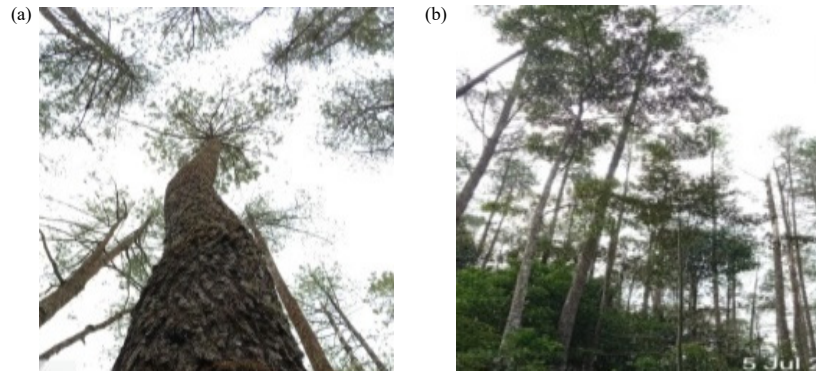


Fig. 6(a-b): Condition of the canopy of *Pinus merkusii* in the Parsingguran Protected Forest, (a) Back view and (b) Front view

Table 4: Number of stems and condition of *Pinus merkusii* in the Parsingguran Protected Forest Area

Strain	Straightness				Roundness of shape		Crown condition				Branching angle	
	3	4	5	6	Globular	Slightly rounded	2	3	4	5	A	B
Aceh	43	167	161	26	245	152	105	184	66	42	349	48
Tapanuli	3	16	86	132	223	14	74	104	42	17	19	218
Total	46	183	247	158	468	166	179	288	108	59	368	266

products in the form of latex with the formation of farmer groups under the supervision of forest farming group. The treatment carried out in collecting sap can affect the health of the pine. The main causes of disease are pathogenic living organisms or physical environmental factors. Collecting pine sap can be done by wounding or tapping the pine trunk so that if the tapping is carried out with excessive wounding, it will result in many wound scars growing with fungus and affecting the health condition of the pine²².

Based on the canopy condition, the Aceh strain of pine has a higher canopy health condition than the Tapanuli strain of pine. Damage to tree crowns in a forest area can be caused by high competition between populations in the area and can also be caused by human treatment in an effort to utilize forest products²³. Apart from pine, in the stands in the Parsingguran Protected Forest area, there are also many species of broad-leaved trees such as kemenyan, anti-fire, simartolu and hapas-hapas. From an economic perspective, the utilization of forest products in the form of wood for building construction needs and the utilization of non-timber forest products from tapping pine sap is quite high. Tapping pine sap using the poke technique will produce higher levels of sap in a short time at a low cost²⁴ but the impurity content is high and the pine easily collapses.

The straightness level of *P. merkusii* stems in the Parsingguran Village Protected Forest area is at 25, 50, 75 and 100% straightness (Table 4). Based on data in the field, the average straightness of *P. merkusii* trunks is at a straightness level of 75% with a total of 247 trees consisting of 161 strains

of Aceh pine and 86 strains of Tapanuli. *Pinus merkusii* with a straightness level of 25% with a total of 46 trees (43 Aceh strain pines and 3 Tapanuli strain pines), 50% straightness with a total of 183 trees (167 Aceh strain pine trees and 16 Tapanuli strain pine trees) and 100% straightness with total number of 158 trees (26 Aceh strain pine trees and 132 Tapanuli strain pine trees). Based on the stem straightness, the stem straightness of the Tapanuli strain pine is higher than that of the Aceh strain pine²⁵.

The straightness of the tree can be influenced by the shape of the tree's branches. Based on the results of observations of the straightness of the *P. merkusii* stems in the Parsingguran Protected Forest, it can be seen that the Tapanuli strain of pine has a higher level of stem straightness than the Aceh strain of pine. The level of stem straightness can be influenced by the density of species in one area²⁶. The higher the density of food stands, the higher the level of straightness of tree trunks in an area (Fig. 7a-b).

Pinus merkusii in the Parsingguran Protected Forest has a trunk shape that falls into the round and slightly rounded class. There were 468 round *P. merkusii* trees and 166 slightly round trees (Table 4). Based on data from the analysis of the level of roundness of the trunk, the Aceh strain of pine with a roundness level that falls into the round class consists of 245 trees and 223 of the Tapanuli strain of pine and the stems with a slightly rounded level of roundness consist of 152 of the Aceh strain and 14 of the Tapanuli strain of pine. Based on stem roundness data in the Parsingguran Protected Forest area, it was found that the level of stem roundness of the

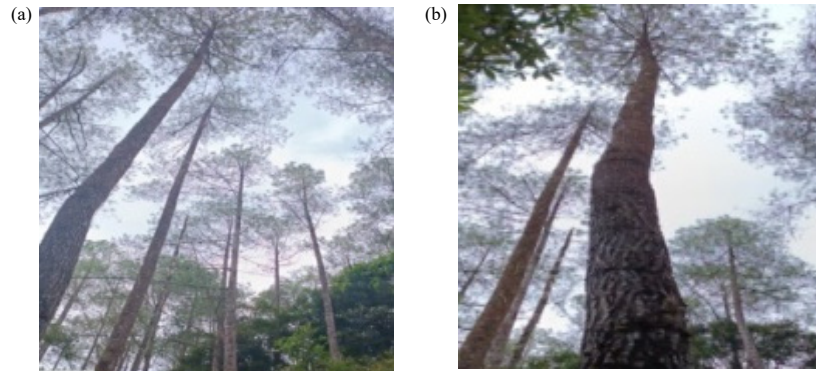


Fig. 7(a-b): Straightness of *Pinus merkusii* trunks in the Parsingguran Protected Forest Area in different views



Fig. 8(a-b): Roundness of *Pinus merkusii* trunks in the Parsingguran Protected Forest Area in different views

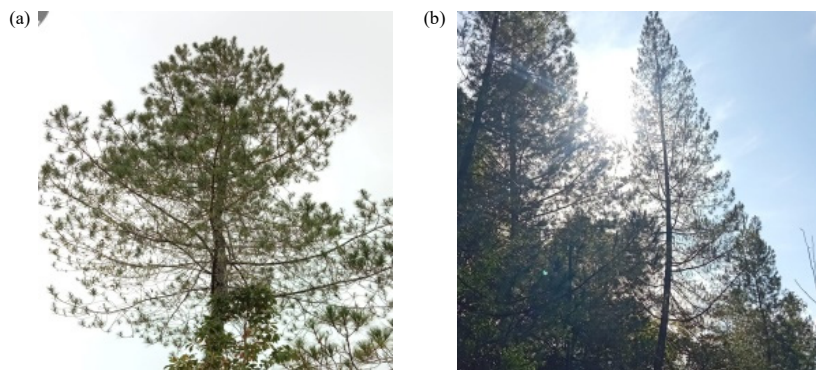


Fig. 9(a-b): Branching angles of *Pinus merkusii* in the Parsingguran Protected Forest Area in different views

Tapanuli strain pine was higher than that of the Aceh strain pine²⁷. Tree branching is one of the factors that can influence the roundness of a tree. Stems that fall into the slightly rounded category can be caused by bumps from tree branches or clumps of moss attached to the tree. Pine is a tree species with a high degree of trunk roundness (Fig. 8a-b).

Based on observations of *P. merkusii* branching angles in the Parsingguran Village protected forest (Table 4), it can be seen that the branching angle of *P. merkusii* on average forms

an angle of $>70^\circ$ with a total of 368 trees (349 Aceh strain pines and 19 Tapanuli strain pines) and trees with branching angles forming an angle of $50-70^\circ$ with a total of 266 trees (48 Aceh strain pine and 218 Tapanuli strain pine). Based on branching angle data, it was found that the branching angles of the Aceh strain pine tend to form larger angles ($>70^\circ$) with the trunk while the branching angles of the Tapanuli strain pine form smaller angles ($50-70^\circ$) with the trunk (Fig. 9). The high variation in branching patterns is a morphological description

of certain phases²⁸. Branching patterns show dynamic properties because plants continue to develop and are also influenced by environmental factors such as temperature, humidity and light intensity.

In an area with dense stands, trees tend to be straighter and the branching angle forms a sharper angle with the trunk. Conversely, if the forest stands in an area that is sparser, the trees tend to have a larger diameter and the branching angle forms a larger angle with the trunk. Stand density in an area can influence the physical properties of plants, which occurs as an effort to adapt plants to the environment²⁹. This is because the quantity of light that can penetrate to the forest floor is influenced by the density of stands in an area. The denser the stands, the less quantity of light that enters and the sparser the stands, the greater the quantity of light that can enter.

Pine trees are a type of tree that needs a lot of light. Stand density affects the amount of light a tree receives, which can influence the morphological structure of the tree. The quantity of light greatly influences the photosynthesis process in a plant, so that a plant's efforts to adapt to the environment in obtaining light can affect the physical form of the plant. In pine forests with a high density, pine tree trunks tend to be slimmer, straighter and rounder and have a high canopy in an effort to obtain light, which plays a role in the plant photosynthesis process.

Environmental conditions: An analysis of environmental physical factors was carried out to determine the influence of environmental conditions on changes in pine morphological characters. Environmental conditions can influence the composition of a species in a stand. The environmental conditions of a forest area affect the physical form of each species in the forest area. Data on physical environmental conditions can be seen in Table 5.

In some stands other than genetic factors that cause differences in species *P. merkusii* with different strains, the morphology of pine in the same strain can also be different. These morphological differences are due to the influence of external factors that influence tree morphology. Stand density affects the temperature, humidity and light intensity in a stand so that the temperature, light intensity and humidity in the observation plots vary depending on the level of stand density in each observation plot and other factors such as average rainfall in the area and altitude.

Altitude: Measurements of physical environmental conditions were carried out in several observation plots with different levels of stand density and altitude. Based on the results of

measurements in the field, the location of the observation plot was carried out at an altitude of 1654-1832 m above sea level (Table 5). Altitude can influence the temperature in an area and the types that can grow in that area. Based on previous research, pines can grow in groups at an altitude of 500- 2,500. The Aceh strain of pine can grow at an altitude of 800-2000 m above sea level. Based on altitude data in the Parsingguran Protected Forest area, the Aceh strain of pine is the type that can grow the most in this area, while the Tapanuli strain of pine can grow at an altitude of 1000-1500 m above sea level. In the pine stands in the Parsingguran Protected Forest area, the Aceh strain of pine is the type most commonly found compared to the Tapanuli strain of pine.

pH: Soil pH at the research location is in the range of 4.5-6.8, with an average pH of 5.52 (Table 5). The pH of the soil in a land affects the type and composition of plants in that area. According to previous research, pine can grow in areas with a soil pH of 4.7-5.4. Pine is a type of plant that can grow in forest areas where the soil pH is acidic³⁰. The physical condition of the soil affects the capacity of nutrients that can be consumed by plants. In general, pine stands rarely grow broad-leaved plants. Pine litter contains allelopathic substances that can inhibit the growth of other plants under pine stands, thereby affecting nutrient availability and soil pH conditions in the stands. In the pine stands in the Parsingguran Protected Forest area, no pine population was found at the seedling level, so the pine life cycle in the area is difficult to occur. Difficulty growing pine populations in stands can be caused by stand density in the area. The higher the density in an area, the higher the level of competition within the area.

Light intensity and temperature: The light intensity in the observation plot is in the range of 643-3896 lux, with an average light intensity of 1801 lux. Light is an important component for plants, which plays a role in the photosynthesis process. Light intensity has a direct effect on the photosynthesis process of each plant, the mechanism for opening and closing stomata, chlorophyll synthesis and cell differentiation, which is expressed by increasing height, diameter, leaf size and leaf and stem structure. The intensity of light in a forest area influences other environmental conditions, such as temperature and humidity in the area. The air temperature in the Parsingguran Protected Forest area is in the range of 17.2-20.6°C, with an average temperature of 18.43°C (Table 5). The higher the light intensity in an area, the higher the temperature in that area. Air temperature affects plant life activities, including the processes of photosynthesis, respiration, transpiration,

Table 5: Measurement of physical environmental characteristics

Parameter	Value range
Altitude (MASL)	1645-1832
pH	4.5-6.8
Temperature (°C)	17.2-20.6
Light Intensity (lux)	643-3896

Table 6: Parsingguran rainfall data

Year	Annual precipitation (mm)	Average (mm)
2015	2946	245,58
2016	1715	142,91
2017	2186	182,16
2018	2225	185,41

growth, pollination and fertilization^{30,31}. The size of the influence of environmental conditions is influenced by other factors such as humidity, water availability, plant types and rainfall in a forest area³². Annual rainfall data in the Pollung District can be seen in Table 6.

Based on data from the Central Statistics Agency (2019), rainfall is quite high, with annual rainfall data from 2015-2018 at a rainfall level of 1715-2946 mm per year, with an average rainfall of 142.91 mm and the highest rainfall in 2015, namely 2946 mm per year. Rainfall is one of the factors that can influence environmental conditions in an area. If rainfall in an area increases, the temperature in that area will decrease and air humidity will increase. The Parsingguran Village Protected Forest is a tropical rainforest area and is a forest area suitable for growing pine stands. Pine species can grow in areas with an altitude of 200-2,000 m above sea level, with rainfall between 1,200-3,000 mm per year³².

Future research should explore the genetic diversity of *Pinus merkusii* and other pine species in the Parsingguran Protected Forest to better understand their adaptability and potential for conservation. Additionally, studies on the impact of climate change on pine health and growth would provide valuable insights for forest management strategies. This study was limited to a single area within the Parsingguran Protected Forest and utilized a 5% sampling intensity, which may not fully represent the forest's overall biodiversity. Furthermore, the morphological focus of the study did not consider genetic or ecological factors that could influence species differentiation.

CONCLUSION

The results of the morphological analysis of *P. merkusii* in the Protected Forest area of Parsingguran Village, Pollung District, Humbang Hasundutan County found 2 strains of pine, namely the Aceh strain pine and the Tapanuli strain pine with the Aceh strain pine (401 trees) being the most numerous

types compared to the Tapanuli strain (233 trees) as local strains so that the Tapanuli pine strain is under threat. Based on morphological analysis, the Aceh strain of pine has a rougher bark structure and deeper grooves than the Tapanuli strain of pine. The Tapanuli strain of pine has a taller, slender and straighter trunk shape than the Aceh strain of pine. The Aceh strain of pine has an average leaf length of 16.55 cm, an average fruit length of 5.46 cm, while the Tapanuli strain of pine has an average leaf length of 12.16 cm, an average fruit length of 7.74 cm. Stand density is one of the factors that greatly influences the health condition of trees. The health condition of the pine canopy in the Parsingguran Protected Forest area falls into classes 2 and 3 (unhealthy). The straightness of pine trunks in the Parsingguran Protected Forest area is, on average at a straightness level of 75%.

SIGNIFICANCE STATEMENT

This study discovered the presence of the Aceh strain pine (*Pinus merkusii*) in the Parsingguran Protected Forest, an area previously believed to be dominated by the Tapanuli strain. The findings highlight the broader tolerance and adaptability of the Aceh strain, which enables it to thrive and outcompete the Tapanuli strain in this region. This discovery can be beneficial for the management and conservation of pine species in Sumatra, particularly in understanding their ecological roles and distribution patterns. This study will help researchers uncover the critical areas of pine species distribution and their environmental adaptability that many researchers were not able to explore. Thus, a new theory on the ecological resilience and potential of pine strains may be arrived at.

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