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Study on Morphological characteristics and **T**ree-ring growth **of** Three Exotic Tropical Pine Species in the Taung Lay Lone Reserve Forest, Southern Shan State

Kyi Kyi Khaing, Research Assistant 2
Aye Nyein Chan, Research Assistant 3

Forest Research Institute

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KyiKyiKhaing, Research Assistant 2
Forest Research Institute, Yezin

Abstract

Specimens of three tropical exotic pine species cultivated in Taung Lay Lone reserve forest, Southern Shan State, were collected from Taung Lay Lone reserve forest, Southern Shan State, identified and studied. The morphological characteristics of their bark, needle leaf, female cone, male cone and seeds were described, discussed, and presented with their photographs and photomicrographs. The number of leaves per dwarf shoot of the three species studied is (3 – 5) needle leaves in *Pinus caribaea*, (3) needle leaves in *Pinus kesiya* and (5) needle leaves in *Pinus maximinoi*. The bark of *Pinus caribaea* was pale reddish-brown whereas *Pinus kesiya* was dark brown and *Pinus maximinoi* was pale yellowish-brown. In this study, the highest thickness of bark was found in *Pinus maximinoi* where as the lowest was in *Pinus kesiya*. These characteristics are useful in identification of the *pinus* species. Growth of three tropical exotic pine species was assessed. Rainfall was decreasing and temperature was increasing, at that time growth rate was decreased.Among the three species studied, *Pinus kesiya* was the best in growth during the first (10) years but *Pinus maximinoi* was observed the best growth during (33)years than other two species.

Keywords: Exotic Tropical Pine, Female cone, Growth,Male cone, Needle leaf, Tree-ring analysis

သစ်တောသုတေသနစခန်း၊ တောင်လေးလုံးကြိုးဝိုင်းမှ အပူပိုင်းနိုင်ငံခြားထင်းရှူးသစ် (၃)မျိုး၏ ပြင်ပရုပ်သွင်လက္ခဏာများနှင့် နှစ်အလိုက်ကြီးထွားမှုတို့ကိုလေ့လာခြင်း

ကြည်ကြည်ခိုင်၊ သုတေသနလက်ထောက် (၂)
သစ်တောသုတေသနဌာန၊ ရေဆင်း

စာတမ်းအကျဉ်း

ရှမ်းပြည်နယ်၊ တောင်ကြီးမြို့နယ်၊ သစ်တောသုတေသနစခန်း၊ တောင်လေးလုံးကြိုးဝိုင်းတွင် စိုက်ပျိုးထားသော အပူပိုင်းနိုင်ငံခြားထင်းရှူးသစ်(၃)မျိုး *Pinus caribaea* Morelet.၊ *Pinus kesiya* Royle ex Gordon *နှင့်* *Pinus maximinoi* H.E Moore တို့၏ ပြင်ပရုပ်သွင်လက္ခဏာနှင့် နှစ်အလိုက်ကြီးထွားနှုန်းတို့ကို လေ့လာခဲ့ပါသည်။

၎င်းသစ်(၃)မျိုး၏အခေါက် (bark)၊ အပ်ချောင်းပုံအရွက် (needle leaf)၊ ဖိုအင်္ဂါ (male cone)၊ မအင်္ဂါ (female cone) နှင့် အစေ့ (seed) တို့၏ လက္ခဏာများကို ပုံများနှင့် တကွ ဆွေးနွေးတင်ပြထားပါသည်။ *Pinus caribaea* ၏ အခေါက်မှာထူပြီး နီညိုရောင်အဖျော့၊ *Pinus kesiya သည် ပါးသောအညိုရောင်နှင့် Pinus maximinoi တွင် ထူ၍ အဝါရောင်သန်းသော အညိုရင့်ရောင်ရှိသည်။ Pinus caribaea* သည် အကိုင်းတိုတစ်ခုတွင် အရွက်(၃ရွက်မှ၅ရွက်)၊ *Pinus kesiya တွင် (၃ရွက်) နှင့် Pinus maximinoi တွင် (၅ရွက်)ရှိသည်။ Pinus caribaea* နှင့် *Pinus maximinoi တို့၏အစေ့မှာအညိုဖျော့ရောင်ရှိ၍ Pinus kesiya အညိုရင့်ရောင်ရှိသည်။* ပြင်ပရုပ်သွင်လက္ခဏာများကိုသိရခြင်းသည် သစ်ပင်မျိုးစိတ်များကို မျိုးမည်ဖော်ရာ၌ အသုံးဝင်ပါသည်။ ထို့အပြင် *၎င်းသစ်(၃)မျိုး ၏ နှစ်အလိုက်ကြီးထွားနှုန်းကိုလည်း လေ့လာဖော်ထုတ်ထားပါသည်။ လေ့လာတွေ့ရှိချက် များအရမိုးရေချိန်သည် တဖြေးဖြေးလျော့သွားပြီး၊ အပူချိန်မှာတဖြေးဖြေးတိုးလာသည်။ ကြီးထွားနှုန်းသည်လည်း ရာသီဥတုနှင့်ဆက်နွယ်နေသည့်အတွက် တဖြေးဖြေးနှေးသွား သည်ကိုတွေ့ရသည်။ ပထမ(၁၀)နှစ်တွင် Pinus kesiya သည် ကြီးထွားနှုန်း အကောင်းဆုံးဖြစ်၍(၃၃)နှစ်တွင်Pinus maximinoi သည် ကြီးထွားနှုန်း အကောင်းဆုံး ဖြစ်သည်ကိုလေ့လာတွေ့ရှိရပါသည်။*

Study on Morphological characteristics and Tree-ring growth of ThreeExotic Tropical Pine Species in the Taung Lay Lone Reserve Forest, Southern Shan State

1. Introduction

Myanmar forests are classified into eight types viz. tidal forests, beach and dune forests, swamp forests, evergreen forests, mixed deciduous forests, dry forests, deciduous dipterocarp or indaing forests, and hill and temperate evergreen forest in which *Pinus* spp. are found.

The order Coniferales or coniferae are all woody and mostly evergreen, and consist of 41 genera and approximately 400 species of trees and shrubs, widely distributed in the temperate, subtropical, and tropical regions of both hemispheres. Two sub-groups in Coniferae are recognized, the Pinaceae and Taxaceae (Pearson & Brown 1932).

Pinus is one of the genera belonging to the family Pinaceae under the order Coniferales of gymnosperms, nonflowering group of the plant kingdom. It is contained in the subfamily Pinoideae. The genus *Pinus* is widely distributed in the Northern hemisphere, containing about 75 species of this genus (Pandey 1997).

Pinus is the most important genus of family Pinaceae which is the largest and the most recent of the modern conifer. Pines usually grow on the slopes of hill and form dense and extensive forests of evergreen trees in the North temperate regions of the world.(Kaur 2006).

Altogether 5 genera and about 20 species are included in family Pinaceae. According to Kress *et al.* (2003), *Pinus armandii* Franch, *P. caribaea* Morelet, *P. insularis* Endl, *P. kesiya* Royl ex Gordon, *P. merkusii* Jungh. & de Vriese, *P. roxburghii* Sarg and *P. wallichiana* A.B. Jacks were grown in Myanmar. Among the seven species *P. roxburghii*Sarg and *P. caribaea* More were cultivated. These species were distributed in Kachin State, Kayah State, Chin State, Mon State, Shan State, Mandalay Region, Sagaing Region, Bago Region and Taninthayi Region in Myanmar (Kress *et al.* 2003 & PhyoAung 2020).

Shan State is one of the natural pine regions in Myanmar. Pine plantations have been established on a large scale in the Shan State since 1980, using indigenous species *P. kesiya* Royle ex Gordon. Due to the slow growth and poor form of the indigenous species, six exotic tropical pine specieswere introduced from Central American region since 1981. These species were also planted in the Taung Lay Lone research station in 1986 (Chaw ChawSein & AungZaw Moe 2015).

Indigenous *P. kesiya*, and six tropical exotic pine species such as *P. petual, P. caribaea, P. oocarpa, P. elliottii, P. maximinoi*and *P. petula*Var. *tecunumanii*were planted in the Taung Lay Lone Research Station in 1983-1984 when the Forestry II project came into being with Asian Development Bank assistance (Aung Zeya 1992). Pines are among the most commercially important of tree species, valued for their timber and wood pulp throughout the world (Earle 2015).

The needle leaves of the gymnosperms are an important microphyllous type. Many species of *Pinus, Picea*and other coniferous genera are exposed to xerophytic conditions only

during the winter when low soil and air temperature prevent water absorption and conduction and do not prevent water loss from the leaves. In the leaves of these plants, in addition to reduced leaf surface there are heavy cutinization and sunken stomata (Eames & Mac Daniels 1947).

Factors such as rainfall, both annual total and monthly distribution, temperature and soil characteristics among others affect tree vigour. When these factors are unfavorable trees become stressed and physiologically weakened resulting in these trees exhibiting abnormal characteristics (Aung Zeya 1984).

Tree-ring data can be used to reconstruct the yearly variations in climate that occurred prior to the instrumental climatic records. These reconstructions can extend the climate record backwards in time and increase its length sufficiently to improve the existing knowledge on climatic variability. Such improvements could help man to better anticipate possible future climatic changes as well as to better understand those of the past (NyiNyiKyaw, 2003).

In Myanmar, natural and plantation forest of pine are much important for timber as well as for paper pulp and other uses. The climatic factor was considerably important for growth of pine forest for production of pine trees. Dendrochnological method is also important to estimate growth rate and climatic condition.

Although morphological and other studies of genus *Pinus* were made by previous researchers, comparison on the morphological and growth rate observations were not made yet and it is for this reason a more comprehensive study on morphology and growth rate of three *pinus*species has been undertaken in this research.

The aim of this research is to provide differences and similarities of the morphological characters of the three species of genus *Pinus.* To achieve this aim, the objectives are to identify and compare the morphological characteristic and growth rate of the three species of *Pinus.* The three species studied in this research are *Pinuscaribaea*Morelet.,*Pinuskesiya*Royle ex Gordon *and P. maximinoi*H.E More.

2. Literature Review

In genus *Pinus,* the plants were trees or rarely shrubs, evergreen, with regularly whorled branches; branchlets strongly dimorphic; long branchlets bearing scalelike leaves and spreading leaf bundles; short branchlets bearing leaves in bundles of 2–5(–7); winter buds were large, with numerous scales (Zhengyi & Raven 2013). The full-grown plant of *Pinus* was a large tree giving rise to a series of widespread branches. In most of pine trees, a whorl of branches was produced each year. The branches were dimorphic, the two forms being characterized as long shoots and dwarf shoots (Pandey 1997).

The leaf of *Pinus* was xeromorphic. There were two kinds of leaves, the scale leaves and the green acicular foliage leaves which were commonly termed as needles. The dwarf shoots or the shoots of limited growth bear the foliage leaves while the long shoots or the shoots of unlimited growth bear scale leaves on them (Pandey 1997).

Pines are monecious, producing both male and female cone on the same tree. Thus, they produce both microspores and megaspores. Spore formation begins when the trees are approximately ten years old (Schooley 1997 and Saw Win 1992).

The male cone was produced in the axil of a scale leaf at the base of the current year's shoot and thus replaces a shoot of limited growth. The female cone developed laterally in the axil of scale leaves. They were formed in cluster in place of long shoot of unlimited growth. The seed had a thin membranous wing which was derived from the surface of the ovuliferous scale. The wings helped in the dispersal of the seed. The germination of pine seed was epigeal as the cotyledons came upwards above the soil. The tap root was elongated and possesses strong lateral roots. The root hairs were found only in the young roots and root tips. In young roots there was fungal growth of ectophytic mycorrhiza. When the appearance of this fungus the root hairs of the root disappear (Pandey 1997).

Dallimore& Jackson (1948) stated that cones were solitary, in pairs, or occasionally in threes, ovoid symmetrical, bright brown, 2 – 3 inches long, 1.25 inches wide, short and stiff; scales about 0.75 inches long, 0.33 inch wide. Seeds were about 0.33 inches long with a round-topped wing.

Pollen cones were usually borne in spikelike clusters at base of first year branchlets, sessile, cylindric or ovoid. Seed cones were pedunculate or subsessile, erect or pendulous, cylindric or ovoid, maturing in second or third year (Zhengyi& Raven 2013).

Pines species might vary in fundamental characters, i.e., shape of leaf, number and arrangement of ducts and stomata, or character of hypodermal layer, or the fundamental structure in one species might compare exactly with that of a leaf of another species displaying similar characters but differing widely in appearance, owing to minor characteristics (Sutherland 1934).

Pinus caribaea Morelet. had been widely planted as an exotic in the Southern Hemisphere and native to central America.

Pinus kesiya Royle ex Gordon occured in North East India, Myanmar and Thiland, at altitudes generally between 800 and 1500 m, occasionally to 2000 m. Further east, in Laos, Vietnam and on the island of Luzon in the Philippines, its altitudinal range was greater and it was found up to 2700 – 3000 m above sea level in a much better climate. It was used for timber, turpentine and resin. Softwood timber was used for e.g. construction, pulp and furniture. It was used for the manufacture of particle board and pulp, but its usefulness depends on the quality of the wood. Oleoresin of good quality was tapped from these trees (Sutigno,1983; Farjon, 2010).

Trial site of Shan State was in the unclassed forest which consists of denuded land. It has shallow soil and frequent rock outcrops. Moreover, the trial site was attacked by shoot borer every year since 1992. It adversely affected the height and girth growth. Tropical pine species were introduced and provenance trials were carried out. In the provenance trials, 15 provenances for *Pinus maximinoi,* 7 provenances for *Pinus caribaea,* 7 provenances for *Pinus oocarpa,* 5 provenances for *Pinus patula*and 4 provenances for *Pinus kesiya* were tested in the Shan State in 1988.

Development of native and exotic pine plantation was in great progress in the South East Asian region where long fiber pulp, which these pines provide, was the high demand for paper and allied industries that have been established in Shan State. Observation on locally grown *Pinus kesiya* of Myanmar either in plantations or in natural stands also exhibited very poor growth. That is the reason why tropical pines from the Central American region were put on trial in Myanmar, so as to find out whether they perform equally well as has been reported (Gyi, et al., (1987), Greaves (1980), Aung Zeya (1992) andKyawSoe (1997).

Health and growth of trees were influenced by natural factors such as rainfall, temperature and soil characteristics. This implies that while abnormal patterns in rainfall and temperature such as long rainless intervals between heavy showers and high temperature as well as poor soil characteristics adversely affect vigour and growth of trees sometimes leading top death in extreme cases, the former two factors hasten the metabolic activity of insects, shorten the life cycle enable more generations of insects to attack already weakened trees. (Aung Zeya 1984).

Global climate change may have profound effects on the forest structure, composition and productivity of terrestrial ecosystems (Zefan and Fu 2018). The anatomical features of tree rings reflect information about past climatic conditions, and the variation of rainfall patterns from year to year was reflected in tree-ring width pattern (Zar Chi Hlaing 2012).

In the tropical region of South and Southeast Asia, a number of groups initiated the establishment of a high-resolution tree-ring data network to understand monsoon variability and related global parameters only in the recent past. The earliest studies on periodic tree-growth analysis in the tropics date as early as 1850 with the research of Brandis in India (Liese 1986).

Microscopical methods were also often necessary to establish the botanical identity of commercial samples of medicinal plants, timbers and fibers (Metcalfe & Chalk 1950).

3. Materials and methods

3.1 Study Site

The study area of exotic tropical pine plantations were situated in Taung Lay Lone Reserved Forest in Taunggyi Township, Southern Shan state78'99"54° North Latitude,78'69"52° East Longitude. In this research station, many indigenous and exotic pine plantations were established since 1986. The weather record was not taken from the study sites. It was taken from Taungyi station which was about 10 kilometres away from the plantation sites.

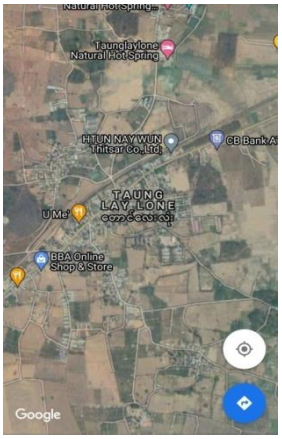


Figure (1) Study Area

Climatic data were illustrated based on1984 to 2019 of the Department of Meteorology and Hydrology 33 year record for the study sites. The average annual rainfall of the study areas was47" (1203 mm) in 1987-2019; the highest maximum temperature was 38˙ C and the lowest 4˙ C for the same period. The data was divided into four decade, each decade containing 10 year duration; the last group had 3 years.

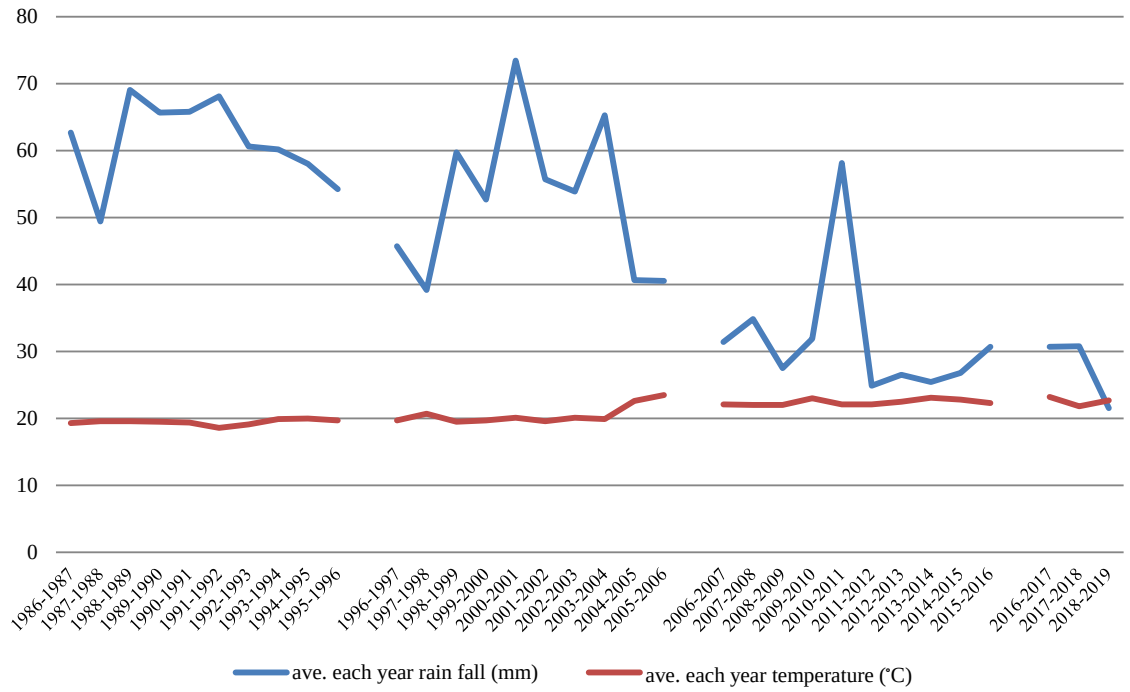


Fig. 2 Ave. each year rainfall (mm) and ave. each year temperature(D.C)
Table 1. Information of study sites

Location	**Altitude**	**Latitude**	**Longitude**	**Rainfall(mm)**	**Temperature(C)**
Taung Lay Lone Reserved Forest,Taunggyi Township, Southern Shan Region	2975 ft	78'99"54°	78'69"52°	547 – 1865 (mean 1202) mm	18.6 – 23.5 (mean 21)

3.2 Measuring the sample

The specimens of vegetative and reproductive parts, bark, and stem wood of three species of the *Pinus* were collected in the year of 2019 from the felling trunks of unknown height which were already cut and fallen down according the plantation management plan. Small portions of bark and wood of stem near at breast height level were taken. The specimens are killed and fixed in 50% ethyl alcohol for further study.

Twenty stands were randomly selected in the exotic tropical pine plantation of each species for taking the disc samples.The largest and lowest radial diameters of each disc were measured to know all the tree-rings present in the tree. The meteorological data (monthly rainfall and temperature) of study size for 33 years period (1987 to 2019), were collected from the township Meteorology and Hydrology Department of Taungyi.

3.3 Data Analysis

Ring widths were registered with a measuring system (Measure J2X) with a resolution of 0.01 mm and all cores were cross-dated by Microsoft Excel 2007 and SPSS 20at Anatomy Laboratory of Forest Research Institute (FRI) Yezin, Myanmar.

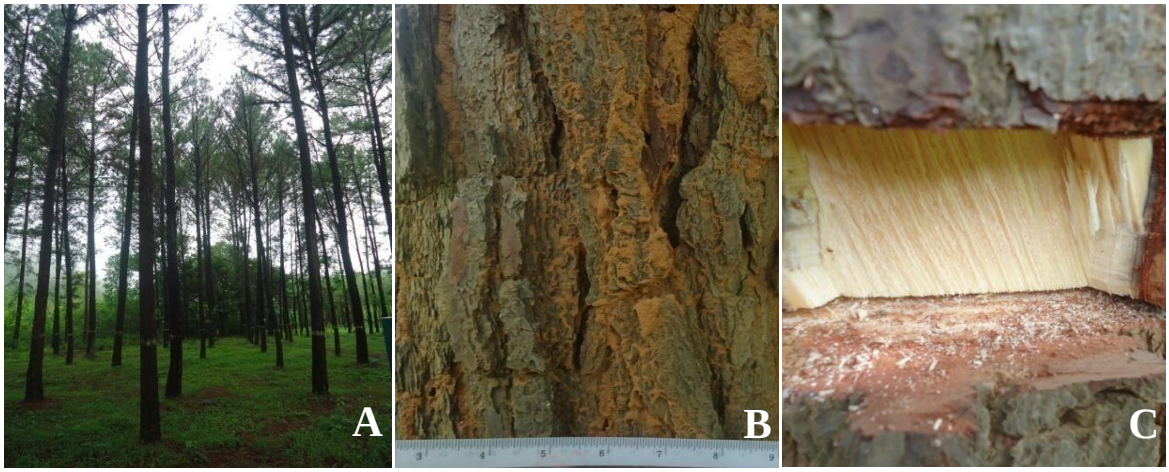
4.RESULTS

4.1 *Pinus caribaea* Morelet.

***Pinus caribaea* Morelet., Rev. Hort. 1: 107. 1851**

Synonym: *Pinus caribaea* var. *anomala* Rowlee
Pinus caribaea var.*caribaea*
Pinus recurvata Rowlee
Local Name: Htinyu, Tinyu
Common Name : Caribbean pine, Cuban pine
Family: Pinaceae
Locality: Taung Lay Lone Research Station, Taunggyi Township, Shan State Specimen examined: Kyi Kyi Khaing & Aye Nyein Chan, 27 - 7- 2020
Cone period: May to September

Large trees, perennial, evergreen, monoecious, aromatic; trunk circular, straight; bark 1.0 – 3.2 cm thick, gray or pale reddish brown with longitudinal and horizontal deep cracks, irregular bark flakes present; wood soft and light, sapwood yellow and heartwood reddish brown; branch whorled, branchlets green to orange brown; the dwarf shoot 17 – 24 mm long, persistent; needles 3 – 5 per bundle on the dwarf shoot, dull green or pale yellow-green, straight, stout, the needles 11.3 – 23.3 cm long; male cones cylindrical, 11 – 13 mm by 5 – 6 mm, arising at the tip of the long shoot; bearing numerous, microsporophylls, each microsporophyll bears two microsporangia or pollen sac on its underside; female cones pendulous, ovoid to ovoid-conical, 9 – 10 cm by 4 – 5 cm, subsessile or on a short stalk, cones persistent, dark brown, solitary or in pair or three; megasporophyll in spiral, mostly numerous, each with typically 2 inverted ovules; cones dehiscent, ovoid, subsessile, cones with densely scales, dark gray, persistent; seed scales reflexed or spreading, apophyses lustrous; umbo ending in a straight, minute prickle; seeds endospermic, colour gray or light brown, 4 – 7 mm by 2 – 5 mm, narrowly mottled, rhombic-ovoid, including 2 wings.



A. Plants in natural habit. **B.** Stem bark as seen.**C.** A portion of stem showing exposed wood**.**

D.A branchlet with leaves**E.** Leaves of three or four or five needles

F. Various sizes of male cones and female come. G. Seeds

Figure 3 Habit of *Pinus caribaea* Morelet.

4.2 *Pinus kesiya* Royle ex Gordon

***Pinus kesiya* Royle ex Gordon, Gard. Mag. L. 16: 8. 1840**

Synonym: *P. khasyana* Griff. Itin. PI. Khasyah Mts. 58. 1848

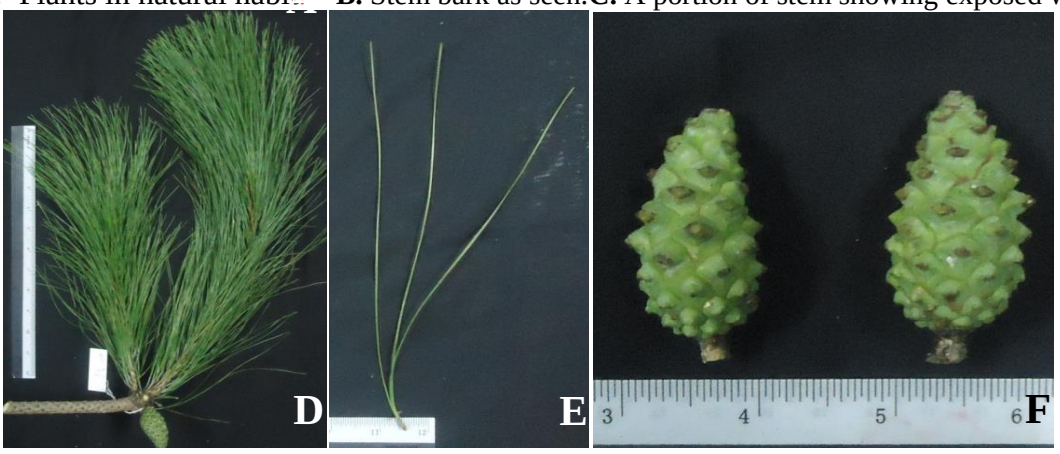
P. insularis var. *khasyana* (Griff.) Silba. Phytologia 68: 51. 1990.

P. insularis Endl., Syn. Conif. 157. 1847.

Local Name: Htinyu, Tinyu
Common Name : Khasi pine
Family: Pinaceae
Locality: Taung Lay Lone Research Station, Taunggyi Township, Shan State
Specimen examined: Kyi Kyi Khaing & Aye Nyein Chan, 27 - 7- 2020
Cone period: May to September

Large trees, perennial, evergreen, monoecious, aromatic; trunk circular, straight; bark 1.0 – 1.2 cm thick, brown with longitudinal and horizontal deep cracks, irregular bark flakes present; wood soft and light, sapwood pale yellow and heartwood brown;branches whorled or opposite or rarely alternate, branchlets yellowish brown to orange brown, shiny;the dwarf shoot 1.5 – 5.0 mm long,persistent; needles3 per bundle on the dwarf shoot,dark green, straight or twisted, slender, soft, the needles 11.7 – 22.4 cm long;male conescylindrical, 12 – 22 mm by 4 – 7 mm, arising at the tip of the long shoot; bearing numerous microsporophylls, each microsporophyll bears two microsporangia or pollen sac on its underside; female conespendulous, ovoid to ovoid-conical, 5 – 6.5 cm by 2.5 – 3 cm,subsessile or on a short stalk, cones persistent, bright brown, solitary or in pair or three; megasporophyll in spiral, mostly numerous, each with typically 2 inverted ovules; cones dehiscent, ovoid, subsessile, cones with densely scales, dark gray, persistent; seed scales narrowly suboblong, apophyses; umbo small, slightly protruded; seeds endospermic, colour dark brown, 5 – 7 mm by 3 – 4 mm, slightly appressed, ellipsoid, including 2 wings.

A. Plants in natural habit **B.** Stem bark as seen.**C.** A portion of stem showing exposed wood**.**



D. A branchlet with leaves**E.** Leaves of three needles. F. Various sizes of female come.

G. Various sizes of male cones.

H. Seeds

Figure 4 Habit of *Pinus kesiya* Royle ex Gordon.

4.1.3 *Pinus maximinoi* H.EMoore

Pinus maximinoi H.EMoore, Baileya 14:8 1966.

Synonym: *P. douglasiana* var.maximinoi (H.E.Moore) silba

P. escandoniana Roezl
P. hoseriana Roezl
P. pseudostrobusvar.tenuifolia Shaw
P. tenuifolia Benth.
P.tzompoliana Roezl

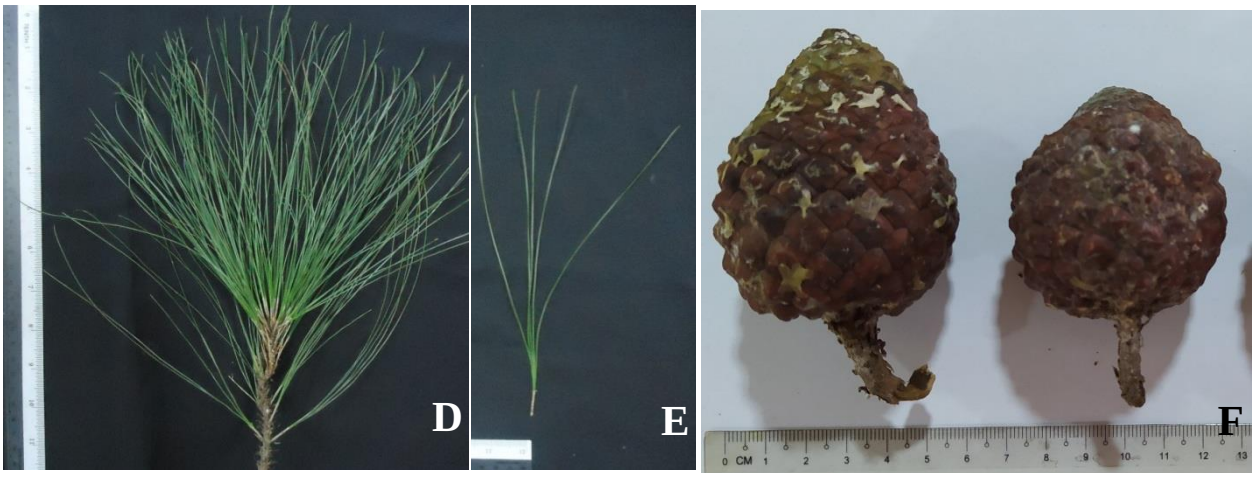
Local Name: Htinyu, Tinyu
Common Name : Pinocandelillo, ocote, pinocanis, pinabete
Family: Pinaceae
Locality:Taung Lay Lone Research Station, Taunggyi Township, Shan State
Specimen examined: KyiKyiKhaing& Aye Nyein Chan, 27 - 7- 2020
Cone period: May to September

Taxonomic Description

Large trees, perennial, evergreen, monoecious, aromatic; trunk circular, straight; bark 1.7 – 4.2 cm thick, yellowish brown with longitudinal deep cracks, irregular bark flakes present; wood soft and light, sapwood pale yellow and heartwood brown; branches whorled or opposite or rarely alternate, branchlets reddish brown; the dwarf shoot 20 – 44 mm long, persistent; needles 5 per bundle on the dwarf shoot, dark green, straight, slender, stout, the needles 7.4 – 34.2 cm long; male cones cylindrical, 11 – 22 mm by 5 – 9 mm, arising at the tip of the long shoot; bearing numerous microsporophylls, each microsporophyll bears two microsporangia or pollen sac on its underside; female cones pendulous, ovoid to ovoid-

conical, 6 – 9.3 cm by2.5 – 5.0 cm, subsessile or on a short stalk, cones persistent, bright brown, solitary or in pair orthree; megasporophyll in spiral, mostly numerous, each with typically 2 inverted ovules; conesdehiscent, ovoid, subsessile, cones with densely scales, dark gray, persistent; seed scales suboblong, apophyses; umbo small, slightly protruded; seeds endospermic, colour light brown, 6 – 8 mm by 4 – 5 mm, slightly appressed, ellipsoid, including 2 wings.

A. Plants in natural habit. **B.** Stem bark as seen.**C.** A portion of stem showing exposed wood**.**



D. A branchlet with leaves **E.** Leaves of five needles. F. Various sizes of female come.

G. Various sizes of male cones. H. Seeds

Figure 5 Habit of *Pinus maximinoi* H.E Moore.

Table 1 Quantitative morphological characteristics of the three *Pinus* species

Species	***Pinus caribaea* Morelet.**	***Pinus kesiya* Royle ex Gordon**	***Pinus maximinoi* H.E Moore**
Bark colour	Gray or pale reddish brown	Brown	yellowish brown
Branchlets	Green to orange brown	Yellowish brown to orange brown	reddish brown
Dwarft shoot	17 – 24 mm	1.5 – 5.0 mm	20 – 44 mm
Leaves	3 – 5needles, dull green or pale yellow-green, straight, stout, 11.3 – 23.3 cm	3 needle, green, straight or twisted, slender, soft, 11.7 – 22.4 cm	5 needle, dark green,straight,slender,stout,the needles 7.4 – 34.2 cm
Male cone (length)	11 – 13 mm	12 – 22 mm	13 – 25 mm
Female cone size (length)	9 – 11 cm	5 – 6.5 cm	6.0 – 9.3 cm
Seed scales	Apophyses	Apophyses, narrowly suboblong	Apophyses, suboblong
Umbo	Slightly projecting	Small, slightly protruded	Small, slightly protruded
Seeds colour	Gray or light brown	Dark brown	Light brown
Seeds size	4 – 7 mm	5 – 7 mm	6 – 8 mm

4.2.1 Weather condition of study area

According to climatic data, 1987 to 2019 of the Department of Meteorology and Hydrology 33 year record for the study sites which a dry month will defined by January to April and December, wet and moist will defined by April to November (Fig.6). The data was divided into four decade; wet and moist conditions were decreased decade by decade and dry conditions were increased decade by decade (Fig.7).

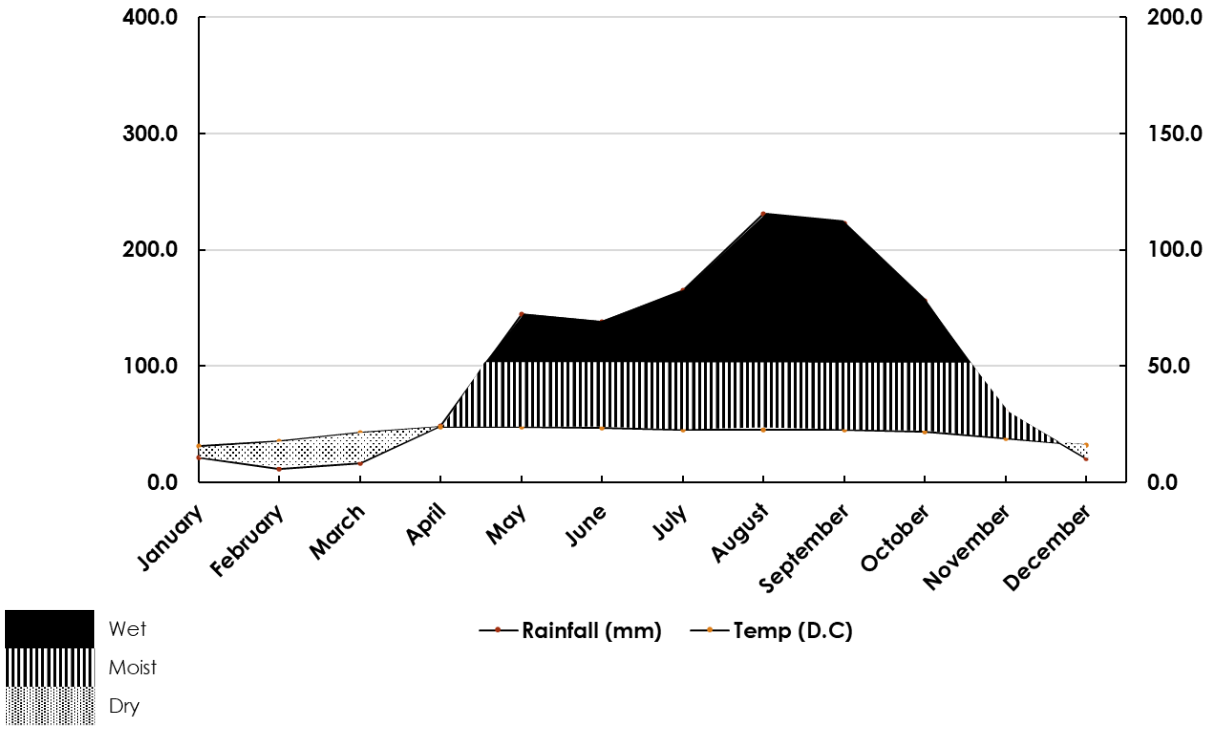


Figure.6 Weather condition (Ave RF (mm) and Ave Temp (D.C)) of study area (1987 to 2019)

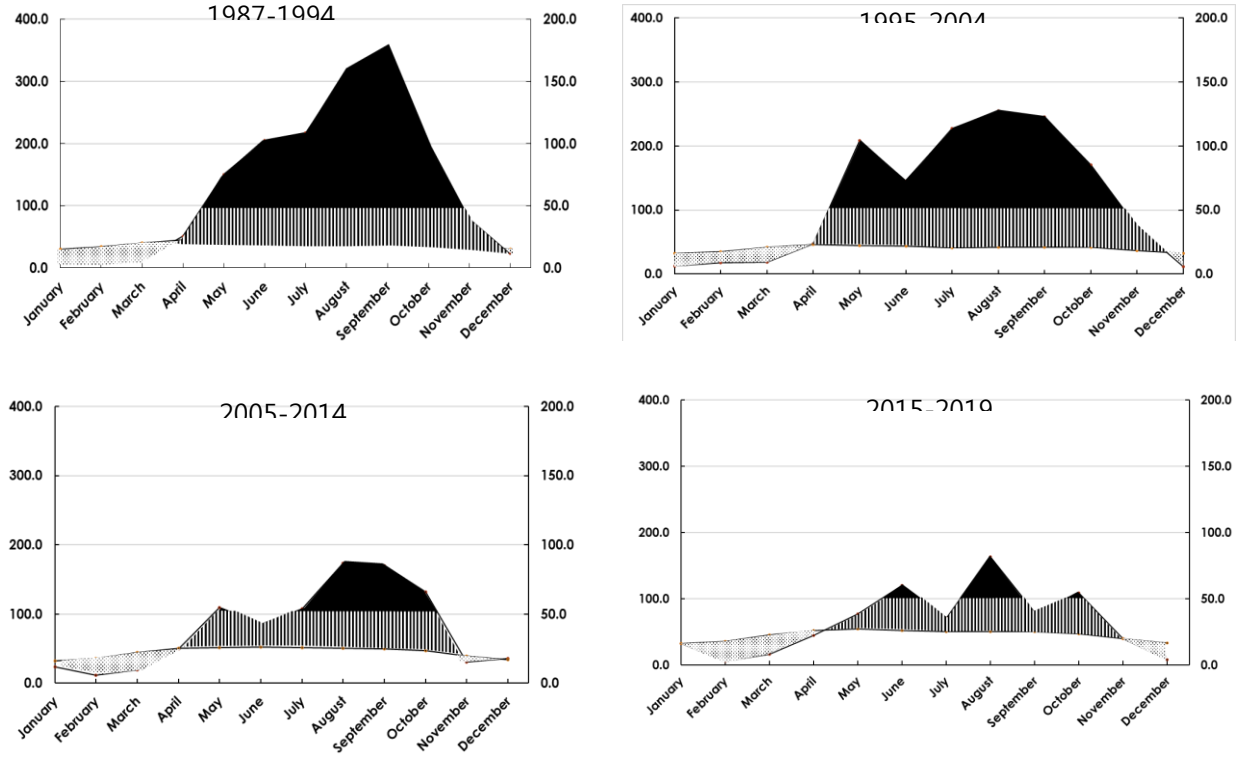


Figure.7 Weather condition (Ave RF (mm) and Ave Temp (D.C)) of study area base on 10 years duration

4.3.1 Weather condition and annual ring width of *Pinus caribaea*

In this study, to estimate the growth rate of *Pinus caribaea*, 20 sampled trees were used by analyzing tree-rings. Average growth ring width of *P. caribaea* was 1 – 26 mm (5.1 mm), radius for (35 years)176.8 mm,(Fig. 13).Radial increment of first ten years duration of *P.caribaea* was 63.51 mm, second ten years duration was 52.59 mm and third ten years duration was 43.25 mm where the mean annual rainfall was47.33"(1202 mm). Rainfall decreased from the first year to the last year and temperature increased from the first year to the last year, at that time the annual ring width decreased. The average annual rainfall was positively correlated with ring width (mm) of *P. caribaea* (Cor. 0.662). Average annual temperature (Deg.C) was negatively correlated with ring width (mm) of *P.caribaea* (Cor. -0.693) (Fig.14, 15& 16).

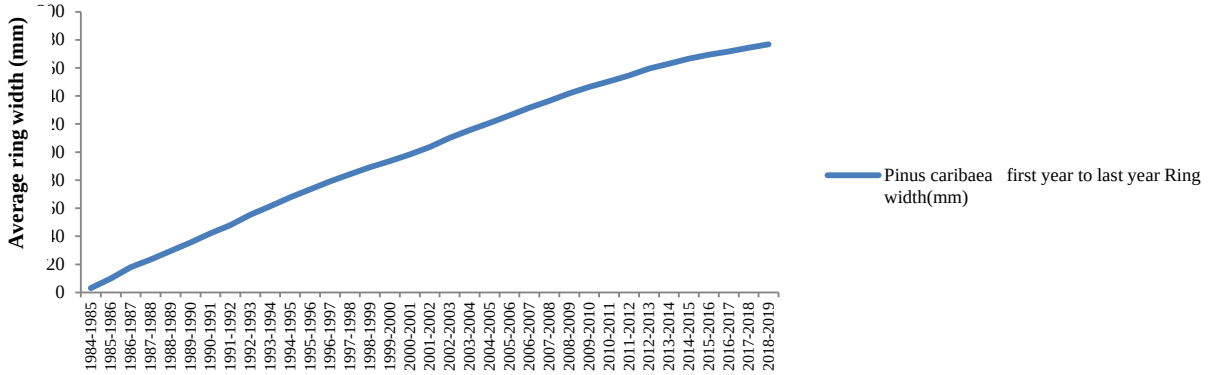


Figure 13 Ring width (mm) of *Pinus caribaea* for first year to last year.

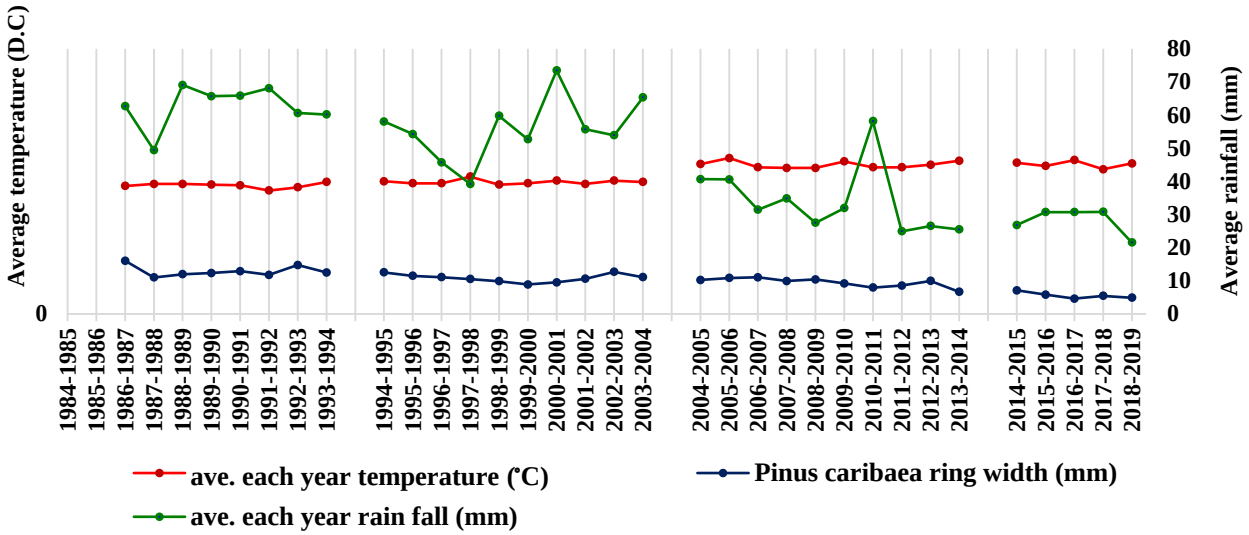


Figure. 14 Average annual weather (Rainfall and Temp) and Average annual ring width (mm) of *Pinus caribaea*

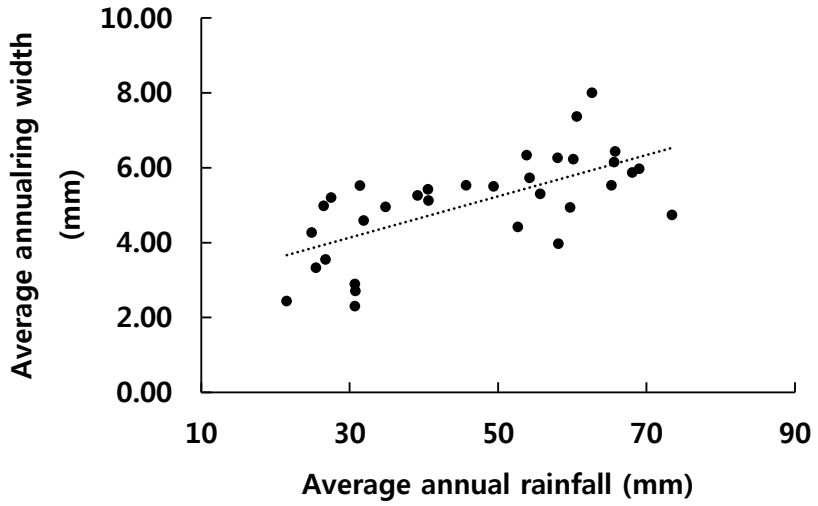


Figure. 15 Average annual rainfall (mm) and average annual ring width (mm) of *Pinus caribaea*(Cor.0.662)

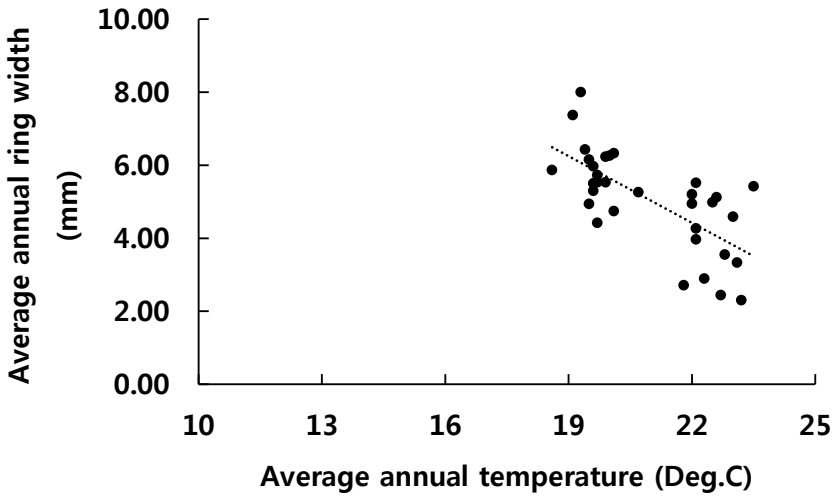


Figure. 16 Average annual temperature (Deg. C) and average annual ring width (mm) of *Pinus caribaea*

(Cor. - 0.693)

4.3.2 Weather condition and annual ring width of *Pinus kesiya*

In this study, to estimate the growth rate of *pinus kesiya*, 20 sampled trees were used by analyzing tree-rings. Average growth ring width of *P. kesiya* was 0.5 – 16.5 mm (mean 4.5 mm), radius for (33 years)145.69 mm,(Fig. 17). Radial increment of first ten years duration of *P. kesiya* was 68.68mm, second ten years duration was 43.63mm and third ten years duration was 28.6 mm where the mean annual rainfall was 47.33"(1202 mm). Rainfall decreases from first year to last year and temperature increases first year to last year, at that time the annual ring width decreases (Fig.18). The average annual rainfall was positively correlated with ring width (mm) of *Pinus kesiya* (Cor. 0.729). Average annual temperature (Deg.C) was negatively correlated with ring width (mm) of *Pinus kesiya* (Cor. - 0.734)) (Fig.19&20).

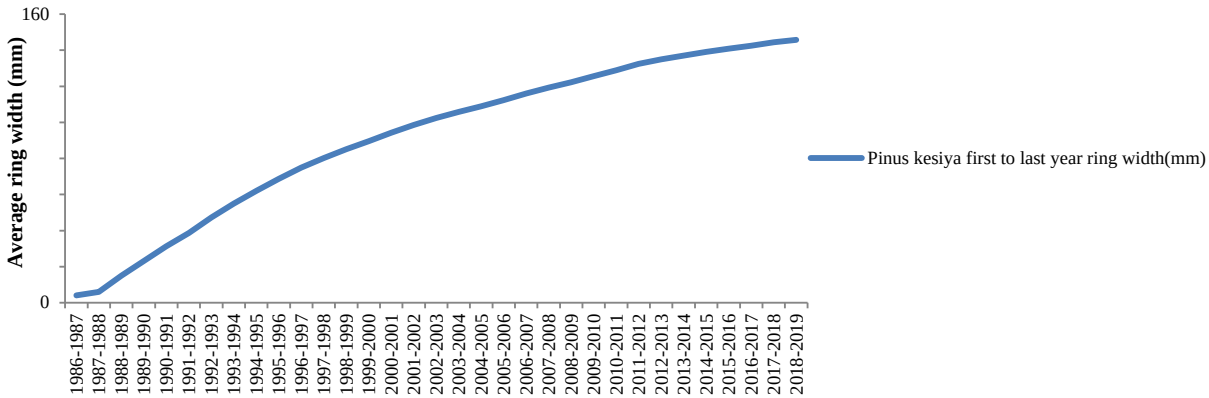


Figure 17 **Ring width (mm) of *Pinus kesiya* for first year to last year.**

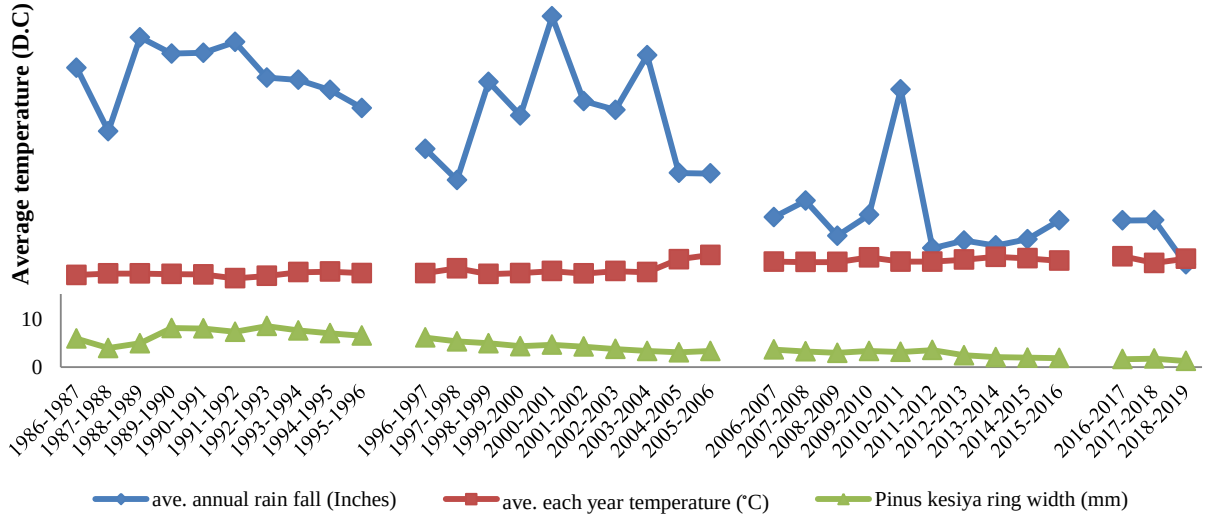


Figure. 18 Average annual weather (Rainfall and Temp) and Average annual ring width(mm) of *Pinus kesiya*

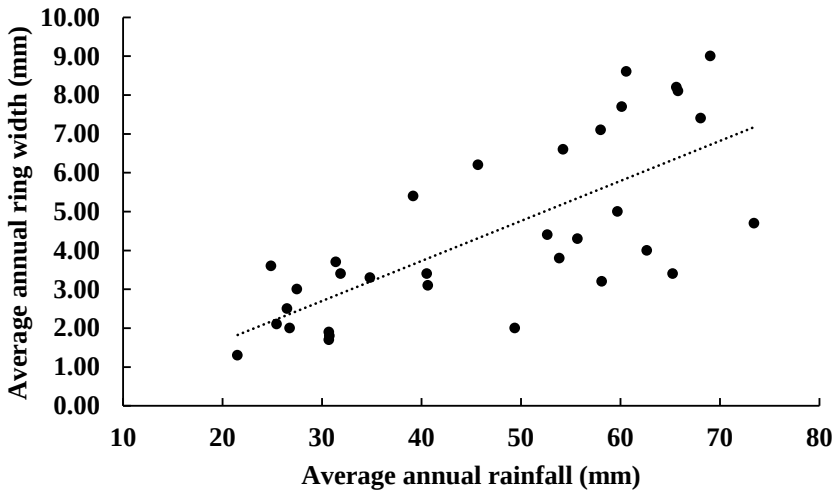


Figure. 19 Average annual rainfall (mm) and average annual ring width (mm) of *Pinus kesiya*(Cor. 0.729)

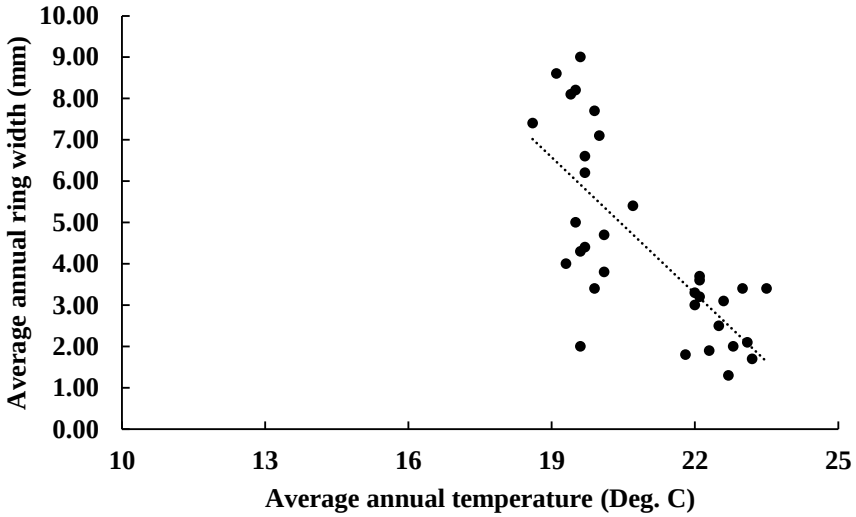


Figure. 20 Average annual temperature (Deg. C) and average annual ring width (mm) of *Pinus kesiya*(Cor. – 0.734)

4.3.3 Weather condition and annual ring width of *Pinus maximinoi*

In this study, to estimate the growth rate of *pinus maximimoi*, 20 sampled trees were used by analyzing tree-rings. Average growth ring widthof *P.maximimoi* was 0.5 – 16.5 mm (mean 4.5 mm), radius for (34 years) 145.69 mm,(Fig. 21). Radial increment of first ten years duration of *P. maximimoi* was 64.79 mm, second ten years duration was 55.21mm and third ten years duration was 40.53 mm where the mean annual rainfall was 47.33"(1202 mm). Rainfall decreases from first year to last year and temperature increases from first year to last year, at that time the annual ring width decreases (Fig.22). The average annual rainfall was positively correlated with ring width (mm) of *P. maximimoi* (Cor. 0.729). Average annual temperature (Deg.C) was negatively correlated with ring width (mm) of *P. maximimoi* (Cor. -0.734)) (Fig.23& 24).

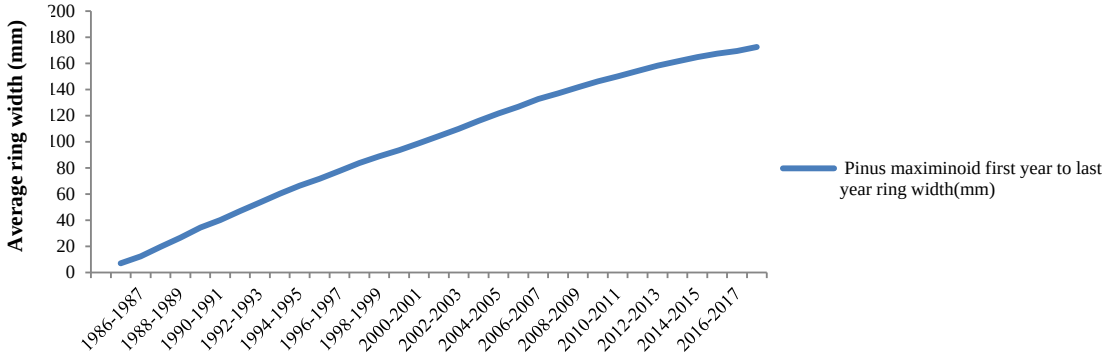


Figure 21 *Pinus maximinoid* first year to last year ring width (mm).

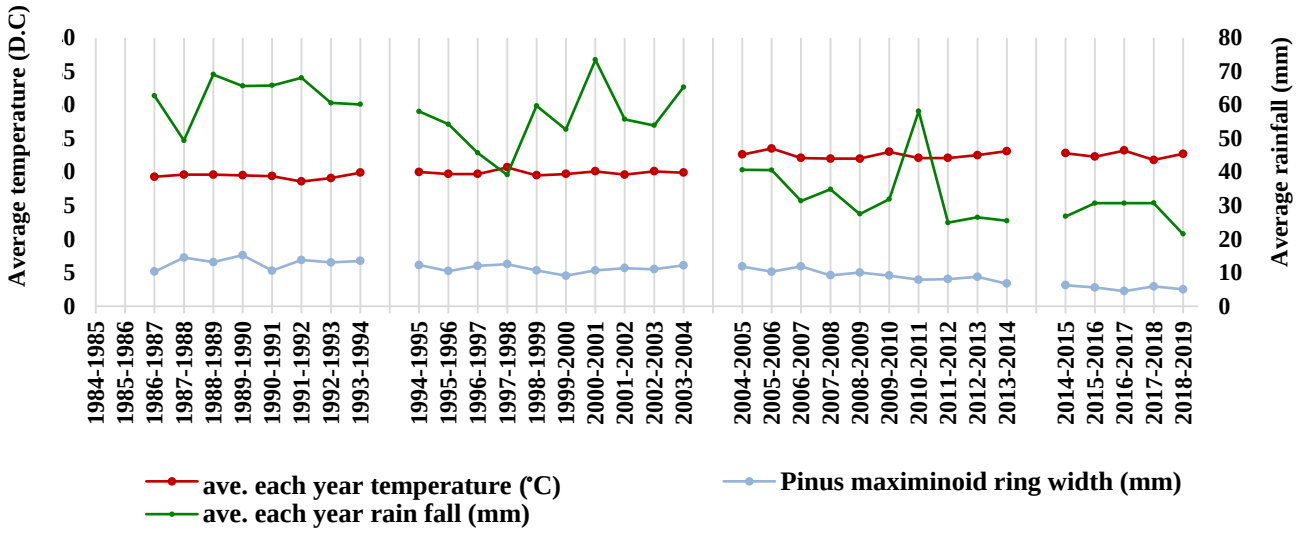


Figure. 22 Average weather (Rainfall and Temp) and Average annual ring width (mm) of *Pinus maximinoid*

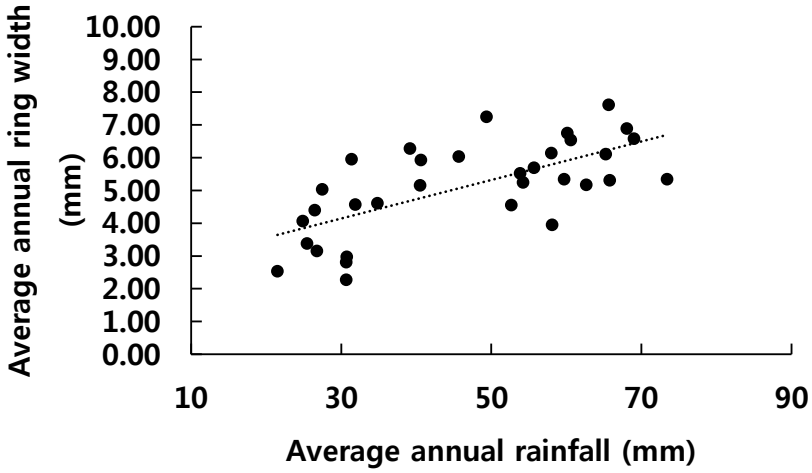


Figure. 23 Average annual rainfall (mm) and average annual ring width (mm) of *Pinus maximinoid* (Cor. 0.675)

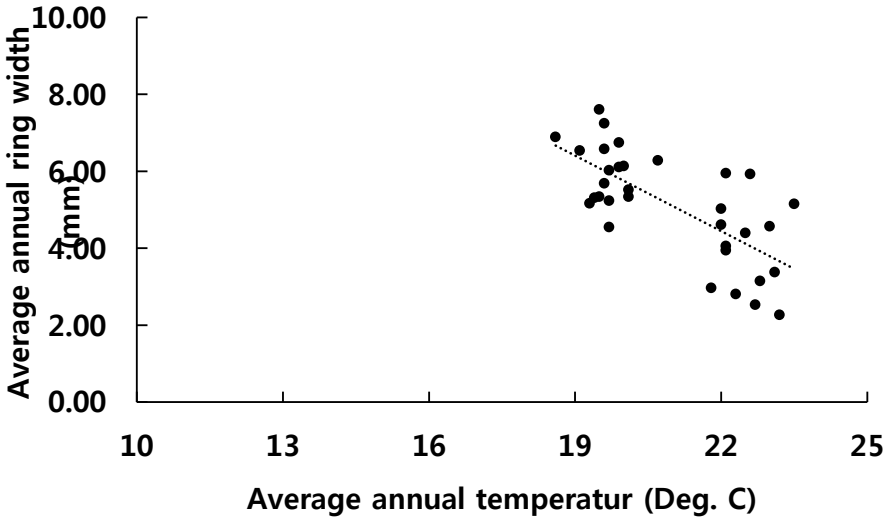


Figure. 24 Average annual temperature (Deg. C) and average annual ring width (mm) of *Pinus maximinoi*(Cor. – 0.710)

4.4.1 Annual ring width (mm) of three *Pinus* species studied

In the three species studied, average growth ring width of *P. maximinoi* was the highest 5.1 mm, 169.1 mm radius (33 years), that of *P. kesiya* was the lowest 4.5 mm, 145.69 mm radius (33 years) in the same plantation. According to this finding, average growth ring width of *Pinus caribaea* was 5.1 mm (33 years) that is nearly the same with *P. maximinoi*. Radial increment of *P.kesiya* was found to be the highest in first ten years duration (68.68 mm) but it was found to be lower in third ten years duration (28.6 mm) where the annual rainfall was about 47.33"(1202 mm). These characters were agreed with those mentioned by Saw win (1992), Kyaw Than (1997), Mehm Ko Ko Gyi et al. (1987), Chaw Chaw Sein & Aung Zaw Moe (2015).

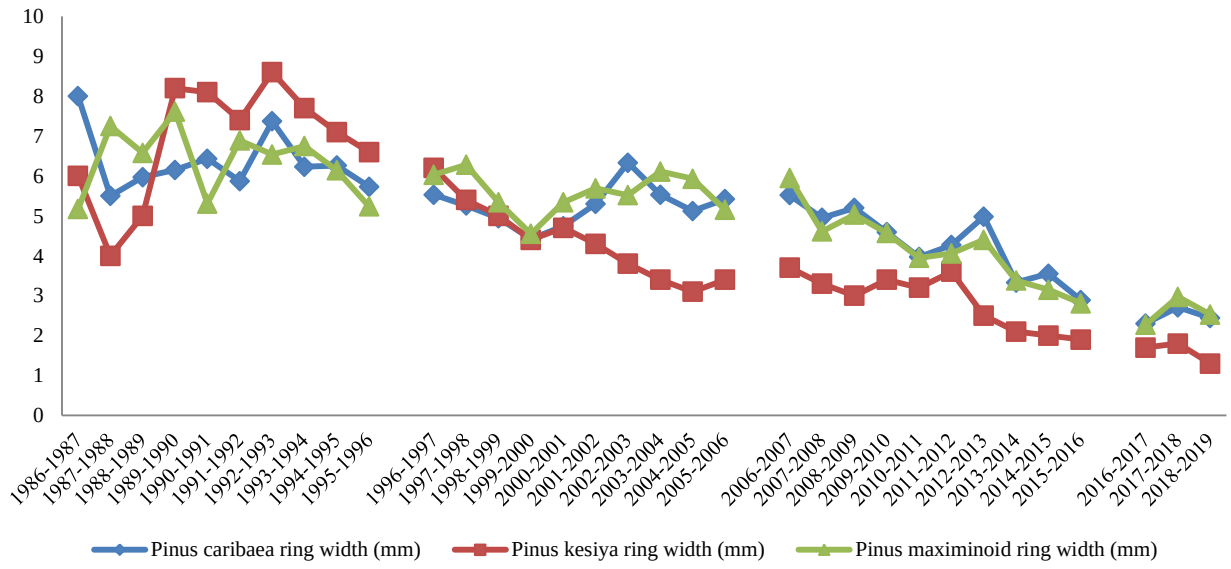


Figure. 8 Average annual ring width (mm) of three *Pinus* species studied

Table 2. Average tree-ring width (mm) of three *Pinus* species studied

Species	Age (year)	GBH (cm)	First to last year growth rate (mm)	Average growth ring width (mm)
Pinuscaribaea	33 (1987-2019)	89.9	168.0	5.1
Pinuskesiya	33 (1987-2019)	86.4	145.7	4.5
Pinusmaximinoi	33 (1987-2019)	101.9	169.1	5.1

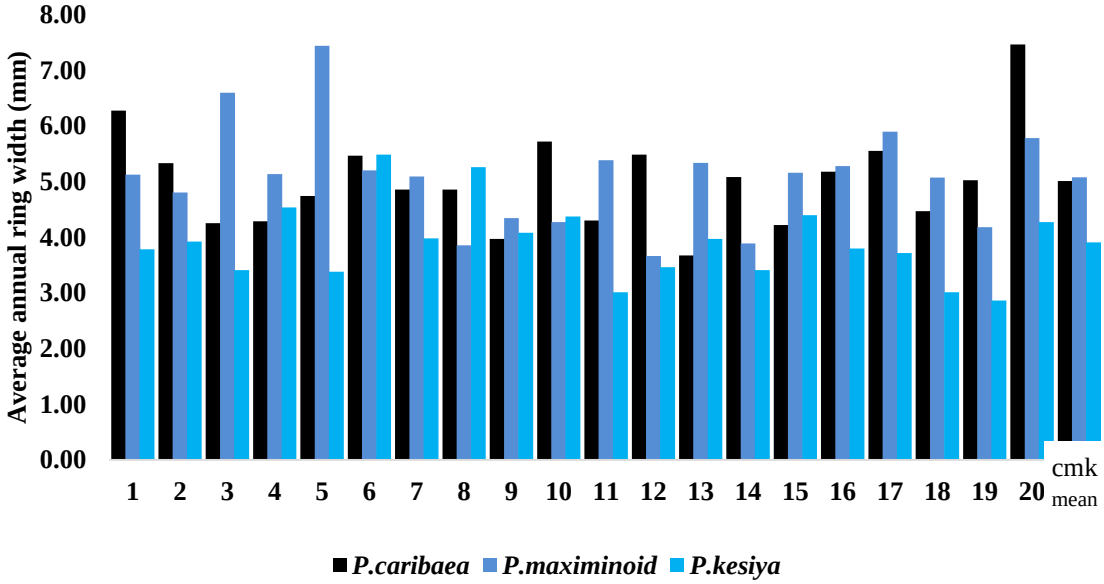


Figure. 9 Average annual ring width (m

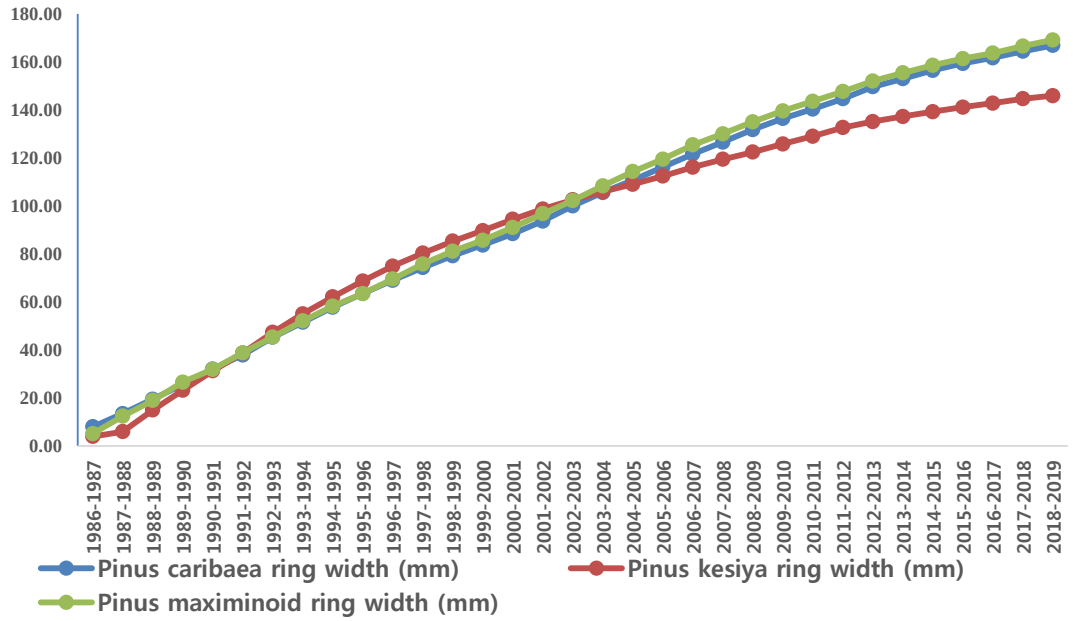


Figure.10 Cumulative annual ring width (mm) of three *Pinus* species studied

In the three species studied, standard deviation of *P. caribaea* is 2.2, *P. kesiya* is 1.4 and *P. maximinoi* is 1.3. Ring increment (ring width) was not significantly different among the same age and same plantations sites $p < 0.342$.

Table.3 Mean, minimum, maximum Std. Deviation and Sig. of three species

Ring **Descriptives**

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
P.maxi	33	5.0545	1.33534	.23245	4.5811	5.5280	2.30	8.00
P.cari	33	4.5361	2.24419	.39066	3.7403	5.3318	1.31	9.00
P.kesi	33	5.0979	1.44593	.25170	4.5852	5.6106	2.13	7.79
Total	99	4.8962	1.72490	.17336	4.5521	5.2402	1.31	9.00

Ring **ANOVA**

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.450	2	3.225	1.086	.342
Within Groups	285.127	96	2.970		
Total	291.577	98			

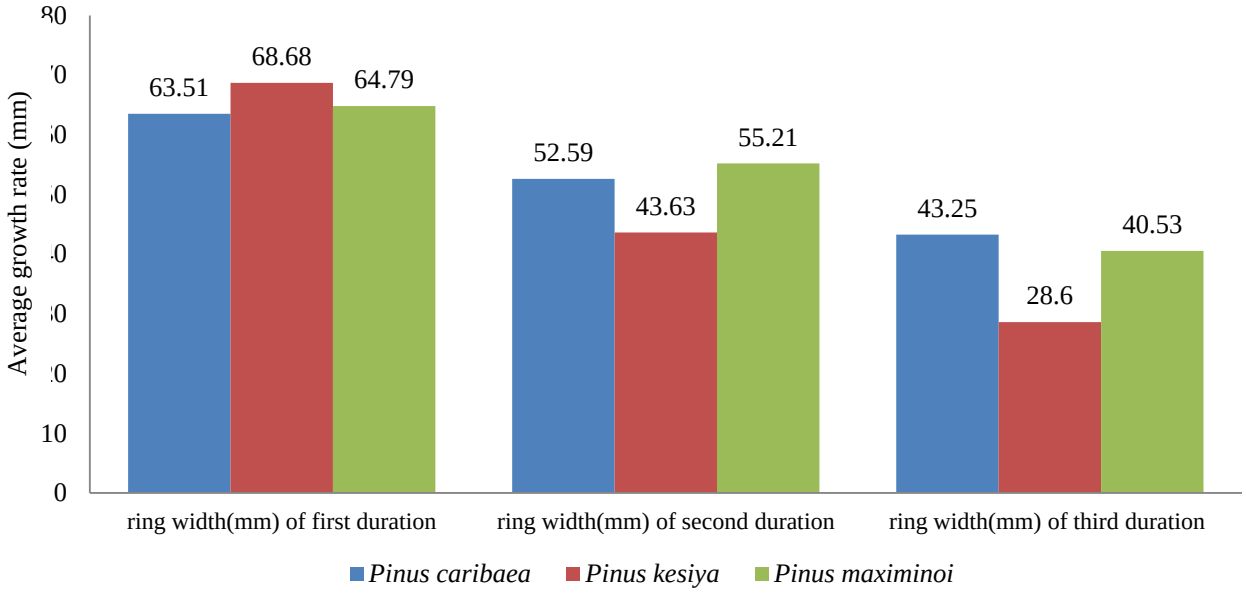


Figure 11.Ring widths (mm) of each duration of three *Pinus* species studied.

4.4.2 Weather condition and Annual ring width

In this study, ring widths were depending on rainfall and temperature. Rainfall was decreasing from first year to last year and temperature was increasing from first year to last year, at that time the growth rate were decreased. (Fig. 12).

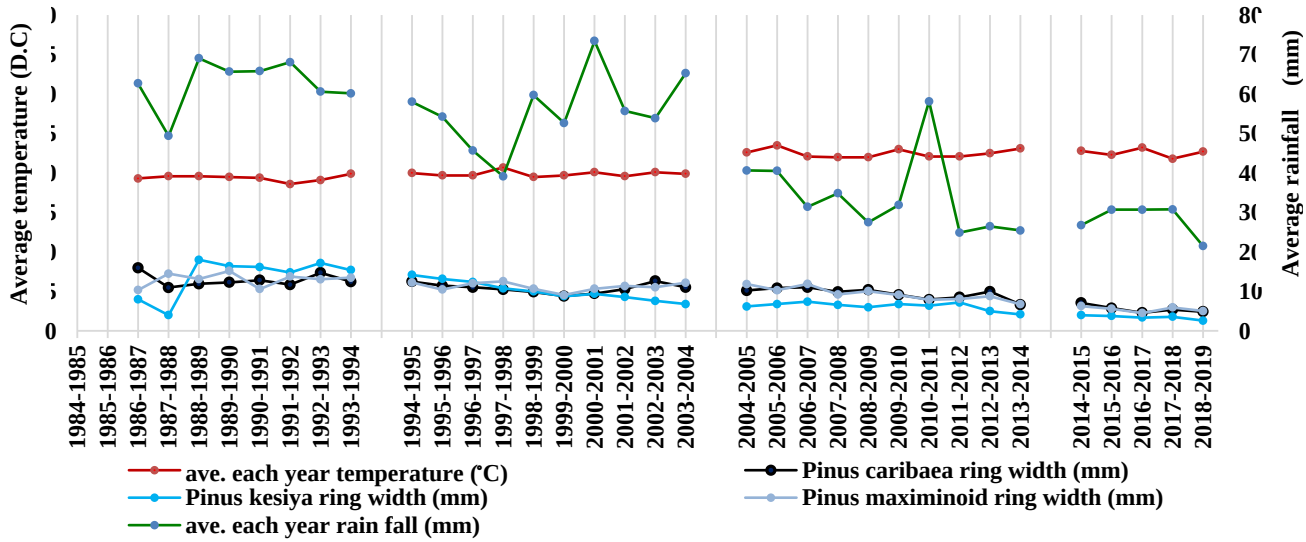


Figure. 12 Average annual weather (Rainfall and Temp) and Average annual ring width of three *Pinus* species studied

5. Discussion and conclusion

The morphological characteristics and growth of three species of the genus Pinus were studied in this research. The studied species namely *Pinus caribaea* Morelet., *P. kesiya* Royle ex Gordon and *P. maximinoi* belongs to the family Pinaceae. The specimens were

collected from Taung Lay Lone Reserved Forest in Taunggyi Township, Southern Shan state in July 2019.

The habits of the studied species were large perennial, monecious and evergreen trees. The branches were whorl or opposite or rarely alternate. Bark colour of *P. caribaea* Morelet. was gray or pale reddish brown, brown in *Pinus kesiya* Royle ex Gordon and gray brown or yellowish brown in *P. maximinoi*. These characters were agreed with Zhengyi et al. (2013) and Phyo Aung (2020).

The branchlets colour was green to orange brown in *P.caribaea* Morelet., yellowish brown to orange brown in *P. kesiya* Royle ex Gordon, and reddish brown in *P. maximinoi*. These characters were in agreement with Schmidt et al. (2004), Zhengyi et al. (2013) and Phyo Aung (2020).

The numbers of needles were found to be different in all the studied species. It was observed that 3 per bundle in *P.kesiya* Royle ex Gordon and 5 per bundle in *P. maximinoi*. The needles of all species were located on the dwarf shoot. These characters were in agreement with Phyo Aung (2020) and Zhengyi et al. (2013). In this study, 3 – 5 neeldes were found in bundle of *P. caribaea* Morelet but Phyo Aung (2020) stated that 4 per bundle in *P.caribaea* and Zhengyi et al. (2013) stated that *P.caribaea* needles were usually 4 or 5 in number per bundle.

The needles of *P. caribaea* Morelet. and *P. maximinoi* were stout. However that of *P.kesiya* Royle ex Gordon was soft. These characters were in agreement with Schmidt et al. (2004), Zhengyi et al.(2013) and PhyoAung (2020).

The colours of needles were dark green in *P. kesiya* Royle ex Gordon and *P. maximinoi,* dull green or pale yellow green in *P. caribaea* Morelet. These characters were agreed with those mentioned by Zhengyi et al. (2013) and PhyoAung (2020).

In the present study, male cones of all tree species studied were cylindrical, arising at the tip of the long shoot. Female cones were pendulous, ovoid to ovoid-conical, subsessile or on a short stalk, persistent, bright brown, solitary or in pair or three. Those findings were agreed with by Zhengyi et al. (2013) and PhyoAung (2020).

The seed colour of studied species were variable, gray or light brownin *P.caribaea* Morelet., dark browninin *P.kesiya* Royle ex Gordon and gray or light in *P. maximinoi*. These characters were agreed with those mentioned by Zhengyi et al (2013) and PhyoAung (2020).

The sapwood of *P. caribaea* is found to be yellow and that of heartwood reddish brown. The sapwood of *P. kesiya* and *P. maxininoi* is pale yellow and their heartwood is brown.

According to climatic data in the duration 33 years, rainfall was decreasing but temperature was increasing, at that time the growth rate of all species were decreased. Average annual rainfall was positively correlated and average annual temperature was negatively correlated to average annual ring width of the three *Pinus* species.

In the three species studied, average growth ring width of *P. maximinoi* was the highest, 5.1 mm, 169.1 mm radius (33 years), that of *P. kesiya* was the lowest 4.5 mm, 145.69 mm radius (33 years) in the same plantation. According to this finding, average growth ring

width of *P. caribaea* was 5.1 mm (33 years) that is nearly the same as that of *P. maximinoi*. Radial increment of *P. kesiya* was found to be the highest in first ten years duration (68.68 mm) but it was found to be lowest in third ten years duration (28.6 mm) where the annual rainfall was about 47.33"(1202 mm). These characters were agreed with those mentioned by Saw win (1992), Kyaw Than (1997), Mehm Ko Ko Gyi et al. (1987), Chaw Chaw Sein & Aung Zaw Moe (2015).

In this study, standard deviation in the growth rate of *P. caribaea* is 2.2, that of *P. kesiya* is 1.4 and *P. maximinoi* is 1.3. Average growth rate of three *Pinus* species are found to be not significantly different in the same age and same plantations sites $p < 0.342$.

In the present study, the morphological characteristics of three species of the *Pinus* were found to be different in number of leaves and the size of male cones, female cones and seeds.

In conclusion, the present research can provide information on differences morphological characters which are useful in identification and classification of non-flowering plants. In addition, correlation of growth rate and weather condition of the other species of the genus *Pinus* could be also estimated.

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