ACTA FORESTALIA FENNICA

178

NOTES ON *PINUS KESIYA* AND *P. MERKUSII* AND THEIR NATURAL REGENERATION IN WATERSHED AREAS OF NORTHERN THAILAND

HAVAINTOJA MÄNNYISTÄ (PINUS KESIYA JA P. MERKUSII) JA MÄNTYJEN LUONTAISESTA UUDISTUMISESTA POHJOIS-THAIMAAN VEDENJAKAJA-ALUEILLA

Antti Turakka, Olavi Luukkanen & Suree Bhumibhamon

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Seloste

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HELSINKI 1982

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Large numbers of pine seedlings were found in *Pinus kesiya* Royle ex Gord. stands only. Two of the examined four localities where this species occurred also included various intermediary height classes under the mature trees. In dense stands the number of seedlings was generally smaller as compared to stands with lower seed tree densities. Neither one of the two localities where *P. merkusii* Jungh. et de Vriese was investigated indicated sufficient natural regeneration. Young pines (over 5 m in height) seemed to survive the frequent ground fires quite well, whereas younger seedlings were destroyed and the ground layer vigour was lowered in these cases.

In situ sowing experiments at the beginning of the dry season indicated a faster development and better survival of emerging *P. kesiya* seedlings as compared to *P. merkusii.* Soil preparation and exposure to sun decreased the seedlings survival in both species. Utilization of natural regeneration and direct sowing of pines as a silvicultural method as well as the general significance of the two pine species in the succession of plant communities under the influence of forest fires is also discussed.

Kahdesta mäntylajista vain *Pinus kesiya* osoittautui tyydyttävästi luontaisesti uudistuvaksi. Tiheä siemenpuusto ilmeni haitalliseksi. Usein toistuvat metsäpalot olivat myös huonon uudistumisen yhtenä syynä. Palon jälkiä todettiin kaikissa tutkituissa metsiköissä. Kylvökokein todettiin mäntylajeista *P. merkusiin* sirkkataimien kehittyvän hitaammin ja olevan alttiimpia tuhoille. Kuivuus oli sirkkataimien tuhoutumisen tärkein syy, mitä osoitti myös heikompi taimettuminen täydessä auringonvalossa olevissa taikka muokatuissa kylvölaikuissa verrattuna puuston alla oleviin taikka muokkaamattomiin laikkuihin.

ODC 174.7 *Pinus kesiya*: 174.7 *Pinus merkusii*+ (593)+231+435.3

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PREFACE

The present work is an attempt to incorporate field research in a tropical country into the study program of Finnish forestry graduates. In this regard the results should not only be evaluated with the immediate scientific value or practical applications in mind but also in respect to the possible continuation and development of the co-operation between Finnish and foreign forest researchers.

Thailand was a natural choice for this experiment in international research, due to the connections which have existed between the Faculty of Agriculture and Forestry of the University of Helsinki and the Faculty of Forestry at Kasetsart University in Bangkok already for fifteen years. Within this program, Thai forestry graduates have participated in Finnish research activities. However, a growing interest towards Thai forestry and tropical countries in general is also to be found among the younger generation of Finnish forest researchers and forestry students. Along with the experience on tropical forest management already acquired by a number of senior faculty members and specialists in Finland, this increasing general interest led to the initiation of the present study.

Kind advice and research facilities during the field work were provided by Kasetsart University. In particular, we wish to thank Dr. Chongrak Prichananda and Dr. Somsak Sukwong, former and present dean of the Faculty of Forestry, respectively, for their generous help. Assistance in field work was obtained from Mr. Pinit Buadaeng and Mr. Markku Siltanen. The English language was checked by Mr. John Derome, M.Sc., and the manuscript was typed by Ms. Leena Kotilainen. Financial support was also offered by the Society of Forestry in Finland. The authors are grateful for all these contributions.

The work in the present investigation was divided among the authors as follows: The first author (A.T.) collected the field data and presented the results in his M. For. thesis; the second author (O.L.) proposed the general outline of the work after visiting the study region, was the principal advisor of the thesis work, and prepared the final manuscript; the third author (S.B.) was responsible for the practical arrangements in the field as well as for the supervision of data collection.

Antti Turakka *Olavi Luukkanen*
Suree Bhumibhamon

Helsinki and Bangkok
February 1981

CONTENTS

1. INTRODUCTION

1.1. Pines in Thai forestry

Both *Pinus kesiya* Royle ex Gord. and *P. merkusii* Jungh. et de Vriese are native forest trees in Thailand and found in the northern parts of the country in particular. *P. kesiya* occurs mostly at higher elevations (1000 to 2300 m; Lizardo 1954), whereas *P. merkusii*, being a more typical tropical species, grows from sea level up to about 1800 m (Cooling 1968). *P. kesiya* is only found in the northern Thai provinces, but *P. merkusii* also has a limited distribution in the central part of the country. Both species have a fragmented range over large areas of southern and south-eastern Asia (Critchfield and Little 1966). They are also used in plantation forestry outside their natural ranges in many tropical countries (Mirov 1967).

Ecologically, as well as from the point of view of forest management, these pines in Thailand are of local importance only, since they occur over less than one per cent of the forest area of the country. The total area of natural pine stands is 230 000 ha (Premrasmi and Smitinand 1960). Pines usually grow in mixed stands, together with deciduous broadleaved trees, the estimated area of pure natural pine stands in Thailand being only 28 000 ha (Bryde et al. 1965).

Utilization of pines in Thailand is restricted by tight governmental legislation, although the unauthorized cutting of pine trees cannot be avoided. One of the most common ways of utilizing pine trees in Thailand is gradual shaving of the stem base (in order to obtain resinous, highly valued fuelwood) until the tree is toppled by the wind. Such a practice has also been observed in India and Burma (Troup 1921). As industrial raw material, the pine forests of Thailand have so far been utilized through resin tapping only. The potential use of native and introduced pines in the pulp industry in Thailand has received serious attention during recent years, but existing plans have not yet been materialized.

The first pine plantations were established at Baw Luang in 1963. The total area of planted pine stands in the country is about 6000 ha. Much basic research on pines, particularly as far as gene conservation, species and provenance testing or nursery techniques are considered, has already been done in Thailand. The genetic investigations on pines were initiated in cooperation with Danish forest geneticists (cf. Thai-Danish . . . 1975). Various aspects of the improvement and management of pine forests are now studied by the Pine Improvement Center and several plantations and nursery centers administered by the Royal Forest Department, as well as by the Faculty of Forestry at Kasetsart University in Bangkok.

1.2. Forest site classification

The forests in Thailand have generally been classified into types according to a system originally used in India and Burma. For instance, Samapuddhi (1955) divides the forests in Thailand as follows:

A. Evergreen forests
   1. Tropical evergreen forests
   2. Hill evergreen forests
   3. Mangrove forests
   4. Coniferous forests
B. Deciduous forests
   1. Mixed deciduous forests
   2. Deciduous dipterocarp forests
C. Beach forests
D. Swamp forests.

A somewhat more detailed classification for forests in Thailand has been presented by Smitinand (1966):

1. Evergreen forests
   1.1. Tropical evergreen forests
      1.1.1. Tropical rain forests
         1.1.1.1. Lower tropical rain forests
         1.1.1.2. Upper tropical rain forests

1.1.2. Dry or semi-evergreen forests
1.1.3. Hill or lower montane evergreen forests
1.2. Coniferous forests
1.3. Swamp forests
1.3.1. Fresh water swamp forests
1.3.2. Mangrove swamp forests
1.4. Beach Forests
2. Deciduous forests
2.1. Mixed deciduous forests
2.1.1. Moist upper mixed deciduous forests
2.1.2. Dry upper mixed deciduous forests
2.1.3. Lower mixed deciduous forests
2.2. Dry dipterocarp forests
2.3. Savanna forests.

Both of these classification systems represent the *physiognomic-ecological* approach of vegetation ecology, which is mainly based on the morphological characteristics of plants and the studies of the plant community. Formations, the principal units employed in this approach, are defined as ”plant communities that are dominated by one particular life form, and which recur on similar habitats” (Mueller-Dombois and Ellenberg 1974). Hierarchial systems with entities both above and below the formation level have also been constructed on the basis of these principles. However, it should be emphasized that the definitions for formations and other units used in such classifications may greatly differ according to the author or research tradition in question. Physiognomic-ecological vegetation studies have also been applied to vegetation mapping in locally restricted areas. Such a work has been presented by Küchler and Sawyer (1967) for northern Thailand.

When functional (instead of structural) characteristics of plant communities and the role of components of the ecosystem other than vegetation are emphasized, a somewhat different terminology may be applied to a hierarchial classification. For instance, the entire biosphere may be divided into mega-ecosystems (e.g. according to marine, limnic or terrestric conditions) and these in turn into macro-, meso-, micro- and nanoecosystems, the mesoecosystems being roughly parallel to the formation level (Ellenberg 1973). In principle, this classifivation also permits division down to the lowest level, for instance to individual forest stands. For tropical regions in particular, an attempt has also been made to apply this system to existing plant communities in various parts of the world (Brünig 1972, Tropical Forest Ecosystems 1978, p. 40).

In contrast to the physiognomic-ecological approach, which most often finds a practical application in larger plant community units, the *floristic-ecological* orientation (cf. Braun-Blanquet 1965) starts with the smallest units of the plant cover. Individual forest stands, as understood in forest management, often correspond to the basic entity of this classification, the *association*. Forest site types as developed in Finland by Cajander (1909) also represent the floristic-ecological research tradition, and the Finnish forest types can be understood as association types. The nearest analogies for the forest types usually applied in the tropics, including those available for Thailand in Smitinand's (1966) classification, are thus not to be found among the association types (e.g. Finnish forest site types) but on a higher organisational level corresponding to biocenose complex types or alliance types (*kasvustoyhdistymätyyppi* in Finnish) of the floristic-ecological classification systems.

A close interrelationship between environmental factors and the vegetation is already implied in Cajander's forest site type classification, although the plant cover characteristics are used as the main classification criteria. In contrast, in systematizing the plant communities on a worldwide scale the environmental characteristics often become decisive. In extreme cases, climatic data alone may be used for the delimitation of plant communities of different levels. This kind of approach often also aims at the classification of whole ecosystems instead of plant communities alone. Vegetation zones and biomes (cf. Walter 1973, 1977), biogeoclimatic zones (Krajina 1960, 1965) and Holdridge's life zones (cf. Holdridge et al. 1971) are examples of this approach in phytosociology (for details cf. Mueller-Dombois and Ellenberg 1974). It should be mentioned here that the delimitation of vegetation zones within the boreal and temperate regions has already lead to detailed classification systems which not only take into account the north-south variation in macroclimate, but also the altitudinal variation and other climatic factors. The work carried out in this field by Finnish researchers has also included the definition of vegetation zones and subzones in eastern Asia, but unfortunately not yet in the tropical regions (Hämet-Ahti et al. 1974).

1.3. Shifting cultivation

Ecological investigations on pine forests in Thailand have mainly involved studies in watershed areas. Natural pine stands and other mountain forests which are often less productive and less attractive for direct industrial exploitation, may be ecologically important in the conservation and regulation of water resources (Komkris 1969). Such an impact may have considerable significance far beyond the area where these forests are located. Effects of stand density have also been studied by Ruangpanit (1971) who found, for instance, that surface run-off and erosion in pine forests distinctly increases as soon as the stand closure decreases to less than 70 %.

Shifting (swidden) cultivation is a common form of land use in watershed areas of northern Thailand, being practised by the ”hill tribe” population in particular. The social structure and tradition of shifting cultivators, as well as the ecological consequences of various forms of land use, have received considerable attention, and some comprehensive treatises are already available (Kunstadter et al 1978; cf. also Sarmela 1979). According to the literature (Kunstadter 1970, Kunstadter and Chapman 1970, Smitinand 1970), shifting cultivation in the northwestern highlands of Thailand occurs over a wide altitudinal range. Shifting cultivators are divided into distinct ethnic groups which have each adapted their own tradition of shifting cultivation to a particular ecological environ-

Fig. 1. General view of the mixed pine and broadleaved forest at Khun Tan (classified as dry dipterocarp type) where *Pinus kesiya* and *P. merkusii* occurred near each other.
Kuva 1. Yleisnäkymä mänty-lehtipuusekametsästä Khun Tanin (kuivaksi dipterokarpustyypiksi luokitellulla) tutkimusalueella, jolla Pinus kesiya ja P. merkusii esiintyivät lähekkäisissä metsiköissä.
Photo: S. Bhumibhamon

ment. For instance, higher elevations (lower montane forests above 1000 m) are dominated by maize and opium cultivation by the Yao, Hmong (Meo) and Lahu tribes, whereas the Karen and Lua' tribes subsist on rice and cotton cultivation in the dry evergreen forests at lower elevation.

In addition, shifting cultivation is also common among northern Thais, often as a supplement to "normal" irrigated agriculture, on forested marginal lands along the valleys and foothills for growing both rice and cashcrops, such as cassava.

The lengths of the cultivation and fallow cycles vary according to ethnic group, crop plants and the relationship between population pressure and land availability. Investigations have shown that one year of field crops combined with ten years or more of fallow for a particular swidden lot (as traditionally done by the Karen and Lua' swidden farmers) ensures a soil nutrient level which is sufficient for maintaining the productivity of the land (Kunstadter et al. 1978). Uncontrolled population growth has, however, lead to a continuous increase in shifting cultivation and to a corresponding decrease in the forested area, not only in the northern mountain areas but practically over the whole country and among the Thai population as well. As a result, the forest area of Thailand has decreased from 60 to 32 % during the last 30 years (Thammincha 1980). The present annual decrease in the forest area for the whole country is estimated as half a million ha.

In addition to the expansion of shifting cultivation (which is now spreading through the last forested watershed areas) and associated cutting and burning, grazing of cattle (buffaloes and cows) also increases the frequency of prescribed or accidental forest fires. Especially in pine forests, which are often too infertile for shifting cultivation of agricultural crops, fires aimed at stimulating grass growth seem to restrict the regeneration of many forest trees, including the pines (Khemnark et al. 1972).

1.4. Management of pine forests

Despite the limited utilization of pine forests in forest management in Thailand, some recommendations for silvicultural practices have been given (Khemnark et al. 1972). For instance, if such stands are to be cut, care must be taken to avoid too large clear-cut areas and to facilitate natural regeneration. Regeneration of dipterocarps from stump sprouts and complementary planting of pines in the openings has been suggested as one possibility. On poor soils, the establishment of pine stands using planting only seems to be too expensive. Suitable methods for improving the natural regeneration of pines would therefore also find a practical application in watershed areas.

Earlier investigations on the regeneration of *P. kesiya* and *P. merkusii* forests are based primarily on sporadic observations rather than on planned experiments. In the Philippines, Lizardo (1954, 1955) has described the regeneration pattern of natural *P. kesiya* forests. Pine forests have also been studied in Vietnam by Champsoloix (1958). A summary of the silvicultural characteristics of *P. merkusii* throughout the whole of South-East Asia is also available (Cooling 1968), as well as an extensive literature review on *P. kesiya* as a forest tree (Armitage and Burley 1980).

1.5. Aim of the study

The aim of the present work was to clarify the structure of selected natural *P. kesiya* and *P. merkusii* stands, with particular attention on the amount and quality of naturally-occurring seedlings and young trees in these stands. In addition, an attempt was made to study the seed germination and seedling emergence in relation to germination conditions using *in situ* sowing experiments. Furthermore, basic information required in the management of pine stands in watershed areas of northern Thailand and in the planning of more detailed further investigations was obtained.

2. NATURAL STANDS AND THEIR REGENERATION

21. Study sites

211. Mae Sot

Mae Sot Village is located in Tak Province, close to the Burmese border (cf. Fig. 2 which illustrates the location of all study sites). The study site (16°45' N., 98°49'E., elevation 450 m) was at a distance of 44 km from Tak on the road leading to Mae Sot. The stands growing on this site were mostly classified as dry dipterocarp forest and the highest places in particular had a sparse admixture of *P. merkusii*. Teak (a characteristic component of the mixed deciduous forests) and pine were occasionally found growing relatively close to each other but they never occurred within the same stand, however.

Soils of the pine stands were mostly red and lateritic. The area was difficult to traverse because of the varying relief of the terrain. Visible signs of soil erosion, caused by the steepness of slopes, were also common. The slope in the study stand had a 40 to 60 % inclination towards the northwest.

212. Doi Pui

In the immediate vicinity of Chiangmai, on the western side of the city, the peaks of Doi Suthep and Doi Pui Mountains reach an altitude of more than 1600 m. The experimental plots in this locality (18° 46' N., 98°58'E.) had an elevation between 1500 and 1600 m.

The forests in the Doi Pui are mainly represented by the hill evergreen type, with *Castanopsis*, *Lithocarpus* and *Quercus* as typical tree genera. Single *P. kesiya* trees were observed from 1100 m upwards. The large variation in the vegetation cover was caused by the considerable differences in elevation. *P. merkusii* also occurred on the driest sites, mostly together with various dipterocarps. The study stand in this locality was growing on a SE slope (inclination of about 50 %).

213. Doi Inthanon

Doi Inthanon, the highest mountain in Thailand (2595 m), is located about 70 km SW of Chiangmai. The vegetation of the mountain area (which is protected as a national park) changes from mixed deciduous forests along the lower slopes to dry dipterocarp and finally to hill evergreen forest. Near the summit, the vegetation consists of unique humid (subtropical) evergreen forests with a rich epiphytic vegetation. Of the pines, *P. kesiya* occurs from an elevation of 800 m upwards, partly in mixed stands with evergreen oaks, partly also in pure stands.

The investigated stand (18°41' N., 98°27'

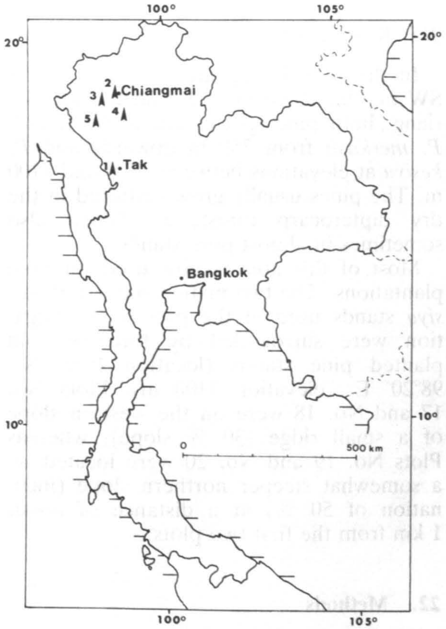

Fig. 2. Location of study sites in northern Thailand. (1) Mae Sot, (2) Doi Pui, (3) Doi Inthanon, (4) Khun Tan, (5) Baw Luang.

Kuva 2. Tutkimusalueiden sijainti Pohjois-Thaimaassa. (1) Mae Sot, (2) Doi Pui, (3) Doi Inthanon, (4) Khun Tan, (5) Baw Luang.

E., elevation ca. 1000 m) was a permanently marked seed collection stand lying on a small ridge. The average inclination of the slope was estimated as 30 %.

214. Khun Tan

Khun Tan National Park is situated in Lampun Province. Both pine species are found on the mountain Doi Khun Tan, *P. merkusii* as an admixture in the open dipterocarp forests on the lower slopes, and *P. kesiya* at somewhat higher elevations on drier sites. These pine species are found close to each other and presumably sometimes within the same stands.

The selected site (17°21' N., 90°20' E., elevation 700 m) included one plot in a *P. merkusii* stand and three plots at a distance of about 300 m from the first one, in a *P. kesiya* stand. The terrain was quite rough, the average inclination of the slope being estimated as 40 % for the four plots.

215. Baw Luang

In the Baw Luang area, about 130 km SW of Chiengmai on the road to Mae Sariang, both pine species are to be found: *P. merkusii* from 750 m upwards and *P. kesiya* at elevations between 1000 and 1100 m. The pines usually grow scattered in the dry dipterocarp forest, *P. kesiya* also sometimes in almost pure stands.

Most of this area is now used for pine plantations. The two mature natural *P. kesiya* stands used in the present investigation were surrounded by three-year-old planted pine stands (location 18°9' N., 98°20' E., elevation 1100 m). Plots No. 17 and No. 18 were on the western slope of a small ridge (30 % slope), whereas Plots No. 19 and No. 20 were located on a somewhat steeper northern slope (inclination of 50 %) at a distance of about 1 km from the first two plots.

22. Methods

Sampling by non-permanent plots was used for clarifying the structure and natural regeneration of pine stands. The selection of the plots was based on list of seed collection stands (Wisupakan 1979). Quite frequently, difficulties were met in finding the listed stands. Therefore, the selection of stands was largely based on their accessibility through existing roads. In each selected stand, the plots were placed subjectively within the area of highest pine density (in mixed pine-broadleaved stands) or, alternatively, within the most representative part of the stand as far as the stand structure was concerned (pure pine stands). The measurements were carried out between September and December in 1979.

Sample plots were rectangular in shape, 20 m x 40 m in size. On each of the five localities, four plots were measured either in one stand or in separate stands situated near to each other. The plot boundaries were determined using a 20-m measuring tape and temporarily marked with plastic ribbons.

The forest type was determined according to the classification developed by Smitinand (1966), using the tree species composition and general physiognomy of the vegetation as guidelines.

All measurements were made on pines only; observations on other species were limited to a separate stem count for each broadleaved species. The height of the pine trees was determined using a Haga hypsometer, except for the shortest stems which were measured with the aid of a scaled bamboo stick, 6 m in length. Seedlings and young trees up to a height of 2 m were divided into height classes as follows: (1) 0–10 cm, (2) 11–20 cm, (3) 21–50 cm, (4) 51–100 cm, (5) 101–150 cm, (6) 151–200 cm, and (7) 2–10 m. The frequency of trees in each of these classes was determined.

The stem diameter of all pines more than 2 m in height was measured at breast height in two directions. Bark thickness was also determined using the conventional bark measuring device; however, in old trees the bark had to be shaved off with a knife before this measurement could be made.

Each plot was mapped by making a drawing which indicated the position of all trees on the plot. Projections of the tree crowns were drawn with the aid of two perpendicular measurements of crown pro-

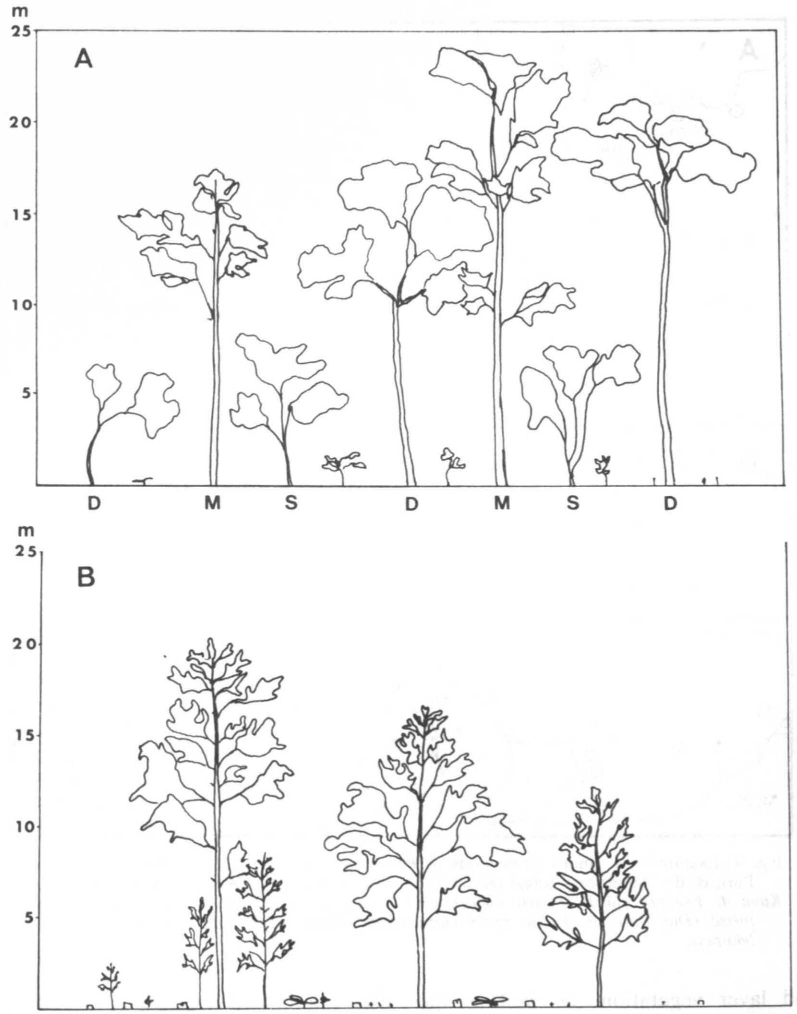

Fig. 3. Examples on stand profiles of pine forests. A, *P. merkusii*, dry dipterocarp forest (Mae Sot); B, *P. kesiya* dry dipterocarp forest (Baw Luang, thinned). Tree species is indicated as follows: D, *Dipterocarpus tuberculatus*; K, *P. kesiya*; M, *P. merkusii*; S, *Shorea obtusa*.

Kuva 3. Esimerkkejä männiköiden metsikköprofiileista. A. P. merkusii, kuiva dipterokarpusmetsä (Mae Sot); B, P. kesiya, kuiva dipterokarpusmetsä (Baw Luang, harvennettu). Puulajit on merkitty seuraavasti: D, Dipterocarpus tuberculatus; K, P. kesiya; M, P. merkusii; S, Shorea obtusa.

jection width (outer limits were estimated ocularly). Pine crown profiles were also drawn horizontailly for each plot (cf. Figs. 3 and 4). This mapping and drawing work also included a determination of slope direction and inclination.

Detailed vegetation analyses were not carried out. Instead, the coverage of the

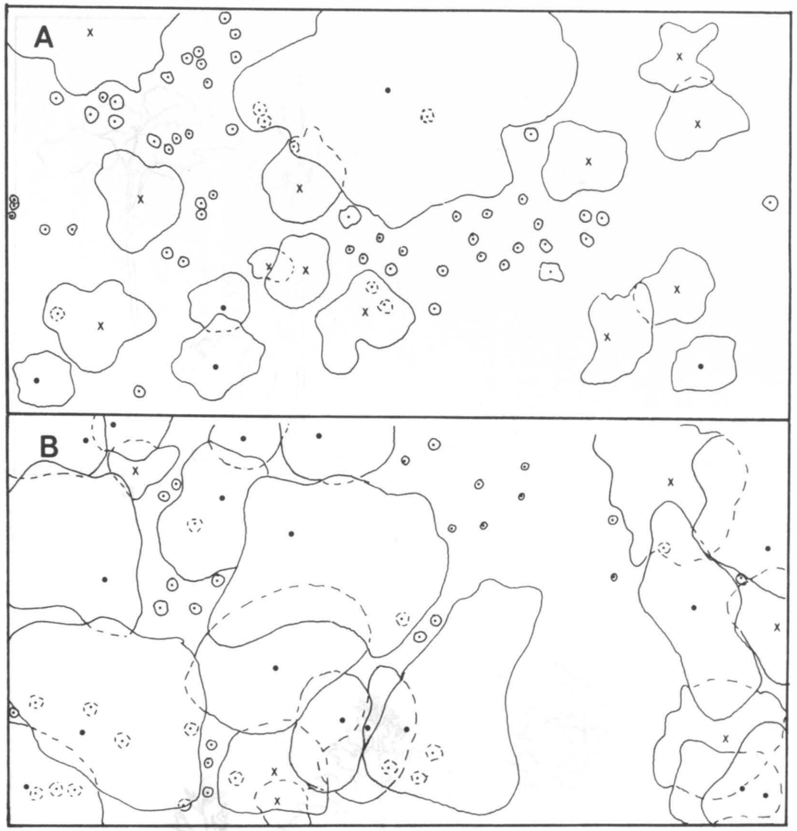

Fig. 4. Examples on canopy projections of *P. kesiya* stands. A, hill evergreen forest (Doi Pui); B, dry dipterocarp forest (Khun Tan). Species notations: (•) pine, (x) broadleaved.
Kuva 4. Esimerkkejä P. kesiya -metsiköiden latvusprojektioista. A, vuoriston ainavihanta metsä (Doi Pui); B, kuiva dipterokarpusmetsä (Khun Tan). Puulajit: (•) mänty, (x) lehtipuu.

ground layer vegetation, as well as the canopy closure, were estimated ocularly. Damage to trees and cone production were also recorded.

23. Results

231. Forest type

The pine stand in *Mae Sot* was determined as dry dipterocarp forest. *P. merkusii* comprised less than 5 % of the stems, most of which belonged to various species of the Dipterocarpaceae family. Table 1 lists the broadleaved trees found at this locality as well as on the other study sites.

The ground layer consisted mainly of grasses, *Imperata cylindrica* being the most conspicuous. *Carex* species and ferns were also common. The total coverage of the ground layer was about 50 %.

The experimental stand on *Doi Pui* Mountain was clearly different from the one mentioned above. *P. kesiya* was the dominant species here, broadleaved species representing only 20 % of the total number of stems. The general physiognomy of this stand was also less xerophy-

Table 1. Number of stems of broadleaved tree species (>2 m in height) found on sample plots No. 1–16. Plot size 800 m^2.
Taulukko 1. Lehtipuiden runkojen (> 2 m) lukumäärä koealoilla n:o 1–16. Koealakoko 800 m^2.

Species *Puulaji*	Mae Sot 1	 2	 3	 4	 Σ	Doi Pui 5	 6	 7	 8	 Σ	Doi Inthanon 9	 10	 11	 12	 Σ	Khun Tan 13	 14	 15	 16	 Σ
Antidesma sp.	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—
Careya arborea Roxb.	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Castanopsis acuminatissima (Bl.) A.D.C.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—
Castanopsis indica A.D.C.	—	—	—	—	—	—	3	3	—	6	—	—	1	2	3	—	—	—	—	—
Dalbergia cultrata Grah.	—	—	—	—	—	11	3	3	6	23	1	--	4	—	5	—	1	—	2	3
Dipterocarpus obtusifolius Teysm.	2	2	7	—	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
D. tuberculatus Roxb.	—	30	32	3	65	—	—	—	—	—	—	—	—	—	—	6	2	—	8	16
Garcinia speciosa Wall.	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—
Helicia javanica Blume	—	—	—	—	—	—	—	—	4	4	—	1	—	1	2	—	—	—	—	—
Melanorrhoea usitata Wall.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—
Pentacme suavis A.D.C.	3	3	6	10	22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phyllanthus emblica L.	—	1	—	2	3	9	4	4	7	24	—	1	—	—	1	—	—	2	—	2
Protium serratum Engler	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—
Quercus brandigiana Kurz	—	—	—	—	—	—	—	—	—	—	—	2	—	—	2	—	—	—	—	—
Q. indica Kurz	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	2
Quercus sp.	—	1	1	—	2	2	—	—	4	6	1	1	1	8	11	—	—	—	2	2
Schima wallichii Choisy	—	—	—	—	—	—	—	—	—	—	3	2	3	4	12	—	—	—	—	—
Shorea obtusa Wall.	7	48	18	33	106	—	—	—	—	—	—	—	—	—	—	1	4	4	—	9
S. robusta Gaertn. f.	7	—	—	—	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Styrax benzoin Dryand.	—	—	—	—	—	—	—	—	1	1	—	—	2	1	3	—	—	—	—	—
Ternstroemia japonica Thunb.	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—
Wendlandia paniculata A.D.C.	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—
Others – *Muut*	—	4	8	3	15	2	3	3	—	8	—	—	1	—	1	3	—	—	3	6
Total – *Yhteensä*	19	89	72	52	232	24	13	13	22	72	5	7	16	19	47	10	7	8	15	40
Stems/ha – *Runkoluku/ha*	237	1112	900	650	725	300	162	162	275	225	62	87	200	237	147	125	87	100	187	125

tic, which led to its classification as hill evergreen forest. On Doi Pui the ground layer was sparse, having a coverage of 30 % (except for Plots No. 6 and No. 7, where the stand density was distinctly lower and the ground layer coverage reached 60 %). Sedges were common in the ground layer, whereas grasses occurred sparsely.

The study stand on *Doi Inthanon* also represented the hill evergreen type. *P. kesiya* accounted for about 40 % of the total number of stems, but more than half of the total timber volume. The number of broadleaved species was exceptionally high in this stand (cf. Table 1). The ground layer was sparse and consisted mostly of herbs, which had a total coverage of about 20 %. However, on Plots No. 9 and No. 10 a somewhat higher ground layer coverage was found, grasses also occurring on these plots.

The stands investigated in the *Khun Tan* National Park exhibited characteristics of both hill evergreen and dry diprerocarp forest. Oaks (*Quercus* spp.), for instance indicated a resemblance to the former type. However, the predominance of grasses (e.g. *Imperata cylindrica*), the dryness of the soil, and the frequent occurrence of such broadleaved tree species as *Dipterocarpus tuberculatus* and *Shorea obtusa* in

Table 2. Number of pine seedlings (height classes 1-6), young pines (2-10 m, height class 7), and mature pines (>10 m, height class 8) on sample plots at different localities (n); for young and mature pines, mean height (h), breast-height diameter (d), and bark thickness (b) are also indicated. Plot size 800 m^2.
Taulukko 2. Männyntaimien (pituusluokat 1-6), nuorten mäntyjen (2-10 m, pituusluokka 7) ja varttuneiden mäntyjen (>10 m, pituusluokka 8) lukumäärä (n) sekä nuorten ja varttuneiden mäntyjen keskipituus (h), rinnankorkeusläpimitta (d) ja kuoren paksuus (b) koealoittain eri tutkimusalueilla. Koealakoko 800 m^2.

Locality and pine species *Tutkimus-alue ja mäntylaji*	Plot No. *Koe-alan no*	Height class — *Pituusluokka*													
		1	2	3	4	5	6	7				8			
		Number of seedlings (n) *Taimien lukumäärä (n)*						n	h m	d cm	b mm	n	h m	d cm	b mm
Mae Sot *P. merkusii*	1	4	—	—	—	—	—	—	—	—	—	4	21.3	38	22
	2	—	—	—	—	—	—	—	—	—	—	2	19.3	50	29
	3	—	—	—	—	—	—	—	—	—	—	2	26.5	51	30
	4	—	—	—	—	—	—	—	—	—	—	3	18.3	34	23
	x̄	1.0	—	—	—	—	—	—	—	—	—	2.8	21.0	41	25
Doi Pui *P. kesiya*	5	—	1	8	2	3	2	57	6.2	8.8	8	1	26.0	66	16
	6	2	20	38	20	2	1	4	5.8	10.6	12	1	24.0	48	16
	7	5	4	21	10	2	1	2	3.4	6.2	5	—	—	—	—
	8	—	—	1	—	1	2	196	6.3	7.0	8	3	29.0	56	24
	x̄	1.8	6.3	17	8.0	2.0	1.5	65	6.2	7.4	8.3	1.3	27.4	56	21
Doi Inthanon *P. kesiya*	9	8	1	1	—	—	—	—	—	—	—	12	28.3	44	21
	10	8	4	—	—	—	—	—	—	—	—	9	28.1	42	21
	11	4	—	—	—	—	—	—	—	—	—	8	30.0	52	21
	12	4	—	—	—	—	—	—	—	—	—	4	29.5	46	22
	x̄	6.0	1.3	0.3	—	—	—	—	—	—	—	8.3	28.8	46	21
Khun Tan *P. merkusii*	13	2	—	—	—	—	—	—	—	—	—	4	18.0	37	24
Khun Tan *P. kesiya*	14	39	—	—	—	—	—	—	—	—	—	17	21.1	29	16
	15	81	—	—	—	—	—	—	—	—	—	10	22.4	27	16
	16	39	—	—	—	—	—	—	—	—	—	21	23.2	31	21
	x̄	52	—	—	—	—	—	—	—	—	—	15	22.3	30	18
Baw Luang *P. kesiya*	17	29	—	2	—	—	2	9	7.1	13	13	5	14.7	29	21
	18	38	5	15	8	4	2	11	5.9	7	10	7	13.2	23	19
	19	95	61	7	—	—	—	—	—	—	—	12	21.4	39	23
	20	54	33	2	—	—	—	—	—	—	—	5	15.2	30	23
	x̄	54	25	6.5	2.0	1.0	1.0	5.0	6.4	10	11	7.3	17.2	32	21

the stands led to the classification of all plots in this locality as dry dipterocarp forest. The ground layer coverage was 70 % on an average. Erosion (caused by the rough relief) had led to a patchy distribution of the ground layer, which mainly consisted of grasses.

The pine species on Plot No. 13 was *P. merkusii*. The proportion of pine stems on this plot was about 25 %. In contrast, only *P. kesiya* was found on the rest of the Khun Tan plots, which were also clearly dominated by pines (60 % of the total stem number were pines).

The two stands at *Baw Luang* were both of the dry dipterocarp type. Only in this locality were the sample plots established in stands where selective cutting had been carried out. All other trees, apart from *P. kesiya* had been removed in this cutting. Broadleaved trees of the shrub layer (including stump sprouts) had been left intact on Plot 18, however. The ground layer consisted mainly of grasses and herbs and had a coverage of 30 to 40 % on Plots No. 17 and No. 18, and about 80 % on Plots No. 19 and 20.

232. Stand structure

The experimental stands showed a considerable variation in stand structure, as can be seen from Table 2. The table shows the distribution of pine stems according to height class for each plot separately, as well as at each location on an average. At three locations (Mae Sot, Doi Inthanon, and Khun Tan), only mature trees and occasional young seedlings were found, the intermediary height classes being totally absent in these stands. *P. merkusii* (found only at Mae Sot and Khun Tan) formed sparse stands only, but *P. kesiya* also grew in dense or, as the result of removal of broadleaved trees (Baw Luang), pure stands. The canopy closure varied considerably, from almost open stands to 80 % closure. As a rule, however, the pines were always taller than the broadleaved species, regardless of stand density.

233. Occurrence of seedlings and young trees

The experimental stands varied distinctly as far as the amount of regrowth was concerned. Natural regeneration was evident, however, in all stands, although not in all sample plots. The smallest number of seedlings and young trees was found in both of the *P. merkusii* stands. At Mae Sot, regrowth was present on one plot only, where the four seedlings found were all growing around a single seed tree. At Khun Tan, the only plot representing this species also indicated an extremely low regeneration rate (only two seedlings were observed).

As a whole, the number of seedlings and young trees in the *P. kesiya* stands was somewhat greater. Table 3 illustrates the relationship between "seed trees" (pine stems more than 10 m in height) and young trees and emerging seedlings, and

Table 3. Average densities of seed trees, (>10 m h), young regrowth and emerging seedlings in pine stands at different study sites.
Taulukko 3. Männiköiden siementävän puuston (>10 m h), nuorten puiden ja pikkutaimien keskimääräinen tiheys eri tutkimusalueilla.

Locality *Alue*	*P. merkusii*			*P. kesiya*		
	Mature trees *Siemenpuita*	Young trees and seedlings *Nuoria puita ja taimia*		Mature trees *Siemenpuita*	Young trees and seedlings *Nuoria puita ja taimia*	
	n/ha	n/ha	<10 cm,%	n/ha	n/ha	<10 cm,%
Mae Sot	34	12	100	—	—	—
Doi Pui	—	—	—	16	1297	2
Doi Inthanon	—	—	—	106	81	80
Khun Tan	50	25	100	200	663	100
Baw Luang	—	—	—	91	1178	43

shows the number of trees per hectare in both groups. The percentages of small seedlings (less than 10 cm in height, corresponding to an age of less than two years) is given separately in this table for each locality.

The results also show that only the *P. kesiya* seedlings on Doi Pui and at Baw Luang represented stabilized regrowth. At the rest of the localities nearly all the seedlings could be regarded as ephemeral. However, in the *P. kesiya* stand at Khun Tan, too, the number of seedlings was high, although all seedlings belonged to the <10 cm size class.

The stand which showed the highest number of seedlings (Doi Pui, about 1300 seedlings/ha) had a surprisingly sparse seed tree canopy. All seed trees at this locality bore an abundant crop of maturing cones. Except for the *P. merkusii* stand at Mae Sot, cones were also observed in all remaining experimental stands.

In denser stands, such as the Khun Tan *P. kesiya* stand, the seedlings tended to occur more abundantly in canopy openings. The low number of seedlings on Doi Inthanon was associated with a high canopy closure percentage (pine and broadleaved trees together amounted to a 70–80 % closure and, in addition, the intermediary shrub layer added to the high degree of light interception). As a result, the ground layer was also less vigorous in this stand.

The low density of mature *P. merkusii* stems at Mae Sot was compensated for by an abundance of broadleaved trees. The broadleaved species (mostly *Dipterocarpus* spp.) amounted to more than 700 stems/ha, which increased the total canopy closure to more than 50 %. The broadleaved trees had a relatively small impact on pine regrowth, since young pines and broadleaved trees mostly occurred in the same intermediary canopy layer (an obvious exception was Plot No. 5, in which young pines were to some extent overshadowed by hardwoods). The removal of broadleaved trees at Baw Luang had decreased the canopy closure to 30–50 %; this situation was clearly associated with a high seedling density.

No straight-forward relationships were found between seedling density and ground layer vegetation on the basis of the numerical results. However, in most experimental stands, a higher density of pine seedlings was often observed in places where the mineral soil had been exposed, as compared to patches of dense ground layer vegetation.

234. Damage in pines

Except for the stand at Khun Tan and Plots No. 17, 18 and 20 at Baw Luang, direct damage on stems, caused by man, was observed on all sample plots. Many stems had been pared down to more than half of the diameter in order to obtain kindling to be used in cooking stoves. In many of the stands, although not in the sample plots, pine stems had been felled and left more or less intact on the ground. This practice was also observed in the seed collection stand and some selected plus trees (*P. kesiya*) in the Doi Inthanon National Park.

No insect damage was observed on the sample plots. In a mixed *P. merkusii* – dipterocarp stand near Baw Luang (Huey Bong), however, green cones, about one-year-old, were found to have dropped prematurely. Damage caused by unidentified insects was also present in these cones.

On Doi Pui (Plot. No. 8) some young pines had obviously died as a result of the high density of the stand. In this stand mistletoe (species not determined) was also observed on two mature *P. kesiya* trees; however, no detrimental effects of this parasite were visible.

235. Effect of fire

Each experimental stand showed singns of fire. The base of pine stems was blackened, often charred, up to a height of 1 to 2 m. The growth of mature trees did not seem to be affected by fire, except in cases where the stem base had been pared by man. No signs of canopy fire were observed.

P. merkusii stems at Mae Sot had the most severe man-made stem damage; consequently, fire had aggravated this effect more than in the remaining stands. The resinous wood at the base of the pared stem seems to catch fire easily and burn to some extent during each successive fire. On Doi Pui, the mature *P. kesiya* trees had suffered from fire only slightly (the most recent burn scars were estimated to have been caused by a fire two years earlier). The old pine regrowth (with a height of 5 m or more) also seemed to have developed a bark layer thick enough to prevent fire damage. However, a few young seedlings killed by the fire were still visible in this stand.

The vigour of the ground layer seemed to have decreased as a result of fire at Huey Bong (not far from the study stand at Baw Luang), in the exceptionally xerophytic *P. merkusii* – dipterocarp stand. Patches of mineral soil had been exposed and a number of seedlings (less than one year old) were found in these places. The high number of seedlings on the actual study plots at Baw Luang was thus interpreted as indicating that there had been no fires during the past few years. These plots had also been protected by intensified fire control because of the near-by pine plantations.

Fig. 5. An exceptionally dense young stand of *Pinus kesiya* on Doi Pui (Plot No. 8).
Kuva 5. Poikkeuksellisen tiheä nuori Pinus kesiya -metsikkö Doi Puin tutkimusalueella (koeala n:o 8).
Photo: M. Siltanen

3. SOWING EXPERIMENTS

31. Material and methods

Seed of *P. kesiya* and *P. merkusii* was supplied by the Huey Geow Seed Center at Chiangmai. *P. kesiya* seeds originated from Baw Luang (near Hod, Chiangmai Province; 18°9' N., 98°20'E., elevation 1100 m). The seed had been collected in December, 1977, and a cutting test indicated the viability as 86 %. *P. merkusii* seeds were collected from Om Koi, Chiangmai Province (17°52' N., 98°17'E.) in April, 1976; the cutting-test viability for these seeds was 95 %.

The experimental site, Huey Bong, was about 12 km NE of Baw Luang, at an elevation of 900 m. The dry dipterocarp forest at this site also had an admixture of *P. merkusii.* Among the broadleaved species, *Dipterocarpus tuberculatus* was the most common, followed by *Shorea obtusa.* Stand density was about 100 stems/ha, the canopy closure reaching 50 to 60 %. The mean height of the dipterocarps was about 15 m, whereas the pines were considerably taller (about 25 m). The ground layer (coverage 70 %) consisted of grasses, *Carex* species and xerophytic herbs.

Half of the experimental plots were established in a small clearing, where the ground layer coverage was approximately 50 % and the mineral soil exposed in many places. The soil surface was hard-packed and dry since much of the humus had been destroyed by fire. The ground layer vegetation consisted of the same species as found under the canopy, although the grasses, sedges and herbs were more stunted in growth. Small seedlings of *Dipterocarpus tuberculatus* and *Shorea obtusa* were also found among the ground layer vegetation.

The regeneration method consisted of sowing pine seeds on untreated as well as on prepared soil. Ten 120 cm x 60 cm blocks were established under the canopy and ten similar-sized blocks in the clearing. Eight 30 cm x 30 cm square plots were marked out within each block. Every second of these plots was prepared by turning the topsoil with a spade. 100 seeds of either *P. kesiya* or *P. merkusii* were sown on each plot. Since both pine species were sown on five blocks under the canopy as well as in the clearing, the total number of seeds used was 8000 for *P. kesiya* and 8000 for *P. merkusii.*

After soaking in water for 36 hours, the seeds were sown on 19 October 1979. Thereafter, germination was checked daily over a period of 25 days by counting the emerged seedlings (those having a hypocotyle length at least three times the seed length). Damage to seeds and seedlings was also recorded during the observation period.

Meteorological data were collected at Baw Luang Pine Plantation, at a distance of 12 km from the site of sowing experiments, using a rain gauge and a thermohygrograph. The thermohygrograph was placed on the ground (at 1100 m elevation) in a stand similar to that used in the actual experiment and shielded against direct sunlight.

32. Results

321. Weather conditions

The sowing experiment was carried out between 19 October and 14 November 1979, immediately after the end of the rainy season. The soil moisture content was therefore still relatively high during the course of the experiment. Precipitation had been about 20 % below average, however, during the last weeks of the rainy season. In the course of the first half of October the total precipitation was 213 mm. During the sowing experiment, precipitation occurred on three days only (totalling 13 mm).

The daily mean minimum and maximum temperatures during the course of the experiment were 15.2 and 28.1°C respectively. Figure 6 shows the daily maximum and minimum temperatures during the whole period, as well as the precipitation records.

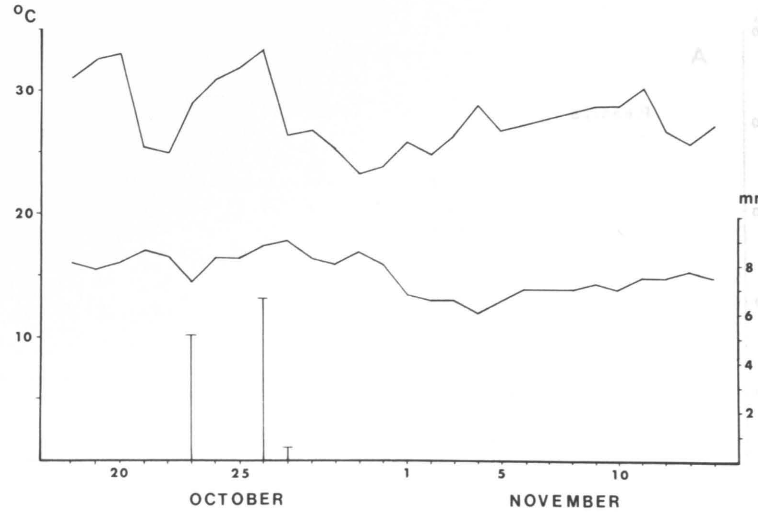

Fig. 6. Daily maximum and minimum temperatures (°C, upper and lower curves respectively) and precipitation (mm, vertical bars) at Baw Luang during the sowing experiments.
Kuva 6. Päivittäiset maksimi- ja minimilämpötilat (°C, ylempi ja alempi käyrä) ja sademäärä (mm, pystyjanat) Baw Luangissa kylvökokeen aikana.

322. Germination of P. kesiya seeds

Emerged *P. kesiya* seedlings were first observed on the eight day after sowing. By the tenth day, the largest seedlings had reached a height of 2 cm and the first needles were visible. By the 14th day when the tallest seedlings were 5 cm in height, the first empty seed coats had been shed (cumulative germination percentages are shown in Fig. 7).

On the plots shaded against the afternoon sun by the tree canopy, the largest number of new emerging seedlings was recorded between the 9th and the 14th day after sowing. After two weeks the germination percentage had reached 80 % on a number of plots. The maximum numbers of seedlings per plot were observed about three weeks after sowing. Soil preparation did not affect germination on plots situated under the tree canopy. The largest observed number of seedlings was 53 per plot, on an average, in the shaded plots, although considerable variation was found among the plots (somewhat larger variation was found in prepared plots as compared to untreated ones).

The germination percentage on the plots which were fully exposed to sunshine was distinctly lower than in the above-mentioned plots. In the exposed treatment group, the first seedlings emerged on the tenth day after sowing. The number of seedlings per plot began to decrease 16 days after sowing. On an average, the maximum number of seedlings per plot was 8 and 23 for prepared and untreated plots respectively. The individual variation among plots was considerable; for instance the maximum number of seedlings on prepared plots ranged from zero to 35 seedlings per plot.

An analysis of variance indicated that at 18 days from sowing (when most seeds had germinated and the decline in seedling number was not yet distinct) the lower germination percentage on prepared plots, fully exposed to the sun, differed statistically significantly from that on exposed untreated plots ($P<0.05$).

323. Germination of P. merkusii seeds

Seedlings of *P. merkusii* emerged about two days later than those of *P. kesiya:* the first seedlings were observed on the tenth day after sowing. The largest numbers of

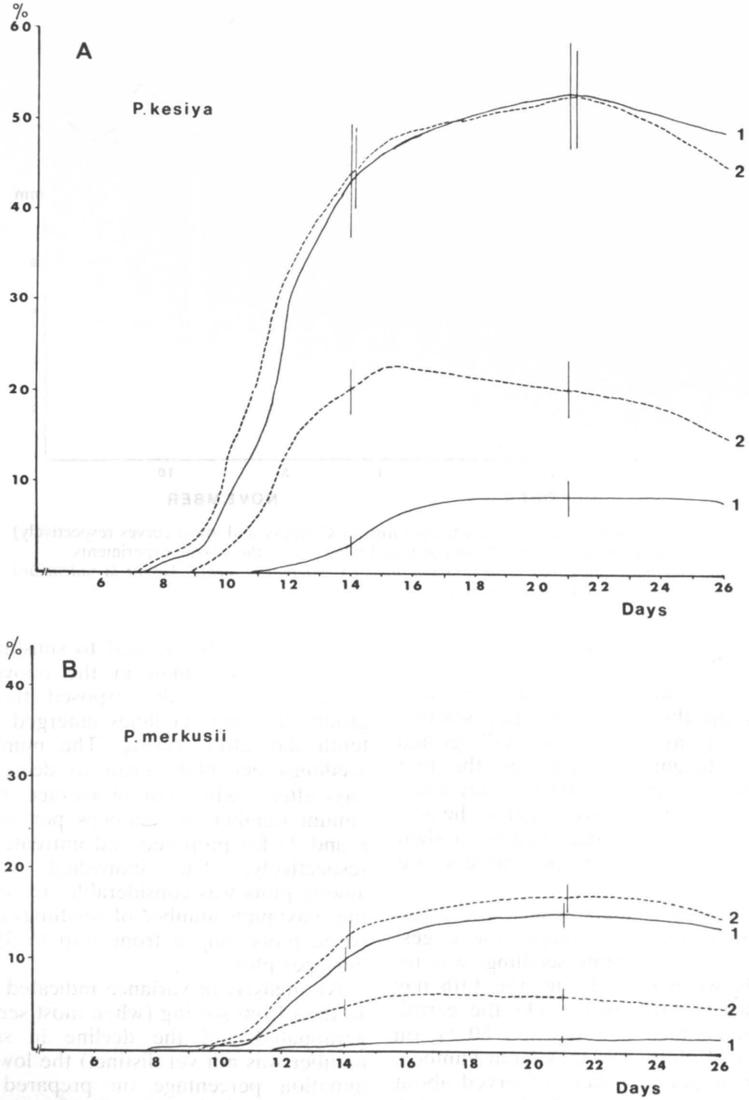

Fig. 7. Cumulative germination percentages of *P. kesiya* (A) and *P. merkusii* (B) seed as a function of time from sowing (days) under forest canopy (upper curves) and on exposed plots (lower curves). 1, after soil preparation; 2, on untreated soil. Vertical bars equal $\pm s_{\bar{x}}$.

Kuva 7. P. kesiyan (A) ja P. merkusiin (B) siementen kumulatiivinen itävyysprosentti kylvöhetkestä lasketun ajan (vrk) funktiona metsikön suojassa (ylemmät käyrät) ja aukealla (alemmat käyrät). 1, muokatulla maalla; 2, muokkaamattomalla maalla. Pystyjanoin on kuvattu $\pm s_{\bar{x}}$.

newly-emerged seedlings were found between the 11th and the 16th day. Three weeks after sowing the number of seedlings varied between 2 and 25 per plot on prepared soil and between 6 and 32 on untreated soil on the shaded plots. The mean germination percentages were 15 and 17 respectively. These differences were not statistically significant.

P. merkusii seeds germinated extremely poorly in the exposed clearing. Out of a total of 20 prepared plots, eight plots produced no seedlings. Newly-emerged seedlings were first observed on the 13th day after sowing. The largest number of seedlings on exposed, prepared plots was seven seedlings; the germination percentage was 1.4 % on an average.

Untreated, exposed plots showed the first signs of germination by the 11th day. Two weeks after sowing, only one plot out of 20 was without seedlings. The largest number of seedlings was found when the plots were inventoried on the 18th day; however, four empty plots were found at this check. The average germination percentage was 6 %. The difference between the number of emerged seedlings on prepared exposed and untreated exposed plots was statistically significant ($P<0.05$).

324. Damage to seeds and seedlings

Drought was the principal cause of the poor germination of the seeds in the sowing experiments, on the exposed plots in particular. Emerged seedlings were also frequently killed by desiccation. Between 9 November (three weeks after the beginning of the sowing experiment) and 14 November, a decrease in the number of seedlings was observed on nearly all the individual 30 cm x 30 cm plots. 18 % of the total number of *P. kesiya* seeds sown emerged but subsequently died off on exposed and 11 % on shaded plots during this period only. The corresponding percentages for *P. merkusii* seedlings were 11 % on exposed and 8 % on shaded plots.

Animals, such as rodents, birds and insects, obviously destroyed both seeds and emerged seedlings. The exact number of unaccounted seeds could not be determined, since an unattended buffalo herd, grazing on the experimental site on 27 October, mixed the topsoil to some extent, and the seeds became partly covered by mineral soil. It was estimated, however, that all seeds and seedlings on 17 *P. kesiya* plots and 29 *P. merkusii* plots (out of 80 plots for both species) were destroyed before the end of the observation period. Seed coats were often found, especially on *P. merkusii* plots, after the seeds had been eaten or carried away. Tracks and droppings indicated that small rodents had been active on the plots, although no seed-eating animals were seen in the area. However, pine seeds which were stored in the living quarters of the investigators, were readily eaten by rats (*Rattus* sp.).

Animal damage into emerged seedlings was observed as broken cotyledons and hypocotyles. At the end of the 26-day observation period, 1.6 % of the *P. kesiya* seedlings and 14.2 % of the *P. merkusii* seedlings remaining on the plots showed signs of damage by small animals.

4. DISCUSSION

41. Site requirements of P. kesiya and P. merkusii

P. kesiya and *P. merkusii* are found mostly on two different types of soil in northern Thailand. *P. merkusii* grows on poor, well-drained soils, usually together with rather xerophytic deciduous broadleaved tree species, such as *Dipterocarpus tuberculatus, D. obtusifolius, Pentacme suavis* and *Shorea obtusa*. These stands are often open, with a ground layer mostly consisting of grasses and sedges.

Pure *P. merkusii* stands are found in Thailand on sandstone rocks of the Phu Kradoeng Plateau near Loei (Cooling 1968). "Pine forests" as implied in the forest type classification used by several investigators (e.g. Samapuddhi 1955, Smitinand 1966) refer to these areas. In contrast, the *P. merkusii* stands of northwestern Thailand are mostly classified as dry dipterocarp forests, owing to the predominant broadleaved component.

P. kesiya, on the other hand, is also competitive on more mesic sites in association with evergreen hardwoods. Soils of such stands are podsolic, however, and not generally suitable for shifting agriculture (Holdridge et al. 1971). In the present investigation, *P. kesiya* was mostly accompanied by *Castanopsis indica, Quercus* spp., *Schima wallichii, Dalbergia cultrata* and *Phyllanthus emblica* in these stands (the two last-mentioned species being deciduous). The soil moisture content in such stands was also found to be distinctly higher as compared to the *P. merkusii* stands of the dry dipterocarp forests; this fact also contributed to the development of a ground layer consisting mainly of mesophytic herbs.

Of the localities used in the present study, the *P. kesiya* stands on Doi Pui and Doi Inthanon (both at an elevation of over 1000 m) were the most typical representatives of hill evergreen forests. The most distinct dry dipterocarp forest among the pine stands studied was that at Mae Sot (450 m a.s.l.), the last two experimental areas, Khun Tan (700 m) and Baw Luang (1100 m), showing characteristics of both of these forest types.

At Baw Luang, the gradient in forest type from dry dipterocarp to hill evergreen forest was clearly visible along the Chiangmai - Mae Sariang road between an elevation of 800 m to the highest point at Baw Luang (1100 m). The proportion of pines increased successively along this gradient, and *P. kesiya* replaced *P. merkusii* at the highest elevations. Pines which grow on dry sites generally seem to be more competitive on higher elevation; at lower elevations the broadleaved species are more predominant on these sites (J. Granhof, personal communication).

According to earlier investigations (e.g. Vidal 1960, Cooling 1968), *P. kesiya* often seems to be more competitive than *P. merkusii*. This variation may be to some extent caused by the differing climatic requirements of the two species: *P. merkusii* is a true tropical species and the only one of the genus *Pinus* having a natural range also south of the equator, whereas *P. kesiya* can be considered as a subtropical species.

The reason for the occurrence of *P. merkusii* in the highlands (at 700-900 m elevation), as well as near to sea level (elevation of 250 m in the Srisaket region), has primarily been attributed to edaphic factors (Cooling 1968). In any case, the relationship between the range of *P. merkusii* and the distribution of poor, podsolic soils is quite close.

Pines were found to exceed the broadleaved trees in height on all study sites used in the present investigation, in dry dipterocarp forests as well as in hill evergreen forests. Regardless of the less specific edaphic requirements of pines, it was clearly evident that the growth of pines (at least as far as *P. kesiya* was concerned) was distinctly better on more mesic sites. The pine stands of high quality on Doi Inthanon and Doi Pui offered a good example in this respect. Genetic factors may also have determined the quality of

the Doi Inthanon pine stands, since provenance trials (investigated by Pine Improvement Center) have shown the Doi Inthanon origin to exhibit the best growth rate and performance among various *P. kesiya* sources.

42. Fire as an ecological factor

Fire decisively determines the ecological conditions of pine forests in tropical and subtropical regions. Pines frequently occur as pioneer species, invading areas which have been deforested in connection with shifting agriculture or other practices. For instance, shifting cultivation in the Philippines affects the distribution of *P. kesiya* forests, by both destroying them and providing new areas for invading pines (Lizardo 1955). The relationship between shifting cultivation and the ecology of pine forests has also been investigated in connection with the *jhum* system of agriculture in the Khasi highlands of India: according to Troup (1921), the even-aged natural regrowth of *P. kesiya*, which invades fallow land after a couple of years of field crops, has regularly been cleared for agriculture after a period of seven to eight years.

Holdridge et al. (1971) did not find signs of recent shifting cultivation in *P. kesiya* or *P. merkusii* forests in Thailand in their investigation carried out on Doi Suthep (near the Doi Pui study site used in the present investigation). They attributed this to the low soil fertility of the pine forests. However, some traces of possible older shifting cultivation were observed in the earlier Doi Suthep investigation. The rapid leaching of the soil in dry dipterocarp forests which include *P. merkusii* and the poor suitability of these areas for shifting cultivation has also been emphasized by Khemnark et al. (1972).

Apart from shifting cultivation, burning also affects the forest ecosystem through natural or escaped fires. In the absence of fire, the succession of plant communities would proceed towards a denser and more mesophytic stand in the present open pine forests (Küchler and Sawyer 1967). The importance of broadleaved tree species would increase under such conditions in particular. Consequently, the regular fires stabilize the present situation in the pine stands by preventing natural succession. When fires are totally absent, pines would be found only on the very poorest soils.

Regular burning leads to continuous soil degradation. The main cause of soil degradation is the exposure of the mineral soil after fire and subsequent leaching and erosion. This process has been described in the Laotian highlands by a succession model (Vidal 1960). In this model, the hill evergreen forest (*forêt dense humide d'altitude)* develops after shifting cultivation towards the original composition through successional secondary forest stages. Repeated fires cause a decrease in the production potential of the site, which may eventually lead to savanna-like communities, to pine forest, and finally to open oak forest. Pines thus represent a crucial step in the forest succession on poor and degraded sites.

Fires occur almost every year in the northern Thai highlands. All the study sites examined in the present investigation also showed signs of recent burning. During the dry hot season between February and April, the ground layer is extremely dry and catches fire easily. The fires are man-made almost without exception. The local population starts the fires in order to stimulate the growth of grasses on grazing lands at the end of the dry season, as well as for crop planting and hunting purposes. In dry dipterocarp forests, the ground layer vegetation, when burned, already begins to develop before the onset of the rains. Shedding of leaves and sprouting of new leaves and flowers by many deciduous tree species is also accelerated by fire (Vidal 1966, Küchler and Sawyer 1967). Young leaves are also needed for many purposes by man, for instance for thatching. Fires also render the forests more accessible by diminishing the amount of debris, ground vegetation and epiphytes.

Annual fires accelerate the mineralization of nutrients from the plant biomass. In natural mixed deciduous forests (containing teak), the amount of organic matter annually consumed by fire has been estimated as 7 to 8 t/ha. The amount of organic material in the topsoil of the mixed pine forests is about half of the corresponding amount in teak forests; consequently the rate of nutrient mineralization must be lower in pine forests. Large amounts of nitrogen are lost from the nutrient cycle as a result of fire, although burning may also stimulate the growth of certain nitrogen-fixing herbaceous species (Sukwong 1973).

Leaching of nutrients is accelerated on steep slopes. Studies carried out in Lampang Province, Thailand, have demonstrated that erosion was decreased over a period of three years to one ninth that of the previous level after the control of fires became effective in a mixed deciduous (teak) forest (Komkris et al. 1969). These results also showed that the increase in the erosion of watersheds after annual fires is associated with an increase in the surface runoff. A litter layer decreases the erosion risk and improves the physical properties of the soil, for instance by stimulating the activity of the soil microfauna and improving the porosity and water-holding capacity of the soil.

Forest fires in pine stands are limited to the ground and shrub layers and do not affect the upper canopy of the stands. As observed in the present investigation, mature pines are affected by fire only if the stem bases have been damaged by man. Poor cone crops in *P. merkusii* in the Mae Sot area were probably caused by a combination of mechanical stem damage and subsequent forest fire.

The natural regeneration of pines seems to be closely related with the occurrence of forest fires. The present results indicated that pine seedlings are common in places where the mineral soil is exposed as a result of fire. For instance, in Huey Bong (near the Baw Luang experimental site) bare patches in the ground layer were up to several hundred m^2 in area, such places showing no growth of grasses or other ground layer plants in November, i.e. one month after the end of the rainy season. Young *P. merkusii* seedlings were found, however, in such places.

Pines are adapted to a high level of solar radiation, and pine seedlings generally do not survive under strong shade (Champsoloix 1958). Thus fire may favour the development of pines by checking the ground layer and shrub vegetation. Frequent fires also decrease the severity of any single burning and thus diminish the danger caused by fire to young pines which have passed the seedling stage.

Both pine species in Thailand are well adapted to fire. This is particulary true for *P. merkusii* (in which the northern provenances possess a distinct grass stage, cf. Luukkanen et al. 1976.), but seedlings of *P. kesiya* are also quite well protected against ground fire, since the apical meristems are sheathed by a dense tuft of needles (Lizardo 1954). However, frequent fires will kill the pine seedlings. In the present study, the pine seedlings were all less than two years old at three localities out of the five which were investigated. These young seedlings would probably have been killed in the next fire. Natural regeneration was most likely successful in the *P. kesiya* stand at Baw Luang because of the strict fire control in this area.

The young pines growing on Doi Pui had survived despite recent fires. This was probably due to the sparse ground layer vegetation which had decreased the intensity of burning. In addition, most young pines had already passed the stage when they are most susceptible to fire. This situation is comparable to the results obtained in the Philippines (Lizardo and Caleda 1959): All pines with a diameter of less than 5 cm died in a planted 6-year-old *P. kesiya* stand. Of the trees belonging to the 10-cm diameter class 88 % were destroyed by fire, whereas the number of trees with a diameter of 15 cm decreased by 11 % only after burning. The growth of the surviving trees decreased by about 50 %. In the investigation carried out in the Philippines the ground vegetation consisted of a dense grass layer. Other studies have suggested that a height of 2.5 m is the limit for resistance against fire (Lizardo 1955); an age of five years has also been defined as such a limit for *P. kesiya* (Champsoloix 1958).

It might be speculated that the natural regeneration of *P. merkusii* would, under extreme environmental conditions, generally be more succesful than that found in the above-mentioned cases, due to the grass stage of this species. This is probably also true for the Om Koi region in NW Thailand where both pine species are found (J. Granhof, personal communication). The two *P. merkusii* stands investigated in the present study, however, both indicated a very poor rate of natural regeneration. Possible causes for this were the low density of the mature pine stand, poor flowering and cone production, animal damage, competitive grass vegetation and the high frequency of shading broadleaved trees, as well as the annual fires which prevent the pine seedlings from reaching a fire-resistant grass stage.

43. Natural regeneration as a silvicultural method

The establishment of pine stands for timber production using natural regeneration has been investigated for instance in Vietnam and the Philippines. It has been recommended that 10 to 15 *P. kesiya* seed trees per ha should be left and then removed after four to six years (Lizardo 1955, Champsoloix 1958). In the present study, in comparison, sufficient natural regeneration was achieved in the *P. kesiya* stand on Doi Pui with 16 seed trees per hectare.

The main reason for poor natural regeneration in the experimental stands of the present study was obviously the too high stem density. As a result, there was not enough light for the establishment of permanent regrowth.

Supporting evidence for the possibility of using natural regeneration as a silvicultural method in tropical or subtropical regions is available from the southern states of the U.S.A. In particular, the seed tree method has been found useful in the regeneration of *P. palustris* and *P. elliottii*, which both resemble the pine species found in Thailand as far as their ecological adaptation is concerned (for instance, the grass stage is common in *P. palustris*). A sufficient seed-tree density was defined as 25 trees per hectare (Mann and Enghardt 1975). As regards *P. palustris*, a somewhat denser shelterwood stand has been found to lead to higher seed production and to decrease the unfavourable effect of competing grass vegetation (Croker and Boyer 1975).

The present studies on germination and seedling emergence were not carried out under the best possible experimental conditions. Normally, the germination of pine seeds starts at the beginning of the rainy season (after several months of seed dispersal) in April or May. On the other hand, the soil moisture content was still high at the beginning of the sowing experiments, and seed germination was also artificially accelerated by allowing the seeds to imbibe water prior to sowing.

Faster and more complete germination was observed in *P. kesiya* as compared to *P. merkusii*. Earlier studies (Cooling 1968) also indicate that seeds of *P. kesiya* maintain a higher viablity during storage and that this species also exhibits a faster germination rate under laboratory conditions (cf. Bhumibhamon et al. 1980). The relatively poor germination percentages observed in the present study after the sowing of *P. merkusii* seeds was probably due to the larger amount of water needed for the germination of seeds of this species as compared to *P. kesiya*. Poor germination of *P. merkusii* in the field has earlier also been reported by Bhumibhamon and Atipanumpai (1980) on a dry site on Doi Pui.

Exposure to sun seemed to be one of the most important factors determining germination in the present experiments. The maximum number of emerged seedlings on exposed plots was about a half to one third of the corresponding figure on the shaded plots (cf. Fig. 7). This was obviously due to the water loss through increased evaporation and transpiration from seeds, seedlings and the soil surface on the exposed plots. The shade, caused for instance by *Dipterocarpus tuberculatus*, was clearly a factor promoting pine seedling emergence in the present work, since water deficit was the most immediate environmental stress.

No distinct effects of soil preparation on germination and seedling emergence were observed under the tree canopy. In contrast, soil preparation clearly decreased the survival rate of exposed *P. kesiya* or *P. merkusii* seedlings to less than 50 % of the result obtained for exposed seedlings on intact soil. This was due to the increased effect of drought after removal of the ground vegetation during soil preparation.

Most of the earlier investigations emphasize the favourable effect of soil preparation in connection with natural regeneration of the pine species in question (Troup 1921, Lizardo 1955, Caleda 1960, Cooling 1968, Bhumibhamon and Atipanumpai 1980). According to Champsoloix (1958), soil preparation is not necessary, however, to achieve satisfactory results in the natural regeneration of *P. kesiya.* On the contrary, the grass vegetation protects the seedlings against too intensive solar radiation. Lizardo (1955) also emphasizes that *P. kesiya* seedlings germinate well under *Imperata cylindrica* and other grass species, provided the seeds are in contact with the soil surface. The possible inhibitory allelopathic effect of this grass on pine seeds should, however, be taken into consideration (Bhumibhamon et al. 1980).

The usefulness of soil preparation may conceivably depend a lot on the site quality. In the present study, the germination experiment was carried out in a pine stand of the dry dipterocarp forest type, with a sparse ground layer and a more or less burnt-off litter layer. Thus the pine seeds were in close proximity to the mineral soil, even on intact plots. On more mesic sites, or in stands with a dense ground layer vegetation and a larger amount of litter, soil preparation would probably have a considerable positive effect.

Providing the soil moisture content is sufficiently high, soil preparation increases the water supply of the seeds and emerging seedlings. A covering of mineral soil also prevents the seeds from being carried away with runoff water (Lizardo 1955). Soil preparation also decreases the effect of ground cover competition and increases the amount of light, which may be important for seedling survival under a tree canopy (Bhumibhamon and Atipanumpai 1980). In southern parts of the U.S., where the seasonal climate and other conditions to some extent resemble those prevailing in northern Thailand, soil cultivation in connection with prescribed burning definitely improves the natural regeneration of *P. palustris* stands (Croker 1975).

Drought was the main factor which contributed to the relatively high seed and seedling mortality found in the present investigation. Water deficit also distinctly decreased the germination rate, especially as far as the exposed plots are concerned. The present results also clearly indicated that slowly germinating seeds gradually disappeared from the sowing plots.

The most likely animals causing seed damage were rodents and birds. A higher proportion of the seeds tended to be destroyed on the exposed plots, whereas the rate of destruction was lower under the canopy. Of the two pine species, *P. merkusii* was more susceptible to seed damage, which may have been associated with the slower germination rate also found in this species.

The main cause of damage in emerged seedlings was water deficit. Seedlings of *P. kesiya* were smaller than those of *P. merkusii* and thus more susceptible to drying. Small animals (most likely insects), however, frequently attacked the seedlings of the latter species in particular.

In the Philippines, rodents, birds and ants have been found to be the principal cause of pine seed damage, although the problem is not considered serious (Lizardo 1955). An investigation carried out in a *P. palustris* stand in Alabama, U.S.A., revealed that the total proportion of damaged seeds and seedlings was 75 %; of the damages, 10 % were caused by insects, 57 % by small mammals and 33 % by birds and larger mammals (Boyer 1964). A different situation has been found in India, where Troup (1921) considered insects to be the most serious cause of damage to pine seedlings. In Thailand, earlier results on germination of *P. merkusii* in Doi Pui indicated that the germination percentage could be increased to some extent by employing pesticides (Bhumibhamon and Atipanumpai 1980).

44. Sowing as a regeneration method

Sowing has not been used as a regeneration method for pine in Thailand. In India, however, broadcast sowing has been used in the establishment of *P. kesiya* stands on fallow land after shifting agriculture. According to Troup (1921), other methods, such as sowing in rows followed by weeding have also been tested in the regeneration of this species, especially on sites with vigorous grass growth. The same author also reports that the first information about sowing of *P. kesiya* in central India dates back to 1916. The sowing, carried out along ploughed furrows, was not successful, however, since most of the seedlings were destroyed by insects during the rainy season and the remaining ones perished during the dry season; this was interpreted as indicating that the climate was too dry for *P. kesiya.*

The limited amount and high price of pine seed are two factors which render sowing unlikely as a regeneration method for pine in Thailand at present time. The increasing supply of seed orchard seed may nevertheless change this situation in the future. The most likely applications of pine sowing are probably to be found on the sparsely-forested fallow areas which remain after shifting cultivation (where sowing could be combined, for instance, with prescribed burning and soil cultivation), or, alternatively, in open, mixed pine stands which are found on poor soils.

45. Conclusions

The proportion of plantations in the total area of pine forests in Thailand is increasing steadily. The planned expansion and development of pulping industry in the country is , however, largely dependent on existing pine resources. Natural pine stands also remain ecologically important, since they occur as successional stages in some of the watershed areas of northern Thailand. The protection of the watersheds, as well as the establishment of pine stands of industrial use, are measures which both warrant more detailed investigations on the process of natural regeneration in pine stands.

Most of the earlier studies concerning the natural regeneration of *P. kesiya* or *P. merkusii* emphasize the importance of fire control for the survival of young pine stands (e.g. Troup 1921, Lizardo 1955, Champsoloix 1958, Khemnark et al. 1972). The present results also indicate that the success of natural regeneration in pine stands is immediately increased, if forest fires can be prevented during the period of highest susceptibility. This was beautifully illustrated by the vigorous young natural pine stand of the Baw Luang area.

A measure which could be introduced as a standard practice would be the removal of all but the 15 or 20 best mature pine stems per hectare, and at the same time the removal of shading broadleaved trees. Additional soil preparation could be useful on sites with a dense ground layer vegetation. Prescribed burning prior to soil preparation might also be attempted. Watershed areas, which are often seriously threatened by soil erosion, must in any case be managed with extreme care, by gradually applying the silvicultural measures to well-defined small areas at a time.

Finally, it can be concluded that the present results clearly demonstrated the urgent need for further studies on the regeneration and reproduction biology of *P. kesiya* and *P. merkusii* in Thailand, especially as far as seed crops, optimal seed stand densities, effects of fire and the problems of fire control are concerned.

5. SUMMARY

Natural pine stands were investigated at five localities in northern Thailand. At three localities the pine stands consisted of *Pinus kesiya,* at one locality only *P. merkusii* was found, and in one study area both pine species were present in separate stands.

Large numbers of pine seedlings were found in *P. kesiya* stands only. Two of these stands also included pines representing various intermediary height classes. In dense *P. kesiya* stands the number of seedlings was generally smaller as compared to stands with lower seed tree densities. Pine seedlings were frequently found in canopy openings and on patches of exposed mineral soil in particular. Even sparse *P. kesiya* stands seemed to be capable to produce enough seed for natural regeneration.

All sample plots showed signs of forest fires. However, mature pine trees indicated fire damage only in cases where the stem bases had been previously pared using an axe (collection of resinous pine wood to be used as kindling was a common practice in all areas investigated). Young pines (>5 m in height) also seemed to survive the frequent burning quite well. Annual fires, however, had destroyed all younger seedlings and also decreased the vigour of the ground layer vegetation in some cases.

Indirect evidence on the decisive role of forest fires as far as natural regeneration is concerned was obtained from the stands having the largest number of pine seedlings: successful natural regeneration was associated with a low frequency of fires or with less intensive burning of the ground layer.

A separate sowing experiment was carried out in order to investigate some of the factors affecting germination and seedling emergence in more detail. Seeds of both pine species were sown on prepared or untreated soil on exposed plots as well as on plots under the canopy. *P. kesiya* seeds germinated somewhat faster as compared to *P. merkusii* seeds. Exposed plots showed a lower germination percentage and a higher seedling mortality than those protected by the tree canopy. Soil preparation also distinctly decreased the number of emerged seedlings on exposed plots.

The higher susceptibility of *P. merkusii* seeds and seedlings was interpreted as one possible factor which may diminish the success of the natural regeneration of this species. Drought was the main cause for low germination and survival percentages, although some damage on seeds and seedlings caused by insects and small mammals was also observed. Differences in cone and seed crops in mature pine stands were also found in connection with the study on natural stands; of the two pine species *P. merkusii* exhibited lower cone yields during the present investigation.

Utilization of natural regeneration as a silvicultural method in the pine stands of northern Thailand would require fire control at least during the critical years of seedling emergence and during the stabilization of the regrowth.

Previous studies suggest that pines represent a distinct successional stage in the development of certain mountain forests in South-East Asia. Protection against fire during a longer period of time would thus ultimately lead to more mesophytic forest associations. On the other hand, an increase in forest fire frequency in mesophytic forests would lead to a reversal of the successional development, due to the leaching of nutrients and other forms of soil erosion, with pine forests or savanna-like associations as a result. Restoration of fallow farmlands after shifting cultivation of agricultural crops could thus also proceed through pine forest stages, although the present pine forests are frequently found on soils which are too poor to be used for shifting cultivation. Experience from other countries indicates that a relatively small number of pine seed trees would be needed for natural regeneration, provided other conditions are favourable.

An increase in the amount of pine seed produced in seed orchards in Thailand would possibly allow sowing of pine to be used as a method of artificial regeneration in the future, at least in experimental scale. In any case, artificial regeneration by planting or sowing will be the only possibility in areas where pine seed trees are not present in a sufficient number. Regardless of the prospects of such forest industry projects in Thailand which would utilize pine as raw material, natural pine forests and the various ecological processes associated with them will deserve the effort of further, more detailed investigations.

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SELOSTE

HAVAINTOJA MÄNNYISTÄ (*PINUS KESIYA* JA *P. MERKUSII*) JA MÄNTYJEN LUONTAISESTA UUDISTUMISESTA POHJOIS-THAIMAAN VEDENJAKAJA-ALUEILLA.

Tutkimuksen tavoitteena oli selvittää pohjoisthaimaalaisten luontaisten männiköiden metsikkörakenne ja eri-ikäisten taimien esiintyminen ja runsaus näissä metsiköissä. Kylvökokein pyrittiin lisäksi tutkimaan kummankin mäntylajin siementen itämiseen ja sirkkataimien alkukehitykseen vaikuttavia ympäristötekijöitä.

Aineisto koostui viidestä eri puolilla Pohjois-Thaimaata sijaitsevasta mäntyesiintymästä, joista kolmessa puulajina oli *P. kesiya* Royle ex Gord., yhdessä *P. merkusii* Jungh. et de Vriese ja yhdessä molemmat lajit erillisinä metsikköinä.

Vain *P. kesiya* -metsiköissä todettiin uudistumisen kannalta riittäviä taimitiheyksiä. Kahdessa tämän puulajin metsikössä oli myös eri-ikäisiä nuorempien puiden ikäluokkia. Taimimäärä oli pienempi tiheissä *P. kesiya* -metsiköissä kuin harvan latvuskerroksen alla. Taimet kasvoivat yleensä aukkopaikoissa, varsinkin kohdissa, joissa mineraalimaa oli paljastunut.

Siementävän puuston harvuus ei näyttänyt olevan *P. kesiyan* taimiston synnyn esteenä, edellyttäen, että siemenpuita oli edes jonkin verran olemassa. *P. merkusiin* taimia ei sensijaan todettu kummassakaan tämän puulajin tutkimuskohteessa riittäviä määriä.

Kaikilla tutkimusmetsiköihin sijoitetuilla koealoilla havaittiin metsäpalojen jälkiä. Varttuneita puita ei tuli kuitenkaan ollut pystynyt vaurioittamaan, ellei runkoa aikaisemmin ollut vahingoitettu. Kirveellä aiheutetut runkovauriot ja näin syntyneiden korojen hiiltyminen oli kuitenkin melko yleinen ilmiö kaikkialla tutkituilla alueilla. Paikallisen väestön (joka tutkimuskohteissa yleensä kuului vähemmistökansallisuuksina oleviin vuoristoheimoihin) tapana oli sytykkeinä käytetyn ja suuresti arvostetun mäntytervaksen keruu pystypuiden tyveltä, mikä yleisesti oli johtanut mäntyjen katkeamiseen tuulessa.

Yli viisimetriset nuoret männyt osoittautuivat jo kulonkestäviksi, mutta pienemmät taimet olivat vaurioituneet taikka tuhoutuneet kokonaan vuosittain toistuvissa metsäpaloissa. Toistuvat kulot vähensivät selvästi myös kenttäkerroksen kasvillisuuden elinvoimaisuutta.

Metsiköt, joissa taimitiheys oli suurin, osoittivat epäsuorasti tulen ratkaisevan vaikutuksen metsikön uudistumiselle: tiheä taimisto havaittiin vain kohteissa, jotka olivat säästyneet kuloilta useamman peräkkäisen vuoden ajan tai joissa kenttäkerroksen palaminen oli ollut tavallista lievempää.

Kylvökokeessa siementen itämistä seurattiin sekä muokatulla että muokkaamattomalla maalla. Osa kylvökoealoista sijotettiin aukealle, osa taas oli latvuskerroksen varjostamia. *P. kesiyan* siementen itäminen oli nopeampaa kuin *P. merkuusiin* (jonkin verran suurempien) siementen itäminen. Siemenet itivät heikommin ja sirkkataimet kuolivat useammin aukealla kuin varjossa. Muokkaus vähensi selvästi aukealla eloonjäävien sirkkataimien määrää.

P. merkusiin siementen hitaampi itäminen ja suurempi sirkkataimikuolleisuus tulkittiin tämän lajin heikomman luontaisen uudistumisen mahdolliseksi syyksi. *P. merkusiin* sirkkataimien vähyys kylvökokeessa johtui ennen kaikkea kuivuudesta (koe suoritettiin välittömästi sadekauden jälkeen, jolloin maa oli kosteaa, mutta ilman suhteellinen kosteus alhainen). Hyönteisten ja pikkunisäkkäiden aiheuttamia tuhoja todettiin jonkin verran mutta näiden merkitys oli kuivumiseen verrattuna pienempi. Silmävaraiset havainnot siemenpuiden käpymääristä viittaisivat myös *P. merkusiin* heikkoon käpy- ja siemensatoon tutkimuksen tekoa edeltäneenä ajanjaksona (*P. kesiyan* käpyjä havaittiin sensijaan runsaasti).

Johtopäätöksenä tuloksista voitiin todeta, että mäntyjen luontainen uudistaminen käytännön metsänuudistusmenetelmänä Pohjois-Thaimaassa edellyttää ehdotonta metsäpalojen torjuntaa usean vuoden ajan taimien alkukehityksen turvaamiseksi.

Mäntymetsä on Kaakkois-Aasian vuoristoalueilla kasvillisuuden sukkessioon metsäpalojen vuoksi kiinteästi kuuluva tyypillinen kasviyhdyskuntavaihe. Kulojen estäminen johtaa sukkessiossa lehtipuiden yleistymiseen ja mesofyyttisempään kasvillisuuden yleiskuvaan. Vastaavasti saattaa lehtipuuvaltainen metsä kulojen seurauksena muuttua männiköksi, jossa maaperä lisäksi on yleensä vähäravinteinen ja eroosio pitkälle edennyt.

Thaimaan vuoristoseuduilla yleisten hylättyjen kaskipeltojen metsittymisen nopeuttaminen voisi luontevasti tapahtua mäntymetsävaiheen välityksellä. Nykyisin jäljellä olevat mäntymetsät ovat tosin useimmiten rajoittuneet alueille, joita maaperän köyhyyden vuoksi ei ainakaan enää käytetä kaskipelloiksi. Mikäli siementäviä mäntyjä kuitenkin on riittävästi kaskien läheisyydessä, saattaa luontainen uudistuminen (kulontorjuntaa lukuunottamatta) ilman erityisiä toimenpiteitä johtaa männyn taimistojen syntymiseen. Siemenpuiden puuttuessa voidaan mäntymetsä tietenkin aikaansaada vain viljelemällä.

Jo perustettujen männyn siemenviljelysten tuottamat siemenmäärät sallisivat mahdollisesti myös kylvön käytön uudistusmenetelmänä. Riippumatta siitä, miten mäntyraaka-aineeseen pohjautuvan metsäteollisuuden suunnittelu Thaimaassa edistyy, luontaisten mäntymetsien ekologian tutkimista olisi syytä joka tapauksessa jatkaa entistä tehokkaammin.

ODC 174.7 *Pinus kesiya*:174.7 *Pinus merkusii*+ (593)+231+435.3 ISBN 951-651-053-1

TURAKKA, A., LUUKKANEN, O. & BHUMIBHAMON, S. 1982. Notes on *Pinus kesiya* and *P. merkusii* and their natural regeneration in watershed areas of northern Thailand. Seloste: Havaintoja männyistä *(Pinus kesiya* ja *P. merkusii)* ja mäntyjen luontaisesta uudistumisesta Pohjois-Thaimaan vedenjakaja-alueilla. Acta For. Fenn. 178:1–33

Seedlings and young pine trees were almost exclusively found in *Pinus kesiya* Royle ex Gord. stands only. Dense pine stands generally showed less vigorous natural regeneration. Poor regeneration was also associated with a high frequency of forest fires. All investigated stands exhibited signs of fires. Sowing experiments indicated a slower development and a higher susceptibility to damage in *P. merkusii* Jungh. et de Vriese seedlings as compared to those of *P. kesiya.* Drought was the main cause for low germination and survival percentage, as also indicated by the poor development of seedlings on sowing plots exposed to full sunlight or on cultivated soil as compared to those under the canopy or on uncultivated soil.

Authors' addresses: (Turakka & Luukkanen) Department of Silviculture, University of Helsinki, Unioninkatu 40 B, SF-00170 Helsinki 17, Finland. (Bhumibhamon) Faculty of Forestry, Kasetsart University, Bangkok 9, Thailand.

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