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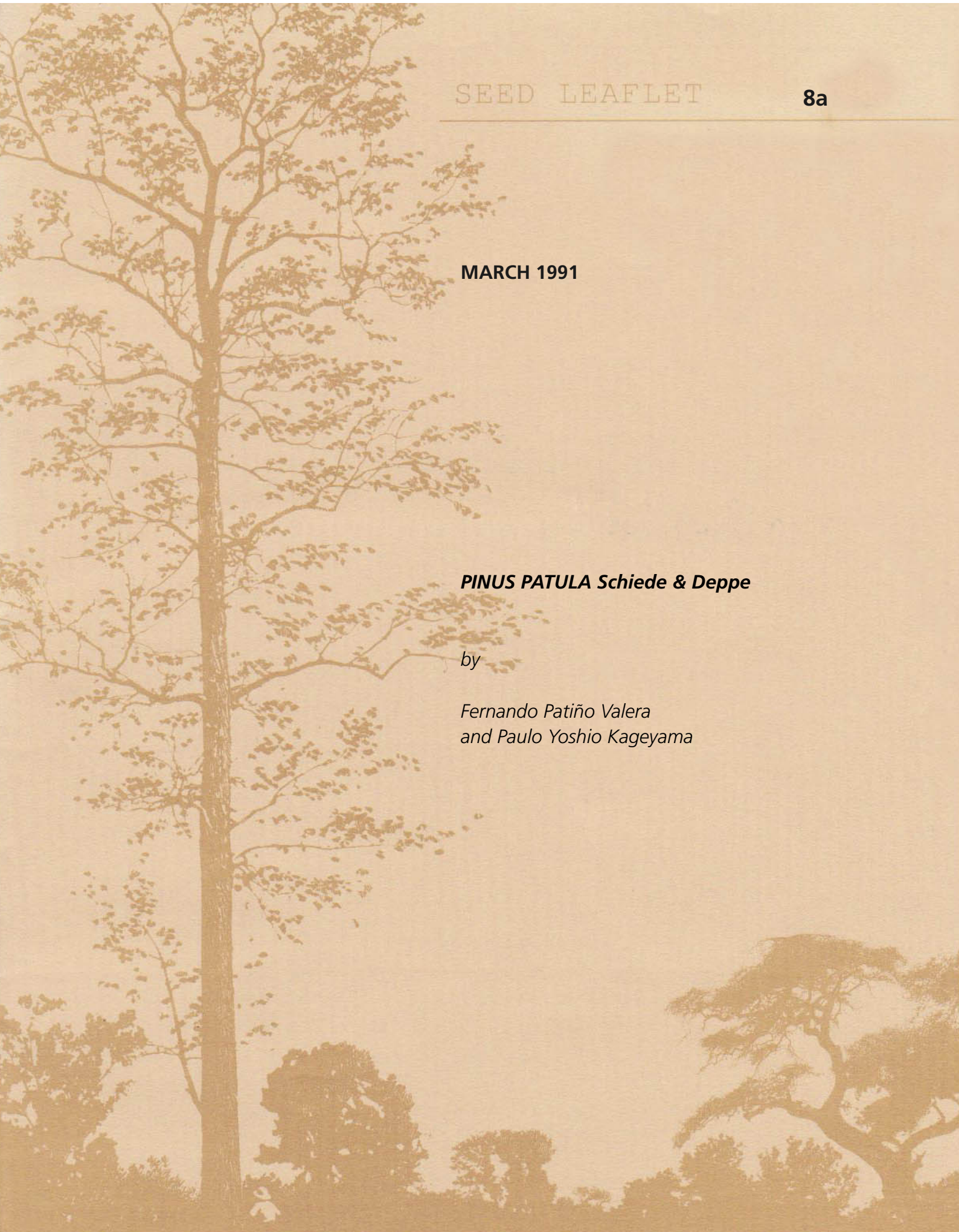

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PINUS PATULA Schiede & Deppe

by

Fernando Patiño Valera
and Paulo Yoshio Kageyama

DANIDA FOREST SEED CENTRE

Title
*Pinus patul*a, Schiede & Deppe

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Contents

1. TAXONOMY **1**

Botanical nomenclature 1

Synonyms (Styles in Wormald 1975) 2

Common names 2

2. GROWTH HABIT **2**

3. DISTRIBUTION **3**

Natural distribution 3

4. VARIATION AND GENETIC IMPROVEMENT **7**

Geographic variation in natural populations 7

Genetic variation between populations 7

Genetic variation within populations 8

5. IMPORTANCE FOR PLANTATIONS AND USES **9**

6. REPRODUCTIVE BIOLOGY **10**

Flowering and development of cones and seed 10

Cone and seed characteristics 10

Seed dispersal and germination 11

7. PESTS AND DISEASES OF CONES AND SEED **12**

8. PRODUCTION AND COLLECTION OF CONES AND SEED **13**

Flowering and fruiting age 13

Selection of stands and trees 13

Seed production 14

Estimating the cone crop 15

Determining seed maturity 17

Collection methods 17

Seed orchards 18

9. SEED PROCESSING **19**

Seed extraction 19

Dewinging 20

Cleaning the seed 20

10. SEED STORAGE **21**

11. REFERENCES **23**

1. TAXONOMY

Pinus patula was first described by Schlechtendal and Chamisso based on two botanical samples collected by Schiede and Deppe in the state of Veracruz in Mexico. One sample was collected between Cruz Blanca and Jalacingo, the other in La Joya, in regions covered with volcanic lava.

The description of the species appeared in 1831 in the Linnaea Review, volume VI, page 354. Since then many authors have studied its taxonomy as well as its growth. adaptation and utilization.

The broad variation of many species in the genus Pinus and their ability to hybridize, producing fertile offspring, have made numerous modifications of the systematic order of this genus necessary. Thus, in 1914 Shaw published a taxonomic system for the pines which included Pinus patula in the large group Insignes comprising all the species with serotinous (1) cones. "*Pinus patula* is now placed by Little and Critchfield (1969) in the section Pinus subsection Oocarpae, a classification which has replaced that of Shaw. The subsection Oocarpae includes, besides *P. patula*, 6 other American pines. *P. radiata* Don, *P. attenuata* Lemm. and *P. muricata* Don occur in North America (mainly West Coast region and Lower California); *P. greggii* Engelm. ex Parl. and *P. pringlei* Shaw are confined to Mexico whilst *P. oocarpa* Schiede is distributed from Mexico throughout Central America to Northern Nicaragua.

The subsection is characterised by the species having leaves, mostly 3 per fascicle, but varying between 2 and 5; the hypodermis consists of cells of 2 different shapes, with resin ducts mostly medial, more rarely internal or septal. Spring shoots are either multinodal, with 2 or more whorls of branches. or uninodal with one whorl only. Cones are mostly oblique, long-persistent on the tree with the scales opening irregularly to release the seeds; the scales have a prickle or protuberance," (Styles in Wormald 1975).

Botanical nomenclature

Family:	Pinaceae
Genus:	Pinus (Shaw 1914, Virov 1967, Little and Chritchfield 1969)
Latin name:	*Pinus patula* Schiede and Depppe in Schlecht and Cham. (Linnaea 6:354 1831)

.....

1: Serotinous: remain on the tree unopened for one or two years after ripening.

Synonyms (Styles in Wormald 1975)

Pinus subpatula	Roezi ex Gord. Pinetum, Suppl 84 (1862)
P*inus oocarpa* var	*Ochoterenai* Martinez, Anales Inst. BioI. Mex 9(1)65(1940)
Pinus patula var	*Longipedunculata*, (Longepedunculata) Loock ex Martinez, Los Pinos Mexicanos 333 (1948)
Pinus patula var	zebrina Milano in Lilloa 17:146 (1949) now known as *P. patula* cv. "Zebrina"

Common names

a) Within its natural distribution and Latin America: "*Pino chino*", "*Pino colorado*", "*Ocote colorado*", "*Pino patula*", "*Ocote Macho*", "*Pino xalocote*" (Patino 1973, Eguiluz 1978, Vela 1980, Patino *et al.* 1983).

b) In English speaking countries: "Patula" pine, "Mexican weeping pine", "Spreading-leaved pine" (Styles in Wormald, 1975).

2. GROWTH HABIT

In its natural habitat *Pinus patula* grows to heights of 15-30 m, and diameters up to 120 cm.

Vela states that, within the natural distribution, the boles are generally straight and clear with commercial trunks of 10-20 m. The diameter varies between 25 and 50 cm, according to density and age, reaching a diameter at breast height of more than 1 m in old stands. The same author states that in Huayacocotla, Veracruz, and to a minor degree in other localities, trees are found with marked swellings of the bole; these are apparently associated with old branches.

Vela notes that *P. patula* is a species with binodal growth, the branchlets developing two internodals per year, unlike other pines which are uninodal. Norskov Lauritsen (1963) observed that in some cases there is a tendency of uninodal growth in old trees. By the end of winter the needles of the first internodal will start to sprout, and those that reach maturity in spring will begin to develop the second internodal. The needles of this internodal mature in June and July and the needles that appeared in the beginning of the year will fall off during this period.

The species has fascicles of 3 or 4 needles, rarely 2 or 5. The needles are thin and hanging, yellowish to dark green, from 15 to 30 cm long, normally around 20 cm. The branches are thin, fine and generally 4 to each whorl; some branches will fall off in time, resulting in irregular distribution of the branches in the crown and on the stem of the tree.

The bark of mature trees has a thickness of 1-5 cm at breast height depending on the age of the tree. It has fissures making the bark flake off. The colour is dark coffee to reddish.

The species shows a vigorous growth of the root system, which penetrates the soil vertically. The species also has a marked tendency to develop deep roots with little lateral growth. This may explain the high density of trees per ha found in some areas within the natural distribution. The roots grow deep down and will penetrate vertically between the rocks. In the studied profiles Vela found an abundance of root hairs in the upper 30 cm, becoming less abundant with increasing depth. In depths of more than 1 m the root hairs were very scarce.

Pinus patula is found in pure stands or in association with coniferous and broadleaf species. The species associates with the following pine species; *Pinus ayacahuite, P. pseudostrobus, P. douglasiana, P. teocote, P. montezumae, P. leiophylla*, and with *Cupressus benthami, Abies religiosa* and several broadleaf species mainly *Quercus, Alnus, Liquidambar and Clethra.*

3. DISTRIBUTION

Natural distribution

Pinus patula is found in Mexico in a narrow zone with a general orientation from NW to SE, situated in the eastern part of the Hidalgo and Puebla states, western part of Veracruz and northeast Oaxaca, and in a limited part of Tlaxcala state. Furthermore, isolated populations are found in Sierra de Pachuca, in Mesa del Oro, in La Encarnacion, Hgo, Pinal de Amoles, Qro., El Lobo, Municipality of Gomez Farias, Tamaulipas; there may also be isolated populations situated between Tamaulipas and the state of Hidalgo and in San Luis Potosi.

Vela noted that the *P. patula* distribution area may be included in a rectangular formed by the following geographical coordinates: from a little north of 18°N to approximately 23°20'N latitude and between 97° and 99°45'W longitude.

The area referred to is found above La Sierra Madre Oriental, in the areas known as Sierra de Hidalgo, Sierra del Norte de Puebla, Cerro del Tigre in Gomez Farias, Tamaulipas; Sierra de Pachuca, Cofre de Perote and Pico de Orizaba. In the Eje Neovolcanico, and in Sierra Madre de Oaxaca, in Cerros de Jasco and in La Calentura in Sierra de Pinal de Amoles Qro.

Vela prepared a distribution map of the species, not including the occurrence of P. patula var *longipedunculata* Loock ex Martinez.

Barrett (1972) quotes personal communication with biologist Francisco Gonzalez Medrano who collected herbarium samples at the borders of the states of Tamaulipas and Nuevo Leon, extending the distribution area until 24°05'N.

Barrett added the natural distribution of the typical variety to the map prepared by Vela and included the probable distribution of *Pinus patula* var *longipedunculata* Loock ex Martinez. Barrett indicated a distribution for this variety in the state of Oaxaca which includes areas located in the region of Papalos-Cuicatlán, immediately south of the limit of the distribution of the typical variety, in the heights of Huautla de Jimenez, Oax, as well as in the regions of La Cumbre and Llano de Flores, where the distribution area forms narrow belts on top of the Sierra Madre del Sur.

Vela indicates that because the natural distribution mostly covers mountainous areas, there are great variations in climate and edafic factors.

Vela also states the *P. patula* is found growing in a belt between 1800-2200m above sea level, but it is generally found in heights above 2000 m; below these limits the species is found less abundantly and is no longer dominating, forming mixed stands with oak (Quercus spp.) and liquidambar (*Liquidambar* spp.).

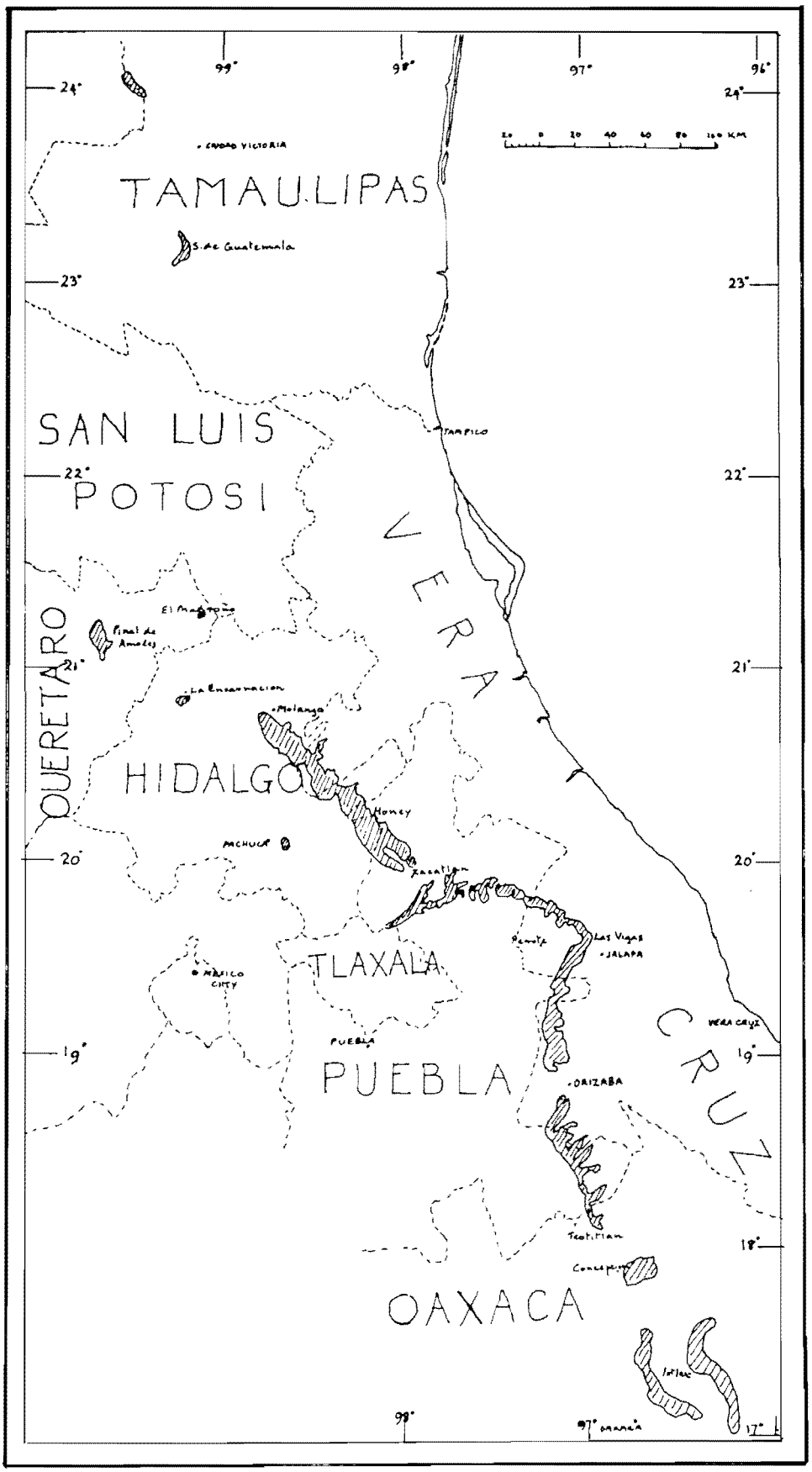
Vela reports to have seen isolated trees of *P. patula* on the eastern slope at altitudes of 1650 m in Zacualpan, Veracruz and near Tetela de Ocampo, Puebla. At 1700 m near Landa Queretaro the species was found mixed with *Pinus greggii* and in Cerro del Tigre, Gomez Farias, Tamaulipas, mixed with the following species: *Liquidambar, Querqus, Magnolia, Taxus* and *Pinus*.

The pine forest, Pinal de Amoles Qro, is found from 2200 to 2700 m., while in the desert of Los Leones, D.F., the altitude limits range from 2000 to 3100 m.

In Molango and Acaxochitlan Hidalgo the upper limits are 2400-2500 m descending to 2000 m. From Acaxochitlan to Cofre de Perote the limit lies about 2400 m although it in certain parts raises up to 3000 m, in Pico de Orizaba the highest registered altitude was 2940 m.

In Chignahuapan Puebla the species is found between 2700 and 3000 m.

Vela concludes that the species is distributed between 1600 and 3000 m, and that the forests with a dominance of *P. patula* are found between 1800 and 3000 m.



MAP 1 Distribution of P. patula

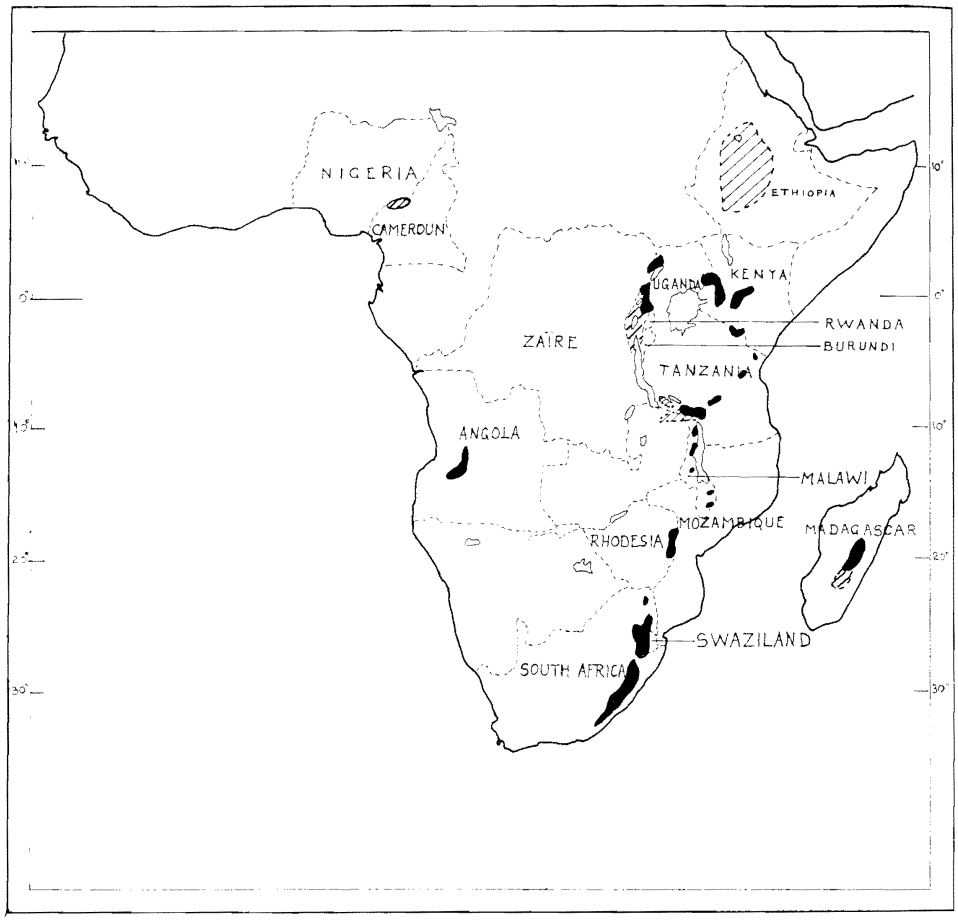
in Mexico

(after Barrett, 1972)

Distribution of *Pinus patula* as an exotic

Wormald (1975) shows the occurrence of *Pinus patula* in Africa and notes that the species has been introduced mainly to South Africa, Swaziland, Zimbabwe, Madagascar, Malawi, Tanzania, Kenya, Uganda, Angola and Cameroon.

Pinus patula has also been introduced into Asia: India and Sri Lanka and into America: Argentina, Brazil, Colombia, Ecuador and Jamaica.



MAP 2 Occurrence of P. patula in Africa

4. VARIATION AND GENETIC IMPROVEMENT

Geographic variation in natural populations

The phenotypical variation in natural populations, not considering the genetic difference between provenances, are important to indicate the potential genetic variation of a species. Studying different populations within the natural distribution of *Pinus patula*, Barrett (1972) found gradual variations in morphological characters of the needles and cones, associated with the latitude of the origin and not suggesting discontinuity of the species. The *pedunculata* (Loock ex Martinez) variety is not, according to Barrett, a separate genetic entity, and was probably classified botanically as a variety because of the way of sampling.

The varieties found in South African plantations, such as the "rough bark" variety, are probably expressing a provenance effect, which indicates the importance of provenance tests of this species. However, the hypothesis that the material might be a variety or local race should not be rejected.

Genetic variation between populations

Various seed collections have been carried out to study the genetic variation between provenances beginning with Loock (1947) and followed up by the intensive sampling by Barrett in 1971. In the same year different provenance tests for this species were established in Zimbabwe. The collection was carried out by the Instituto Nacional de Investigaciones Forestales de Mexico, with support from FAO, so that provenance trials could be established at international level, permitting intensive sampling and wide coverage of the natural populations. According to information from INIF the seed collected throughout this programme was distributed to various countries at the end of 1982.

The provenance tests in Zimbabwe show that the local variety was less sensitive to attacks of Pineus spp. than 8 Mexican provenances. In provenance trials in New Zealand the local provenance was superior to 4 Mexican provenances, 3 of the typical variety and 1 of *longipedunculata* variety, with regard to vigour and stem form. These results show the importance of the local race of the species, although the provenance sampling had not been the most complete in these tests.

16 provenances planted in Argentina show significant variation in growth habit between provenances. Evidence of variations connected to altitude or latitude of the original seed source was not found. Populations and origins located in the central and northern part of the distribution range of the species mature earlier than the southern provenances. The fastest growing provenances were Zacatlan and Altotanga (Puebla) and Zuacualtipan (Hidalgo); the slower growing were: State of Oaxaca and Southern Mexico. In the three best sites in Argentina, the height of the best provenance was 20 % better than the one of lowest growth, which expresses quanti tatively

that the variation is not as significant as for example *Pinus oocarpa* or *Pinus taeda*. The growth of trees from commercial seed sources in South Africa, which were included in the trial, was about average and 10 % lower than the growth of the improved sources. These results show the true potential of using seed of suitable sources and, to a certain extent, also the potential of commercial seed from South Africa. It should be noted that the South African seed has been used in several countries for a long time, and has constituted the base populations for many provenance programmes within the species.

A trial including 10 provenances of *Pinus patula* in 6 localities in Zimbabwe, reveals the existence of variations between populations as to height, diameter, volume, stem form and wood density. The local race, originating from seed-orchard seed, proved to be better than all other provenances, both for volume and for stem form, which emphasizes the importance of selection. As to wood density, the local race showed the lowest density of all the tested provenances, which perhaps suggests a negative correlation between growth and stem form and wood density. Among the Mexican provenances the difference between highest and lowest density was 12%, confirming the insignificant variation between populations of the species.

Genetic variation within populations

The main improvement programmes within populations of *Pinus patula* have been carried out in African countries, based on the populations established in South Africa and Zimbabwe. The origin of these seed sources is unknown but it is probably Los Reyes and Hidalgo.

The characteristics considered for genetic improvement are as follows: volume, stem form, branching habit, crown form and wood quality. The selection of superior trees in populations for establishment of seed orchards is carried out in several countries in Africa, mainly in South Africa, Kenya, Madagascar and Malawi.

Variation and genetic control within populations, as an instrument in selection, is estimated through progeny tests in different countries where programmes for genetic improvement are carried out. In a study of genetic variation among families of *Pinus patula* in two African localities significant differences emerged among the families for all the investigated characteristics. Comparing the progenies from South Africa with those from Zimbabwe, superiority for the former was found concerning volume production; however, as to stem form and branching the latter showed better results. The heritability for 16 characteristics associated with growth, stem form, branching and crown of the trees has been determined at 18 and 30 months.

At 30 months, an average heritability, in a narrow sense at single tree level. of 0.20 for height and of 0.18 for basal area at breast height (1.3m) was found. In Brazil, Kageyama *et al.* (1977) established a progeny trial of trees selected in Zimbabwe. At 5 years, the average heritability in a narrow sense at single tree level, was 0.23 for height, 0.17 for diameter at breast height

and 0.20 for stem straightness. The corresponding coefficients of variation were 2.92, 4.42 and 7.23, respectively, indicating significant variation in the studied populations, particularly for stem form and diameter.

Research on genetic variation between and within populations will play a major role for the species as improvement programmes develop in different countries in Africa and South America, e.g. Argentina, Brazil and Colombia.

5. IMPORTANCE FOR PLANTATIONS AND USES

Pinus patula is a widely planted species in the world. The success of this species as an exotic, like that of *Pinus radiata*, would have been difficult to predict by studying the conditions in the limited area of natural distribution. The species is planted from Ecuador to a latitude 31° south in Africa and extends to 42° southern latitude in New Zealand.

The species is mainly planted in African countries, but is also used in Australia and Asia (Australia, New Zealand, Papua New Guinea, India) and on a smaller scale South America (Argentina, Brazil, Colombia). According to Wormald (1975) the total area planted until 1970 was approximately 450.000 ha. The countries planting the largest areas in this period were South Africa followed by Swaziland, Zimbabwe, Kenya and Madagascar.

From 1966 to 1970 the estimated plantation establishment in the world was about 30,000 ha per year, which was more than in the previous 5-year period. A similar growth rate would bring the total plantation area up to 1 million hectares by 1984, showing the importance of the species for plantation use.

Pinus patula has been planted in a wide range of soils; it will show fairly acceptable growth even in poor soils, but will give better results in deep fertile soils. The production will in suitable localities reach 35m^3/ha/year. The production on the majority of sites where the species is planted will be around 20m^3/ha/year. On poor sites the production will drop to 10m^3/ha/year.

The wood of *Pinus patula* has been used for several purposes both within the area of natural distribution in Mexico and in the different countries in which it has been planted. The species is used for sawmill timber for light construction and for production of boxes. In South Africa the species is used for pulp and floors.

In Mexico *Pinus patula* is used for: pulp, sawn timber, veneer and plywood, boxes, pit props, sleepers, telegraph poles and construction wood.

In Mexico the species has been widely used for protection of watershed areas as well as for conservation and restoration of degraded soils. The results have been excellent both by fulfilling the objectives and with good production.

6. REPRODUCTIVE BIOLOGY

Flowering and development of cones and seed

Pinus patula is said to be an early species as to occurrence of flowers, particularly in plantations where cones may be found at the age of 5. Similar cases may occur in natural populations and seed production begins about the age of 15.

As in most other monoecious conifers, the female flowers are normally found in the upper part of the crown, while the male flowers are found in the lower part.

The female conelets have two inverted ovules. The male stroboli have greenish yellow stamens and are produced in large quantities. The flowering season occurs in January and February in the states of Oaxaca and from January to April in the states of Puebla, Mexico, Veracruz and Hidalgo.

The male flowers dry out and fall off after pollination, while the conelets remain; they do not increase in size before the spring of the following year, when the fertilization occurs after which the cones start growing. The cones will develop from March/April throughout spring and summer. Seed collection may start in the autumn.

The information about cone and seed maturity differs between authors. Some state that the cones develop over a period of 22 months and others state that the period is 30 months. Differences are probably due to the fact that the species has serotinous cones, for which the time of maturity does not represent a critical point.

The synchronization of the male and female flowers is good at altitudes of about 1500 m. At lower altitudes the male flowering will gradually become later and the synchronization less favourable. The conditions for dispersal of pollen are important in the pollination and seed production processes.

Cone and seed characteristics

A study of cone samples from single trees throughout the natural distribution of the species showed that the cones of *Pinus patula* are similar to other serotinous species in that they remain on the tree for a long time and have irregular times of opening. The cones are extremely different in size and shape as well as in asymmetry and length of peduncle.

The values for cone characteristics, for weight and length of the cones, are very distinct even though it is evident that the differences in natural conditions may be due to phenotypic variation. The variations have been verified at provenance level, between provenances as well as for individuals.

Cone length differs distinctly between provenances. But the typical within-provenance variation makes it difficult to differentiate varieties and it is concluded that genetically distinct entities cannot be distinguished by cone character.

The greater length of the peduncle is found in all provenances of the longipedunculata variety. However, the provenances from Oaxaca generally show a higher percentage of cones with this character.

Cones of *Pinus patula* from Zimbabwe had a potential seed content of 200300 seeds per cone. Only part of the ovules are fertilized. In practice, 22 to 93 seeds per cone have been obtained. The variation in number of seeds from plantations is due to the environmental conditions of these localities.

A determination of seed characters from 16 provenances covering the natural variation of the species was carried out by Barrett (1972). The average weight of 1000 seeds was 8.5 g with a variation between provenances from 6.3 g to 10.3 g.

As to length and width of the seed, average values were 5.5 mm and 2.5 mm respectively. The variations between provenances were small, lengths between 5.1 mm and 5.8 mm and widths from 2.3 mm to 2.7 mm. Length and width of the wing of the seed average 17.4 and 5.1 mm, respectively.

As to seed colour, several tones of black were found in 88 %, 12 % of the seed having a tone of dark brown. There was a great individual variation, not associated with provenances. The colour of the wing varied between chocolate and chestnut, with at least 5 different tones, more associated to individuals than provenances.

Seed dispersal and germination

The seeds of the serotinous cones have a relatively long viability on the tree. Seed of *Pinus patula* may not lose more than 40 % in germination when remaining on the tree without opening for up to 7 years.

The cone scales open gradually, which is a favourable feature for the species. This way some seed will always be available for germination at a time when the environment will give the best chance for survival. The strategy is extremely favourable for the survival of the species in natural conditions, as seed, available from different years, will gradually be released for regeneration. It is also possible that the seed in this way may escape predators more easily.

Because of the hygroscopic character of the wood fibres in the cones, the dehiscence is dependent on the ambient humidity and will increase with decreas humidity. Therefore, the trees will release larger quantities of seed during the dry period of the year, when there are the best possibilities for contact with the soil. Fires also help in the dispersal of the seed, especially when the trees die and all the cones open totally.

Wind is the principal dispersal agent because of the presence of wings. Some other possible dispersal methods may be mentioned: floating, transport by birds, rodents and insects, which have not been studied so far.

Natural regeneration will occur after dispersal where the right conditions for germination exist. Observations in clearings of the Sierra de Agua Fria for-

ests in Molango Hidalgo, Mexico, showed that the number of trees of *Pinus patula* would be about 6,000 per ha with an average height of about 5 m. In Sierra Norte de Puebla sites were found with about 50,000 plants per ha (average plant height 10 cm). Natural regeneration is prolific in plantation in South Africa, Malawi, Zimbabwe, Madagascar and New Zealand.

The initial development of the species in natural regeneration depends on light requirements. In dense populations it will therefore occur in the open spaces with good light conditions. Vela (1980) confirms these observations in an experiment with shade intensities of zero, one third, two thirds and three thirds. He observed lack of vigour and chlorosis in plants that were grown in shade intensities of more than one third.

7. PESTS AND DISEASES OF CONES AND SEED

The principal pests attacking cones and seed of the genus Pinus in Mexico are: *Conophthorus poderosae* (*Coleoptera: Scolytidae*) which attacks cones; Megastigmus (*grandeosus Hymenoptera: Torymidae*) whose larvae feed on seed: *Dioryctria* spp. (*Lepidoptera: Pyramidalidae*) which attack the cones; *Laspeyresia* spp. (*Lepidoptera: Oleothreutidae*) which attack cones and seed. Although these species were found in numerous pine species native to Mexico, attacks on *Pinus patula* were not reported.

According to Wormald (1975) none of the insects which attack cones and seed of *Pinus patula* in its natural distribution have been introduced into other countries by seed import. One example of *Chloropholus carinatus* (*Coleoptera: Cerambycidae*) was observed in cones of the species in East Africa, but the damages were insignificant.

In South Africa, Malawi and East Africa light attacks in stored seed have been noted. Among the detected insects the following may be mentioned : *Cryptolestes minutus, C. pusillus* and *Oryzaephylus surinamensis* (*Cucujidae*); *Stegobium paniceum, Lasioderma serricorne* (*Anobiidae*); and *Tribolium confusum* and *T. castaneum* (*Tenebrionidae*) (*Pyralidae*).

There has been reported occurrence of *Peridermium conigeum* and *P. mexicanum* infecting the branches and cones, preventing the formation of seed. The damage caused by this disease may be severe but *Pinus patula* is considered less susceptible than *P. pseudostrobus* and *P. montezumae*. The alternative host is Querqus; the disease is thus confined to areas where the genera occur together.

The species most susceptible to attack of *Peridermium conigenum* are: *Pinus leiophylla, P. montezumae, P. oocarpa, P. patula* and *P. teocote*. The attack makes the cones swell, deforming them into several times their original size. Infested cones do not produce seed and the scales resemble simple protuberances.

Attacks on cones and seed of *Pinus patula* by birds or mammals have not been reported. However, Wormald (1975) mentions that the bird, *Kakatoe roseicapilla*, which destroys the cones of *Pinus radiata* in Australia, may damage the cones of *P. patula*.

8. PRODUCTION AND COLLECTION OF CONES AND SEED

Flowering and fruiting age

Pinus patula flowers at an early age. In Zimbabwe female flowers are normally observed in the plantation at the age of 3. Male flowering normally begins in the fourth year and the production of viable seed starts after the fifth year.

In the *Pinus patula* plantations, established at an altitude of 3000 m in the experimental forest plots at San Juan Tetla, (National Institute for Forest Research), female and male flowers have been observed at the age of 5 and 6, respectively. The production of viable seed starts after the eighth year.

In natural stands detailed studies have not been carried out permitting exact determination of the age of flowering and fructification for *Pinus patula*. But some observations make it possible to suggest that flowering and consequent seed production are established between the age of 10 and 15. According to Vela (1980) seed production starts at the age of 15.

Selection of stands and trees

Natural stands or plantations to be used for seed collection should be at least 15 years in order to have a stable and abundant seed production. Seed should not be collected from isolated trees because of the increased risk of self-pollination and the negative effect of inbreeding between closely related individuals.

Seed trees should be selected according to special characteristics. They should be of good form, healthy, vigorous, light branching without loose knots, and with good natural pruning. In particular spiral growth, forked and unhealthy trees should be avoided.

It is essential to avoid collection of seed from poor phenotypes or trees which produce empty and non-viable seed. Willan mentions the following general guidelines for seed collections:

1. Collect seed only from healthy vigorous trees of reasonably good form that are making average or better than average growth.
2. Where possible, collect from mature or nearly mature trees. Overmature trees should be avoided, since seeds from them may be of low viability.
3. Avoid isolated trees of naturally cross-pollinating species, since these are likely to be self-pollinated. Seeds are likely to be few, of low viability, and

any seedlings produced are frequently weak or malformed.

4. Avoid collecting in stands containing numerous poorly formed, excessively branchy, off-colour, abnormal or diseased trees.

It should be mentioned that the trees of best phenotype are not the best seed producers. Willan therefore recommends that large-scale collection should be carried out in trees which are average or better than average, both in form and seed production.

For small-scale collections and for research purposes collection from dominant or co-dominant trees of average quality is recommended. Seed should be collected from a minimum of 10 trees, preferably from 25 to 50 trees, in each stand. The seed trees should be at least 100 m apart to reduce the risk of collecting from half-sib parents.

In seed production areas in natural populations, the number of trees per ha varies according to species. Patifio and Villarreal (1976) mention that for some Mexican pine species it is considered adequate to leave 30 to 40 trees per ha in natural forest. Thus taking into account that the seed production areas consist of individuals which have been kept for their excellence in form and seed production. In the natural forest these are generally well developed and mature trees.

In seed production areas in plantations there should be 180 trees per ha at the age of 20. Seed production plantations on Fiji are thinned leaving 200 trees per ha.

Seed production

Seed production per tree varies considerably both in natural stands and in plantations. In seed stands in Madagascar with 500-700 trees per ha 11.5 ton of cones are harvested, i.e. 40 cones per tree. Cone harvests in Mexico vary greatly with collections from 3-100 kg per tree.

In Madagascar an average weight of 50 gr per cone is found and 36.8 gr per cone in Pinal de Amoles, Queretaro, Mexico.

The number of seeds per cone obtained in different countries are listed in the following table:

		Number of seeds per cone
Kenya	1956	93
Zimbabwe	1969	45
"	1969	57
South Africa	1969	35
East Africa	1969	75-80
Mexico	1972	22

Some relations between cone and seed are given below (Wormald 1975; Carrillo &Avila 1979).

		Collected cones (kg)	Seed obtained (kg)
Kenya	1956	30	1/2
Zimbabwe	1973	91	1
Madagascar	1973	100	1-2
Mexico	1979	450	5

The values obtained in Zimbabwe, Madagascar and Mexico are very similar and indicate a relation weight of seed/weight of cone of 1:9 while the relation found in Kenya was somewhat higher, 1:7.

Pinus patula seeds are small, and the numbers very variable. The following values per kg are quoted by Wormald (1975):

Seed origin	Seeds/kg thousands
Mexico	97-158 (Mean 117) 116-146 197
Kenya	145-166 147 125-150 130 110-145
Tanzania	105-127
Zimbabwe	145 100-150 (Mean 127)
Malawi	110
South Africa	110-130 72 145 132
Queensland	122-164 (Mean 140)

18 seedlots of *Pinus patula*, which covered the distribution range in Mexico, contained 85.000 seeds/kg as the lowest value and 181.100 seeds/kg as the highest. The average of the 18 lots was 133.000 seed/kg.

Estimating the cone crop

The cone crop may be estimated once the cones have reached full size and are still green; this is approximately 2-3 months before the cones become mature.

The evaluation of the potential crop may be done by making a subjective estimate of the cone crop per tree. Some authors suggest a count of the cones in part of the crown (e.g. one quarter of the crown), and afterwards extrapolate the information to the whole tree. For conifers in Arizona and New Mexico "Few" cones per tree was defined as 1-20, "Many· as 21-160 and "Loaded" as over 160 cones per tree. Quantitative classifications of this type will clearly vary to a great extent according to species, provenance and site conditions.

The evaluation may be divided into two stages -one during the flowering season and the other one month before collection.

Irrespective of the method used to estimate the cone harvest, it is important to consider the following points (Patiño *et al.* 1983).

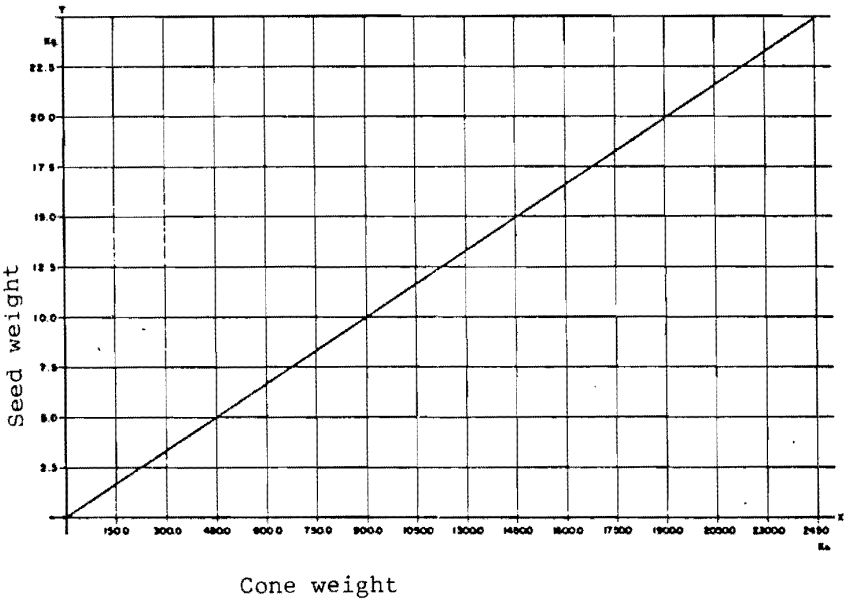
- Assess several trees in the stands chosen for seed collection in order to know the variation in seed production among the trees.
- Avoid isolated and edge trees so as not to overestimate the production.
- Do not count old cones that remain on the trees and which may resemble new cones, as they close with increasing humidity.
- Some cones should be examined to find the average seed content.

Once this information has been obtained, the harvest may be classified:

- from nothing (no cones) to very abundant (many cones in more than half the seed trees and 50% of these with abundant production).

To estimate the seed content per cone a lengthwise cut is made by a cone cutter, machete or similar tool and the number of filled exposed seeds are counted.

For 15 years Carillo and Avila (1979) have gathered information on seed collection and extraction and have found a relation between cone weight and seed weight (full seeds). Seed production as a function of cone weight was established for 15 pine species, *Picea mexicana* and *Pseudotsuga flahaulti*. The diagram for *Pinus patula* is shown below:



Equation of estimate = 0,01043

Seed weight without impurities and empty seeds expressed in kg. as a function of cone weight; locality Zacualtipan Hgo.

Determining seed maturity

Before seed collection it is important to make sure that the seeds in the cones have reached physiological maturity.

Care must be taken to avoid collecting immature cones, which is particularly likely at the beginning of the collection season. Time of maturing varies between and within trees in anyone stand, and if collection is made too early, a large proportion of immature cones may be collected which will either not open, or produce weak seed. It is generally best to lose some of the crop by delaying and ensuring that all cones are mature. Careful note should be taken of variation in maturing dates between stands, and collections should be organised to suit.

The maturity of cones and seed is accompanied by physical changes which may be used as maturity indicators, the changes in colouring being the most outstanding.

The following ways to determine the maturity of the seed are noted:

a) Preparation of tables showing times of fructification for species of interest.
b) Observation of colour of cones and seeds
c) Observation of the texture of cones and seeds.
d) Direct inspection of cones and seeds, and
e) Specific gravity and moisture content of cones.

Seed maturity may be determined by laboratory methods or field methods.

Laboratory methods

a) Dry weight
b) Chemical analysis
c) X-ray radiography
d) Moisture content of fruits

Field methods

e) Specific gravity of cones
f) Examination of seed contents by cutting test, and
g) Colour of cones.

Several indices should be taken into consideration to make a correct estimate of cone maturity as it is not possible to make a reliable estimate based on one criterion alone. Colour and specific gravity are found most adequate.

Collection methods

The serotinous cones remain on the tree for several years and it is therefore necessary to climb the tree to collect them.

The most convenient equipment for climbing forest trees are ladders and ropes. The use of spurs is not recommended as severe damage may be caused to the cambium of the tree. This is especially so when the same trees are climbed frequently, both in natural stands and plantations.

The choice of equipment will also depend on what may be available locally. No matter what method is used, the operators must have adequate safety belts and ropes and the necessary tools to detach the cones.

In seed orchards the cones may be collected from platforms mounted on vehicles, from which the external parts of the crowns may easily be reached. For *Pinus patula*, the tools used in Mexico have been branch cutters, as the cones are practically without peduncles and often sit in joints. The bell type hook, developed in Honduras, has been used for *Pinus patula* var *longipe-dunculata* and for some populations of *Pinus patula* south of the natural distribution where peduncles occur. This hook will detach the cones in many pine species without cutting the branchlets thus avoiding the loss of future harvests; it may easily be made locally.

In Mexico, the cone harvest of *Pinus patula* may take place from October to February. But as the cones are serotinous, they will remain on the tree without opening for prolonged periods and the cone collection may consequently take place in more convenient periods.

The seed may remain in the cones of the trees for more than 7 years, with loss of viability not exceeding 40 %.

Collections in Kenya are carried out from October to March and in Tanzania in October. In Madagascar the cones are collected from March to May.

Seed orchards

The majority of countries with improvement programmes for *Pinus patula* have established seed orchards based on superior or "plus" trees, either by vegetative propagation or based on progenies produced from seed.

Though many countries are selecting plus trees to establish seed orchards, the most intensive and advanced work is carried out in the African continent. Wormald (1975) recorded the number of plus trees of *Pinus patula* in 7 African countries to be 436 trees. The selection intensity used in the different programmes has varied. However, if we consider the plantation area above 12 years old, which according to the author was approximately 110,000 ha, one may perceive the great value.

The efficiency of selection is demonstrated through the high quality *Pinus patula* stands in Zimbabwe, which originate from clonal seed orchards. The average of 8 provenances in clonal seed orchards showed an increase of 10 % in volume, 13 % in stem form, and a 3 % decrease in wood density, at the age of 6.

The introduction from South Africa played an important role in the expan-

sion of plantations of the species in Africa. The origin of the breeding populations is unknown and one may perceive the limitations which this genetical material may have in future improvement programmes.

It would be of great importance for the continued improvement of the species to establish provenance trials with a broad genetic base from adequate provenances.

9. SEED PROCESSING

When the cones have been transported to the plant for seed extraction, they should be stored in a well ventilated place in order to allow the cones to lose as much moisture as possible, before starting the drying process which will open the cone scales for seed extraction.

The cones may either be dried in the sun or in drying kilns.

The opening time for the cones dried by the sun will vary according to temperature and humidity. Extraction of cones of *Pinus patula* in ambient conditions in Mexico City (altitude 2250 m) mean annual temperature of 18°C and precipitation of 750 mm. takes approximately 6 weeks to get the highest possible seed yield.

The cones open readily with heat. Three days in the sun is sufficient to open cones completely in Kenya. The cones open when placed in polythene covered concrete frames. In the dry season the temperature in these frames regularly rises to over 50°C. The seed is extracted by tumbling the cones in a wire mesh cylinder which allows the seed to fall through into a trough. The initial drying extracted about 85 % by weight of the available seed, a further 15 % could be obtained by wetting and redrying the cones. In Zimbabwe artificial heat is used to supplement heat from the sun for opening the cones and in New Zealand cones are placed on racks in a steam-heated kiln and kept at 66°C for 8 hours. In Queensland cones are placed in near boiling water and are then heated over wood fires for about 24 hours. When cones close after having been open, it is very difficult to get them to reopen; Kenyan experience is that cones could be reopened by soaking and redrying. Where long hours of sunshine and low humidity is predictable, sun extraction is much cheaper and is a practical method even for large quantities of seed.

A successful pretreatment for opening cones is to submerge the cones into boiling water for 30-50 seconds using half full sacks and afterwards expose them to the sun. In Mexico, this practice reduces drying time for *P. patula* cones by approximately 30 %.

Seed extraction

Once the cone scales have opened, the seed may be released. Manual methods may be used to extract the seed either by shaking the cones or moving

them with appropriate tools so that the seed will be released. These operations should be carried out over a canvas sheet or a tarpaulin which will allow the seed to be gathered easily and without major damage.

Extraction may also be carried out in a cone tumbler (cylinder, box etc.) with walls covered by wire netting. When the tumbler is rotated the cones will hit each other and the wire netting, thus releasing the seed.

The wings or other impurities which may still be attached to the seed must be removed.

Dewinging

It is important to remove the wings from the seed in order to avoid problems during storage (fungus contamination) and to facilitate handling and increase the purity percentage of the seed. The method should not cause mechanical damage to the testa of the seed.

The wings can be removed by rubbing the seed between the hands. For large quantities the system used by the British Forestry Commission of tumbling seed in a clean cement mixer with a small quantity of water was found to be successful in Kenya. This process did not appear to raise the moisture content of the seed unduly. In Zimbabwe the use of an air hose in a sack has been found to be very effective.

Suitable tumblers may be made from drums, turned by hand or motor, or a cement mixer may be used. In Honduras, best results are obtained with *P. caribaea* and *oocarpa* by tumbling about 75 litres of seed with wings for 15 minutes, adding 1.5 litres of water by sprinkling, and then tumbling for a further 45 minutes (Robbins, 1983).

One kind of dewinging equipment used in Mexico is a cylinder covered with wire netting. Brushes of soft bristles rotate in the cylinder and loosen the wings by rubbing the seed against the wire netting. This method allows processing the seed at a reasonable rate without significant damage.

Cleaning the seed

After dewinging, the seed will generally contain impurities which must be removed. Cleaning may be carried out by hand or mechanically. Among the manual methods are screening and winnowing - either by a natural wind flow or by use of a domestic fan.

Among the common mechanical equipment are commercial cleaning machines. They consist of a feeding funnel to regulate the flow of seed moving over graduated screens, which separate seed and waste by vibrations produced by a motor and pulleys. The seed consists of full and empty seeds, and the latter have to be removed to increase the quality of the seedlot. The separation of full and empty seeds may either be done by placing the seedlot in a container with water and separate them by flotation or by use of equipment producing an air-flow graduated according to the seed in process.

It is important to point out that in the case where seed has been stored for a long period and/or have a low humidity content, flotation should be carried out with necessary care and precaution, as the majority of the seeds may float despite the fact that they are viable.

After cleaning, the seed may be sun dried on a sheet, about two seeds thick, and raked frequently. The seed will lose about 1.0-1.5 % in moisture content (fresh weight basis) per hour. Small quantities may be dried in the laboratory in an oven with temperatures of 40°C to 45°C.

When dry, the seed may be stored. The seedlots should be homogenized by thorough mixing before storage. To avoid damage from insects and fungi, especially when the seed are not stored in sealed containers and may reach the ambient equilibrium, the seed may be treated with chemicals either as a powder or as a liquid solution, which requires subsequent drying.

Whenever possible, the use of chemicals should be avoided since they may reduce viability.

10. Seed Storage

Two principal ambient factors should be considered when seed is stored: humidity and temperature. The more critical factor is humidity. According to the humidity requirements, tree seed are classified as orthodox (which may be stored at a low moisture content) or recalcitrant seed (which are difficult to store).

The seed of the genus Pinus is orthodox. The seed may be stored satisfactorily for long periods. The seed store better the lower the temperature and the lower the moisture content.

For storage of orthodox seed for periods up to 5 years, a moisture content of 5-10 % and temperatures of 0-5°C are recommended. For longer periods, the same moisture content and minus 18°C is recommended.

For seed of Mexican conifers and *P. caribaea* var *hondurensis* and *P.oocarpa* the most favourable storage conditions would be: moisture content 6-8% (based on fresh weight) and temperatures in cold storage between 3-4°C.

To maintain the moisture content of the seed within the adequate limits, it is important to store in air-tight containers to avoid interchange of humidity. They should be of rigid materials: fibres, plastic or metal and with a pressure lid; or soft materials such as polythene bags of a thickness of at least 4 microns.

A 9 % germination decrease has been reported in seedlots of *Pinus patula* kept in cold storage for 50 months (initial germination 89 %; final germination 80 %). The seed was stored in metal containers with pressure lids and

temperatures of 0-5°C. Seed of this species may be stored at temperatures of approximately 20°C, low relative humidity for 9 months without great loss of germination.

P. patula seed stores well and maintains its germination capacity for a year or even longer when stored in open bins at room temperature in Nairobi, Kenya. However, it is advisable to store it in insect proof, air tight containers in a cool place. The most important single factor in storing seed is its moisture content and the humidity of the store. In New Zealand the moisture content is reduced to 5 or 6 % before storage, yet in Kenya no drying, other than that achieved by the sun after dewinging the seed, was found necessary. If the seed is to be stored for more than two years, it is advisable to do so in air tight containers at a moisture content of less than 10 % and in a temperature of about to 4°C.

Results from laboratory tests carried out at the Forest Research Institute, INIF, Mexico, with various seedlots of *Pinus patula*, indicate that it is possible to keep seed in cold storage for more than 10 years without great loss of germination capacity.

The germination capacity of the species may be considered good, fluctuating between 75 and 90 %.

In seedlots processed by INIF the initial germination percentages fluctuated between 60 and 98 % with test periods of 28 days. An average of 84 % was obtained for 32 seedlots, covering the distribution range of the species.

Carrillo and Talavera (1983) worked with 5 seedlots of *Pinus patula* from 5 Mexican provenances, and correlated moisture content with germination per cent obtained in the laboratory during 8 months of storage. The humidity contents varied for newly collected lots between 8,7-10,9%. They did not find any relation between the measured factors in as much as the highest germination values (90 %) were obtained with intermediate humidity contents (9,6 %) and the lowest germination percentage (80 %) with humidity contents of 9,9 %.

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