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Published 1972
Reprinted 1976

TECHNICAL PAPER 21

FACTORS INFLUENCING OCCURRENCE
OF CYPRESS PINE REGENERATION
IN NEW SOUTH WALES

by

C.J. LACEY

FORESTRY COMMISSION OF N.S.W.

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FACTORS INFLUENCING OCCURRENCE OF
WHITE CYPRESS PINE REGENERATION
IN NEW SOUTH WALES

by C. J. Lacey

Summary

The history of the cypress pine regeneration problem in New South Wales is recounted and a description is given with some experimental results of the biological and environmental factors which interact from year to year to produce varying amounts of regeneration. The biological developments include flowering, seed production, seed shed, germination and seedling establishment. The environmental factors of most importance include rainfall and soil moisture, soil type, overstorey, grass, shrub and litter cover, grazing and fire.

Introduction

White cypress pine is distributed extensively on a wide array of light textured soils in western Queensland and western New South Wales and is the most important timber species in this region. It occurs in pure stands or more commonly in association with a large number of hardwood species, mostly eucalypts, though none of these associated species have a range identical with that of cypress and none are as extensively distributed.

Lindsay (1967) has described the major forest types of the New South Wales cypress pine zone and the geographical and topographical distribution of white cypress pine together with statistics of the associated climatic changes. Cypress pine occurs in semi-arid regions where considerable variations in temperature and evaporation exist between seasons. The average annual rainfall may show either a slight summer or winter maximum or may be evenly distributed. However, average monthly evaporation in all localities greatly exceeds rainfall throughout the year except for several winter months. Hence summers are hot and dry whilst winters are comparatively cool and moist. These seasonal changes exert considerable influence on seed germination and the development or regeneration of all tree species in the area.

Description of the ecology or growth characteristics of white cypress pine is hampered by the fact that the botanical nomenclature of this species has been quite confused for a number of years. In this paper the common name "white cypress pine" or "cypress pine" refers to the species formerly known as *Callitris glauca* R. Br ex R.T. Baker et H.G.Sm. but considered by Garden (1956) as *C. hugelii* Carr and by Blake (1958) as *C. columellaris* F. Muell. Blake also considered that *C. intratropica* F. Muell ex R.T. Baker et H.G.Sm. was the same as *C. columellaris*, and thereby embodied what were previously considered as three separate species under the one name. Under Blake's nomenclature *C. columellaris* occupies three distinctly different habitats and it is therefore not surprising that there are superficial differences in appearance. However, the observation by Stocker (1966a) indicates these differences are heritable. When white cypress pine from Queensland was grown in the Northern Territory alongside *C. intratropica* there were

marked foliage and form differences. Furthermore, Gay and Evans (1968) have referenced distinctions relating to chemical, mechanical, anatomical and growth properties.

Therefore, under the circumstances, reference to the common name of white cypress pine is more explicit. This will be used in this paper and it is sufficient to define it from a forestry viewpoint as that species of *Callitris* which constitutes important commercial forests in south-west Queensland and western New South Wales. For the purpose of the subject it is necessary to point out that it is the same species on which Hawkins (1966) carried out investigation into the flowering and seeding habits. Hawkins referred to it as *C. columellaris*, but it shows at least conspicuous varietal differences from *C. intratropica* on which Stocker (1966a) has also published observations of the flowering and seeding habits.

Recent History and Current Status

Regeneration of white cypress pine occurred prolifically between 1880 and 1905 and from 1952 to the present time. In the intervening period it was almost completely absent. Consequently, even though provision for obtaining regeneration is an essential requirement for developing a silvicultural system for any species and would warrant attention in cypress pine research for this reason alone, this aspect of its silviculture is of especial interest.

Around the turn of the century a number of reports referred to the development of dense cypress pine regenerations (pine scrub) in western districts. Various annual reports of the Forest Branch of the Department of Mines, the Royal Commission of Inquiry into the Western Division 1901 and the Royal Commission of Inquiry into Forestry 1908, all made particular mention of the development which in most cases was considered a serious problem for the grazier. The suggested causes of the problem were the occurrence of a succession of high rainfall years, the decline in the frequency of fires, and the large scale clearing of the vegetation which presented openings for regeneration establishment.

History was repeated in the 1950's which were also characterised by a number of high rainfall years in most western localities. The scrub and timber regrowth of various species which resulted have intensified the graziers' difficulties in that herbage production, visibility and mobility have been reduced, particularly in the Western Division of the state. This has been reported in detail by an Inter-Departmental Committee (1969). The Committee concluded that the problem in the Western Division was "a natural feature of the environment occurring as the result of a combination of several factors and accentuated by the absence of natural fires".

From the accounts provided in these reports on scrub and timber regrowth, the influence of high rainfall years, clearing and fire is apparent. However, one factor that has not been clarified is that of grazing, particularly by rabbits and sheep.

In the Inter-Departmental Committee's report, due to the conflicting evidence, no conclusion was drawn to the effect of grazing on scrub and timber regrowth. The reason for this could be that no differentiation was made between the palatability of various species. Cypress pine, as opposed to some scrub species, is palatable to rabbits, sheep and cattle, and the effect of grazing in preventing regeneration establishment has been demonstrated by means of fenced enclosures within State Forests on many occasions. Such experimental work has shown conclusively that when stock and rabbits are excluded some regeneration will result. Consequently, if rabbit infestation was heavy, as is generally contended, and high stock numbers prevailed in the

Western Division in the 1890's, it can only be assumed that the pastures were sufficiently luxuriant to provide alternative fodder to cypress pine seedlings.

The recent era of regeneration beginning in 1952 coincided with the exceptional sequence of high rainfall years and the reduction of the rabbit population by the myxomatosis virus. Favourable rainfall periods had occurred prior to 1952 and massive germination had been noted, but rabbits prevented this from becoming established. At the present time, under undisturbed conditions, regeneration commonly occurs in stands of about 50,000 stems per acre (120,000 per ha) (Figure 1) and rates of over a million seedlings per acre (2½ million per ha) have been registered. The phenomenon has been aptly referred to as "wheatfield regeneration".

This demonstrated regeneration capacity of cypress pine does of course far exceed the extent required. Hence the 1905-1952 problem of no regeneration has become completely reversed, compelling a new approach to cypress pine management. Prior to 1952, when very little regeneration could be obtained, there was no possibility of providing for a second rotation. Management was oriented towards an organised and gradual liquidation. This problem has now been replaced by the difficulty of removing the bulk of the seedling numbers in order to allow rapid diameter increment of those remaining to merchantable, sawlog dimensions. Thinning treatment of present regeneration stands is made essential by the nature of the growth of the species. Cypress pine stands do not have a well developed facility for self-thinning but rather all stems tend to cease growth and can subsist in this condition for very long periods of time. Mortality occurs in badly over-stocked stands, especially when the basal area exceeds 80 square feet per acre (18 m²/ha) but so slowly that there is very little growth advantage to the remaining stems. Hence such stands are virtually unproductive and may remain so indefinitely.



L632/33

FIGURE 1 - "Wheatfield" cypress pine regeneration of variable density, attaining rates in excess of 70,000 stems per acre (170,000 stems per ha).

The difference in growth between thinned and unthinned regeneration is illustrated by Figure 2. The cost of such treatment may be sufficiently low to guarantee reasonable financial returns, but the economics are naturally made much more attractive if this cost can be avoided or reduced by sound silvilculture.

In addition to the thinning problems now prevalent in traditional cypress pine areas, management considerations have had to be extended to the large areas in which the pine component of hardwood-pine forests has been greatly increased. This changing pattern has meant that forests previously consisting predominantly of hardwood, with little or no future value, can now be incorporated under management plan for sustained yield of cypress pine.



L677/11

FIGURE 2 - 1956 regeneration thinned to 8 ft. (2.5 m) spacing in 1960, compared with unthinned regeneration in background. Yarrigan State Forest.

The areas of cypress pine forests in New South Wales currently having excessive regeneration is not known. However, as previously mentioned, in parts of the Western Division of the State and particularly around Cobar, it has occurred to such a degree as to be regarded as a weed species which seriously hinders the management of the land for grazing. With the decline in financial returns from sheep grazing, it is possible that the best use of the land is in timber production alone or in combination with grazing. In the State Forests of the Central Division, the problem has usually been considered greatest in the southern districts of Forbes and Dubbo. In actual fact it is just as pronounced in the northern forests of the Baradine-Pilliga-Narrabri region, but has been largely overlooked there because its occurrence is mainly on areas considered to be of inferior site quality or that have traditionally been under less intensive management.

The history of the regeneration of cypress pine, culminating as it has in the present situation where vast tracts of country require thinning, makes it imperative that foresters

are fully conversant with the influences of the many biological and environmental factors which interact from year to year to produce varying amounts of regeneration occurrence. The biological developments include flowering, seed production, seed shed, germination and seedling establishment. The environmental factors of most importance include rainfall and soil moisture; soil type; degree of overstorey; grass, shrub and litter cover; grazing and fire and insects.

More data is required on all these aspects and this will take a long time to collect. In the meantime this paper summarises the available information on the subject. The information is derived from old records and from personal observations of field officers of the Forestry Commission of New South Wales, as well as from experimental work.

As a result of the age structure of cypress pine stands in New South Wales, variations that could be expected to occur with age, such as quantities of seed produced, could not be investigated fully. Observations have been confined to those stands which commonly comprise present day commercial cypress pine forests which are of indefinite age, and to recent regeneration which is up to twenty years old.

Flowering

Information on the development of male and female cones of white cypress pine has been given by Baker and Smith (1910), Baird (1953), the Annual Report of the Queensland Department of Forestry (1960) and Hawkins (1966).

Baird's information is the most complete and is contained in a detailed study of the life history of the genus *Callitris*, with particular attention given to *C. robusta* (syn. *C. preissii*). Some details of flower development in white cypress pine still require clarification but essentially the behaviour is the same as for *C. robusta* and the following description is taken from Baird.

"...the young male cones and the small branches which bear the primordia of the female cones can be recognised in November or December. There is little change through late summer and autumn and the pollen does not ripen until the following spring. Trees shedding pollen can be found from early August to late October but on any one tree the cones ripen almost simultaneously and pollen is shed over a period of ten to fourteen days with a peak of two to three days when pollen is released in dense clouds. The majority of (female) flowers are pollinated in September. During the next few weeks the sporophylls thicken slightly and almost cover the ovulets but there is little increase in diameter. These minute cones, 2-3 millimetres in diameter, remain unchanged for a year or more before growth is resumed some time between September and November. Once started growth is comparatively rapid.... cones have almost, if not quite reached their full size at fertilisation....fertilisation occurs in April and developing embryos are found through May and June."

The interval between pollination and fertilisation has not been determined for white cypress pine. Baird gives the season and duration of stages for a number of species and states that the interval is 18-20 months for *C. endlicheri* (syn. *C. calcarata*) and probably longer for *C. glauca*.

Flowering occurs in white cypress pine at an early age. In one instance at Narrandera Forestry Commission Nursery a three year old tubed seedling produced a single developed cone when less than two feet (0.6 m) in height. In the field individuals have been noted to produce cones at six years. At this time the regeneration may be less than four feet (1.2 m) high. In such instances only several female cones are produced and these are borne on short branchlets close to the stem apex. Several cones may be produced by a small proportion of young cypress pine stems 4 to 8 feet (1.2 to 2.5 m) in height even under conditions of extreme stand density.

Seed Production

Seed matures in the early summer following fertilisation of the female cone. Seed collections made in October have shown high viability and seed may be mature before this time.

Stand density markedly influences the quantity of seed in any one year. In very dense stands there is scant seed and at basal areas of over 80 square feet per acre (18 m²/ha) the supply is usually negligible. Experimental work with seed traps for the 1969-70 seed crop gave the data presented in Table 1. Over the range of basal areas examined, seed production was inversely proportional to basal area. However, the highest basal level in this experiment was only 62 square feet (14.2 m²/ha) and an appreciable quantity of seed was still produced.

TABLE 1 - Seedfall for 1969/70, related to Total Basal Area

Plot No.	Basal Area (sq.ft./ac.)	Stocking (stems/acre)	Weight of Seed/acre (lbs.)	No. of Seed/acre (thousands)	No. of Seed/lb. (thousands)	Percentage Unfilled Seed
A	62	320	6.0	315	52	51
C	32	140	20.5	727	35	29
F	20	60	48.7	1616	33	12

The number of seed produced per acre for the lowest basal area is comparable with figures given by Hawkins (1966) for good seed years in Queensland. Hawkins found in a five year study that seed production varied from 0.6 lbs. per acre (0.5 kg/ha) in a poor year to 62.3 lbs. per acre (55.5 kg/ha) in a good year. However, because of the effect of stand density on seed production, figures were provided for the Queensland data.

Table 1 also shows that in this instance seed weight was lowered with increasing basal area and that this is related directly to the percentage of unfilled seed.

The limit at which decreasing total basal area ceases to increase the seed crop cannot be determined without more intensive sampling techniques. However, it is evident that individual trees can carry considerable quantities of seed. In Table 2, data is presented from a total cone collection made from two trees. Seed numbers were estimated by determining the number of cones per pound and seed number per cone.

TABLE 2 - Seed Numbers Produced by Individual Trees

Location	Diameter Breast Ht. (inches)	Height (feet)	Stand B.A. (sq.ft./ac.)	Seed Nos. (thousands)
Baradine	10	42	10	142
Forbes	23	55	Open Grown	1218

The open grown tree produced almost as many seed as the 24 trees in plot F, the most prolific producer in the seed trap experiment.

Individual trees vary consistently in their production of seed. As mentioned, suppressed trees exhibit little flowering and therefore have poor seed production, while the dominants of the stand or trees that are free grown form far more seed. As a consequence of normal variation, some trees in a stand are consistently more prolific seed producers, independently of their dominance classification.

Different stands also exhibit different behaviour in seed productivity within the same general climatic conditions. In the 1969 seedfall in the Baradine district, local variations in seed abundance were detected between stands of similar age and history of logging and treatment operations. This variation was maintained into the 1970 season. The difference would appear to be due to an intrinsic feature of the stands through such influences as site or insect damage. Little is known of site effects, but a certain amount of insect damage to developing seed is usually manifest in all cypress pine stands and is possibly more pronounced in some localities.

Seed Dissemination

Dissemination of the seed is a natural consequence of the cone drying out. Usually this occurs from October to January, with the majority of the seed crop falling in a four week period of November/December. Most seed is shed in close proximity to the tree and this pattern is illustrated by Figure 3, which shows two groups of seed trees surrounded by dense patches of regeneration. Although most of the seed falls close to the seed trees it is evident that the winged seed of cypress can travel for a considerable distance. The absolute distance is naturally dependent on the height of the tree, stand density and wind strength at the time of shedding. Isolated seedlings have been recorded up to four hundred yards (350 m) from open grown parent trees. Widespread dissemination is demonstrated by Figure 3 and in the regeneration patch in the foreground there are five seed trees with scattered regeneration at distances up to three hundred and fifty yards (320 m) from the nearest seed tree. It is possible that some seed is transported from the position where it first falls by whirlwinds, which are not uncommon during summer throughout the cypress pine zone. Subsequent movement of seed by wash could also account for its spread on sloping sites, though sloping sites are of restricted occurrence in cypress pine areas.



L680/14

FIGURE 3 - Occurrence of regeneration in patches surrounding seed trees and showing isolated regeneration spread over a wide area. Group in foreground has five seed trees.

Germination

In Table 1 it was shown that high stand density lowered seed weight and that this was related to an increase in the percentage of unfilled seed. Plot A had far less filled seed than Plot C, which in turn had slightly fewer than Plot F. This effect is directly reflected in the germination capacity of the seed from the three plots and in Table 3, when total seed is considered, germinative capacity is inversely proportional to stand density. However, when only filled seed is considered, stand density has no effect and the relationship of germinative capacity with filled seed shown in Table 3 is very close and only differs by the amount of rotted seed.

It can be concluded that increasing stand density results in a higher percentage of unfilled seed, but that the germinative capacity of filled seed is unaffected. It is also evident from the high germinative capacity of filled seed that there is negligible seed dormancy.

TABLE 3 - Percentage Germination of Cypress Pine Seed Related to Basal Area

Plot No.	Basal Area (sq.ft./ac.)	Percentage empty seed	Percentage filled seed	Percentage rotted seed	Germinative Capacity Total Seed	Germinative Capacity Filled Seed
A	62	51	49	5	44	90
C	32	29	72	0	71	100
F	20	23	77	5	72	96

The occurrence of the small amount of rotted seeds from the seed traps is probably a chance effect depending very much on rainfall and moisture retention by the traps.

The germination tests carried out above were under a constant temperature of 20°C, and all viable seed had germinated in approximately three weeks. The result of viability testing on a separate seed lot is given in Figure 4. There was little difference in germination rate or percentage between untreated seed and seed that had been dry stored for four weeks at a low temperature of 5°C. However, seed stratified (moist cold stored) at 5°C for a four weeks' period showed an interesting effect in that, although the germination rate was initially increased, the time taken for all sound seed to germinate was not reduced. Apparently there was a difference in response between seeds to the stratification process.

Field germination has been commonly observed in the autumn to early winter months (late March to June) under good soil moisture conditions following high rainfall. Germination associated with high rainfall has often been dense whilst only scattered regeneration has been noted following low rainfall. Timing is also critical because high rainfalls occurring at a later date, such as in August/September, have not given a heavy germination comparable with that of early rains. There have been no confirmed observations of germination occurring during the summer months of October/January and only isolated observations in February. It is unlikely that the prevailing climatic conditions in summer, of high temperature and low frequency of effective rainfall, would enable germination to occur.

The inhibitory effect of high temperature is apparent from laboratory testing. Scott (1969) found that germination of cypress seed from New South Wales was reduced from 95 per cent at a constant temperature of 20°C, to 9 per cent at 25°C. Mr. A.G. Floyd (pers. comm.) found that a seed lot from the Pilliga region had a germinative capacity of 100 per cent at a temperature of 15°C, 94 per cent at 20°C, but nil at 25°C.

High temperatures also increase evaporation and make it less likely that moist conditions could be sustained long enough in summer for germination to occur. In Table 4 data is supplied for monthly variation in temperature, rainfall, evaporation and frequency of effective rainfall for two widely separated localities in the cypress pine zone. The data for effective rainfall is from Hounam (1947, 1950), which in turn is based on the criteria by J.A. Prestcott that for germination and satisfactory plant growth the factor $\frac{P}{E}$ 0.75 should exceed 0.54. This is a general index only and does not necessarily relate specifically to the germination requirements of cypress pine. The data simply serves to show that in both localities the winter period has a higher frequency of effective rainfall, though this is less pronounced where there is a relatively high annual total rainfall which is largely distributed through the summer months (Narrabri).

The occurrence of germination in any one year has been linked with the current seedfall of the previous summer. This implies that cypress pine seed does not remain viable in the field from year to year. The reduction in viability under field conditions was examined for the 1969/70 seedfall on Plot F, referred to previously in Table 3. Three collections of 80-100 seeds were made in May from bare ground and from beneath two densities of grass cover, including a very dense sward. The collections were laboratory tested at 20°C for three weeks, but all three failed to show any germination.

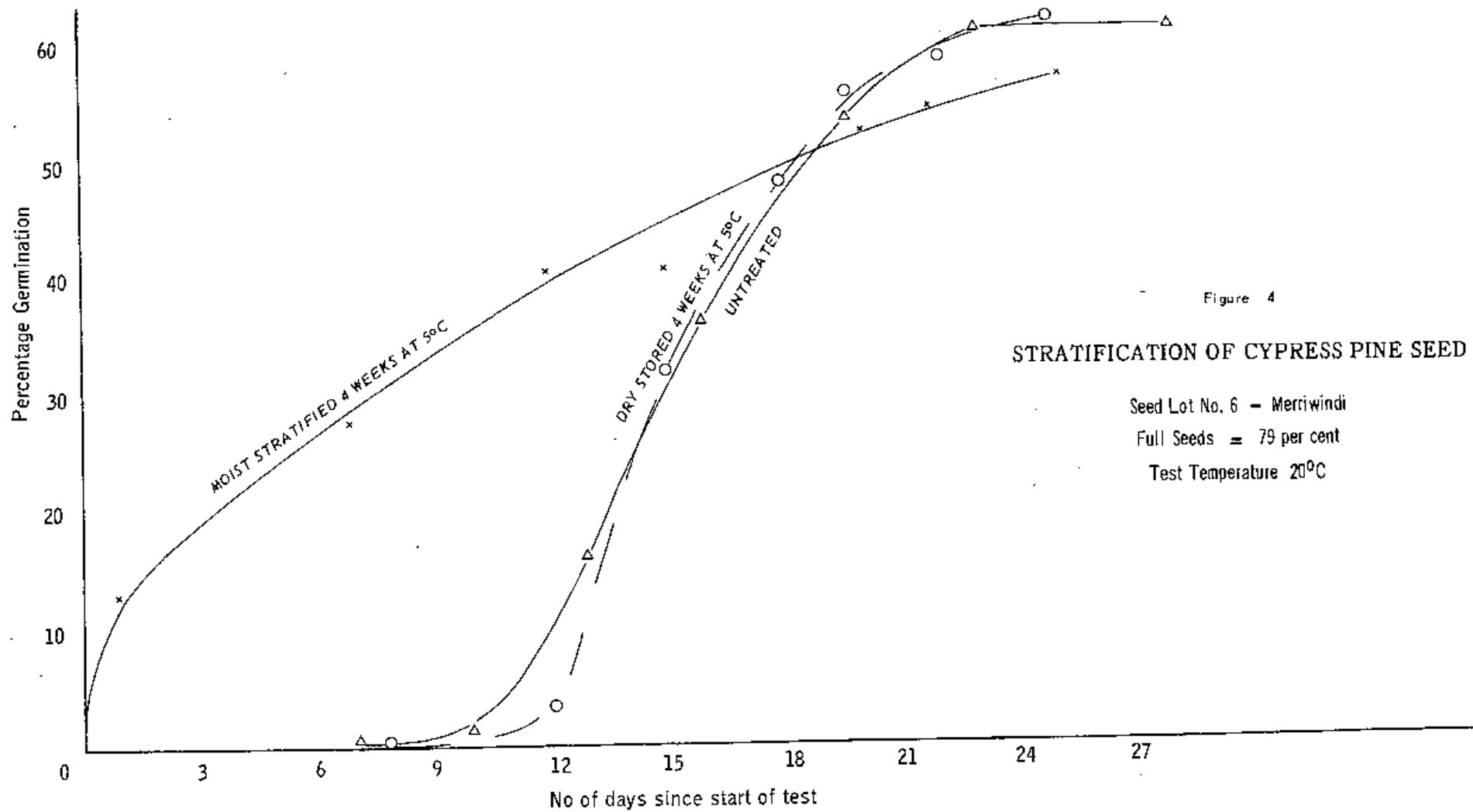


Figure 4

STRATIFICATION OF CYPRESS PINE SEED

Seed Lot No. 6 - Merriwindi
 Full Seeds = 79 per cent
 Test Temperature 20°C

TABLE 4 - Climatic Conditions for Two Locations of White Cypress Pine in New South Wales

NARRABRI (Summer rainfall maximum)

	J	F	M	A	M	J	J	A	S	O	N	D
Mean maximum temperature (°F)	95.6	93.2	88.6	80.2	70.9	63.8	62.7	67.2	74.1	82.1	89.2	94.0
Mean minimum temperature (°F)	66.7	65.6	61.3	53.0	45.4	40.8	38.2	40.3	45.6	53.0	59.5	64.3
Mean rainfall (points)	320	318	205	122	193	196	176	149	146	247	261	201
Mean evaporation (inches)	12.1	10.1	9.0	6.6	3.7	2.7	2.7	3.4	5.1	6.8	9.6	10.8
Per cent frequency of effective rainfall ($\frac{P}{E} \times 0.75$)	38	38	45	52	52	80	74	63	48	48	45	44

GRIFFITH (Rainfall approximately uniformly distributed)

	J	F	M	A	M	J	J	A	S	O	N	D
Mean maximum temperature (°F)	89.2	88.1	82.8	72.7	65.0	58.3	57.6	60.9	67.7	73.9	80.6	86.3
Mean minimum temperature (°F)	61.3	61.5	56.6	49.0	42.9	39.4	37.8	39.1	43.0	48.4	53.7	58.7
Mean rainfall (points)	107	126	168	134	136	145	127	133	111	180	114	114
Mean evaporation (inches)	10.02	7.65	6.42	4.10	2.50	1.74	1.77	2.45	3.90	5.23	7.42	9.32
Per cent frequency of effective rainfall	22	22	21	39	67	88	79	75	48	44	24	5

Approximately forty per cent of the collections were empty and the remaining 60 per cent had rotted contents. This compared to the 72 per cent germination of the seed freshly collected in December 1969 and of which 23 per cent were empty and 5 per cent were rotted.

Viability of cypress pine seed can be accurately determined by cutting tests. Discolouration of the seed contents is directly linked with non-viability, as are insect damage and emptiness. By this method, the results of laboratory tests of fallen seed from plot F were confirmed as a general condition of the fallen seed in the Baradine district. Collections were made in June, 1970, from three widely separated experimental sites and of 1,000 seeds examined on each site only two seeds indicated viability by having sound contents. A similar situation was found to exist in Forbes district where, in four collections made in July, the sound seed was reduced to a range of 0.5 to 3 per cent.

The percentage of empty seed at the time of seed fall is largely a consequence of insect damage of seed in the cone, particularly by hymenopterous insects, and of infertility. Later deterioration is caused by fungal and/or bacterial rots as well as some insect damage.

Despite the biological and climatic hazards to seed supply, germination rates can be very high and actual results of germination in the winter of 1968 for a southern area are given in Table 5. Sampling was carried out on eight 36 square feet (3.34 m²) quadrats for an area on Backyamma State Forest in Forbes district. The germination rate reached over a million per acre (2½ million per ha) and such rates have been previously recorded at Backyamma and elsewhere in the 1950's. The density of the overstorey shedding the seed was about 50 to 60 square feet per acre (11 to 14 m²/ha). Although this would seem rather high for maximum seed production the stand consists largely of mature trees; is on high site quality and still vigorous.

TABLE 5 - Density of White Cypress Pine Seedlings
Arising in Winter, 1968, on Backyamma
State Forest

(Results expressed as rate/acre in thousands for each 36 sq./ft. quadrat)

Quadrat No.	1	2	3	4	5	6	7	8
Rate/acre	377	363	373	752	1316	964	680	563

Over the whole experimental area inspected, of some twenty acres (8 ha), it was almost impossible at this time to find a square foot without several cypress pine seedlings. The germination was in response to an abundant seed supply the year previously, subsequent moist conditions and good grass cover. In contrast when one of a number of these conditions are unfavourable, germination may be entirely absent.

Both hardwood and cypress pine litter probably assist germination by creating good moisture conditions. Germination has often been observed under hardwoods, where there is usually a greater accumulation of litter than in pure cypress pine stands, and beneath fallen crown of cypress pine where its litter is concentrated. Moreover, on sandy soils where there is often scant grass cover, hardwood or cypress pine litter including cypress pine seed is aggregated by rainwashing and

germination is often confined to these areas. Germination can also be found in dense cypress pine stands where litter is in greater quantities than in thinned stands. However, its occurrence in such areas is not common due to poor seed supply and the fact that seedlings are subjected to much greater competitive pressure.

Establishment

Given an abundant seed supply, in the cypress pine zone the most important environmental factor controlling seedling establishment is that of soil moisture which in turn is regulated by soil type, the intensity of rainfall, evaporation, and the soil moisture demands of the established species present. Grazing and fire may also prevent regeneration establishment or result in its complete destruction once it has become established.

Soil Moisture

As a normal development of the limiting effects of soil moisture demonstrated by the data of Table 4, greatest mortality of seedlings can be expected through the summer months immediately following germination. The extent of the mortality depends very closely on the frequency and amount of summer rainfall. In moist summers very high survival of germinated seedlings may be obtained while in dry summers complete mortality may result. In Table 6 the results are given for the survival through the comparatively mild 1968/69 summer of seedlings referred to previously in the germination quadrats at Backyamma State Forest. In this summer there was no definite drought period and rainfall in December, February and March was particularly high.

TABLE 6 - Survival of 1968 Winter Germinated Seedlings through the 1968/69 Summer on Backyamma State Forest

(Results expressed as percentage survival of the counts made in spring 1969)

Quadrat No.	1	2	3	4	5	6	7	8
Percentage survival to April, 1969	19	19	8	12	35	34	22	4

Due to the initial prolific regeneration in this instance, the area would still be severely overstocked if all present regeneration were to survive. Competition from the overstorey would be expected to exert some influence and experiments have been designed to observe the effect of varying basal areas.

In contrast to the results above, at Killarney State Forest in the Baradine District, mortality of 1968 germinated seedlings was complete by January, 1969. Early 1968 summer rainfall was low, particularly in November when only 60 points (15 mm) fell compared to the average of 243 (62 mm) and the seedlings with densities ranging from 80,000 to 407,000 per acre (200,000 to one million per ha) were almost entirely killed during this period.

A feature which modifies the effect of low summer rainfall on seedling survival is the time of germination. It has been consistently observed that seedlings resulting from germination in autumn have a higher survival rate than those arising in late winter or spring. This is no doubt a

consequence of greater development of the seedling, and especially its root development.

Soil Type

Biddiscombe (1963) in a vegetation survey of the Macquarie region of New South Wales noted that by contrast with the sensitivity of many of the Eucalyptus species, a very wide soil tolerance is displayed by cypress pine. In western New South Wales Beadle (1948) has also observed that "...the outstanding examples of the indifference of the climatic climaxes to the soil zones are the *Acacia aneura* association and the association of *E. populifolia* with *Callitris glauca*." Beadle also recorded cypress pine on soils of widely different soil reaction, which ranged from PH5 to PH7.5. Downs and Sleeman (1955) further recorded the presence of cypress pine on terra rossa soil of PH7.9 in the Macquarie region. Data collected by Waring (1950) in the Pilliga region demonstrated that well developed stands of cypress pine can occur on sandy soil of a wide pH range and very low fertility. (However, it is possible that chemical factors may be responsible for the exclusion of cypress pine from certain sandy soils of the Eastern Pilliga outside the area of Waring's investigation.)

The edaphic factor of most importance, governing the occurrence of cypress pine regeneration, is soil texture through its effect on drainage. Cypress pine regeneration commonly occurs on soils with texture ranging from almost pure sand to loam, though these may be modified by sloping topography, gravel in the profile or low annual rainfall. With respect to this latter point it is pertinent that, approaching the western and lower rainfall limits of its range, cypress pine tends to occur on soils having a higher clay fraction, and consequently a higher moisture holding capacity.

Regeneration thus tends to occur on well drained areas and it may extend to exposed positions, such as ridge tops, provided there is reasonable soil depth. In the northern part of the State such regeneration is obvious on ridges where cypress pine occurs with ironbark (*Eucalyptus crebra*) and/or black cypress pine (*Callitris endlicheri*). On this site type once the young cypress pine has attained about eight years of age the adverse effects of low soil moisture levels, which occur seasonally and between years, are greatly reduced and the overstorey may be preferentially killed by drought before the regeneration. This occurred in the locality illustrated by Figure 5 during the 1964/65 drought. The ironbarks in this instance were all killed but the 2 to 5 feet (0.6 to 1.5 m) high regeneration nearly all survived. Naturally, dry shallow soils and clay pans caused by over-grazing and erosion are less favourable for cypress pine regeneration.

Apart from moisture characteristics which are affected by texture, and as previously mentioned, soil texture may exert an indirect influence on regeneration establishment through its effect on ground cover. Very sandy soils are less favourable for grass development than loamy soils and hence there is less protection from insolation for fallen seed and young seedlings. However, even though some soils may be more suitable than others for cypress pine regeneration, it can be accepted that a large range of suitably textured soils will regenerate densely providing the biological requirements are fulfilled.

The ideal physical soil conditions for cypress pine establishment are that the site be moist and well drained. This condition for most seasons is best satisfied by a sandy loam which is the most common texture of cypress pine soil.



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FIGURE 5 - Drought killed ironbark stand with unaffected white cypress pine regeneration stand beneath. Wittenbra State Forest.

Stand Density

In the absence of grazing there is an obvious relationship between stand density and the amount of regeneration which becomes established. Overstocked stands have very little regeneration while understocked stands are seldom without it. However, the presence of established regeneration in understocked stands cannot be interpreted as solely the result of the low competition of the overstorey because, as shown previously, seed quantities are also much greater in these stands.

Stand density affects grass and herb cover similarly to regeneration, consequently cypress pine regeneration and abundant grass cover frequently occur together. Since grass cover is an indicator of the low level of competition within a stand and in addition, therefore, of good seed availability, it is difficult to determine what is the influence of grass cover *per se* on developing cypress pine regeneration. This can only be determined over a long term period with elaborate artificial seeding experiments. However, grass cover probably has a favourable influence in providing shade. It is ephemeral and characteristically dries off in summer and for this reason is less likely to compete with the young pine for soil moisture at a critical period. The inhibitory effect that grass might have should be clarified, but for the moment the essential point is that in cypress pine stands regeneration frequency varies directly with grass cover and both grass cover and regeneration are inversely proportional to stand density. This is illustrated in Table 7.

The regeneration in Table 7 had arisen in four years as a result of thinning for establishment of the experimental plots referred to in Table 1. Plot A was left as a control and no regeneration was present at the time of the plot establishment and none has subsequently developed.

TABLE 7 - Grass Cover and Regeneration,
Merriwindi State Forest

Plot No.	Basal Area	Grass Wt. (lbs/ac.)	No. Seedlings per Acre	Height of Seedlings (in.)
A	62	380	0	-
C	32	890	137	26
F	20	1950	290	31

The influence of stand density on regeneration occurrence and development is further illustrated in Table 8 which contains an inventory taken in 1969 of the regeneration present on two 1.6 acre (0.65 ha) growth plots established in 1940. The two plots are in the same stand but have had a different thinning history. B16 was heavily thinned in both 1940 and 1967. B17 on the other hand was less heavily thinned in 1940 and has been maintained in 1940 both plots had basal areas approximating 80 sq. ft. per acre (18 m²/ha) and there was no regeneration on either plot.

TABLE 8 - Regeneration Frequency and Height Development
Related to Total Basal Area, Yerrinan State
Forest

Plot No.	Basal Area (sq.ft./ac.)			1969	Number of Regeneration Stems/acre	Average Ht. Regeneration 1969 (ft.)
	1940 after Thinning	1967 before Thinning	1967 after Thinning			
B16	11	45	25	26	212	5.6
B17	31	Not thinned		78	33	1.2

The second thinning of the plot B16 in 1967 did not result in an increase of the number of seedlings becoming established but stimulated height growth of those already present.

Grazing

In State Forests, the exclusion of cypress pine regeneration by rabbit grazing was first demonstrated in 1926 by H. Smith, who obtained regeneration at Mission State Forest within a 2.25 acre (0.9 ha) netted enclosure the year following its construction. This was followed by the construction of a series of netted enclosures in many State Forests by the late A.D. Lindsay. These clearly showed the influence of rabbit grazing on a variety of soil and vegetation types. Johnston (1969) has also noted increase in regeneration establishment when sheep and rabbit grazing is excluded.

The intensity of grazing combined with seedling numbers determines whether seedlings will become established, as there is no evidence that cypress pine is particularly favoured by browsing animals. Consequently some regeneration has arisen on areas which have been moderately grazed over long uninterrupted periods. It should be noted that this effect is comparatively rare in State Forests where sheep have been constantly present,

and the conclusion has been drawn from long experience that sheep grazing has to be excluded for areas to be successfully regenerated.

It follows from the observations of sheep grazing on regeneration that sheep can be used to remove unwanted regeneration.

Cattle are usually less severe than sheep on cypress regeneration, but their place in management of cypress forests follows the same general principles.

Fire

The regenerative capacity of cypress pine greatly exceeds that of the hardwoods with which it occurs. This is possibly a compensating factor for the higher fire sensitivity of the pine, enabling its perpetuation in an environment that was frequently subjected to fire long before European settlement.

Cypress pine will produce a new crown following a mild burn, but it does not have the same recuperative capacity as eucalypt crowns following wild fire, nor does it have the defence of a subterranean lignotuber. The chief defence of cypress pine against fire is its characteristic of forming dense stands which almost completely exclude grass and herb cover and in which litter is very quickly broken down. The characteristic of dense stands of white cypress pine with respect to rather insignificant accumulation of fuel is similar to that of *Callitris intratropica*, for which Stocker (1966 b) has noted that undisturbed stands will not carry severe fire and that when such stands are destroyed by fire, it is usually the result of "abnormal fuel accumulation in the wake of cyclonic damage or logging operations".

When white cypress pine occurs with hardwood species the litter accumulated is increased. Fire damage in such stands would therefore be expected to be related to species composition as well as stand density.

Cypress pine is most prone to fire damage when it occurs in the regeneration stage, before it has fully occupied the site and is still surrounded by grass cover. Regeneration stands can occupy the site rapidly and fully, so that the characteristic clean floor is produced, but immunity from crown flaring still depends upon the height of the crown and the intensity of approaching bushfires. It can be expected that crown flaring of dense regeneration will occur on the edge of the stand in contact with the fire, but often the pattern will be that a proportion of these stems will recover and the stems within the stand will be unaffected.

This pattern is described in the summary of result for an half chain square (100 m²) fire study experimental plot. This was laid down in dense regeneration from 1 to 1.2 feet (0.3 to 3.7 m) high, bordering more open country, to examine recovery following the severe fire of 1951 in the Eastern Pilliga. "A severe fire approached the plot from the west and killed all small trees just outside it. The western side of the plot showed a few deaths and all the seedlings were defoliated, although about 80% had shown new foliage three months after the fire. The eastern side of the plot showed only partial or no defoliation and the fire was only a mild one by the time it reached this side." (W.R. Hindmarsh in an internal report on Fire Study Plot No. 6; 2nd December, 1956.)

Insects

Insects can influence regeneration occurrence indirectly, by damaging or disrupting seed formation, and directly, by attacking established regeneration.

An increase in the proportion of empty seed due to insect damage has been referred to in the section on germination (p. 8). Hawkins (1966) also found that poor seed supply was associated with attack by the cypress pine aphid on the seed-producing tree. Aphid attack was also noted in New South Wales in September of 1967 and 1970 during flowering, but it has not been possible to determine its influence on seed production.

Established regeneration is periodically damaged by the cypress pine sawfly *Zenarge turneri rabus* (Moore) and the cypress pine jewel beetle *Diadoxus erythrus* (White). However, mortality has not been so extensive as to interfere with the designs of forest management.

Moore (1962) states that heavy sawfly attack during spring, summer and autumn of the years 1952, 1954 and 1956 was correlated with below average temperature and above average rainfall. Young regeneration rather than older trees, and regeneration on poorly drained areas or on areas of low site quality, appeared to be preferentially attacked. No evidence was found to indicate that sawfly attack alone could lead to death of cypress pine, but it was often a predisposing factor to attack by the jewel beetle which may cause tree deaths.

The effect of the jewel beetle, whose larvae feed in the conductive tissue of trunks and branches of *Callitris* and *Cupressus* species, has been investigated by Hadlington and Gardner (1959). They found that *Diadoxus* did not require predisposing conditions in order to attack introduced *Cupressus* species, but it did require such conditions for infestation of native *Callitris* spp. Native trees attacked had commonly suffered fire or mechanical damage, injury from defoliating insects such as sawfly or aphids (*Cinara tujafilina* del Guer.), or the debilitating effects of drought. Trees were killed when the phloem and cambium around the circumference of the tree are destroyed. Tree deaths are thus apparently a chance effect and the probability of girdling is increased with heavy infestation or infestation at frequent intervals.

Discussion

As a result of their regeneration history cypress pine stands in New South Wales tend to be predominantly even aged. It is considered that if possible this condition should be maintained for ease of management.

It should be noted that regeneration has developed under the current wide spacings (low stand densities) which have been adopted in cypress pine stands to promote rapid growth to merchantability. Dense regeneration development can be expected to interfere with the growth rate of the overstorey and this fact will have to be considered by management. In the southern forests of Forbes, Narrandera and Griffith, where paddock size is sufficiently small to allow intensive grazing, cypress pine regeneration can probably be restricted until required near the end of stand rotation when the crop trees, either through overmaturity or insufficient numbers, are unable to fully utilize the site.

Elsewhere, it would appear that the chief means of regulating regeneration is by manipulation of stand density. Stand density influences the quantity of seed available, seed weight and seed fertility. It also affects seed dissemination

in that dense stands are not so exposed to wind and seed is less likely to be widely scattered. As a result of competition with germinating seedlings the density of the overstorey also influences seedling establishment. However, despite its obvious effects at extreme limits of basal area, the direct relationship of stand density at intermediate levels with the amount of regeneration occurrence cannot yet be specified.

It is probable that even when the relationship of stand density, site and regeneration occurrence is fully understood, a high level of finesse on the part of the foresters will still be required in order to obtain optimum levels of regeneration before the final felling. On the other hand silviculture is considerably simplified if dense stands of regeneration can be satisfactorily treated. Undoubtedly this would involve mechanised thinning. Trials with tractor thinning of dense regeneration in Baradine and Forbes district indicate the feasibility of this approach.

With this possibility in mind, more work is required to fully understand the climatic and biological conditions which result in large scale "wheatfield regeneration". However, it can be stated that in order for wheatfield regeneration to occur, it is necessary to have low density stands in which in the course of time there is a coincidence of high seed production, high seed viability and high soil moisture conditions.

Acknowledgements

I am indebted to the late Mr. A.D. Lindsay for useful records and also to many foresters in cypress pine areas for assistance in measurements and for helpful observations. Particular thanks are due to Mr. A. Floyd for testing and cypress pine seed and for the data presented in Figure 4, to Messrs. R. Turner, T. O'Rourke, P. Garling and A. McCallum for supply of data on germination and seedling densities and to Messrs. G. Vidler, B. Kennedy and K. Wells for their comments on certain sections of the manuscript.

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