FORESTS DEPARTMENT
BULLETIN NO. 53.

WESTERN AUSTRALIA.

PINE ESTABLISHMENT

An Account of Experiments in connection with the Initial Survival of Cluster Pine (*Pinus pinaster*) in Western Australian Coastal Plantations

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FOREWORD.

In many countries the season to plant trees, the class of nursery stock to use and the methods of planting and early tending which give the best results, have been worked out on empirical lines over a long period of time. Western Australia is not in this fortunate position and the development of both reforestation and afforestation projects on a large scale within a comparatively short period of years has shown the difficulty of translating forestry practices from one region to another, even when conditions appear reasonably parallel, so that the need has arisen for a critical examination of many phases of newly adopted practice.

In this publication is set out the results of one section of the investigational activities of the Department. Problems of an initial survival in plantations have the one advantage over most forestry problems that the final results of each series of experiments are available at the end of 12 months or less. Nevertheless the repetition of each experiment annually for a number of years has been found necessary to eliminate or demonstrate, as the case may be, the effects of seasonal differences. For this reason a number of experiments relating to factors which have been shown to be of major importance are being continued, but it is considered that the work has proceeded now for a sufficient number of years to justify the publication of results.

The conclusions set out in the text deal with the results of treatments on initial survival only and the possible effects on later growth of methods which involve such questionable practice as bending the tap root or bunching the root systems at time of planting, although outside the scope of this particular study, have not been overlooked and will form the subject of continued observation and measurement as the trees develop.

The experimental work recorded and summarised in this bulletin has been carried out by field officers simultaneously with and in addition to their routine activities and the officers concerned are deserving of great commendation for the sustained interest they have shown in the oft-times tedious work of laying out and assessing the very large number of field experiments involved.

S. L. KESSELL,
Conservator of Forests.

27th July, 1939.

Summary.

In common with most afforestation projects, the planting of Pinus pinaster on coastal sandplain in Western Australia gives rise to certain establishment problems which relate principally to deaths occurring between the time of planting and the next winter rains. Successive seasons have shown fluctuating percentages of failures in this period and intermittently these have been sufficiently high to warrant a careful investigation of the causes of such failures.

Experiments were confined to the widely separated Busselton (Stirling plantation) and Metropolitan (Gnangara plantation) districts, both situated on the coastal plain, the climate, topography, geology, vegetation and soil of which are briefly described. Both plantations are located on the coastal sands which will be used for the main soft wood planting in this State so that the conclusions reached are applicable essentially for deep sands under similar climatic conditions.

Uniformity trials were made to determine the optimum size for experimental plots.

From the information obtained in the early simple experiments, it has been possible to design more efficient complex experiments to provide estimates of both direct and differential responses.

Accepted planting practice in general use was classed as a control or normal treatment.

Components of planting technique tested were time of planting, plant treatment, plant setting, planting spot treatment, type of planting stock.

Many field trials were made and the results for each district are given.

It has been found that of the factors affecting general control of planting operations the important are planting season, which is best restricted to the period late June to the end of July; preparation of the ground by ploughing with planting at the bottom of cross furrows at Gnangara; subsequent or spring cultivation around the planted pine before the 15th October at Stirling to eliminate competition by grass and herbs in the ensuing summer.

Common faults to be avoided in ordinary planting technique are over short root-pruning, shallow setting of the pine and exposure of the roots which should be guarded against in sunny weather.

Factors investigated which do not appear to be of importance in planting include wrenching, heeling in, method of planting, dispersal of the roots and bagging of the pines for transport to distant plantations providing the bundling is well done.

PINE ESTABLISHMENT

An Account of Experiments in connection with the Initial Survival of Cluster Pine (*Pinus pinaster*) in Western Australian Coastal Plantations

Chapter 1.

INTRODUCTORY.

There are probably few other branches of silviculture in which the effect of faulty technique is so clearly and rapidly revealed as in pine planting. Deaths as a result of careless planting or a failure of the young pines, through other causes, to become established in time to withstand the comparatively severe summer of Southern Australia, stand out in marked contrast with the living plants.

The problems connected with the formation of plantations in Western Australia may be grouped under three heads:—

(a) Nursery Practice, involving inoculation of the nursery with the necessary fungus together with the use of mineral and organic manures, including composts. It was early shown (1) that for the successful raising of plants in nurseries, infection with a symbiotic fungus greatly assisted. On the more fertile soils no difficulty is now experienced in growing planting stock, but on the inferior soils a number of disorders have been investigated and experiments are being undertaken with a variety of artificial fertilisers and composts.

(b) Establishment problems relating to the successful transplanting of the young trees into the plantation. These are mainly concerned with the planting season, methods of preparation of the planting site, lifting and handling of the pines from the nursery, together with details of the actual planting technique.

(c) Growth problems relating to the suitability of the site for the growth of the established pine, which include cultural treatments such as cultivation and the application of artificial fertiliser.

In the Western Australian Forests Department, problems of the first group have been dealt with in a separate set of research projects, while the results of

work on the third group have already been published as Bulletin 50 (2) of the Department. The present publication is devoted to the second group. At the Southern Forest Experiment Station, U.S.A. (3) the project is termed "Initial Survival" and is defined as that shown by the planted stock after the occurrence of the mortality more or less directly brought about by the whole process of planting, including the environment chosen for the planted trees. It is usually best measured at the end of the first growing season. A study of initial survival should not include effect of epidemics, insect infestations, or droughts after the planted trees are well established. The term used at the Lake States Forest Experiment Station, U.S.A. (4) is "early survival."

In planting operations in Southern Australia one or more of the following factors have operated to mask the importance of details of planting technique:—

(a) the use, as the main planting stock, of Pinus radiata which establishes itself readily on the better sites.

(b) the occurrence of cool summer conditions with occasional rains in many districts where the plantations are situated.

(c) the preparation of the planting site by ploughing.

(d) the erroneous acceptance of satisfactory stocking in plantations with a high percentage of initial deaths. This has been brought about by failure to carry out a careful and systematic count of survivals.

Survival of the young pines through the first summer following planting usually means successful establishment and the development of satisfactory stands on those soils which are favourable to the growth of the species. A few deaths known as "winter deaths" occur in July and August almost immediately after planting. Another period of failures is in the months of October and November of early summer, but by far the greatest number of deaths occurs in the mid-summer months of January and February. Light rains usually fall in March or April, but in the case of a long dry summer without these rains further deaths are suffered until the commencement of the winter rains in mid-May.

In Western Australia only a small number of exotic species is suitable for trial in the somewhat harsh climatic and poor soil conditions and of these Monterey Pine (Pinus radiata) and Cluster Pine (Pinus pinaster) are the two species used in the main planting operations. Pinus radiata establishes itself readily on the better quality sites to which it has been restricted in this State, but the percentage of deaths recorded with Pinus pinaster has frequently been high enough to necessitate refilling. This is done when the percentage of failures is more than 15 per cent., or where, as more rarely happens, large blanks occur.

The general practice adopted in any plantation is largely the result of observation of the effect of various factors upon initial survival, plus in some cases, small experiments made at planting time to test the effect of some particular factor in which variation may be considered advantageous. In some cases the results of observation and experiment may not be recorded and moreover, erroneous conclusions may be drawn from a test because of the lack of adequate experimental control. As a result there is frequently a demand for information on the effect of the various components of planting technique under a given set of circumstances, as well as the basis for formulating any particular set of rules which may be followed. Much of the demand is made as a result of past failures. Attention was

first drawn to the importance of depth of setting, as a factor affecting initial survival, by Carter (5).

The data here presented are the results of the first seven years' (June, 1932, to May, 1939) investigations into the establishment technique for Pinus pinaster in Western Australia.

The number and variability of the contributing factors made it obvious at the outset that a study of simple effects had to be the first step as a prelude to a long range policy of complex experiments under varying seasonal influences; and hence the study would be more productive of reward if regarded as a long-term project rather than as a means to precipitate action in a desire to provide immediate improvement in general planting technique. This did not preclude the amendment of existing practice, where desirable, to conform with lessons learnt in the course of the trials. Subsequent results obtained as the project progressed have borne out the wisdom of regarding the initial results as tentative only.

Statistical control and analysis to measure and describe the size and precision of a result is now so widely accepted that it is not necessary here to justify insistence upon the observance of this technique, instead of depending, as formerly, upon the mere magnitude of the difference between results.

Though it may appear that a large scale operation provides ample justification for the drawing of reliable inferences from the result, actually the information is often incomplete or misleading. While it is generally accepted that a single experimental result, without annual verification, is deficient in reliability, it may not be generally appreciated that apparent annual confirmations of a large scale result in general field practice cannot be accepted as valid unless the conditions operating are known to be identical.

Investigations of the type described in this Bulletin are not, however, intended to replace field observation but to supplement it and to provide a means of proving the value of any association of factors regarding which a confusion of thought exists. A single result is attributable to a particular set of conditions only and if it is remembered that this study involves a large and complex series of effects and inter-effects it will be obvious that even a series of experiments carried out under careful supervision does not provide full information. It has been possible, however, definitely to prove the value or otherwise of certain doubtful points.

Many results obtained have been negative, that is, treatments frequently suggested by observation as beneficial have been found by experiment to have little effect. These results have, however, been most valuable in clearing up anomalies and together with the careful record of seasonal and other pertinent conditions surrounding each experiment, have provided indications of further lines of research.

The author is indebted, for their co-operation and assistance, to Messrs. D. H. Perry, J. E. Watson and H. E. Dawson, Foresters, who controlled the planting of the experiments and J. H. Harding, Statistical Clerk of the Forests Department, who helped with the statistical reductions and the preparation of the results.

The chemical and mechanical analyses quoted in this publication were made by the Government Chemical Laboratory, Perth.

Chapter 2.

LOCATION OF EXPERIMENTS.

The principal stimulus behind the inauguration of pine establishment experimentation in Western Australia was the extension of the plantings with Pinus pinaster on the sands of the Coastal Plain where early experience with pine planting had shown that a comparatively high percentage of establishment failures could be expected.

Pine planting in this State must of necessity be restricted to the temperate region of winter rainfall in the South-West within which the natural forests occur. The geological formations are predominantly granite, though precambrian sediments occur in the south, while physiographically the province may be divided into two major physical zones, the eroded edge, known as the Darling Range, of the great plateau of the interior and a narrow littoral strip on the seaward edge of which are found sands of tertiary and recent origin.

Teakle (6) in his designation of the major soil zones of Western Australia has recognised the forest areas of the State as the zone of Grey, Yellow and Red podsolised soils of the temperate sclerophyll forests. Within this zone three soil regions occur, one of which is the Swan littoral region (Coastal Plain) of coastal sandhills and inner clay flats.

The soils of the Coastal Plain are essentially of dune formation interspersed with flats characterised by an indurated coffee-brown horizon. They are deep coarse sands of grey or yellow and sometimes brown colour. They do not reveal any definite profile, but frequently include at depth, thin layers of small pebbles of cemented sand of deep yellow colour. Some of the dunes are calcareous at depth, aeolian limestone having been formed by consolidation of wind-blown sands.

It is on these coastal sands which by analysis are very low in the recognised plant nutrients and quite unsuitable for any other form of agricultural development, that the plantations of Cluster Pine have been established.

The experiments were concentrated, for simplicity of control, in two widely separated districts on the Coastal Plain, the Gnangara Plantation in the Metropolitan District and the Stirling Plantation in the Busselton District, where comparatively large scale planting operations have been in progress.

The Gnangara Plantation, north of Perth, is an old sand dune formation composed of a chain of more or less regular ridges up to 100 feet in height, separated from one another by comparatively wide flats or valleys. On these flats occur small areas of true swamp carrying water throughout the year. There are no streams and the surface flow through the plantation is not appreciable except in very wet seasons.

There are two main groups of soils:—

(a) Sand ridges or sand dunes. These consist essentially of very coarse sands, grey and yellow in colour which are frequently 60 feet deep. The outstanding feature is the very high coarse sand fraction which, in the surface soils, commonly reaches 96 per cent.

(b) Flats, a feature of which is the occurrence of an indurated coffee-brown horizon known locally as "coffee rock." Found at a depth of some four feet from the surface this bed averages about fifteen inches in thickness. This coffee rock rather closely resembles in chemical composition the "Alios" of the Landes, France. The surface soils are grey to dark grey coarse sands.

Mechanical and chemical analyses of samples from both soil groups gave the following figures:—

Dune Type (4a).

Soil No.	1286	1287	1288	1290	1291	1292
Depth	0—4	4—12	12 +	70—96	96—110	110—160
Description ...	Grey sand	Grey to light grey	Light grey	Light grey, brown	Light grey, light yellow	Light grey sand
Coarse sand	...	94·7	...	...	...	...
Fine sand	...	3·7	...	...	...	...
Silt and clay	...	·5	...	...	...	...
Moisture	...	·2	...	...	...	...
Loss on acid treatment	...	·1	...	...	...	...
Loss on ignition ...	...	·8	...	...	...	...
pH *	5·48	5·42	5·48	5·30	5·04	5·51
Water soluble salts ...	·01	...	·01	...	...	...
N	·028	...	·006	...	...	...
CaO	·039	...	Trace	...	...	...
K_2O	·0032	...	·0056	...	...	...
P_2O_5	·0008	·0005	·0003	·0061	·0018	·0026

* 1—2½ Quinhydrone.

Flat Type (2a).

Soil No.	1093	1094	1095	1096	1097
Depth	0—4	4—8	8—48	48—60	60 +
Description ...	Light brown-grey sand	Grey sand	Medium grey sand	Light grey sand	Dark grey-brown coffee rock
Coarse sand	...	92·0	...	...	...
Fine sand	...	6·6	...	...	...
Silt and clay	...	1·0	...	...	...
Moisture	...	·1	...	...	...
Loss on acid treatment	...	Trace	...	...	...
Loss on iguition ...	...	·3	...	...	...
pH	5·58	...	5·60	...	5·20
Water soluble salts ...	·010	...	·038	...	·020
N	·027	...	Trace	...	·050
CaO	·028	...	·001	...	·003
K_2O	·0016	...	·0012	...	·0031
P_2O_5	·0011	·0005	·0004	...	·0144

The Stirling Plantation in the Busselton District is situated at the southern end of the Coastal Plain approximately 150 miles south of Perth. The topography is flat, but swamp and semi-swamp conditions occur. The soils are in all cases sands of varying colour passing to limestone which lies under all soil types at depths of from 60 to 150 inches. The best soil type for the growth of pines is the Wonnerup sand which is essentially a brown sand overlying a yellow sand at 50 inches and

passing through varying shades of yellow or greyish yellow sands to limestone at 150 inches. Chemical analyses were as follows:—

	0—4in.	4—30in.
N	·08	·02
K_2O	·01	·01
P_2O_5	·02	·02
pH	6·4	6·2

The plantings in the two districts provide conditions of two very different types by reason of the variation in initial preparation. In the Gnangara Plantation the land is ploughed prior to planting while at Stirling the trees are planted on unploughed ground among the litter of logs remaining after the felling and burning of the indigenous hardwood forest. Also at Stirling, on the Wonnerup Sand, Pinus pinaster is grown without the aid of artificial fertiliser while on the Gnangara Sands the application of superphosphate is essential (2).

At Gnangara planting operations have, with few exceptions, been restricted to the flats between the dunes. These support a low forest association of Jarrah (Euc. marginata), Marri (E. calophylla), Paperbark (Melaleuca Preissii) with Banksia (Menziesii, ilicifolia, littoralis and grandis). Beneath is a sclerophyllous ground flora of tall heath psammophilous shrubs comprised in the main of Myrtaceae (Leptospermoideae), Papilionaceae, Mimosaceae, Proteaceae, Cyperaceae, Restionaceae, Epacridaceae and Dilleniaceae (Hibbertia). The sand dunes represent a more adverse habitat occupied by a sclerophyllous formation of Banksia (Proteaceae) of three species, with a scattered stocking of somewhat taller Euc. todtiana. The ground flora of the two associations while consisting of members of the same families differ chiefly in regard to genera and species though to some extent to frequency of species. Some plants which are indications of the one association are either missing from or of rare occurrence in the second and conversely other plants comparatively unimportant in the one assume prominence in the other. The most obvious factor responsible for the variation is the depth from the surface of the ground water-table.

The baring of the soil by thorough ploughing, as a method of removing undesirable competition from the native sclerophyllous shrubs is entirely effective in that an almost complete "take" in the planting is secured. This is in contrast with experience in some other countries where density of cover has an important effect on survival, the "takes" on open sites being fewer than under the brush-cover (4).

Before any planting can be commenced sufficient rain must fall to ensure that the soil and subsoil are thoroughly moistened. On these sands, however, it is found that where ploughing has been carried out a few months in advance of planting operations the surface sand remains dry even though soaking rains have been experienced. This dry surface sand must be removed to a depth of about eight inches in order that the plants may be set in the moist sand. The cheapest way to effect this is to plough deep furrows along the planting lines and to plant the pine in the bottom of the furrows.

At Stirling is found a woodland association of Tuart (Euc. gomphocephala) and Peppermint (Agonis flexuosa) with a short psammophilous undergrowth of more soft-leaved and somewhat succulent shrubs though through it are scattered sclerophyllous plants. It consists for the most part of members of the families Liliaceae, Mimosaceae, Papilionaceae, Dilleniaceae (Hibbertia), Restionaceae and Gramineae. This association is being invaded to an extent by chiefly exotic members of the Gramineae and Geraniaceae, the cutting of the Tuart forest, the burning of the bush and the influence of domestic grazing being no doubt the de-

termining factors. Unlike Gnangara grass makes luxuriant growth with the protection of the site from grazing stock.

The most important of the natural factors which operate over the coastal plain is perhaps the rather difficult climate which is characterised by a comparatively long dry summer following winter rains. The mean annual rainfall at Perth is 35 inches and at Busselton 32 inches and only occasional falls are registered in the months of November to March inclusive.

PERTH (METROPOLITAN DISTRICT).

Average Rainfall over 56 years (Points).

Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
34	42	78	168	507	703	672	573	349	216	79	57	3,478

Mean Temperature over 37 years (Degrees F.).

Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum.											
84·6	84·8	81·3	76·1	68·8	64·1	62·7	63·7	66·2	69·0	75·5	81·2
Minimum.											
63·2	63·3	61·4	57·3	52·6	49·5	47·9	48·2	50·2	52·6	56·8	60·8

Highest recorded temperature, 112·2°.
Lowest recorded temperature 34·2°.

BUSSELTON.

Average Rainfall over 51 years (Points).

Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
41	46	86	137	471	651	643	453	305	230	88	52	3,203

Mean Temperature over 24 years (Degrees F.).

Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum.											
82·5	82·3	78·5	73·2	66·2	62·4	60·6	61·6	63·9	67·4	74·0	79·3
Minimum.											
56·2	56·2	53·8	50·6	48·2	46·0	44·6	45·2	46·9	48·4	51·3	53·9

Highest recorded temperature, 105·3°.
Lowest recorded temperature, 32·2°.

The number of days during the wet season on which rain fell, together with monthly total rainfall in points, in brackets, for the seven years under review, are as follows:—

Month.	1932.	1933.	1934.	1935.	1936.	1937.	1938.
			Gnangara.				
June	16 (625)	22 (636)	15 (1113)	15 (419)	15 (814)	15 (897)	14 (551)
July	20 (936)	15 (495)	13 (462)	25 (1057)	20 (466)	11 (253)	19 (539)
August	20 (612)	15 (567)	14 (551)	15 (417)	23 (677)	18 (680)	19 (592)
September ...	10 (158)	11 (323)	20 (332)	18 (367)	10 (210)	12 (269)	13 (352)
			Stirling.				
June	28 (837)	26 (1031)	18 (1142)	15 (673)	18 (743)	18 (923)	21 (328)
July	19 (541)	20 (507)	19 (669)	21 (1037)	23 (515)	19 (441)	25 (782)
August	21 (413)	19 (444)	15 (414)	14 (488)	24 (694)	18 (579)	21 (467)
September ...	15 (174)	15 (506)	23 (352)	21 (373)	14 (232)	18 (237)	14 (181)

The general planting is carried out in the season of the rains, which in Western Australia includes the winter, extending from May to September. After the commencement of the prolonged rains a period must elapse before the soil and subsoil become thoroughly soaked with water. Following planting, reasonably regular rain over a period of four to eight weeks is apparently required to enable the trees to become successfully established before the long dry summer commences.

In general, therefore, planting has been restricted to the period late June to early August. In extreme years planting has been unsuccessful after July, while in other years it has been successful up to early September.

As examination of the rainfall data for the four months June to September for the seven years period under review shows that Busselton and Perth rainfall characteristics differ in that the average number of rainy days for the four months is 70 and 60 respectively, while the average rainfall for the same period is 20½ and 23 respectively. Busselton has a greater number of days on which rain falls but a lower rainfall and it is in these four months that practically all the difference between the two rainfalls is accounted for. In the winter in either area rain seldom lasts for less than two days except for light passing showers and definite breaks in the continuity of rainy weather are seldom less than three days but may under certain conditions extend for much longer periods.

Usually July has a greater number of rainy days in both centres than June but while it has a greater number at Busselton than August, it has fewer at Perth. The total rainfall for July is greater than for August at both centres. The advantage of July over August as a planting month is not then due to the number of rainy days, but is attributable, perhaps, partly to the greater amount of precipitation, partly to the greater rainfall following and partly to the distribution of rainy and dry days.

June has a greater average precipitation than July or August at both centres. The number of rainy days is less than in July on either plantation, but while it is less also than August at Perth, this is not the case at Busselton. The low value of June as a planting month is due perhaps in part to the fewer rainy days, in part to the smaller amount of precipitation received previously to soak the ground and largely to the poorer distribution of rainy days. Long periods of up to 10 days of dry weather occur.

The above characteristics have been regarded for the average. Each season differs somewhat from the average and sometimes June is a very good planting month while on occasions July is unsatisfactory. By keeping a daily rainfall graph and comparing it with those for previous seasons a reasonable forecast can be made on the incidence of rain and the duration of dry spells.

June.

Usually heavy falls are experienced in June, but frequently long periods of up to 10 days of dry weather occur.

Generally speaking, if falls of under 100 points are experienced the length of dry spells is short, but, when falls of 150-200 points occur, dry spells of some days follow. This is qualified by the tendency for equalisation within the month, that is, if the first 10 days are wet, then the second or third 10 days may be mainly dry. Should the dry spell occur in the second 10 days, the third is wet or vice versa. It would be wrong to use 10-day intervals as a definite rule as there is variation within them and some overlapping.

Early continuous rains presage a long dry spell later. Any fine spell may last up to 10 days if it occurs in the second or third week. Lack of rain early tends to indicate that the remainder of the month will be wet.

The incidence of dry spells is greater when the previous falls have been between 100 and 250 points than when under 100 points.

It is better to plant at the commencement of rain (rain usually occurs for not less than two days) or after any long dry spell.

Abnormal years sometimes occur in which the short dry spells usually experienced are replaced by periods of medium to light rain between very heavy falls.

July.

July rainfall appears to be largely influenced by June conditions but generally rain has fallen early in July while the incidence of dry spells is usually in the second, third and fourth week.

When June rains have been light, July falls have been continuous, but, with the increase in June rainfall, an increasing gap of dry weather usually appears in mid July, though in exceptionally wet years this may not occur. The actual position of this dry weather varies within the weeks mentioned above.

If June is dry, July is continuously wet. If June is wet, mid July is usually dry. These conditions grade off with the intensity of June rainfall. In abnormally wet years this dry mid-July period may be bridged by light rain.

When June conditions have been dry, it is fairly safe to plant up till late July, but with good June rains, planting is safest at the beginning of the first July rains and after the first dry spell which will probably be the main one.

August.

The graph for this month is much more regular than the others, its characteristic being medium rain merging into a dry spell which usually gives way to rain in the last two weeks and then a recurrence of dry weather.

The rainfall appears to be influenced by both the preceding months. Dry spells of long duration occur mainly in the middle of the month with occasional short dry spells at the beginning and end.

If June and July are dry, August will probably be wet and the degree of wetness will grade off to a minimum of about 14 days rain.

Dry spells in late July do not continue beyond early August and with equal rainfall distribution for June and July, a dry spell may be expected in mid August. As for June and July, abnormally wet years may occur in which the dry periods are reduced or even replaced by light rain.

It would be better to plant at the beginning of the first rains or after any dry spell. The position would have to be judged from June-July figures.

September.

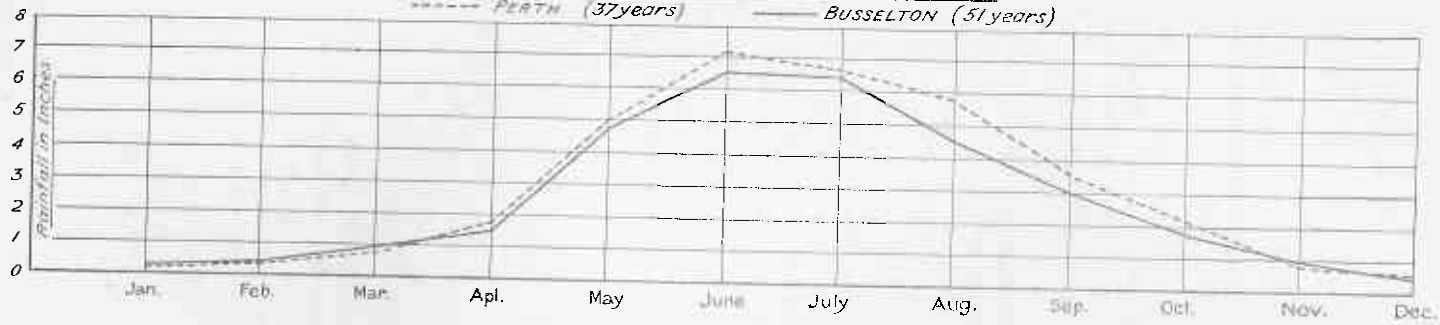
Generally rains in this month do not exceed ½in. per day although they may be frequent. In the years under consideration, the number of days rain has varied from 14 to 23 and there is a tendency for frequent August rains to be followed by very light September falls. Where the peak period of August rain occurs late in the month, September usually experiences dry spells of up to 10 days in the middle or late part of the month.

General Note.

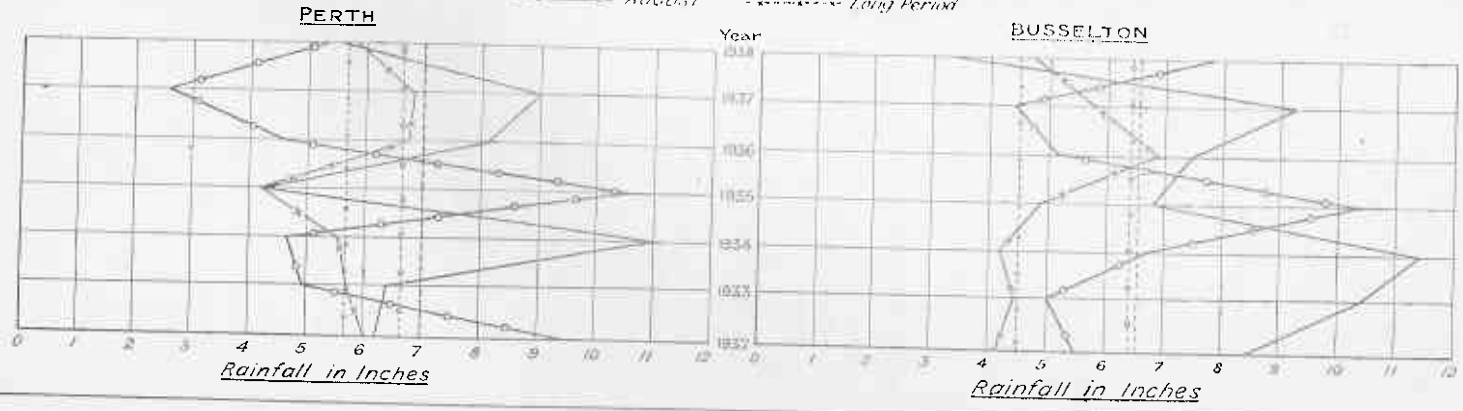
In very wet years, periods of medium and light rain noted above for the various months may be replaced by heavy rain.

In Perth any breaks between rains are fairly definite, but at Busselton, the tendency is for heavy rain to merge into intermediate light rain or for any dry spell to be of very short duration.

Monthly Average Rainfall for a Long Period



Rainfall Totals for June, July & August



Chapter 3.

UNIFORMITY TRIALS.

The samples from which the data are to be obtained must be sufficiently large to ensure reasonable uniformity among the individual plots.

At the Southern Forest Experiment Station in U.S.A. (3) the plantation layout was developed to test each treatment by means of 100 trees, the total number of trees in a study equalling 100 times the number of treatments. The trees are planted in four blocks, each treatment in each block consisting of a row of 25 trees.

In England, MacDonald (7) stated that for most experimental work in the establishment of forest plantations small units are sufficient; for example the effect of artificial manures or of methods of planting can be demonstrated safely on groups containing 30 to 50 trees, provided the treatments are replicated so that the total includes not less than 200 trees.

The shape of plots may be of considerable importance in field experimentation. Christidis (8) observed that in agricultural experiments the number of observations rarely, if ever, is sufficiently large to allow full play to the laws of chance, and therefore the use of long plots constitutes the only means of reducing the effect of patched heterogenity. Convenience in working must not be overlooked in considering shape and although a certain proportion of breadth to length may be desirable on theoretical grounds, it may often be necessary to adopt a different proportion on account of some other essential practical consideration.

With a view to determining the optimum plot size, Uniformity Trials were made with Pinus pinaster in the Gnangara plantation in Compartments 96 and 92 and in the Stirling Plantation in Compartment 40.

Long narrow plots consisting of a single row of pines have been used almost exclusively in the field trials because of the ease of working with single line units, but the influence of plot shape was tested in these uniformity trials by using double lines, plots of four lines in width and in one instance a square plot.

The trial areas were divided into plots of one tree in width and five trees in length and plots of the desired size were built up from these units. Spacing was 6ft. x 6ft. Subdivision of the entire trial area into larger sections was employed to provide blocks for the elimination of inter-block variance. The number of plants used in the different trials varied between 3,000 and 4,000 plants.

The data used were taken from the standard planting in the 1934 season, with the restriction that only one day's planting and one type of planting stock were used in each case, since variations in these factors are on a large scale and would not affect equally all parts of the trial area as would variations in planting performance by different members of planting gangs, etc.

The standard deviation was determined for a number of different sizes of plots.

GNANGARA COMPT. 96.—ACTUAL AND THEORETICAL REDUCTION OF THE STANDARD DEVIATION WITH INCREASE IN SIZE OF PLOT.

Size of Plot.	Standard Deviation.	Standard Deviation as Percentage of Mean.	
		Actual.	Theoretical.
5 line	·359	7·34	...
25 line	·901	3·69	3·2
25 square	·848	3·47	3·2
50 line	1·522	3·1	2·3
75 line	1·799	2·4	1·9
100 line	2·397	2·4	1·6

The standard deviations as a percentage of the mean are low; nevertheless, the figure for a unit of five has been halved by using a unit of 25, in which case the reduction became almost the same as would be expected from theoretical considerations. The decrease in the standard error with use of 25 pines in a square from that with 25 pines in a line is negligible and with the plots of greater size the decrease is extremely small and insufficient to justify their use.

GNANGARA COMPT. 92.—ACTUAL AND THEORETICAL REDUCTION OF THE STANDARD DEVIATION WITH INCREASE IN SIZE OF PLOT.

Size of Plot.	Standard Deviation.	Standard Deviation as Percentage of Mean.	
		Actual.	Theoretical.
5 line	·45	9·39	...
20 double line	1·169	6·0	4·7
20 line	1·040	5·4	4·7
40 line	1·54	4·0	3·3
50 line	1·79	3·7	2·9
60 line	1·71	2·9	2·7
80 four line	2·556	3·3	2·35
80 line	2·167	2·8	2·35

From the table it will be seen that the reduction of the standard deviation (as percentage of the mean) with increase in size of plot, does not differ greatly from the theoretical rate of reduction.

The table shows that the standard deviations as percentages of the mean are low, except in the case of the five unit and increase in size of plot has effectively reduced this, so that with a unit of 20, the standard deviation is down to approximately five per cent.

The actual and theoretical percentages conform fairly closely and the reduction brought about by increasing the unit size is not appreciable beyond the 60 plot. It appears that a unit of 60 is close to the optimum size but, since the standard deviation for a unit of 20 is small, the increase of accuracy obtained by using the 60 units does not appear to be sufficient to justify the additional planting costs. The reduction of the standard error of the difference between two means to about five per cent would require eight replications of (5 line) plots:—

$$9.4 \times \sqrt{2} \div \sqrt{8} = 4.7$$

so that even this can be reduced to a satisfactory size with a reasonable number of replications.

The reason for the low standard deviation and low unit plot required at Gnangara is that the thorough ploughing given at the centre, preparatory to planting, results with normal technique in a 96 per cent. "take," which is very high for Pinus pinaster.

STIRLING COMPT. 40.—ACTUAL AND THEORETICAL REDUCTION OF THE STANDARD DEVIATION WITH INCREASE IN SIZE OF PLOT.

Size of Plot.	Standard Deviation.	Standard Deviation as Percentage of Mean.	
		Actual.	Theoretical.
5 line	·95	23·1	...
20 double line	2·076	12·4	11·5
20 single line	2·037	12·2	11·5
40 line	3·03	9·0	8·2
50 line	2·91	6·9	7·3
60 line	2·692	5·3	6·8
80 four line	5·9116	7·5	5·8
80 single line	3·149	4·7	5·8

The reduction of the standard deviation brought about by increasing the unit size is clearly effective. It is unusual for the actual reductions to exceed the theoretical and in this case it is probably fortuitous. The values most closely agree in the case of the 50 unit plot which, from practical considerations, appears to be an effective size. A unit of 50 was necessary to bring the standard deviation down to five per cent. Greater variation was experienced at Stirling than was the case at Gnangara, but this was to be expected among the native vegetation on the unploughed land. This variation has since been reduced by improved planting technique developed as a result of these experiments.

From these trials the line plots appear as efficient as those of other shape and are being used in the local experiments. A unit of 25 was adopted for Gnangara, while the unit of 50 which had been in use at Stirling was continued.

Chapter 4.

METHOD OF EXPERIMENT.

In the early stages of the study of pine establishment the experiments were all of a simple type designed to determine the essential particulars for investigation. For each individual factor investigated a separate experiment was carried out. In this manner the more important components were emphasised, but, at the same time, the investigation yielded many conflicting or fragmentary answers to the questions it was intended to solve. Progress along these lines, however, made it possible to design and carry out much more efficient complex experiments involving combinations of some of the factors influencing pine establishment.

In the more recent work the aim in experimental design has been to plan the experiment to yield both direct effects and low order interactions (9). The information obtainable from a few well-planned trials of this type is considerable. The advantage of completeness is evident and is in contrast with the earlier work in which only individual comparisons between treatments were possible.

In these complex trials use was made of various types of factorial design in which several factors at different levels could be tested separately and in all combinations in the same experiment. Factorial designs avoid unintelligible results sometimes obtained from indiscriminate comparisons of dissimilar combinations of treatments which, without some knowledge of the subject, might, at first sight, appear desirable.

Since factorial designs increase the number of treatments in proportion to the factors and levels which are tested, block sizes of necessity increase beyond reasonable limits. This trouble was overcome by confounding and since interactions of high order have rarely been significant these have usually been sacrificed to retain full information on direct effects and low order interactions.

Numerous examples exist in agricultural literature of the application of the principles of field experimentation but few are given in forestry papers (10). A greatly increased understanding of the modern methods of field trials as described by Fisher (11), Yates (12), Wishart and Saunders (13), has resulted locally as the study progressed and it is realised that the earlier experiments at least, in Western Australia, would have been improved by more efficient designs.

At the outset four replications were adopted but these were later increased to six and eight.

Where the responses of a considerable number of different treatments had to be studied at the one time, the Randomised Block arrangement was employed as it did not necessitate increasing the number of replicates beyond the standard adopted and in these cases avoided the more cumbersome Latin Square layout that would have resulted. The confounding technique with Latin Squares was not known until recently.

The unit of 25 adopted at the initiation of the experiments was increased to 50, but later reduced to 25 at Gnangara as a consequence of the results of the uniformity trial there. As the pines are normally set in rows, the arrangement of the trials as single line experiments was adopted to facilitate control. Lines were not shown from the uniformity trial to be more variable than plots of other shapes.

It has been considered advisable to carry out the experiments under field conditions with the normal field spacing of six feet by six feet, as the cultivation effect produced by planting trees in close spacing might become an important factor which does not operate in the ordinary plantation. In 1934, in addition to the ordinary field experiments an interesting comparison was made by establishing a similar series of experiments with close spacing at two-foot intervals on a piece of well-cultivated land at the plantation headquarters. Although this check has not been extensively used, there does not appear to be any difference in the results by comparison with the general planting on well-ploughed land in this plantation.

A further advantage of carrying out the experiments under field conditions is that the experimental area forms part of the current year's plantation and thus does not represent a loss of ground or complete loss of expenditure.

An invariable feature in an experiment is that with the exception of the treatment being studied, conditions throughout the experiment must be the same. Minor variations are overcome by proper replication, but any factor which has a greater effect on the plants than the treatment studied must be controlled. Each experiment, therefore, has been confined to the one soil type. Where the field conditions, as far as can be judged, are uniform, the experiments have been arranged in the form of a rectangle, or more rarely a square, with all treatment

rows commencing from a common base-line, as this facilitates both control and assessment. In the larger trials, where the number of treatments has been of the order of twelve or upwards, blocks have been arranged in two rows for greater compactness. Where it has become necessary, in order to observe the restriction to the one soil type, the alignment of the blocks has been altered or they have been separated slightly to fit a soil type, the aim being to reduce the variability within blocks as much as possible and so increase the chances of detecting differences.

For identification, corners have been marked with 4in. x 4in. posts carrying the number of the experiment. A small numbered stake, of about eighteen inches length, inscribed with the treatment number, has been set at the beginning of each row and half-way down the row, that is, with a unit of 50 plants, at numbers 1 and 26. Corner pegs were painted, but black lumber crayon has been found sufficiently durable for the treatment stakes. It must not be overlooked that the appearance of the experimental site will be different, owing to the growth of grass and scrub, at the time of assessment and initial trouble in numbering rows and half-way trees will greatly facilitate the counting.

In the earlier experiments a gang of four men was used for each experiment, two of them being diggers and two planters, working in pairs of one digger and one planter. One pair started with the first plant of the first treatment, the other pair half-way down the row at plant number 26 in the same treatment. Work proceeded from bottom to top and left to right through the blocks so that any variations due to differences in planters were evenly distributed.

With the introduction of large complex experiments requiring as many as 3,200 plants, larger gangs had to be employed to complete the work on the one day. Care was taken, however, that each block commenced was completed before planting was started on the next block. The planting pairs worked in the same consecutive order throughout and the first pair planted the first treatment in each block, ensuring that each pair, except where coincidences occurred, planted a different set of treatments in each block. Before planting was commenced on an experiment the bundles of stock from the various treatments were unbundled and heeled in sufficiently far apart to avoid confusion. Each parcel of heeled in plants was identified by a stake bearing the treatment number. This procedure is standard practice and its adoption avoided adverse treatment of the remaining plants of a bundle which might have been opened several times for the extraction of a few plants. In the larger experiments which might occupy the gang for a whole day, a decided change in weather might occur between the planting of the first and last rows and it is necessary to distribute the change evenly over the treatments by planting by blocks and not by pre-selected treatments.

In general in the South-West, planting is restricted to late June, the month of July and the first week in August. Experiments were commenced about three to four days after the opening of the planting season when the gangs had settled down to the work and while advantage might still be taken of a wider choice of planting stock.

Orderly layout is essential for assessment and to ensure regularity each plant row was provided with sight sticks and each planter a measuring stick to mark off the distance between the trees in a row. A tree-counter, to check the number of trees planted in each row and to move the sight sticks, was employed to assist the officer in charge of the experiment.

In observance of the condition that no modification other than the treatment studied may be introduced, planting in each experiment other than such

special cases as "time of planting" has been done on the one day. Plants used have been of the same grade and seed origin, taken from the same nursery, lifted on the same day and kept under exactly similar conditions except in those trials where variations in one of these factors has been investigated.

Comparisons have been made in most instances with a control or normal treatment. For the purpose of these experiments the ordinary planting practice has been taken as the normal treatment. Details of each component of the technique are given in Chapter V. in the report of the investigation of the separate components, but planting practice consists essentially of the use of planting stock of approximately twelve (12) inches in height, lifted from the nursery lines without any prior treatment in the form of wrenching or shoot pruning. The plants are lifted in small numbers until bunches of 25 to 30 are obtained, graded by discarding the small plants, root-pruned to eight (8) inches and then heeled in while more are lifted to make a bundle of 200 for bagging for transport to the planting site, where they are planted on the day of lifting in pits opened in sandy soil with a spade.

For each experiment a working plan was prepared setting out not only the details of the treatments to be included, but also the area of ground and the number of plants of each stock or treatment to be used, together with the list of dates on which the various actions were required. From the individual working plans a general working plan for the year was drawn up to facilitate control and reduce the risk of error due to failure to provide adequate planting stock or failure to give a required treatment as ordered in advance of the planting date. Randomisation of the treatments, or the drawing of the treatment numbers was done at the time of compilation of the plan.

Particulars of the weather on the day of planting, or other treatment, condition of planting stock, names of planters and especially any variations from the instructions in the working plan, were recorded by the officer in charge and the record attached to the file bearing the plan.

In the assessment, the behaviour of each individual tree was shown graphically in the field book in the relative position which it occupied in its particular treatment row. For example, where assessment was on survival, each living tree was represented by a dot and each failure by a cross. In the earlier trials assessment was made on 1st November as well as in May, after the autumn rains, as it was thought that variations in planting technique, while causing "winter" deaths, might not affect plants alive on 1st November. It was soon found, however, that most of the various factors tested definitely contributed to failures in late summer and assessments are therefore now made on the survivals after the autumn rains in the May following the planting season.

Chapter 5.

EXPERIMENTAL RESULTS.

The various components of planting technique experimented with may be readily grouped as follows:—

Section 1. Time of Planting.

Section 2. Plant Treatment—
Shoot Topping, Root Wrenching, Root Pruning, Heeling in, Root Exposure, Handling Plants for Transport.

Section 3. Plant Setting—
Method of Planting, Exposure of Planting Hole, Depth of Planting, Soil Firming.

Section 4. Planting Spot Treatment—
Hand Cultivation, Furrow Ploughing.

Section 5. Planting Stock.

In tabulating the results here each component has first been dealt with separately as a means of presenting the results in a simple form.

SECTION 1.—TIME OF PLANTING.

The planting season on the coastal plain, which had always been recognised as a comparatively brief one from late June to early August, has been discussed in Chapter 2—Location of Experiments. In the course of this study, experiments have been carried out to test the general assumptions regarding the most suitable time of planting.

Results from these experiments have shown in some cases a serious drop in survivals as early as August 7th and in others no appreciable loss up to as late as September 4th. From the attached records tabulated in order of years the position is clear and it is obvious that the variation must be attributable to some difference in seasonal or other conditions. Examination from the point of view of rainfall has shown that total figures have a general relationship with survivals, but by narrowing down to conditions immediately adjacent to the planting date, some of the variations can be explained.

Stirling.

The time of planting experiments were commenced in 1933, but prior to 1935 were small, the dates tested being at monthly intervals.

In 1934 exceptionally heavy rain fell following the first planting date, 2nd July, three inches being recorded in the first seven days. A significant and serious drop in "takes" occurred on the second planting date, 6th August, which may be attributable to the dry conditions experienced in that month. Planting on 3rd September was significantly worse than in August.

In 1935 heavy rain was experienced up to June 20th and survivals from the planting on 12th were high, the next planting on 26th was significantly worse than 12th, and coincided with a rainless period. The next planting on 10th July was better than 26th June and coincided with a period of heavy rain while on 24th July, the end of the heavy rain, equally good takes were obtained. Light rains followed interspersed with dry spells and a significantly worse take was experienced on August 7th and 21st, while a patch of heavy rain at the end of August brought survivals from 4th September planting up slightly. 1935 was

essentially a year in which heavy rains fell in June and July with light to heavy rains in August and even light rains in September.

In 1936 there was a steady grading off of survivals from 24th July onwards. This year was notable for lack of really heavy rain and for long dry spells. The most sustained rainfall was in August, but was light. Plantings in June and July were not statistically different, but low in contrast with 1935 figures. A big drop was experienced in August, statistically there was no difference between the late August and September plantings, although the early August planting which was in the middle of the rainy period, was better than both September dates. September was fairly dry.

In 1937 late June received heavy falls and fairly regular light to medium falls continued right through till October 20th. The rains in late September were very light, however. July 22nd planting was statistically worse than June, July and early August planting, while September 16th was worse than all dates up to 2nd September except July 22nd. It was noticeable that both these poor dates were dry days followed by little or no rain. The last date, September 30th, was a complete failure and was also in a dry period.

In 1938 fairly regular light rains were experienced in June, but the characteristic heavy rains were absent. There was a break in rainfall in the third week while the last ten days rainfall averaged only four points. July rainfall commenced on the second day and continued throughout the month with heavy falls in the third and fourth week. These falls graded down at the end of the fourth week. Dry spells were experienced in early and mid August. Apart from these dry periods, August rainfall was if anything, above average, particularly in the last fortnight. Rain continued till the first week in September, after which three weeks of rainless weather occurred.

Planting was done in rainy periods, commencing on June 10th and ceasing on 10th August. There was no difference in survival rate for any date. Generally the rainfall for this season was most favourable and the indications were that no serious losses would have occurred until September.

The following table is a summary of survival percentages for the time of planting series at Stirling for the seasons under consideration.

Season.	Planting Date.	Survivals.	Season.	Planting Date.	Survivals.
		%			%
1934 ...	2nd July ...	87	1937 ...	24th June ...	93·5
	6th August ...	57·5		8th July ...	95
	3rd September	36		22nd July ...	83·5
				5th August ...	93
1935 ...	12th June ...	93·5		19th August ...	88·5
	26th June ...	85		2nd September	89·5
	10th July ...	92·5		16th September	78
	24th July ...	94		30th September	10·5
	7th August ...	83			
	21st August ...	82	1938 ...	10th June ...	86·5
	4th September	86		24th June ...	91·5
				15th July ...	90·5
1936 ...	26th June	82		10th August ...	85·0
	10th July ...	83·5			
	24th July ...	76			
	7th August ...	57			
	21st August ...	41			
	4th September	36·5			
	18th September	32			

Gnangara.

At Gnangara the practice as already stated is to plant the pines in the bottom of a plough furrow opened up along the planting line. In this way the dry surface sand is avoided and the plant is set in moist sand. The provision of these favourable conditions largely overcomes the disadvantage of short spells of dry weather in the planting season.

In 1934 there were several dry spells in June, but these were broken by heavy falls of from 1½ to 2 inches in early, middle and late June. The first field planting date, 2nd July, was rainless but was only two days after a fall of two inches and was followed by almost continuous light rain. Survivals were high and significantly better than 18th July which was in the middle of a dry spell of a fortnight. Heavy rains occurred in late July and early August, followed by regular medium to light rain up till late September. Plantings on 15th August and 14th September showed 99 per cent. survivals, that is, a complete recovery from the comparative failure on 18th July.

In 1935 June rains were comparatively light, but unfortunately no dates were tested in this month. July, however, was almost continuously wet and 100 per cent. takes was recorded for 12th. The next date, 19th August, was at the end of a week's rainless weather, but just prior to a period of light rain and further dry weather. The takes dropped to 96 per cent. but the difference was not significant. September experienced regular light showers but planting on 20th showed a very large, significantly worse survival than the other two dates. Probably much of this failure could be attributed to a rainless period of 16 days which commenced on 30th September.

In 1936 early June rains were heavy but 9th to 16th was dry. Planting on 17th June showed 98 per cent. takes and was in light rain and was followed by almost continuous rain to mid July where a break of three days occurred. The next date, 17th July, was in this dry period, but continuous light rain followed and takes remained high. On 17th August takes dropped and were significantly worse than in June and July. This was probably due to rainless weather from 25th August to 10th September. A further significant drop in takes occurred in planting on 17th September, but this was in a period of dry weather with occasional periods of light rain.

In 1937, June experienced regular heavy rains and 100 per cent. takes resulted from planting on 17th. Although there were several dry periods in July, planting on 20th coincided with a wet spell and 98 per cent. takes were obtained. A drop in takes which approached significance was shown by planting on 19th August when planting was carried out on a dry day after a period of light rain extending from 27th July. Fairly heavy falls were received between 21st and 29th August when the falls fell away to regular light rain till mid September. Planting on 16th September was on a wet day but 19 days of practically rainless weather followed and survivals were only 26 per cent.

The control of a complex experiment planted on 29th July on a dry day just after a rainy period produced 99 per cent. takes.

In 1938 regular rains were experienced in June with several heavy falls. The last week was dry, but rains recommenced on July 2nd and continued till the end of the first week in September, when a fortnight of dry weather was experienced. Short dry periods occurred in late July and the first and third weeks in August, but these were of not more than four days duration.

Planting on 21st June and 18th July were slightly better than planting on 22nd August, while the 15th September was worse than all other dates. The Sep-

tember date was in the long dry spell and although average October rains fell, including very heavy rain at the end of this month, the dry conditions were too prolonged to be overcome by later rains.

Summary.

Planting in dry weather in June is usually harmful, but dry conditions of not more than two or three days' duration in July have no serious effect. This, of course, is greatly affected by the distribution of the rainfall prior to the planting date. Later plantings may be successful if rains are regular through August, September and October, but in view of this requirement planting after July is considered to be unsafe. If a protracted dry spell occurs in early September, August planting may be effected and September planting fails even if regular rain follows.

If a long dry period occurs in late September or early October, September plantings fail, but August takes are not seriously effected.

It appears that the ground may dry out in July but favourable conditions can still be obtained by avoiding this period and utilising later rains for planting. The following table is a summary of survival percentages for the time of planting series and controls of other experiments at Gnangara for the seasons under consideration.

Season.	Planting Date.	Survivals.	Season.	Planting Date.	Survivals.
1934—		%			%
Arboretum	11th July ...	96	1936 ...	17th June ...	98
	7th August ...	98		17th July ...	99
	14th September	96		17th August ...	85
Field ...	2nd July ...	95		17th September	45
	18th July ...	85		30th July ...	97
	15th August ...	99			
	14th September	99	1937 ...	17th June ...	100
				20th July ...	98
1935 ...	12th July ...	100		19th August ...	93
	19th August ...	96		16th September	26
	20th September	56		29th July ...	99
	1st August ...	98			
			1938 ...	21st June ...	99
				18th July ...	97
				22nd August ...	86
				15th September	30

SECTION 2.—PLANT TREATMENT.

The various treatments included in this group are treatments which are for the most part given in the nursery and are:—

(a) Shoot topping and pruning;

(b) Root wrenching;

(c) Root pruning;

(d) Heeling-in;

(e) Root exposure;

(f) Handling plants for transport.

(a) *Shoot Topping.*

Seedlings of Pinus pinaster in coastal nurseries attain a height of about twelve (12) inches in the first year and at the end of the second year they reach heights of between three and four feet. Because of the high cost of handling the two-year stock, one-year seedlings are in general use in planting operations. Where seedlings are stunted in their first year, attaining a height of perhaps only 3 or 4 inches, two-year seedlings of 15 to 18 inches in height have been used in some instances, but are not considered desirable stock. This may be due to a variety of causes, such as lack of mycorrhizal infection, lack of adequate artificial fertiliser, death of mycorrhizal fungus through increased acidity, etc.

With the object of retarding height growth to obtain a plant of smaller size in the second-year seedlings, nursery plants of normal growth have been topped in the nursery at various times in their second year. The procedure has been to cut off about one third of the shoot, that is, remove four to six inches, according to the season, spring or autumn, in which the topping is done. In spring the plants are 14-15 months old and in the following autumn 20-21 months. This topping is the removal of portion of the succulent leader as opposed to pruning of half the shoot, which involves cutting through the woody stem.

Stirling.

1934 and 1935: There was no effect of autumn topping.

1937: There was a highly detrimental effect of spring topping, but no effect of autumn topping.

1938: Autumn topping was beneficial.

Shoot Pruning.

Reduction of the shoot has been tried by pruning the stem at half or two-thirds the height at planting time. It was desired to investigate the possibility of improvement in takes by reduction of the leaf surface and at the same time reduce carrying and planting costs by using pines with a smaller top.

Stirling.

1932: Pruning to two thirds height was highly detrimental, but there was no effect of pruning to half the height.

1934: There was no effect of pruning to half the height.

1938: Pruning to half height was detrimental.

(b) *Root Wrenching.*

In a number of nurseries in Australia an operation known as root-wrenching has been carried out with the object of pruning the deep and spreading roots to induce a new development of short roots which would not be seriously broken in lifting. This operation is best done by inserting a sharp spade on each side of the row of plants in such a manner that the tap root is cut 8 or 9 inches below the surface. If two men are working on opposite sides of a row one should be slightly in advance of the other. The effect of the operation is to prune the roots without the shock of lifting the plants. Without very careful supervision, the roots may be cut too short or not at all.

In order to test the effect of wrenching a number of experiments have been made.

Stirling.

In 1936 wrenching was carried out six weeks prior to planting. In one experiment there was no effect of the treatment while in another the treatment was found to be beneficial.

In 1937 wrenching was carried out four weeks prior to planting. In one experiment there was no effect of the treatment, while in another the treatment was beneficial.

In 1938 there was no effect of wrenching three (3), four (4), or seven (7) weeks before planting.

Gnangara.

In 1938 there was no effect of wrenching three (3) or four (4) weeks before planting.

(*c*) *Root Pruning.*

In normal practice, or that most closely approximating general planting practice, the plants are lifted in bunches of 25 to 30, graded by discarding the small plants and root-pruned to approximately eight (8) inches length of tap root, for a pine with a twelve-inch top. These bunches are then placed in a hole and their roots covered with earth until 200 to 250 plants are available for bagging in wet jute sacking for transport to the planting site, where they are transferred to the planting trays.

Pinus pinaster seedlings develop an extensive root system as illustrated by the following figures for one-year old plants:—

Radius of lateral roots	29 inches.
Length of tap root	27 „
Height of plant	16 „

As the cost of excavating holes large enough for such extensive root systems is too high, it has become general practice in this State to prune the tap root to a length of eight inches. Pruning is done by chopping on a wooden block. Some variation may be expected when dealing with large numbers of plants, but close supervision to prevent carelessness minimises this.

There is a tendency in this process to remove all the tertiary and most of the secondary roots of plants with widely ramified root systems.

As eight-inch pruning was arbitrarily decided on for economic reasons, experiments were designed to compare the effect of short pruning to four inches and the use of long roots of twelve inches, which, except for occasional long laterals, is about the greatest length that can be lifted without excessive cost. For these experiments a standard plant with approximately a twelve-inch top, the usual one-year size, has been used throughout because it was realised that root lengths must vary with the size of plant.

Stirling.

In 1934 in one experiment there was no effect of pruning to four inches and eight inches against the use of unpruned plants with twelve-inch roots.

In two other experiments in 1934 and one in 1935 there was no effect of four inches against eight-inch pruning.

In 1938 pruning to four inches was detrimental, while there was no difference between the full length of twelve inches and pruning to eight inches.

Gnangara.

In 1934 experiments similar to that at Stirling were done in the field and arboretum and in both cases four-inch pruning was worse than eight-inch and no pruning with twelve-inch roots.

In separate experiments in the years 1935, 1936, 1937 and 1938, pruning to four inches was worse than pruning to eight-inch lengths.

(*d*) *Heeling In.*

In planting operations some plants are left on the plantation overnight to be available for the planting gangs at starting time in the morning before plants can be lifted and transported there from the nursery. These plants are "heeled in," the term given to sandwiching the plants three or four deep in a narrow trench where their roots are compacted with moist earth.

At Stirling in separate experiments in the years 1933, 1934 and 1935 there was no effect of "heeling in" overnight by comparison with direct planting on the day of lifting.

At the same time it was decided to investigate the suggestion that "heeling in" for longer periods of two to four weeks has a hardening effect on the planting stock and a beneficial effect on initial survival.

Stirling contrast with planting on the day of lifting.

Year.	2 weeks.	4 weeks.
1933	Detrimental	Not tested
1934	No effect	No effect
1935	No effect	No effect
1936	Beneficial	Beneficial
1937 (*a*)	No effect	Detrimental
(*b*)	Not tested	Detrimental
1938	No effect	No effect

Gnangara contrast with planting on the day of lifting.

Year.	2 weeks.	4 weeks.
1934 (*a*)	No effect	Detrimental
(*b*)	No effect	Not tested
1938	No effect of 3 weeks	No effect

(*e*) *Root Exposure.*

In Western Australia the plants are carefully bagged for transport and particular care is taken to avoid undue exposure of the roots while lifting in the nursery and setting in the field. It has been estimated that the various intermittent exposures to which the roots of the plants are subjected between lifting from the nursery and setting in the planting hole, amount to a total of about two minutes. Careless workmen, however, may lengthen this period considerably. In order to test the effect of undue exposure by workmen, plants have on lifting, been laid out experimentally on the ground, with the roots exposed, for varying periods of three to five minutes in both dull weather and bright sunshine. At the end of a three-minute exposure on a warm sunny day in a light breeze the roots are slightly dried, the colour changing from black to dark grey-brown, but on a cloudy day no change was noted. Actually such a three-minute exposure, in which each plant is laid out separately on the ground, should be more severe than several short exposures.

The careful bagging of plants for transport in Western Australia is in marked contrast with the loose bundling of plants which is all that is necessary on some Australian plantations. The experiments were consequently designed to

include tests of the possible effects of exposure for comparatively long periods as in transport of unpacked stock to the planting site.

Stirling.

Year.	Weather.	2 minutes.	5 minutes.	15 minutes.	30 minutes.	45 minutes.	60 minutes.
1934	Sunny	Not tested	Not tested	Detrimental	Worse	Not tested	Worse
	Cloudy	Not tested	Not tested	No effect	No effect	Not tested	No effect
1935	Sunny	Not tested	Detrimental	....	....	....	....
1936	Sunny	Not tested	Detrimental	....	....	....	....
1937	Sunny	No effect of 3 minutes exposure	....	....	....	....	....
1938	Sunny	No difference between exposures of 2, 4, 6, and 8 minutes	....	....	....	....	....

Gnangara.

1933	Sunny	Not tested	Not tested	No effect	No effect	....	Detrimental
	Cloudy	Not tested	Not tested	No effect	No effect	....	No effect
1934 (*a*)	Sunny	....	....	No effect	....	Detrimental	....
(*b*)	Sunny	....	....	Detrimental	....	....	....
1936	Sunny	....	No effect	....	....	....	....
	Cloudy	....	No effect	....	....	....	....
1937	Sunny	....	No effect	....	....	....	....
	Cloudy	....	No effect	....	....	....	....

(*f*) *Handling Plants for Transport.*

Plants to be transported by rail or road to distant plantations are bundled in lots of 200 to 250 and carefully wrapped in jute sacking as in general practice. Frequently plants remain bagged for periods up to two days and a series of experiments have been carried out to test survivals from such transported plants, in contrast with those transplanted direct from the nursery on the day of lifting.

Bagging for Two Days.

Stirling.

1933 Detrimental
1934 No effect
1935 (a) Beneficial
(b) No effect
1936 (a) No effect
(b) No effect
(c) No effect
1937 (a) Detrimental
(b) No effect
(c) No effect
(d) Beneficial
1938 No effect

Gnangara.

1934 (a) No effect
(b) No effect
1935 Beneficial
1936 Beneficial
1937 Beneficial
1938 No effect

Damage in Transit.

The possibility of damage to the roots by standing the bundles on the hard floor of a railway truck and by rough handling of the roots in bagging has been tested.

Stirling only.

1936 No effect of—

(a) Standing the bundles on end on a hard floor for 2 days.
(b) Dropping the bundle roots downwards on to a hard floor from a height of three feet.
(c) Breaking the roots at six inches below the collar by bending the roots back along the stem.

1937 The same result was obtained.

Watering Bundled Plants.

In view of the possibility of drying taking place while the plants are in the bags, or while "heeled in" on the planting site after removal from the bags, watering of the trees subjected to the treatment has been tried.

In 1936 there was no effect of—

(a) Submerging the bundles of plants in a tank of water before despatch from the nursery.
(b) Watering the plants in the field before planting.

The same treatments were given to plants which were bagged for two days in the interval between despatch from the nursery and "heeling in" on the planting site. Again there was no response to treatment. In 1937 the same results were obtained from a similar experiment.

SECTION 3.—PLANT SETTING.

In this group the treatments included were those concerned with the actual planting of young trees in the field. They were:—

(a) Method of planting.
(b) Exposure of the planting hole.
(c) Depth of planting.
(d) Soil firming.
(e) Root dispersal in planting.

(a) *Method of Planting.*

In Western Australia pit planting is standard practice, that is the plant is placed in a hole or pit excavated by means of a spade. Care is taken to set the plant with the tap root pointing vertically downwards but no particular attention is given to the laterals. Several other methods have been tested for reasons of economy. The chief objection raised to these is the impossibility of ensuring that the tap-root is not bent from its vertical position.

On Unploughed Land—Notching.

The plant is set in a notch made by inserting a spade in the ground and then moving it backwards and forwards from the vertical position.

At Stirling in each of the five years, 1933, 1934, 1935, 1936 and 1937, there were no significant differences in the "takes."

On Ploughed Land.

The surface sand remains dry to a depth of several inches during the first winter after ploughing and in this dry sand notching is not possible. For this reason another operation known as spear planting was developed. This is a partial excavation made by the operator inserting the spade and dragging the soil towards himself. The operation may, however, become more costly than pit planting.

In deep furrows especially opened out on ploughed land to expose the moist sub-surface sand, notching and wedging, an operation made with a wedge spade of the same over-all dimensions of an ordinary spade, have been tried, but even under these conditions dry surface sand has been troublesome.

At Gnangara in 1934 in two experiments there was no effect of these treatments in comparison with pit-planting.

(b) *Exposure of Planting Hole.*

In general planting care has always been taken to limit the exposure of the planting hole and out-turned sand by planting within one hour of opening the planting holes, as it was assumed that the drying of the soil would be sufficient in degree to harm the plants. In order to test whether this care is essential, experiments have been made with a number of different periods of exposure.

Stirling.

In 1933 the longest exposure was between opening the hole one morning and planting the following afternoon. There was no response to treatment.

In each of the years 1934, 1935 and 1936, there was no effect of advance holing extending up to two days.

Gnangara.

In 1933 there was no effect of exposure of the planting hole for two hours on a sunny day.

In 1934, opening of the holes for two and four weeks were included in the experiments, but there was no response to treatment. Owing to the sand silting in on drying, the holes were not open to the full depth for the periods planned and in these long exposure treatments it was necessary for the planters to excavate some sand before setting the pines.

(c) *Depth of Planting.*

Normal planting practise formerly provided for setting the plant at the same depth at which it grew in the nursery.

In the early experiments shallow planting setting of 1½ inches below the nursery level and deep planting settings of 1½ inches and 3 inches above the nursery level, were tested. Because these experiments showed no effect of deep planting a setting of 1½ inches deeper than nursery level was adopted as general plantation practice. This provides for a reasonable variation by the planter and still keeps the plant setting within the limits of nursery level and three inches deep. The difficulty met with in keeping the plants from later falling over in treatment combinations of shallow planting and short root pruning caused the shallow setting to be reduced to one (1) inch below the collar. For experimental purposes a setting of six inches deep was arbitrarily introduced, but the cost of excavating the deep holes required for this treatment renders it impracticable in ordinary planting.

Stirling.

1933 No difference between nursery level and three inches deep planting.

1934 Using 1½ inches shallow, 1½ inches deep, and 3 inches deep, there was no effect of treatment.

1935 There was a beneficial effect of 1½ inches deep planting as compared with 1 inch shallow setting.

1936 (a) There was no difference between 1½ inches and 3 inches deep setting, which were both better than 1½ inches shallow planting.

(b) There was no difference between 1½ inches and 3 inches deep planting.

1937 (a) There was no difference between 1½ inches and 3 inches deep planting.

(b) Same result as (a).

Gnangara.

1933 There was no difference between nursery level, 1½ inches and 3 inches deep setting, which were all better than 1½ inches shallow planting.

1934 The same result was obtained in a similar experiment.

1935, 1936, 1937 and 1938 Deep planting of 1½ inches was better than 1 inch shallow planting in each of these four years.

(d) *Soil Firming.*

In 1933 tamping of the soil by hand when filling the planting hole was compared with trampling the soil with the feet. There was no response to treatment.

(e) *Root Dispersal.*

Stirling.

In 1938 in order to test the effect of various arrangements of the roots in actual planting, an experiment was made with the following treatments:—

1. Normal planting.
2. Bending the roots at a depth of three inches into a position parallel with the surface.
3. Planting with the lower half of the roots doubled back.
4. Twisting the roots into a rope-like mass.

There was no effect of treatment.

In the same year the bending of the roots at a depth of three inches into a position parallel with the surface was tested in another experiment. Again there was no effect of treatment.

SECTION 4.—PLANTING SPOT TREATMENT.

In this group the following treatments were investigated:—

(i) Hand cultivation.

(ii) Furrow ploughing.

(i) *Hand Cultivation.*

At Gnangara the ground is thoroughly ploughed so that no scrub or grass develop in the first season after planting, the sand remaining bare.

At Stirling planting is carried out on unploughed land and competition by grass and scrub is of importance in its effect upon initial survival. In order to eliminate this, cultivation has been tried in two seasons:—

Season.

Autumn Cultivation. Prior cultivation of the planting spot in autumn, some six weeks before the holes are opened out for planting.

Spring Cultivation. Subsequent cultivation of the ground around the planted pine in spring about two months after planting.

This cultivation has been carried out over two areas, one with eighteen inches and one with three feet diameter, except in the early years.

Stirling.

1932 18-inch spring cultivation was better than no cultivation. 18-inch autumn cultivation had no effect.

1933 The same result was obtained from a similar experiment.

1934 The same result was obtained.

1935 (a) 3-feet spring cultivation was better than 18-inch spring cultivation, which in turn was better than no cultivation. There was no effect of autumn cultivation of either area.

(b) 18-inch autumn cultivation was better than no cultivation.

1936 Cultivation, irrespective of season, was better than no cultivation, the greater area being the most effective. There was, however, no effect of season.

1937 (a) Spring cultivation was beneficial but there was no effect of area. Autumn cultivation had no effect.

(b) Three-feet spring cultivation was better than 18-inch spring, which in turn was better than no cultivation. There was no effect of autumn cultivation.

(c) There was no difference between 18-inch and 3-feet spring cultivation. Autumn season was not tried.

(d) The same result as (c).

(e) 18-inch spring cultivation was better than no cultivation.

Tools.

1937 (a) Two different tools, a grub-hoe and an ordinary garden hoe, were found to give no difference when used in spring cultivation.

(b) The same result as (a).

Time of Spring Cultivation.

1937 (a) There was no difference between cultivation on 15th September and 15th October.

(b) There was no difference between cultivation on 15th September and 15th October, but both dates were better than 15th November.

(ii) *Furrow Ploughing.*

At Stirling opening up a plough furrow approximately eight inches deep in the bottom of which the plants were set has been tried in comparison with planting on the ordinary surface of the ground.

1935 Furrow planting was better than surface planting.

1936 The same result was obtained.

1937 In this year a double-furrow was included as an additional treatment and both furrow treatments were better than surface planting.

SECTION 5.—PLANTING STOCK.

One year seedlings have formed the bulk of the planting stock of Pinus pinaster in Western Australia. The height attained by the seedlings in the eleven months period, August to July, between sowing and lifting, approximates twelve inches. The comparatively late sowing is made to avoid the nursery weeds which develop freely in the wet months June and July. Good nursery stock continues to grow very rapidly if left in the nursery lines and at the end of the second year some plants reach heights of between three and four feet. Because of the increased cost of handling, the use of stock of this size is impracticable. Lining out, or "transplanting," at the end of the first ten to twelve months has not been found to produce appreciably smaller two-year stock.

Where rabbit damage is experienced it is the practice in some States to use two-year planting stock which suffers less severely from rabbit attack than the smaller and less woody one-year plants. On the Coastal Plain of Western Australia rabbit damage has been of no consequence so far, though there are indications that the numbers of this pest are increasing on the Stirling plantations.

It has been stated that the unsatisfactory development of nursery stock has been one of the problems in afforestation work in this State. Some of the seedlings, however, which show very poor growth in the first year, not reaching beyond three or four inches in height, continue their development in the second year to form apparently satisfactory planting stock of some fifteen to eighteen inches tall.

At Stirling a number of comparisons have been made with one-year and two-year stock from different nurseries. Though the comparisons were incomplete and the results conflicting, it does not appear likely that there will be any constant advantage in using two-year stock of the type available. Moreover, with the improvement which is gradually becoming apparent in these coastal nurseries, uniformly satisfactory one-year stock can be expected and two-year stock from stunted one-year seedlings will no longer be produced.

1932 Coolilup two-year seedlings were worse than one-year Coolilup, which however were inferior to two-year Boranup.

1933 Coolilup two-year, Coolilup one-year and Stirling two-year were worse than one-year stock from three other nurseries.

1934 Stirling two-year seedlings were better than Stirling one-year and also one-year stock from four other nurseries.

1936 Stirling and Wonnerup two-year seedlings were better than Wonnerup one-year stock, but not Stirling one-year.

1938 Keenan two-year seedlings were better than Boranup one and two-year plants, between which there was no difference, but which in turn were better than Keenan one-year stock.

Chapter 6.

DISCUSSION OF RESULTS.

In the seven-year period under review, June 1932 May 1939, a large number of field trials have been made. A fairly complete description of the factors tried has been given in describing the results of the experiments, so that it is only necessary to draw attention to some of the more important aspects of the work and to present the practical application of the study.

It is important that statistical significance does not reveal the practical importance of any difference; that can only be judged by one with technical knowledge of the forest planting operations to which the methods are applied. Nor does the absence of significant differences imply that no difference exists, but it does indicate that the chances are as stated against the observed results being different in similar independent trials.

At the commencement of the study the factors then judged to be of importance were included in the experiments. As the work progressed the importance of other influential factors became apparent and a readjustment of ideas formed from the early results was necessary.

This experimental work has directed attention to and afforded the opportunity for detailed study of the behaviour of pines established in the general planting carried on in the State plantations during the years in which these experiments have been made. The records obtained in this way confirm the conclusions that factors previously unrecognised and neglected have been very important features in the successful establishment of the young trees in their first year.

It has been stated that deaths of the planted pines occur in three distinct seasons, winter, early summer and late summer.

In the Gnangara plantation in July, 1937, in one sub-compartment of five acres, an almost complete early mortality occurred and within one week after planting a lightening in colour was observed in 80 per cent. of the young pines. In extreme cases pines assumed a straw colour. These pines on being submitted to the Government Chemical Laboratory for examination were found to contain strong traces of arsenic. The arsenic was ultimately traced to the drums which had been used for watering the bundles of pines as they were brought from the nursery. Arsenic is used for poisoning Christmas tree (Nuytsia floribunda), a parasitic plant whose haustoria cut the roots of the young pines.

In the Stirling Plantation in the same year a high percentage of deaths, up to 80 per cent., was noted in two sub-compartments in August, a month after planting. These areas had not been previously inspected since planting and a similar cause was then suspected. Chemical analysis, however revealed no trace of arsenic in the young plants.

The cause of death was not discovered for some time, when it was found that the only different treatment these pines had received was a Spring (September) "topping" in the nursery lines when they were 15-months-old seedlings. The actual topping done in this instance was more severe than was intended, the pruning taking place at a height of only five inches above the ground. Small parcels of these seedlings from the same nursery established in two other plantations similarly suffered a high percentage of winter deaths shortly after planting.

Experiments carried out in the 1937-38 season with "Spring" topped stock have confirmed the harmful effect of this treatment.

In the ordinary planting practice "refilling" is carried out when the "misses" or deaths in the planting of the previous season exceed 15 per cent. with a six feet by six feet espacement or its equivalent. In 1936 in the Stirling plantation it was found that refilling was necessary in three compartments, but not in the other four planted in the 1935 winter. Six feet by six feet espacement was used that year. The major variations in the general planting practice that season were planting stock from different nurseries and of different seed origin, the ploughing before planting of some compartments but not others, different dates of planting extending over the month of July, the change in the amount of sunshine and rain on the separate days, the different gangs which planted different parts of the plantation and finally the variation in time of Spring cultivation which extended from the beginning of October to early November.

Except in the case of Spring cultivation, plantings were equally successful and unsuccessful when receiving opposite treatments. All compartments, however, which were given Spring cultivation after the 29th October required refilling.

Although it has not always been done, the aim at Stirling has been to complete the Spring cultivation before November, but it was not until 1937 that, in view of the experience of 1935, experiments were established to test the correctness of the accepted period. Subsequent experiments have shown that mid-November cultivation was harmful by comparison with mid-October. The effect of season will, of course, have a powerful influence in this connection.

In tabulating the results in Chapter 5 each component has been dealt with separately as a means of presenting the results in a single introductory form.

It has already been explained, however, that while only single experiments were possible in the early years, the information obtained from them permitted the use of more recent and more efficient complex experiments, involving combinations of several of the factors to be tested and designed to yield information on interactions as well as direct effects.

Interactions of the highest order have rarely been significant and it was decided to sacrifice the information derivable from them when planning recent trials in which confounding was resorted to for the purpose of reducing block size.

The experimental results are discussed under the following headings:—

1. Factors of importance in the control of establishment operations;
2. Important common faults in ordinary planting technique;
3. Factors investigated which do not appear to be of importance in influencing establishment.

1. Factors of Importance in Control.

(a) *Planting Season or Planting Date.*

Planting can be carried out during the winter rains in the months of June, July and August. The five weeks period from late June to the end of July forms the safest planting season. This is borne out by an examination of the weather data and is supported by results from the time of planting experiments. The distribution of the rainfall within the winter months, however, is of great importance and although this general rule, based on averages, can be given for the best planting time, each season is in itself a separate problem and the period within which establishment will be successful becomes a matter of experience and interpretation of rainfall trends. In some years planting has been unsuccessful after July and in other years successful up to early September. Furthermore, since moistness

of the soil is an essential factor and as the surface sands on recently ploughed areas dry very quickly, it becomes undesirable on such areas to risk loss by planting in the prolonged periods of up to a week or ten days of fine weather which are sometimes experienced even in the mid-winter months.

(b) *Preparation of the Ground.*

Thorough ploughing, the specifications including a nine inch minimum depth, is necessary at Gnangara. In the first winter following ploughing the surface sand which does not become compacted dries very quickly in short spells of three or four days of fine sunny weather in the planting season. Planting in dry sand causes winter deaths which become apparent in three to four weeks. To overcome this and ensure that the roots are set in moist sand, a deep furrow in which the trees are planted is opened up along the planting lines which are placed at right angles to the original ploughing.

At Stirling, ploughing is not essential and as the litter of logs and debris from the felling of the native vegetation is not cleared up furrow ploughing is impossible. The effect of spot-cultivation in autumn prior to planting was tried as a means of preparing the ground. Most frequently there was no effect of this treatment. On this plantation the sand beneath the ash-bed resulting from the burning of a big log frequently remains dry throughout the first planting season. A planting line coinciding with such an ash-bed may show six or eight deaths in a row. These failures showed up clearly in the field book records of the early experiments and in consequence the dry sand has been avoided in the more recent trials by moving the planting spot a foot or two either way.

(c) *Spring or Subsequent Cultivation.*

At Gnangara grass does not develop in the first year following ploughing.

At Stirling, however, a strong development of grass and weeds takes place following the clear-felling of the indigenous timber. This growth is composed of a few Gramineae (the most important of which are the introduced wild oat Avena fatua) and species of Bromus, Stipa and Breeza and members of the families Caryophyllaceae (the most important being the introduced wild pink Tunica prolifera), Geraniaceae, Compositae and Juncaceae.

The effect of cultivation in reducing failures was apparent from the first experiments in 1932. This cultivation, which consisted of hoeing over a diameter of eighteen inches around the pine, was done in the spring following planting.

Spring cultivation, at a cost of eighteen shillings (18s.) per acre for 6ft. x 6ft. espacement, has been adopted as standard practice at this plantation. Cultivation over a greater area, three feet diameter, has sometimes caused a significant increase in "takes," but the practical value of the increase is not great and does not justify the increased cost of the cultivation.

The time at which spring cultivation is carried out is important and recent experiments indicate that spring cultivation should be completed by 15th October, that is, before the grass begins to die naturally with the approach of summer conditions.

With regard to tools, no difference in results was found between the grub-hoe and garden hoe for use in the cultivation, though the garden hoe makes slightly cheaper work.

(d) *Planting Stock*

A number of strains of Cluster pine have been used in planting on the Coastal Plain. These are Northern Landes, Southern Landes, Portuguese (Leiria), Esterel, Corsican, South African (from selected stands) and a small parcel from selected trees from Tunkurry plantation, New South Wales. With the exception of the South African and Tunkurry, each has distinctive morphological characteristics in the young stands.

Until 1935 the main plantings have been made with Southern Landes strain and since that date South African has been used almost exclusively. The experimental stock has been of the strain used in the general planting.

The possibility of variation in initial survival with strain has not been tested and, in view of the desirability of using the better form and faster growing Leiria strain as seed can be obtained, this possibility must not be overlooked.

With the improvement in nursery practice, satisfactory one-year planting stock of twelve to fifteen inches in height can be expected from all coastal nurseries. This has been found to give good results in establishment and if left for two years in the nursery become too large.

2. The Important Common Faults in Ordinary Planting Technique.

(a) *Short Root Pruning.*

In five experiments at Gnangara short root pruning to four inches length has been found harmful by comparison with pruning to the standard length of eight inches. These standards have been used for a pine with a twelve to fifteen inch top.

The results at Stirling have been contradictory, where owing to the lesser reliability of the earlier trials, further investigation is required.

Whenever pruning of the roots is ordered it is found that the length standard of the workman gradually shortens from the length set and, to prevent this, a measuring stick must be available for constant reference.

(b) *Too Shallow Planting.*

Except in two cases, one at Stirling and one at Gnangara, shallow planting at 1 to 1½ inches higher than the nursery level, has been found harmful. Planting at the nursery level has not been shown to differ from deeper settings of 1½ inches and 3 inches which in turn have not differed from each other.

Setting at 6 inches deeper than the nursery level has been found harmful in one experiment, beneficial in another and to have had no effect in a third case.

Owing to the deeper planting hole required, an increased depth of planting is accompanied by increased cost of planting.

Workmen tend gradually to reduce the depth of the planting hole and more or less in consequence the man setting the trees makes his planting more shallow to suit the hole depth. A depth mark on the spade corrects this tendency. A fixed depth is far from obtainable on the rough surface of the ground and it appears that the planting position is satisfactory as long as the plant is not set above the nursery level. To ensure this a depth of 1½ inches below the nursery level has been adopted as standard practice. This will allow a variation by workmen of nearly 1½ inches each way without seriously affecting the survival.

With Pinus pinaster on the coastal sands it has been found convenient to cover the first whorl of branches in order to ensure sufficient depth of setting.

The deep setting has not been found to affect the vigour of Cluster pine in this State, although attention has been drawn to an effect of ½in. deep setting on long leaf and slash pine in the Southern States of U.S.A. where, however, shallow setting resulted in heavy mortality (14).

(c) *Root Exposure.*

Exposure of the roots of Cluster Pine has been found to be less serious than was expected.

On days on which the sky was overcast with clouds, complete exposure of the roots for periods up to sixty minutes has not been found usually to have any effect, though in some instances exposure for 15 minutes was harmful.

In bright sunshine the plants have been capable of withstanding exposure for five minutes in most cases though this period was twice found to be detrimental.

Classification of the weather as fine or cloudy, is, however, unsatisfactory and probably relative humidity is an important factor.

As numerous short exposures are inevitable in lifting, transport and distribution of the plants, care should be taken in sunny weather to keep the trees covered as much as possible to prevent undue exposure of the roots in transference from the plant carrier to the planting hole.

3. Factors Investigated which do not Appear to be of Importance in Influencing Establishment.

Section 2—Plant Treatment.

(i) *Root Wrenching.*

On the whole there is no effect of wrenching at various periods of three to seven weeks before lifting.

(ii) *Heeling In.*

On the whole there is no effect of "heeling in" for periods of two and four weeks before planting.

(iii) *Handling Plants for Transport.*

With the standard practice of wrapping bundles of about 200 plants in thoroughly wetted jute sacking, bagging for two days, as when transported by rail to a distant planting site, has not been detrimental.

Rough handling of the plants, including breakage of the roots, as might occur in transport, has had no effect on survival.

Watering the bundled plants has caused no differences in "takes."

Section 3—Plant Setting.

(i) *Method of Planting.*

Pit planting has not been shown to give better results than the cheaper notch planting.

(ii) *Root Dispersal in Planting.*

Bending all roots to one side just below the collar so that they lie parallel with the surface at shallow depth, doubling the lower half of the roots back towards the surface and twisting the roots into a rope-like mass, did not have any effect in 1938 experiments. These treatments should be further tested.

(iii) *Soil Firming.*

In filling the planting hole, no difference was found between firming by hand and trampling in with the feet.

(iv) *Exposure of the Planting Hole.*

Opening up the planting hole for periods of a few hours to two days, has had no effect. Digging of holes longer in advance of planting is not practicable owing to the sand gradually running back on drying.

(v) *Shoot Topping and Pruning.*

It has been pointed out that Spring topping is highly detrimental. Autumn topping to reduce the size of two-year stock does not appear to have any influence on survival, but its value in reducing costs is very small. Further experiments are necessary to determine whether or not shoot pruning at half height is detrimental, but there does not appear to be any likelihood of gain by this operation.

Seasons and Interactions.

Interactions have been found significant in a comparatively few cases only and in these cases may be due to some particular vagary of the weather about that time. Without further information, it appears that with the factors tested, direct effects are the major factors affecting establishment while differential responses are comparatively unimportant.

Although some variability is noticeable in the factors the results of the analyses have generally been consistent in the range of seasons experienced in the period under review. Statistical significance gives no measure of the practical importance of these results and it has been found that much greater numbers of deaths occur in some treatments in one year than in another, although the controls with standard practice do not vary.

This is well illustrated in a series of experiments of 2^3 design with lifting, root-pruning and depth, each at two levels. Over the range of years 1935, 1936, 1937 and 1938, there was an effect of season, the year 1937 being worse than 1935, which in turn was worse than the years 1936 and 1938, between which there were no significant differences. In these years the total percentages of "takes" in the whole experiments were: 1935, 82.7%; 1936, 90.2%; 1937, 58.8%; 1938, 93.2%; while the controls were 97%, 97%, 99% and 95% respectively. It is of interest that the 1937 experiment was planted in a dry spell, the actual days of planting and the four following days, being dry, while in 1935, a shorter dry spell was experienced, one day following being dry.

The general analysis for effect of seasons showed depth and pruning to be significant, while lifting and interactions were not effective.

From the percentages shown above, it is obvious that the controls, which embody both deep planting and normal pruning, have not been affected by season and therefore that the losses are due to the variations from normal procedure. It

is therefore safe to assume that departure from the normal procedure of deep planting and normal pruning is liable to cause serious losses.

It should be realized that although season has been under consideration, a critical examination of the weather tends to show that under Western Australian Coastal conditions it is more a matter of immediate planting weather than actual seasonal effect.

Conclusion.

With some factors variation has occurred in the results, but this can be expected in tests in which experiments have been repeated a number of times over a period of years. The general trend of the experimental results have been taken to indicate the conclusions arrived at. As corroborative results with the factors tested have been obtained in the two plantations used, a number of seasons have been involved and the trials were conducted on a number of soil types over the years of investigation, it can be assumed that the conclusions are of general application for the range of soils covered in the two plantations named.

An extension of the investigations to the heavier soils of the Darling Range would be desirable to obtain information regarding the practicability of a uniform technique under all conditions.

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