PINE ESTABLISHMENT.

A further report on a Study from 1932 to 1945 of Initial Survival in Plantations of Cluster Pine (Pinus pinaster) in Western Australian Coastal Plantations.

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PART I.—INTRODUCTION.

PLANTING, which has been pursued steadily in forestry for several centuries, consists of planting in the field trees which have been raised in the nursery. It has gradually attracted en ever-widening extent of attention.

It is particularly important that those who are going to carry out the apparently simple act of tree planting should have as much knowledge as possible of the effect of the operations they perform.

Practice built up in other countries of the world, and even in other States of Australia, could not necessarily be expected to be attended with complete success in Western Australia, and, therefore, the various components of planting technique had to be tested under local conditions.

The cause of death of plants is a matter of great complexity, and it can only be hoped that single studies of this nature will lead ultimately to deeper investigation of the problems.

In an endeavour to find the factors of planting technique which influence failure in the first year in pine establishment in the South-West of Western Australia, experiments have been carried out over a period of 13 years, commencing in 1932.

Planting technique, or the steps taken in transferring the trees from the nursery to their new site in the field, has largely been determined by the method of simple observation, building up a background of experience in planting. The validity of the impressions gained in this way is open to question, and the disentanglement of the practices built up from them is a laborious and difficult task. Attention has had to be directed to each step in turn.

The results of the first seven years' investigations into the establishment technique for Pinus pinaster were published a "An Account of Experiments in connection with the Initial Survival of Cluster Pine (Pinus pinaster) in

Western Australian Coastal Plantations," Bulletin 53 of the Forests Department of Western Australia (1). It was pointed out that 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 climate, topography, geology, vegetation and soil of these plantations were described therein, as well as Uniformity Trials made to determine the optimum size of the plot for experimental purposes, and methods of experiment with some particulars of the procedure adopted. This report should, therefore, be read in conjunction with Bulletin 53.

Practically all the work has been done with Cluster pine (Pinus pinaster), which is used for planting on the poor coastal sands extending southwards from 20 miles north of Perth to Cape Leeuwin.

The reasons for the use of Pinus pinaster in this coastal sand planting are that, although the sands are too poor (one to five parts per million of phosphate) to support pine stands unaided, Pinus pinaster makes very satisfactory development with the application of artificial fertiliser in the form of superphosphate. Details of the nutritional studies are given in Bulletin 50 (2), and subsequent unpublished reports. Pinus radiata, although growing under these conditions, is of poor colour and is not likely to develop into a satisfactory crop, except on the better Tuart sands. The author is indebted for their co-operation and assistance to Messrs. D. H. Perry and H. E. Dawson, Foresters, who controlled the planting experiments.

PART II.: AIMS AND TRENDS IN THE STUDY.

The various steps taken in establishing plants in the field have been examined, and a considerable number of them experimented with. These factors studied included those which, so far as was known, were considered to be of importance in planting in Southern Australia. A number of planting manuals have dealt with the supposed importance of root distribution, while particular local practices have included such steps as root wrenching or "heeling in," because they might have an influence on "takes" in the district concerned. Attention was first drawn to the question of depth by Carter (3), who found an advantage in deep over shallow setting in one experiment in Canberra.

From the outset it became apparent that some factor, other than the one experimented with, was causing deaths which were occurring in the controls. Progress in the study showed that, with most of the experiments tried, there was simply no effect of treatment, and, in general, the experiments were yielding negative results.

While a negative result is very valuable, there was a reluctance to relinquish time-honoured practice, and the experiments were repeated many times to eliminate doubt as far as could possibly be done. Certain of these factors, which did not appear from the experiments to be of importance in planting technique, had long been regarded as influencing the success or

failure of planting operations, and it was desired to watch the results over a period of years.

There were other reasons for a continuance of the experiments. Plants continued to die in the controls and, while a complete "take" may not be necessary, it was thought some important factor might ultimately be discovered. Moreover, certain factors had not been tested as frequently as others because attention had been drawn to them at a comparatively late stage.

A feature which has completely changed the ideas on depth of setting and root pruning is that the Root Dispersal experiments have not shown that it is necessary to dispose the roots vertically downwards. In other words, it is not necessary to have the hole deep enough to take the full length of the root. Working from this aspect, no root pruning would be necessary, and the roots could be dispersed in any manner in a hole which might be too shallow for vertical arrangement.

Trials which involved such questionable practices as bending the tap root and bunching and twisting the roots require a great deal of confirmation before it can be accepted that no harm will ensue from the treatments. It will be appreciated that some years must be allowed to elapse to determine the behaviour of these plants up to an age of perhaps ten years before deciding that, apart altogether from establishment, dispersal of the roots has no effect on subsequent development of the plant. Very uncertain results had been obtained from the time of planting experiments, and weather is such a variable factor that it needs almost indefinite testing. Planting in the month of June had been regarded as unsafe in general practice, and was not sufficiently covered in the early trials. A complication arose through the discovery of a comparatively high percentage of deaths in occasional parcels of plants transported by rail, and experiments were designed to test the influences which might possibly bring this about.

The early experiments at Stirling were largely negatived by failure to cultivate around the young trees to eliminate grass a few months after planting. The value of this was discovered in early trials.

At the investigations proceeded, a number of treatments became apparently worthy of trial. The extension of our knowledge and the better understanding of some of the factors which determined success or failure decided the subsequent form of the project.

It appears now the work must be still further continued.

An inherent factor, the type or vigour of the plant, had been given some attention. In ordinary planting practice, the procedure has always been to reject what appear to be the poorer and less vigorous plants. Experiments were, therefore, designed to test the various types of plants in the nursery lines and the stock grown from large and small seed.

The actual cause of death in a plant is probably a very complex matter. Death may be due to such causes as competition by surrounding scrub, disease, insect attack, failure for some reason to make sufficient root develop-

ment before summer, etc., and hence will be influenced by inherent qualities such as immunity to disease, natural vigour, or habit of growth, which vary among the individuals.

Death then may be regarded as a problem in plant physiology, involving, for example, perhaps failure to develop auxins, a function of which is to initiate root growth. It could perhaps be avoided by the application of synthetic chemicals to stimulate necessary plant development.

In Western Australia, on the poor coastal sands, where the use of superphospate is necessary for satisfactory continued development of the pine, lack of the artificial fertiliser does not affect survival in the first summer, which is the subject of the present study.

Experiments are set down in July, except with Time of Planting, and are assessed in the following May after the commencement of the heavy winter rains. Deaths occur over the whole of that period; winter deaths a few days after planting, spring, summer, and then later summer failures up to the break of the dry season.

The use of statistical analyses of all experimental results has been adhered to rigidly. The development and extension since the investigation began in 1932, of the method of analysis, particularly in regard to the use of factorial design and confounding, has permitted a study of the interaction of factors. In many cases still, however, small exploratory experiments are made in the first year of test of new treatments, to be followed later by their incorporation in the more complex design.

Tests for significance prevent the acceptance without question of a result which is merely higher than another. Failure to establish significance does not necessarily mean that no difference exists, or conversely that an established result must be definite. It could still be fortuitous. Statistical significance does, however, indicate that the chances are as stated against a different finding under similar conditions. The practical importance of any difference is not revealed by statistical knowledge of the forest planting operations in which the trials have been made.

PART 3 :

EXPERIMENTAL RESULTS.

he various components of planting technique experimented with were grouped in five Sections for Bulletin 53, and this grouping has been followed here.

Section 1. Time of Planting.

2. Plant Treatment.
   Shoot Topping, Root Wrenching, Root Pruning, Heeling In, Root Exposure, Handling Plants for Transport, Method of Lifting, Care of Plants at Dump.

3. Plant Setting.
   Method of Planting, Depth of Planting, Soil Firming, Root Dispersal, Nothing.

4. Planting Spot Treatment.
   Hand Cultivation, Furrow Planting and Exposure of the Planting Hole.
   Grading of Nursery Stock, Stock for Seed Grading.

In tabulating the results here, as in the Bulletin, each component is dealt with first singly as a means of presenting the result in a single form.

SECTION 1. TIME OF PLANTING.

In a series of experiments extending over the years, various dates of planting were tried, both within the normal planting season, which was recognised as late June to early August, and more recently in an extended season commencing in May and finishing in September.

Considering the month of planting, the means of all the dates in the thirteen years were:—

	STIRLING.		GNANGARA.	
		S.D.		S.D.
June	84.8 % of "takes"	± 12.10	98.7%	± 1.33
July	81.9 % of "takes"	± 16	97.0%	± 5.42*
August	70.2 % of "takes"	± 16.7	93.1%	± 9.41
September	54.95% of "takes"	± 28.24	72.8%	± 29.35

*Omitting one low take of 3.3%, the only one under 94%, the mean became 98.1 and the S.D. ± 2.

There were insufficient May plantings at Ludlow, and this month must be further examined. All dates tried, except two, were in the second half of May, the mean of the whole being 79.8%. The indications, however, are that late May dates will be satisfactory, at least in wet weather.

Examining separate weeks in August, it was found:—

	STIRLING.	GNANGARA.
August 1st to 7th	71.7% ± 12.47	95.62% ± 3.35
8th to 15th	75.7% ± 14.78	94.8% ± 6.12
16th to 31st	65.8% ± 20.40	91.4% ± 11.77

Although the means for August planting at Gnangara are high, there is considerable variation around the mean, and low values have been registered in late August.

The effect of planting in wet and dry weather has also been tested. From the early results it appeared that there was a detrimental effect of dry spells of weather of several days' duration.

Using all dates up to the end of July, the "takes" were:—

	Wet.	S.D.	Dry.	S.D.
Gnangara	98.5%	± 1.78	96.9%*	± 5.96
Stirling	83.1%	± 13.20	82.4%	± 14.77

*Omitting one low take of 73.3%, the only one under 94%, the mean became 98.2% and the S.D. ± 1.75.

Comparing wet and dry planting in the months of August and September:—

	AUGUST.				SEPTEMBER.			
	Wet.	S.D.	Dry.	S.D.	Wet.	S.D.	Dry.	S.D.
Gnangara	89.25	± 13.98	95.3	± 4.44	58.4	± 34.11	77.6	± 28.09
Stirling	74.3	± 17.19	65.5	± 14.57	58.5	± 27.74	53.4	± 30.51

Combining these data, that is all dates after 31st July—

Gnangara	WET 82.1%	S.D. ± 22.89	DRY 89.2%	S.D. ± 18.40
Stirling	71.7%	± 19.26	61.3%	± 21.51

There was great variation in both the classes and very low values were recorded in some instances for wet plantings in August and September.

The reason for previous insistence on the month of July was the desire to take advantage of the more or less continued wet weather which is usually experienced in this month, and to avoid dry spells which are thought to be more frequent in the months of June and August.

Dry spells do occur, however, in July, but at Stirling, of the nine low percentages recorded under 80% in July plantings over the years, five were dry dates and four were wet dates. In June, 5 plantings yielded under 80%, and of these only 1 was a dry date.

At Gnangara, the lowest "takes" recorded in June were 96.7% on a dry date and 96.8% on a wet date.

SECTION 2. PLANT TREATMENT.

(a) Shoot Topping and Pruning were discussed in Bulletin 53, and no advantage was gained in the few trials made.

(b) Root Wrenching.

Wrenching is the operation of cutting the roots at 8 or 9 inches below the surface with a spade inserted on each side of the nursery line. The underlying idea was that a short fibrous, as opposed to a deep spreading, root system might be developed before the plants had to be lifted for planting. In eleven (11) experiments (including two at Mundaring) over the years, with wrenching at various periods in advance of planting, there had been no effect in eight, a beneficial effect in two, and a detrimental effect in one.

(c) Method of Lifting.

In order to avoid damaging the roots, great care is taken in ordinary practice to excavate in front of each row a trench into which the plants are thrown forward in lifting. This has been compared with the cheaper method of levering up or raising the plants somewhat with a spade inserted on each

side of the row and then pulling the plants from the loosened nursery row.

In six (6) experiments at Stirling there was no effect of treatment, and in these years the experiment was duplicated in two nurseries, one on a heavier soil on the river flat and the other on the Wonnerup sand.

Pulling of the plants directly from the nursery line without any prior loosening was found detrimental in each of the three years tried.

At Gnangara in one experiment very careful lifting to retain as much soil as possible around the roots was found to be no better than standard practice which consisted of cutting the roots from one side with a spade and then levering them up from the other side. Stripping of the rootlets from the plants was found to be detrimental, while in the same experiment root puddling had no effect.

(d) Root Pruning.

For normal planting practice, planting with roots of eight (8) inches in length measured from the collar or nursery level, had been arbitrarily decided upon. his was thought to be sufficient for a plant with 15 to 18 inches of top. For economic reasons a greater length of root is undesirable because with setting 1½ inches deep, it would involve excavating the planting hole to a depth of 9½ inches if all roots are to be disposed vertically.

At Stirling conflicting results were obtained in a number of experiments involving pruning of roots to 4", 8" and 12"in. Of a total of 10 experiments, 5 showed no effect of the lengths tried, that is 4", 8" and 12". In four of them pruning to 4" was worse than roots pruned to 8", and in the tenth 4" was worse than 12", but not worse than 855. In eight experiments 12" roots were no better than 8", while in two experiments a difference was established.

However, by combining the results of four experiments of factorial design in 4 separate years, using the three lengths of roots 4", 8" and 12" with four different depths of setting, an advantage of 12" roots over 8" roots, and these in turn over 4" roots was clearly established, the difference being significant at the 0.01 level.

At Gnangara plants with roots of 8" in length gave better results than plants with roots of 4" in length in all the five experiments made.

(e) Handling of Plants for Transport and Care of Plants at the Dump on the Planting Site.

Plants have always been bundled in jute sacking in the nursery before being sent to the planting site, whether or not the site is close to the nursery or distant, involving rail transport. On arrival at the planting site, the general practice was to remove the plants from the bunches, "heel in" and water.

In eight experiments at Stirling there was no effect of leaving the plants in the bundles for two days before planting, and in three others a better result was obtained than with direct planting on the same day.

A number of factors in the handling of plants between lifting and planting have been tried. In combination with leaving the plants in bags and of "heeling in" the trees on the planting site were tested.
for two days instead of planting on the same day, the effects of watering

The plants were watered on arrival at the plantation and also on each succeeding morning in the case of plants not planted on the same day. Some were left in the bundle, others were "heeled in" with both a light and heavy covering of earth. There were thus twelve treatmnts in a 2 x 2 x 3 design.

A combined analysis of the experiments planted in the years 1935-36-37-38 showed no effect of any treatment.

In five experiments at Gnangara, there was in three a beneficial effect of leaving the plants in the bundles for two days, while in the other two there was no effect of this treatment.

Because of the possibility of heating taking place in confining plants in a closed space during transport, bundles of plants were kept in a closed 44-gallon drum at Stirling for 4 days and 8 days without effect on "takes." No rise in temperature wts recorded.

Tying the plants in bundles without bagging, for transport to the planting site, was found to be a failure. Plants from both the inside and outside of the bundle gave a very much reduced "take" in comparison with ordinary bagged plants.

The possibility of rough handling, such as damaging the roots in transport by rail, was tested in experiments in two years by dropping the bundles from a height of three feet on to a hard floor. There was no effect of this treatment.

(f). *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 in actual handling.

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.

As has been stated above, tying the plants in bundles, etc., without bagging, was a failure.

Exposures of five minutes had no effect at Gnangara in both sunny and cloudy weather. At Stirling exposures of five minutes and under had no effect in four experiments, but five minutes were detrimental in two other experiments. Periods of exposure up to 60 minutes caused no effect in cloudy weather, but fifteen minutes and upwards were harmful on sunny days.

(g) *"Heeling in"* is the operation of lifting the plants some weeks in advance of planting and then setting them back in the nursery ground in bundles which can be readily taken up when required for planting. In twelve (12) experiments, with periods of 2, 4 and 6 weeks in advance of planting, the process had no effect seven times, was detrimental four times, and beneficial once only.

SECTION 3. PLANT SETTING.

In this group, the factors tested were those involved in the actual planting of the young trees in the field.

(a) *Method of Planting* :

The cheaper notch planting, that is setting the plant in a notch made by moving the spade backwards and forwards from the vertical position was compared with pit planting.

At Stirling in 8 experiments in the years 1933-4-5-6-7 (twice) and 1942 and 1943 "takes" with notch planting were as good as with pit planting.

At Gnangara in three experiments there was no advantage in pit planting over notching.

(b) *Root Dispersal* :

In general planting practice the aim has always been to have all the roots dispersed vertically, not turned up at the bottom of the planting hole, while formerly they were spread at least to the extent of avoiding serious bunching.

In 1938 an experiment had been designed at Stirling to test the effect of deliberate bunching, twisting and bending of the roots. The treatments were as follow:—

1. Normal planting.
2. Bending the roots at a depth of three inches below the ground 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.

In 1938 there was no effect of treatment.

In 1939 the result was the same.

In 1940 bending the roots parallel with the surface at a depth of three (3) inches below the ground was detrimental by comparison with the other three between which there was no significant difference.

In 1941 there was no effect of treatment.

The experiment was not repeated after 1941 because of the consistent lack of effect of twisting, bending and bunching of the roots ignoring the effect of the shallow setting treatment in 1940.

Height measurements taken in December, 1945, seven years after planting in 1938, gave the following results:—

Treatment 1. 15.1 ft.
2. 15.4 ft.
3. 14.6 ft.
4. 15.6 ft.

There were no significant differences between these means.

(c) *Soil Firming* :

In an early experiment at Stirling in 1933, careful tamping of the soil by hand when filling the hole had been compared with trampling the soil in with the feet and no difference was found.

At Stirling in 1942 and 1943, five treatments were compared —

(1) Filling the hole with loose sand and then firming with a single press of the foot.

(2) Filling the hole with loose sand and then firming by repeated stamping with the foot.

(3) Careful tamping by hand as the hole is filled.

(4) Filling the hole with loose sand with no tamping or firming.

(5) Notch planting.

There was no effect of treatment.

At Gnangara in 1941 and 1942 ordinary planting was compared with filling the hole with loose sand without tramping or firming in any way, so that the pines could be easily lifted from the sand after the planting. There was no effect of treatment in either year.

(d) *Planting Depth* :

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

The effect has been tried of various depths of setting, that is, ordinary level, 1½ inches shallower or higher out of the ground and 1½ inches and 3 inches deeper than nursery level.

At Gnangara shallow setting was harmful by comparison with 1½ inches deep in five field experiments in successive years 1934-5-6-7-8.

At Stirling 1½" shallow setting showed no effect in two years (1934 and 1939), but was harmful in five experiments, 1935 (twice), 1936, 1941, 1942, by comparison with 1½" deep setting.

There was no effect of any treatment in 1939, the takes being approximately 80% in each of the four settings tried, that is, 1½" shallow, nursery level, and 1½" and 3" deeper than the nursery level.

Setting at the nursery level gave as good results as deep setting in the four experiments 1933, 1934, 1939, 1942, but was detrimental in 1941.

Considering very deep setting at Stirling in comparing 1½" and 3" deeper than the nursery level, there was no difference in the results with these treatments in nine experiments in the years 1934 (twice), 1935, 1936, 1937 (twice), 1939, 1941, 1942. There were no diffences between 3" and 6" deep planting in 1935 and 1936.

SECTION 4 — Planting Stock :

In this group, the following treatments were investigated:—

Hand cultivation of the planting spot before and after planting, exposure or opening up of the hole before planting and furrow ploughing.

At Gnangara the ground is thoroughly ploughed, so that no scrub or grass develops 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.

(a) *Spot or hand cultivation* consists of removing the grass over a diameter of eighteen inches to three feet around the plant by hand cultivation in Spring (September to October).

Experiments had shown:—

(a) There was no effect of Autumn cultivation in 7 experiments, but it was beneficial in one experiment.

(b) Eighteen inch Spring cultivation was beneficial in 8 experiments.

(c) Three foot cultivation was better than 18 inches in 3 experiments in Spring, while in two there was no difference.

(d) There was no difference in the effects of a grub-hoe (or mattock) and an ordinary garden hoe in two Spring experiments.

(b) *Opening of the Planting Hole in Advance of Planting* :

In general planting, care has always been taken to limit the exposure of the planting hole and out-turned sand by planting within an 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.

At 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 three later experiments there was no effect of advance holing extending up to two days.

At Gnangara holing two to four weeks in advance had no effect, but could not be applied in practice through the sand silting into the hoels.

(c) *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.

Furrow ploughing was better than surface planting in three experiments.

SECTION 5 — Planting Stock :

In four experiments with types of planting stock, they were graded into dominants or tall plants from the edges of the beds, dominants within the lines, that is, ordinary planting stock, and, thirdly, very small suppressed rejects. The only effect was that the small rejects gave a poorer take, almost a complete failure.

At Gnangara, there were no differences between Leiria and Landes strains in the ordinary season up to early August, but on later planting dates Landes stock gave a higher percentage of takes.

Results with planting stock from different nurseries have been very variable.

Because of the satisfactory development and takes with one-year seedlings, two-year stock, which is usually very large and costly to handle, has not been persevered with.

Stock raised from large seed did not survive better than stock raised from small seed in one experiment at Gnangara.

PART 4 — DISCUSSION OF THE RESULTS.

Experiments in pine establishment were commenced in 1932 and have been continued each year since. Thus a series of experiments in 13 successive years, 1932 - 1944 inclusive, the last being assessed in May, 1945, have been concluded.

The objects in compiling this report are three-fold—

(1) the concise recording of the work done in the period under review.

(2) the provision of a basis from which to plan further experiments.

(3) the demonstration of factors which should be absorbed into standard planting technique.

The complete series of experiments from the inception in 1932 will

be discussed generally under the following headings:—

Planting Season and Weather.

Factors affecting Survival.

Factors which do not appear to have any effect on Survival.

Planting Season and Weather.

Planting has been restricted to the rainy season, June to August. In May, in which month the heavy winter rains commence, it was thought the ground might not be sufficiently soaked to permit planting in safety. The rains commence to fall off usually in early August.

This question was extensively investigated in the first seven years and reported upon in Bulletin 53. It then appeared that, while at Gnangara plantings could be established in early August with reasonable safety, late August and September planting were frequently unsafe. At Stirling the "takes" in August were too low to permit planting in that month. Experiments over the past six years have confirmed those general conclusions. From the data given in Chaptep 3, the percentage of "takes" has dropped sharply below 80% in the first week in August at Stirling. At Gnangara the means for the first and second weeks in August are both high at 5%, but as the S.D. ± 6.12 indicates the variation in the second week is great and a number of low takes in the period were experienced, showing that it is unsafe for general planting. Low takes have been registered for late August, although the mean is high at 91.4% ± 11.77. September plantings show a further steep drop at both centres.

While in general practice planting had been restricted to the month of July on the coastal sands, because of the fear that the dry spells frequently occurring in June would be harmful, the results of these experiments over a period of 13 years have shown that planting in June should be quite successful. At both Stirling and Gnangara mean "takes" equally as good as those for July were recorded.

The effect of planting in wet and dry weather has also been examined.

The experiments druing the first seven (7) years tended to show that, on the coastal sands, planting in dry spells during the planting season was detrimental by comparison with planting on days on which rain fell. The results of the complete series of experiments do not support the indication that dry spells in the planting season affected survivals. From the experimental standpoint, however, the classification into "dry" and "wet" periods is not a very satisfactory one, and the factor is an extremely difficult one to test. Dry spells cannot be forecast with certainty, and planting may be carried out on a fine sunny day with rain after nightfall. Using all planting dates up to the 31st July, there were no differences between "wet" and "dry" dates at either centre, the "takes" at Stirling being approximately 83% in both cases and at Gnangara both were approximately 7%.

Considering August and September plantings, the Gnangara figures

were over 80%, and approximately 90% for the dry-weather plantings. There was great variation, however, as indicated by the Standard Deviations attached. At Stirling the mean "takes" were much lower, and again there was great variation.

The supposed greater possibility of avoiding dry spells was the reason for avoiding June as a planting month and concentrating on July.

At Stirling in June 4 days yielded under 80% "takes" and, of these, only 1 was a dry date. At Gnangara the lowest "takes" recorded in June were 6.7% on a dry date and 96.8% on a wet date.

For July, of the "takes" under 80% at Stirling, they were equally wet and dry.

Summarising this, June is equally as good as July for planting at both Gnangara and Stirling. August is unsuitable at both centres, except that the first week of that month at Gnangara has given results consistently high enough for practical purposes.

May has not been sufficiently experimented with.

Factors affecting Survival.

Root Pruning.
Planting Depth.
Root Exposure.
Grading of Planting Stock.
Cultivation.

The only factors found so far to affect survival have been those listed here, and only extremes of these treatment have been found to be harmful.

Root Pruning.

Because of the extensive root system developed by a one-year seedling on these coastal sands, a certain degree of root-pruning is necessary to permit vertical disposal of the roots without expeneive excavation of a large planting hole. The reason behind the decision to use a root length of eight (8) inches in standard planting practice was that about 9 to 10 inches is the greatest hole depth which can be economically excavated in heavy and stony soils requiring the use of a mattock. A length of root of eight (8) inches means that the depth of the hole must be 9½ inches, allowing for 1½ inches deep setting. Variations around the main length of root and depth of setting necessitate somewhat greater depth of planting hole. Working from this, experiments were made with what were considered to be the two extremes, namely 4 inches, the exaggerated minimum root length that might be expected with careless workmen, and 12 inches, the greatest length of root, excluding a few long laterals, with which trees can be lifted from the nursery, without excessive trenching in advance.

At both centres, in comparing length of roots of 4 inches, 8 inches and 12 inches, in each case set 1½ inches deep, that is, in planting holes of 5½, 9½ and 13 inches respectively, lengths of 8 inches were better than

4 inches. At Stirling only, plants with 12 inch roots gave still better results.

Subsequently, in two further experiments at Stirling, root lengths of 12 inches were compared in planting holes of depths of 9½ inches (as for an 8-inch root length) and 13½ inches. In one case there was no effect, while in the other the deeper hole gave better results.

The discovery from the root dispersal experiments that placing of the roots completely downwards is not essential to survival indicates, however, that long roots can be used even when their length is greater than the depth of the hole.

This is supported to some extent by the results with notching, which are equally as good as with pit planting, for considerable bunching and turning up of the roots occurs in notching in general planting operations.

It would appear, therefore, that no pruning of roots at all is necessary except for cutting back of the occasional very long lateral roots which develop in sand nurseries, but further examination of this point is required. There has been no effect yet of root dispersal treatments on height growth now in the 9th year, but this will be watched further.

Planting Depth.

There was a detrimental effect at both centres of shallow planting, that is 1½" further out of the ground than in the nursery, when compared with 1½" deep setting.

At Stirling, planting at the nursery level, and at 3" deeper, were as successful as with 1½" deep setting. On two occasions six inches deeper setting gave as good results as 3" deeper.

In the early experiments shallow planting setting of 1½ inches shallower than the nursery level and deep planting settings of 1½ inches and 3 inches deeper than 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. In general planting, workmen should be able to keep within these limits. 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 an inch below the collar. For experimental purposes, a setting of 6 inches deep was arbitrarily introduced in a few trials, but the cost of excavating the deep holes required for this treatment renders it impracticable in ordinary planting.

There can be no advantage in setting as deep as 3 inches unless it can be shown necessary to prevent an odd plant being set too shallow in general planting operations. The tendency is always for the digger to make holes shallow rather than deep and for the planter to set shallow. The cost of planting would be increased by deeper setting and it would

be necessary to be sure that the greater depth would be warranted by results.

Experimental work of the type carried out in this investigation is not satisfactory for such a test. In such experiments the workmen take a keen interest, do better work, and allow, in fact, very little variation around a specified treatment or setting.

Root Exposure.

This factor was dealt with in Bulletin 53.

In cloudy weather, exposures by laying the plants out individually on the surface of the ground for periods up to 60 minutes have had no effect. Short exposures up to 5 minutes in bright sunshine had no effect in four experiments, but periods of 5 minutes' duration were harmful in two others. The intermittent exposures in handling the plants from lifting to setting in the plantation are estimated at not more than 2 minutes, but this factor might be further investigated.

Grading of Planting Stock.

The very small suppressed seedlings in the nursery lines, which are always rejected in ordinary planting, were found to give a much reduced "take" by comparison with the dominant plants. No differences were found among these dominant plants, whether they were from the edge rows of the beds, tall big plants with much development of secondary needles, or the general level of plants from the inside rows which form the bulk of the planting stock.

Cultivation.

At Gnangara the site is thoroughly ploughed and then a planting furrow is opened at right angles to the direction of ploughing.

At Stirling on unploughed land, cultivation of the spot prior to planting had no effect, but cultivation over a radius of 9 inches around the plant in spring, two to three months after planting, was beneficial wherever tried. While cultivation of a diameter of three feet gave still better results, the use of 18-inch cultivation has been adopted as producing sufficiently good results for general practice, and is, of course, very much cheaper.

Planting in a plough furrow at Stirling gave better results than planting on the surface of the ground, but this necessitates cost of clearing up of the debris of logs on the ground to permit such ploughing.

Bundling the Plants.

Tying the plants in bundles and leaving the roots exposed without wrapping in jute sacking was very harmful by comparison with the standard method of rolling the bundles tightly in thoroughly wetted jute sacking.

Factors which do not appear to affect Survival.

(a) Root wrenching for periods up to 4 and 6 weeks has had no effect.

(b) "Heeling in" for periods of 2, 4 and 6 weeks in advance of planting has not improved survival.

(c) *Method of Lifting.*

Except for the extreme, pulling the trees up from the nursery lines without any prior lifting, there has been no effect of the cheaper methods. Loosening the trees in sandy soils by levering up the plants with a spade inserted on each side of the nursery line, and then pulling the trees directly from the soil, has proved as satisfactory as more expensive excavation of a trench in front of the nursery row.

(d) *Handling Plants for Transport.*

This involves several operations:—

(a) Bagging the plants for transport to the planting site.
(b) "Heeling in" and covering treatment on arrival in the field.
(c) Watering the plants.

Leaving the plants in the bundles for two (2) days after taking them to the planting site was not harmful in 18 trials. Thus there is no need to make very accurate estimates of daily requirements on the planting site. Watering the plants daily, whether they were left in the bundles or heeled in with varying covers of earth, had no effect.

In practice, therefore, plants may be lifted from the nursery lines two days before they are required for planting, and kept in the bundles either in the nursery or on the planting site. There is no need to remove the plants from the bundles and heel them in, or to water the bundles. This assumes that the jute sacking used in bundling would be thoroughly soaked before use and that the bundles would be protected from the direct rays of the sun by covering with bushes or other screening.

Keeping plants in a bundle in a confined space, that is in a 44-gallon petrol drum, for four (4) and eight (8) days had no effect on "takes."

Tying the plants in bundles for transport without wrapping in wet sacking was harmful. No effect on "takes" was caused by rough handling of the bundles by dropping them on a hard floor from a height of three feet, as might be occasioned in transport.

(e) *Root Disposal in Planting.*

While it has not been the practice for some years to spread the roots in general planting, the aim has always been that the roots should be disposed vertically. Various methods of twisting and bunching of the roots, involving very drastic treatment, have had no effect on survival, or so far, that is after eight years, on subsequent development. This experiment was repeated for four years in succession without any effect of the treatment on survival.

It has always been recognised that a certain amount of bunching occurs in any planting by large gangs, and it was the desire to reduce this as much as possible that caused the reluctance to introduce notching as general practice.

(f) *Notching.*

No advantage of the more costly pit planting was found over notching in eleven experiments.

(g) *Soil Firming.*

It was formerly thought necessary to pack the sand down around the roots in planting by the pit method, and the small tree was required to be fairly firmly set in the ground. No advantage over filling the hole loosely with sand was found in five experiments.

(h) *Shoot Burning or Topping prior to Planting.*

The treatment had no effect on survival except when carried to an extreme, such as by removing more than half of the stem of the plant.

There can be little advantage in cutting off the top half of the shoot except to save in transport and carrying of very big plants.

(i) *Exposure of the Planting Hole* caused by opening up the holes several days in advance had no effect on survival, but usually becomes impracticable through the sand subsequently running back into the holes.

(j) *Size of Seed.*

Plants raised from graded large seed did not have better survival results than stock from small seeds.

Righter (4) stated that the seedling producing the greatest inherent vigour is just as likely to be a runt that originated from a very small seed, as a giant from a large one.

PART V — CONCLUSIONS.

The behaviour of seedlings has been compared in experiments in which the factors considered likely to have a bearing on establishment have been artificially controlled, in that, in each treatment, all factors except the one being investigated have been kept constant.

The study has been largely productive of negative results. Nevertheless, these negative results are of considerable practical importance. Many factors thought to be inimical to establishment, or, on the other hand, steps believed influential in increasing survival have been found to have no effect, and their elimination from planting procedure has brought many changes. Except for extremes in treatment which would probably not ordinarily be reached in practice, practically no factor, if cultivation is excepted, has had any effect on survival in the first summer. Some cultivation is necessary at both plantations. At Gnangara ploughing is adopted, while at Stirling spring cultivation, to remove the grass from close around the young tree, has been found beneficial. As far as nursery stock is concerned, only the little "runts" which would be obviously discarded on lifting have given lower results than the sturdiest dominant plants in the nursery lines. It appears that no pruning of roots is necessary beyond the removal of the odd long laterals which develops in sand nurseries.

The many factors, such as disposing the roots in planting, method of lifting, packing the sand around the roots, "heeling in," wreching, watering the plants, keeping the plants in bundles for several days, opening up of the planting hole in advance, notching, etc., have had simply no effect.

Extensive repetition of the experiments over the years appears to have carried the work with most of these factors beyond the limits of practical doubt.

The safe planting season ends with July, and, while high percentages in takes are sometimes recorded subsequently, the results in August and September are far too variable. The month of May has not been sufficiently investigated.

By comparison with the repeated experiments into other factors, root exposure on lifting does not appear to have been tested thoroughly.

Despite these negative results, failures occur. They are found each year, for example, in the controls. At Gnangara, on thoroughly ploughed ground on which further planting furrows are made, establishment presents no problem if care is taken with the few factors affecting survival as demonstrated in this study. The percentage of "takes" is usually very high, above 95%, but the deaths which do occur are so far inexplicable. Whatever the cause, it has not yet been found. It may be perhaps due to inherent weaknesses in the planting stock. Insects and fungi not so far detected may be responsible for some plantation losses.

Further experiments will only be continued at this centre as a check on the work further south.

At Stirling, on unploughed ground, the survival percentage (about 82% to 85%) is lower than at Gnangara, but it is subject to considerable variation and refilling becomes necessary in some years. The greater failure at Stirling is perhaps due either to the scrub or the different condition of the unploughed ground, with its occasional concentrations of ash which are scattered in ploughing, or more probably to both. Deaths are always noticed in scrub patches, and a page of the field book in which the actual failures are recorded along planting lines illustrates well the location of patches of scrub. Then failures are found on burns devoid of vegetation. Care has been taken to avoid the patches of dry sand occasionally met with on "burns" by moving the site of the planting hole. These deaths are independent of any treatment given in an experiment and are hence, of course, met with in the controls. It must be remembered, however, that most of the plants occurring in the scrub patches and on the burns survive the summer, and hence scrub or burn or planting treatment, while perhaps contributing factors, are not in themselves the cause of death.

In general planting over the years, notable failures have occurred at odd times with stock transported over considerable distances to other plantations. The sudden deaths of the trees in one planted section has, as

previously recorded, found to be due to watering from a drum which had previously contained arsenic, but no such explanation could be found in the other cases. The lack of success in revealing in this study any factor which could account for such failures led to the belief that they might be connected in some way with transport. Heating might have occurred in closed vans. Bundles of plants have been kept for eight days in an empty 44-gallon drum with a lid on it without effect on survival in the field.

The pine can stand a considerable amount of rough treatment, and it appears that the death of any plant in the field is not capable of any single explanation or attributable to any variation, except extremes of any known factor. A partial solution of the problem may rest upon the establishment of selected trees by the elimination of individuals without certain important characteristics which might be determinable. Differences between trees have been recognised in such characteristics as habit, branch development, rate of growth, resistance to insects and fungi, and there might be inherent differences affecting survival in the field. An attempt to study differences in the natural vigour of planting stock has not so far revealed any way in which these may be detected in the nursery.

It is possible to have overlooked some simple fault which has had a powerful influence in the failures referred to or in the variable results at Stirling, though these two cases may be in no way connected.

Extensive field experimentation with the various components of planting technique seems unavoidable in the study, for it would be difficult to supplement it by laboratory work.

In the early trials over-simplification by limiting the number of treatments in an experiment lessened the chances of arriving at useful conclusions, and, in fact, in some cases, nullified the work. Subsequently the use of factorial designs with all combinations of treatments broadened the scope. Repetition of identical experiments for four years and more yielded concrete answers where somewhat conflicting results have been obtained, earlier, in some instances. Interactions were frequently not significant, particularly those of the higher orders, and where they did have effect, were generally not of practical importance.

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