PRELIMINARY NOTES ON SEEDING AND SEEDLINGS IN RED AND HARD BEECH FORESTS OF NORTH WESTLAND AND THE SILVICULTURAL IMPLICATIONS

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SYNOPSIS

Evidence supporting the correlation of heavy flowering years and climatic factors in beech species is presented. The pattern of the 1960 seed fall is described. Estimates are made of the volume of seed which falls in mature red and hard beech forests during a mast year. The number of resultant seedlings and their early survival rate is described. It is shown that mortality is high in the virgin forest and few seedlings persist to become part of the forest floor advance growth. The nature of the virgin forest advance growth is discussed and it is shown that beech seedlings can persist for many years beneath the parent stand, even though light demanding. The growth rates and the response to full light of advance growth seedlings are considered and it is demonstrated that such seedlings may make up a large proportion of regenerated stands. It is shown that heavy shade is favourable and heavy duff unfavourable to seedling establishment. Past thought on silvicultural systems for beech forests is reviewed and a modified uniform system is recommended for conversion of virgin forest to even-aged beech stands. This is designed to minimise the understocking which may result from competition by weed species, seedling mortality, swamping, etc., under a clear-felling-with-seed-trees system. The aim is to build up a full stocking of sturdy advance growth, years prior to logging, so that the new crop is already present when the old crop is felled. The early results of a trial of this system are reviewed.

INTRODUCTION

This paper, as the title indicates, does not describe a completed study. An attempt has been made to draw together the preliminary results of several small-scale experiments commenced over the past three years. These have yet to be tested in the field. No attempt is made to categorize the remaining area of virgin beech forest in North Westland according to its suitability for the regeneration method advocated herein. Nor is the management potential of each of the

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many beech forest types examined in detail. This note merely attempts to demonstrate, in general terms, a possible method of obtaining full regeneration in virgin beech forests on suitable topography.

SEED YEARS

It was noted by A. L. Poole (1948) that the known heavy flowerings of beech in 1935, 1938, and 1948 had been preceded by spring-summer-autumn seasons which were hotter than usual and that a belief in the correlation between a hot, dry season and a heavy flowering in the following spring was commonly held by European foresters. In the same paper a table is presented showing the deviation of mean daily temperatures from normal in the spring-summer-autumn season preceding flowering years. These deviations are, in general, markedly positive.

In a paper on red beech *(Nothofagus fusca)* silviculture Conway, 1952, further discusses this phenomenon and presents a table correlating heavy flowering with a dry summer in the preceding season. He records heavy flowering in the Reefton district in the spring of 1935, 1944 and 1951 and partial flowering in 1941. These observations are probably equally applicable to North Westland forests. Heavy flowerings have subsequently occurred in this district in 1956 and 1959.

Examination of meteorological data, recorded at Granville Forest, reveals that in the ten-year period, from the 1950-51 season to the 1959-60 season, the hottest and driest spring-summer-autumn periods were in 1950-51, 1955-56 and 1958-59. A heavy flowering occurred in the following spring on each occasion.

Available records are not sufficient to allow comment on the amount of flowering between mast years. The writer noted that in the spring of 1958 and 1960 the number of flowers formed was so few as to have a negligible effect on the seedling population. As silvicultural work must undoubtedly be tied to the mast years, the average interval between heavy seedfalls is of some interest. The seedfalls of 1957 and 1961 were both heavy, carpeting the floor of red and hard beech *(Nothofagus truncata)* forest with seedlings. Mast years are thus possible at intervals as short as three years. Since 1935, including the 1941 partial mast, the interval between heavy seed falls has averaged five years, with a range of three to seven years.

THE 1960 SEED FALL

In the autumn of 1960 a heavy seed fall occurred in North Westland beech forests. Advantage was taken of this fall to gain basic data on:

(a) duration and pattern of seed fall
(b) volume of seed per acre
(c) seedling establishment
(d) seedling survival.

The study involved red and hard beeches – the species of greatest commercial importance locally.

To follow the course of seed fall, 6ft x 3ft wooden trays lined with polythene were placed in the beech forests. Six trays were placed beneath red beech and twelve beneath hard beech. The trays were scattered over a wide area immediately east of Totara Flat between the altitudes of 600ft and 1200ft.

The first evidence of seed fall was observed in lowland beech forest in open growth trees of red beech on 2 March 1960. Trays were placed in red beech forest the following day. Collections were made three days later during which time seed had commenced to fall under forest conditions. Collections were then made at convenient intervals – 3 to 4 days during the peak of the fall and 5 to 7 days thereafter.

(a) Duration of fall

Seed fall in red beech forest commenced in the period 3-7 March. Averaging the data from six trays the following pattern results. In March, 70% of the total seed fell, in April 21%, in May 2%, and in June-July 6%. The last collection was made on 18 July, and although some seed fell after this date it was not a sufficiently large amount to be of significance.

In hard beech forest seed fall commenced during the period 23-27 March, three weeks later than that of red beech. In March, 26% of the total seed fell, in April 61%, in May 9%, and in June-July 4%.

In both species the period of heavy fall finished by 21 April when 85% of hard beech seed and 92% of red beech seed was down.

Seed did not fall in a regular manner. Although there was an overall trend of diminishing daily amounts from the peak of the fall, the pattern was a fluctuating one with sporadic upsurges. These upsurges occurred at the same time in red and hard beech forest. The amount of seed released in any one period appeared to be a reflection of the interplay of rain, wind, temperature and seed ripeness.

Damage to seed on one tray occurred during one period and was attributed to mischievous chewing by birds – possibly kakas. It is known that some exotic birds (notably sparrows) are partial to beech seed but at no time were native birds observed gathering fallen seed and their role is unknown.

(b) Volume of seed fall

In the six trays under red beech forest the total number of seed per tray ranged widely from 679 to 1766, averaging 1290. This average is equivalent to about three million seeds, or 50 lbs. of seed per acre.

In the twelve trays under hard beech forest the total number of seed per tray also ranged widely – from 54 to 1407, averaging 542. This is equivalent to about 1⅓ million seeds, or 20 lbs. of seed per acre.

Because of the limited number of trays these data should be regarded as indicative rather than precise. It would appear, however, that the production of seed is considerably less uniform in hard beech forest than in red beech forest. In North Westland, when the majority of lowland red beech flowers only scattered individuals of silver beech *(Nothofagus menziesii)* may be found in the same condition. It is possible that this applies to hard beech to a lesser degree – i.e. that the wide range in seed production represents variation in the productivity of individual trees.

(c) Seedling establishment

All trays were placed in mature stands with the exception of one tray in red beech forest which was beneath a pole stand. Under most of the trays the forest floor was composed of the normal litter over duff of the virgin forest. Under two of the hard beech trays, however, the floor had been scarified by bulldozer. The data which follow are therefore representative, in the main, of the conditions found in a well-stocked, mature and untreated beech forest.

Tree per cent is defined as the number of seedlings which become established in the forest from each 100 seeds shed. According to Jacobs (1955) a high figure by world standards is 10%, a low figure 1% and a very low figure 0.1%. In order to determine the tree per cent it was assumed that the amount of seed per square yard which fell into a seed tray differed little from that which fell in the immediate vicinity of the tray. Accordingly two plots, each six feet long and three feet wide, were placed parallel to the tray, one on each side, and the number of seedlings therein was counted. This number was used in deriving tree per cent. The count was made on 21 November 1960, a date by which, it was considered, all viable seed had germinated but summer insolation and desiccation mortality had not commenced.

For the six trays in red beech forest the average tree per cent was 2.8%, with a range of 0.3% to 4.6%. The average of three million seed per acre therefore produced about 85,000 seedlings.

For the twelve hard beech trays the average tree per cent was 2.1% with a range of 0.0% to 18.3%. An average of 1⅓ million seeds per acre thus produced about 28,000 seedlings.

(d) Seedling survival

The production of several million seeds per acre may, at first, appear to be a wasteful process. As is shown above, however, only a small percentage of these seeds develop into seedlings. This small percentage and subsequent seedling mortality are both related to the covering of the forest floor. This presents a far more hostile environment to seedlings than does the nursery bed. The floor beneath the seed trays represents an average condition for the beech forest. A variable thickness of leaf and twig litter overlies a layer (which may be quite deep) of decomposing organic matter. The radicle of the germinating seed is often unable to secure a hold in the loose, open surface litter and is dried out soon after appearance. When the litter is deep and open a seed may be covered by such a depth of material that it has insufficient reserves to allow the cotyledons to gain the surface. These are two of the fates of newly germinated or germinating seeds. Wilting of the radicle and toppling of the seedling is not uncommon and is probably of fungal origin. Thus at the very outset many seedlings are lost. Those that survive are rooted largely in the litter and underlying duff. It is probable that the available nutrient in this material is not high. Of greater importance is the fact that the open texture of the duff allows it to become very dry in the summer following germination. The seedlings which survive the earliest hazards are faced with the possibility of desiccation while still quite young. This is the factor responsible for most of the mortality of the first six months. The slow growth rate of seedlings in the unaccommodating duff renders them prone to insolation at the root collar and burial by litter on steep slopes.

The early survival of 1960 seedlings will now be examined in detail. During the last ten days of September 1960 no rain fell. An occasional seed was observed to have germinated during this period. On 1 October, more than a half-inch of rain was recorded and on 3 October, newly germinated seedlings were abundant on the forest floor throughout the district. From 1 October to 21 November 9.55 in. of rain were recorded and this together with warm temperatures provided good conditions for early survival. From 21 November to 17 January 1961, only 3.43 in. of rain were recorded at Granville. The average for this period is about 13 in. Temperatures were higher than normal. During this period summer insolation and desiccation mortality was high. When the seed tray plots were re-examined on 17 January 1961, only 31% of the red beech seedlings and 52% of the hard beech seedlings present on 21 November 1960, had survived. Survival in red beech ranged from 10% to 48% and in hard beech from 34% to 100%.

In January 1958 several square-yard plots were laid down in red beech forest in order to follow the progress of seedlings of the 1957 seed fall. On 30 November 1960, the number of 1957 seedlings was recounted and the 1960 seedlings were enumerated for the first time. On 17 January 1960, the 1960 seedlings were again counted to establish summer mortality figures.

Eight plots were placed in the open, 11 in light shade and 10 in dark shade. Over the three-year period involved, the survival of 1957 seedlings was 17% in the open, 34% in light shade and 55% in dense shade. Over the seven-week period from November to January the survival of 1960 seedlings was 21% in the open, 50% in light shade and 61% in dense shade. The early survival and later persistence of small seedlings is thus related to the amount of shade received.

Two further examples may be cited to show the effect of shade on the survival of young seedlings. Both are concerned with areas of forest in which the floor was scarified by bulldozer to expose mineral soil. In both, the seedling population was assessed by systematically placing square-foot plots at 6ft x 6ft spacing. Shade conditions were subjectively assessed. In the first, a naturally seeded area of hard beech forest, the population of 1960 seedlings on 28 February 1961, was found to be 42,000 per acre in the open, 75,000 in light shade, 120,000 in moderate shade and 150,000 in dense shade.

The second was an area of derelict silver beech forest which was hand sown with red beech seed early in spring 1960. On 1 March 1961, the resultant seedling population was 40,000 seedlings per acre in the open, 88,000 in light shade, 132,000 in moderate shade and 120,000 in dense shade. 1231 plots were placed in the first area and 699 in the second.

THE ADVANCE GROWTH

In a heavy seed fall the mature beech forest produces about one to four million seeds per acre. An average of less than three per cent of these seeds produce seedlings. During the summer after seed fall a variable percentage of the resultant seedlings is lost by desiccation and insolation. The extent of these losses depends on the climate in that summer, on the degree of shade available to seedlings and on the condition of the forest floor. In the virgin forest, the floor is covered by a layer of decomposing humus which becomes dry in summer and is then unfavourable to seedling survival. Because of the shade of the parent stand and the inhibiting nature of the duff, growth of seedlings is slow, averaging less than one inch per annum. Therefore, the seedlings are subjected to the hazards imposed by small size for years after seed fall. From the large amount of seed of a given fall a few seedlings eventually struggle through and join the ranks of survivors of previous seed falls to become part of the forest floor advance growth. The number of advance growth seedlings found on the floor varies with the forest type. In some cases they are sufficiently abundant to fully regenerate the forest when the parent crop is removed. In others the advance growth must be fostered, by improving the conditions for seedling survival, if the forest is to be regenerated in this manner.

Red and hard beeches are light-demanding species. Thus, in the virgin forests, trees of pole size are not found beneath a canopy of mature trees. They may, however, exist in canopy gaps formed by the death of an over-mature veteran. By this means the forest is often regenerated in nature. Although the beeches (reference here is to red and hard) are not shade *tolerant* to the extent that stems of all sizes may be found on one small area, they may be remarkably shade *persistent*, existing as slowly growing seedlings in the shade of the parent stand. Each seed fall adds a few more seedlings to the advance growth, thereby balancing the continuous mortality of these stagnant individuals. The result is probably a relatively constant average advance growth population for forests of a given type on a given site. For example, in a hill country hard beech type assessed in the winter of 1958, the following distribution of seedlings was found:

Height Class	*Seedlings/acre*	*% Total*
0-2 in.	12,350	19.5
2-4	16,310	25.7
4-6	14,360	22.7
6-8	7,220	11.3
8-10	4,610	7.3
10-12	2,690	4.2
12-16	2,690	4.2
16-20	1,030	1.6
20-24	460	0.7
24-30	600	0.9
30-36	140	0.2
36-48	290	0.5
48-60	260	0.4
60-72	370	0.6
	63,380	100.0

Although this area was logged in 1952 the opening was light and these data are probably close to those which would be recorded in a virgin forest. They show the rapid decrease in number of seedlings with increase in size.

The significance of the advance growth of the virgin forest floor was not fully appreciated until recent times. Regenerated stands which were thought to have originated by seeding, following the felling of the original stand, have been found to have a large element of advance growth formed in the seed years prior to felling. It is now believed that in some cases the whole of the regenerated stand may have arisen from pre-falling seedlings. Because this fact was not earlier appreciated the data on advance growth are not extensive. A study in 1960, carried out in conjunction with the thinning of a 45-50 year old pole stand has thrown some light on the subject and will be described.

The development of an individual stem, from the earliest seedling stage, may be studied by examining the growth rings which are present at ground level. It was considered that if, in the stump of a beech tree, a centre core of minute rings was surrounded by a zone of expanded rings, this centre core could be interpreted as an advance growth stage and the first expanded ring as the ring which was formed in the year of release of the advance growth seedling. In the stumps of pole red beech from the study area this pattern was clearly evident. Several definitions are required in order to clarify the discussion which follows.

Advance growth is seedlings and saplings which occur beneath and are shaded by the parent stand.

Releasing is the process whereby advance growth is exposed to full sunlight by removal of trees of the parent stand.

Post-release seedlings have enjoyed full sunlight since the time of germination.

In examining beech stumps two major cases arise:

(a) Changes in the dimensions of rings from the centre to the outside of the tree are relatively smooth in pattern – i.e. no sudden changes in growth rate occur. This is interpreted as a tree of post-release seedling origin.

(b) A sudden change in ring width does occur – the minute rings of a centre core are surrounded by greatly expanded rings, with no gradation in ring size. This is interpreted as a tree of advance growth origin which has been suddenly and completely released.

In the second case, the minute rings could be and have been misinterpreted as a slow growth rate in the dense thicket stage following releasing. Three observations are contrary to this interpretation. The first is that the battle for dominance in the thicket stage is a continuous process. No sapling suddenly achieves dominance. Therefore no sudden and large expansion ring width can be explained in this manner. The second is that dominance once achieved in an untreated stand is retained. Pole stand trees are the survivors of thicket stage dominants and as such have a considerably faster growth rate during this stage than the measured width of centre core rings would suggest. The third observation is that in even-sized stands of beech the number of expanded rings is relatively constant while the number of minute rings varies widely from tree to tree. Interpreted as a slow thicket stage this would suggest that all stems achieved dominance at about the same time even though some had an advantage of up to a hundred years growth over others. This is obviously fallacious.

This phenomenon is stressed because it is believed that misinterpretation of stem analyses in pole beech sample plots has occurred through failure to segregate the advance growth stage from the post-release stage. This has resulted in confused data on the growth rates of red beech and failure to appreciate the significance of advance growth in the regeneration of beech stands.

In the study, referred to above, 110 pole stumps were examined from a 45-50 year old pole stand of red beech of windthrow origin.

It was found that 69% of these poles were of advance growth origin. Most of this was of seedling size at the time of release but scattered saplings occurred, presumably beneath small canopy gaps. The parent stand was composed of large mature to over-mature red beech and was fully stocked at 30-40 stems per acre.

Of the pole stumps examined 75 were of advance growth origin. Thirty-five of these stems originated from advance growth that was less than ten years old at the time of windthrow, fifty-five from advance growth less than twenty years of age and sixty-three from advance growth less than thirty years of age. The largest advance growth sapling encountered was 3.2 in. in stump diameter at the time of windthrow and over 100 years of age. The number of advance growth seedlings and saplings thus tapered off with increasing age but as previously noted the numbers are constantly replenished in mast years. Eighty per cent of the advance growth was less than 0.6 in. in stump diameter at the time of windthrow which agrees with observations of existing advance growth.

The rate of growth of these pre-release seedlings was quite variable. This is to be expected because this rate is sensitively controlled by the amount of light reaching the forest floor which in itself is variable. In advance growth seedlings up to 20 years of age the growth rate averaged 84 rings per inch but varied from 36 to 164 rings per inch. In seedlings and saplings older than 20 years the rate averaged 104 rings per inch, ranging from 62 rings per inch to 174 rings per inch.

One interesting feature revealed by stump analysis was the ability of long-suppressed seedlings and saplings of red beech to begin vigorous growth immediately full light was made available. The largest sapling averaged 62 rings per inch or more for its +100-year advance growth period and 4.4 rings per inch in the first twelve years after releasing. The rate of diameter growth was thus accelerated fourteen times. Measurements of the last few advance growth rings and the first few post-release rings showed that the response was immediate, and in some cases the rate of diameter growth was increased over twenty times when full light became available. A rapid response of this type is possible only where the duff is not a limiting factor to seedling growth rate. In hard beech types, in which the duff is of considerable depth, the response to releasing is slow.

The importance of advance growth, in the regeneration of areas of beech forest which have been cut to date, has not yet been made the subject of a detailed study. Red beech sample plots thinned by the writer have been largely of advance growth origin. Study of other red beech sample plot records in the Reefton and North Westland districts suggests that at least a portion of the stand on several of these plots has arisen similarly. The new crop in several hard beech areas is all of advance growth origin. These widely separated examples suggest that advance growth may make up a large portion of the regenerated beech forest. If this is so, then it obviously has important silvicultural implications.

THE SILVICULTURAL IMPLICATIONS

The aim of beech management in this district is the conversion of the virgin forest of mixed podocarp-beech to even-aged beech stands, at the same time fostering the less easily contrived podocarp regeneration. Some of the difficulties involved in this operation are described by Conway (1952). Regeneration has generally been regarded as a process which takes place *after* logging from seed trees which have been retained at the time of logging. The writer believes that the establishment of the new crop *before* logging may result in more satisfactory regeneration.

The following extracts from Conway's paper illustrate the trend of past thought on the regeneration problem, with particular reference to red beech.

> Regeneration released by ring-barking and removal of culls . . . suggests strongly that red beech would prosper under the Group Selection System as defined by Troup. . . . It is also apparent from an inspection of roadways, tramways and forest margins that the Shelter-Wood Strip System is readily applicable. . . . [These] systems require a higher standard of logging practice and conduct than we now enjoy. We are doubly fortunate therefore that the red beech species in particular, being aggressive and light demanding, fits into the Uniform System and that this same system is the one most readily adapted to the present methods of sawmillers. The risk from catastrophic windthrow must remain a calculated one. . . . Under the Uniform System, twelve to fifteen beech seed trees per acre are required. . . . At present it is the practice to reserve three to five healthy, vigorous trees of good form per acre, the balance of seed being obtained from trees of less perfect form. . . . It is contended that the quality of the ensuing stand can be improved by subsequent silvicultural selection of the better stems. . . .

When writing of the second crop Conway states:

> Red beech is a light demanding species, unlike *Fagus sylvatica*, and accordingly the gradual transition from development thinnings to regeneration fellings as practised in Europe is unnecessary. Moreover, there is no need for the sequence of seeding, secondary and final fellings, each of one third to one quarter of the crop by volume, sinc the young crop requires no overhead protection. A heavy or total felling may thus be made, according to circumstance. When the end of the rotation corresponds to a mast year, the whole of the crop may be removed in one operation. Where there is reason to doubt that full regeneration will pe obtained, due for example to insufficient preparation of the ground, some seed trees may, of course, be left as a precautionary measure.

The efficacy of the seed tree method, which is described above, may be gauged by the development of regeneration on past sawmill areas in which this system has operated, usually quite fortuitously. Planned ground preparation, to improve seed bed conditions, is admittedly lacking in such areas. Before assessing the effectiveness of seed trees in regenerating the logged forest it is obviously important to determine whether the new crop is of post-release or advance growth origin.

In red beech forest regeneration has, in most cases, taken the form of islands of well-stocked thicket scattered in a sea of weed species foremost of which is *Hystiopteris incisa.* In areas which were logged during or soon before a seed fall, this thicket may be attributable to the retained seed trees, but in many cases it probably represents the naturally occurring pre-logging advance growth. Scattered thicket clumps do not constitute satisfactory regeneration for unless red beech is grown in a tight stand, trees become short-boled, heavily-branched, dead-spiked and barely merchantable. A complete coverage of regeneration is required to ensure good form in the subsequent stand. It is thus necessary to improve the stocking which has generally been obtained in the past, either by improving seed-bed conditions using the seed tree method or by increasing the stocking of advance growth which occurs in the virgin forest.

There are several disadvantages in trying to achieve this aim by using the seed tree method. First, if an attempt is made to establish seedlings in a heavily-opened red beech stand, from scattered seed trees, these seedlings are faced with strong competition from light demanding weed species. Secondly, the mortality of both red and hard beech seedlings is considerably higher in open than in shaded conditions. Thirdly, if preparation of the forest floor is envisaged, a considerable backlog of cut-over areas would need to be covered in the short time between flowering and seed fall each mast year.

The fourth objection to this method is that isolated seed trees or seed tree groups, in the North Westland district, are highly susceptible to wind-throw and post-logging deterioration. In red beech, under the latter circumstances, death spreads from the top of the crown and in a comparatively short time the tree is completely dead. This is attributed to exposure, a conveniently non-analytic term for what is probably a combination of adverse factors. Thus if the conditions in the first seed fall after logging are unfavourable to seedling establishment no new crop may arise, for the seed source may be non-existent in subsequent seed years, and the forest floor will be covered with secondary species. It is considered that a uniform system, in which development and regeneration thinnings are not practised, is in fact a clear-felling-with-seed-tree system with its attendant disadvantages.

Some listed by Troup include:

(a) Desiccation and general deterioration of the soil through exposure to sun and air currents.

(b) Increase of swampiness in areas which tend to be swampy (anathema to red beech).

(c) A rank growth of grass and weeds which may interfere with regeneration and add to the cost of establishing it.

It is considered that the system best suited to the regeneration of red and hard beeches is the uniform system as formally described by Troup. This much is known:

(a) The initial survival of red and hard beech seedlings is considerably greater in shaded than in open conditions.

(b) Although both species are light demanding the seedlings show strong persistence under a heavy canopy.

(c) Shade-suppresed seedlings can begin vigorous growth when full light is made available.

(d) Advance growth has contributed a major part to most of the well-regenerated stands which have been examined in detail.

(e) The litter and duff of the virgin forest is a poor medium for seedling survival and growth.

(f) Unless a full stocking of regeneration is obtained subsequent form is poor.

These observations and those concerning seed fall must be used as a basis in selecting the most suitable system for obtaining regeneration. It is believed that the aim should be to improve the vigour and increase the amount of naturally-occurring advance growth so that the new crop is already established when the parent crop is felled.

The uniform system cannot be applied in the initial conversion of virgin podocarp-beech forest to an even-aged beech stand. Volumes per acre are not large and, under present conditions, markets are not such that repeated loggings for small volumes could be economically attempted. With over-maturity, a commonplace condition of the beech element, it is doubtful whether even light loggings could prevent deterioration of the stand. The control of light and insolation, which is the principal feature of the uniform system, could however, be achieved by manipulation of the understorey.

Most of the beech forests of the district are mixed in structure with a sub-tropical rain forest element. As such they often have dense understoreys composed usually of kamahi *(Weinmannia racemosa)*, quintinia *(Quintinia acutifolia)* or both. When this understorey is removed, without disturbing the over-storey, a considerable increase in the amount of light reaching the forest floor can be achieved – in many forest types an amount approaching that of full sunlight.

The amount of advance growth occurring on the floor of the virgin forest varies with the forest type and is controlled by the condition of the floor and the amount of available light. The second factor is, of course, controlled by the density of overstorey and understorey. On sharp ridgetops and along the edges of terraces, where light values are probably higher and the humus layer is thinner, a well-marked band of advance growth saplings is commonly encountered. Usually, however, the bulk of natural advance growth is less than 12 in. in height. It is probable that advance growth rooted in the mineral soil rather than the thick layer of duff could progress to greater size, even under the same light conditions.

Taking all known factors into consideration it is considered that the aim in regenerating virgin beech forest should be to build up a full stocking of sturdy advance growth *before* logging rather than to attempt to establish seedlings in the logged forest. The procedure would be first to remove the thick duff layer from a large portion of the forest floor, several years ahead of logging, by use of a small bulldozer. Part of the understorey will of necessity be cleared at the same time. Experience already gained suggests that this clearing should be as light as possible to maintain a forest environment and prevent the influx of undesirable weed species. An advance growth of beech may then be built up on the scarified soil over one or several seed years – as further experience dictates. When it is considered that the stocking of seedlings is adequate the understorey may be removed to provide light for their further development. It has been found that poisoning is a quick and efficient method of removing both kamahi and quintinia. The degree of light may be manipulated by poisonings of varying intensity. This method would allow a greater build up of advance growth than is possible in the virgin forest. It has the following advantages over the clear felling with seed tree method:

(a) The initial survival of seedlings is greater because of the shade of the parent stand.

(b) The weed problem is minimised.

(c) Light and insolation are controllable.

(d) The full seed source of the virgin forest is available for regeneration purposes.

(e) The risk of windthrow and death of the seed source is minimised.

In steeper hill country the use of a bulldozer is impracticable and an alternative method of ameliorating the unfavourable duff conditions must be found.

It is not unusual in cutover forest to find groups of vigorous rimu *(Dacrydium cupressinum)* seedlings or saplings concentrated on old snig tracks. This feature indicates that a preference for mineral soil also exists in this species. In these cutovers the seed source usually consists of scattered malformed or undersized trees left in milling. It is possible therefore, that in scarifying the soil of the mixed podocarp-beech forest, while in the virgin condition, a significant amount of rimu regeneration will be achieved, the full seed source of the mature rimu being available.

The conversion system advocated above is closer to the uniform system than to any other of the classic silvicultural methods. For the gradual altering of forest floor conditions it will rely on manipulation of the understorey rather than fellings in the overstorey. It could be called a "modified uniform system".

THE "MODIFIED UNIFORM SYSTEM" IN PRACTICE

Immediately before seed fall in 1960 a T.D.14 bulldozer was used to scarify an area of hard beech-rimu forest on easy sloping country. The area had been previously cut for rimu but hard beech was difficult to market and hence was left. As a result the forest was little removed from the virgin condition and was a suitable place for a trial of the system. Part of the understorey was smashed down and the duff was peeled off with the dozer blade. The resultant debris was pushed into heaps. The forest floor was thus made a patchwork of scarified and untreated, debris-covered ground in the ratio of about 50:50. It was considered that if the scarified area became well regenerated the area as a whole could be classed as fully stocked.

On the scarified area the mineral soil was, in the main, exposed. Hard beech soils are somewhat leached and infertile – less so than soils under mountain beech but more so than those under red beech. With decrease in fertility there is also a loss of structure in the A horizon and a tendency to softness and wetness. On the trial area the A horizon, rather than breaking into crumbs, as might be expected on a good red beech site, tended to mire and reacted in a plastic manner. Deep channels were formed by the tractor tracks and some exposed surfaces were left in a flat compact condition. As a result, winter rains washed the fallen seed from these surfaces and along tractor tracks into pools of water. Much seed was lost from very open patches in this manner. In places a thin cover of duff remained over the mineral soil and this, acting as a fine net, trapped the seed and held it in place until germination took place. In the roughened soil between tractor tracks the seed was similarly held. During rain much of the area was under water.

Towards the end of seed fall the mature beech shed large numbers of leaves which covered the scarified area in a thin layer. This is possibly a natural mechanism for covering fallen seed but may be an annual autumnal event. With the exception of the leaf fall the ground remained unclothed throughout the winter.

Germination commenced in early October. From a count made on 29 November 1960, and 17 January 1961, survival was estimated as 75% over this period – for average conditions.

In late February 1961 when the seedling population was assessed (one year after scarifying) regrowth was surprisingly light. More than 90% of the scarified area remained bare, apart from hard beech and occasional broadleaf *(Griselinia littoralis)* seedlings. Over the remaining area small patches of grasses, herbs and mosses appeared.

As previously stated the number of seedlings ranged from 42,000 per acre in the open to 150,000 per acre in dense shade. These data reflect the effect of shade on survival but are complicated by the fact that in the open category more seed has probably been lost by rain-wash than in the shaded categories. It is nevertheless apparent from measurements and from observation in the field that, for maximum survival, minimum disturbance of the understorey is necessary.

On 28 February 1961, an untreated area of forest similar, and adjacent to the scarified area, was also assessed for seedlings by use of square foot plots. The forest floor in this area consisted of litter over duff. The average number of 1960 seedlings was estimated to be 2,750 per acre – less than one-fiftieth of the number on scarified ground under similar shade conditions. This is a striking example of the effect of duff on seedling establishment. Those 1960 seedlings that were encountered in the untreated area were situated either on uproot mounds or on moss-covered logs.

In hard beech forests of this type there is another important reason for scarification. The floor is densely covered with shade tolerant suckers of quintinia. On opening the canopy these suckers develop vigorously and can smother hard beech advance growth. Their removal is thus necessary and can be achieved by scarification. It is probable that re-establishment on scarified ground would require a considerable time. In removing duff and sucker growth the existing hard beech advance growth is sacrificed, in order to establish a heavier crop under more favourable edaphic conditions and one that is free from competitors. On the plots in forest adjacent to the scarified area the average number of advance growth seedlings was 48,000 per acre. It can be seen that if the soil is scarified and heavy shade conditions are maintained during the initial development period this number can be trebled in one heavy seed fall. With subsequent losses it is still probable that the number occurring naturally can be doubled. When naturally occurring advance growth of hard beech is released, by providing full light, the strangling effect of quintinia sucker growth commences and the undesirable characteristics of the duff continue to operate. In a trial of this nature the mortality of the small (less than 10in. in height) seedlings was about 30-40% over the two-year period following releasing. Average annual height increments of the same seedlings were only about $\frac{3}{4}$in. to 2in. Both mortality and slow growth rate are attributable to the inhibiting duff. In the same area seedlings on snig tracks were growing 18in. or more per annum.

The results of the scarification trial have indicated several improvements which could be made. First the understorey should be disturbed as little as possible in the initial scarification so that maximum shade is maintained. This could be done by reducing the size of both scarified and untreated patches by use of a smaller machine. The second improvement, particularly on the poorly structured hard beech soils, would be a roughening of the surface to prevent seed wash. This could be quickly accomplished by a cut with discs after initial removal of duff. As an operational method it should be possible to do the work of duff removal and associated understorey clearing several years in advance of a heavy seedfall and to quickly rework the treated area with discs immediately before seed fall.

CONCLUSION

As stated at the outset, the aim in this paper is to outline a possible method of achieving full regeneration in virgin beech forests. It should be made clear, however, that the scope for this method is at present limited. Hard beech dominates the bulk of the remaining beech forest. It is a difficult species from the silvicultural, utilization and marketing viewpoints and is at present lightly cut or uncut on sawmill areas. It is obvious that work designed to achieve regeneration in hard beech forest which is being cut only for rimu is economically indefensible, unless there is some prospect of the beech element achieving a greater marketability than it enjoys at present. This is the crux of the beech management problem in North Westland.

Should it be decided to attempt intensive work to obtain full regeneration in hard beech forests it is believed that the method outlined in this paper will give greatest chances of success. The fact that it may be carried out years ahead of logging largely overcomes one of the major problems of beech silviculture – dependence on mast years.

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Quotation from the address of Mr Carlton Pollard (delegate to the 5th World Forestry Conference) to the 1960 annual conference of the N.Z. Timber Merchants Federation.

". . . every country must use land to the best advantage. Our previous ideas of forest conservation are outdated and won't work. In New Zealand hundreds of acres of virgin forest are lying idle – there is no increase in growth and they are not producing. Tremendous areas of our native forests should be cut and replanted in species which grow faster. Trees must be removed from the stagnation stage and brought into production forthwith. It will mean a reappraisal of our forest resources and land uses."

As reported in *N.Z. Timber Journal*, 1961