needles are preferred by horticulturists, the best opportunity for this selection is in the northern (Canadian) areas. This character is particularly distinct (but not measured) among the sources from Nova Scotia- and Prince Edward Islands.

Acknowledgements

Appreciation is extended to about 100 cooperators in the United States and Canada who kindly assisted in acquiring seed samples. The author is also indebted to Messrs. H. R. BUCKINGHAM, A. R. BOND and S. SINES of the Maryland Department of Forests and Parks for offering seed beds in the State Forest Tree Nursery. Thanks also to Dr. L. E. CRONIN and Dr. V. F. FLYGER of the Natural Resources Institute for advice and support of this study, to Mr. V. PLUME and Mr. R. HUBBARD for assistieg in establishment and measurements, and to Mrs. S. L. BURNS for preparation of the manuscript.

Gratitude is also due to Mr. J. A. WINIESKI of the Pennsylvania Deparlment of Forests and Waters, Dr. L. D. PRYOR of the Australian National University and Dr. K. STERN of the Institute for Forest Genetics and Forest Tree Breeding (Germany) for making available the data on one-year heights from their cooperative experimenta.

Thanks also for review of the manuscript and suggestions to Dr. J. W. ANDRESEN, Dr. R. L. BAKER, Dr. H. D. GERHOLD, Dr. D. M. HARMAN, Dr. H. B. KRIEBEL, Dr. C. E. SCHOMAKER, Dr. F. J. SCHWARTZ. Prof. W. C. SOMMER, Dr. C. TSAI, Mr. J. A. WINIESKI, and Dr J. W. WRIGHT.

Summary

Nine characters of eastern white pine (*Pinus strobus* L.) from 99 geographic sources were studied in a replicated experiment at the State Forest Tree Nursery in Harmans, Maryland, in 1963—1964. Heights were available also from 20 other sources planted in single plots, and from 1-year tests in Australia, Germany and Pennsylvania.

Seed weights were inversely correlated with latitude, and rapid germination was related to low elevations in the north. The rapidity of seed coat dropping was inversely proportional to the number of cotyledons, that were most numerous among the seedlings from the latitudinal extremes (Manitoba and South Carolina). Date of terminal bud set in 1-year trees varied by 45 days and was inversely correlated with latitude. There was also an inverse correlation between latitude and a tendency to resume secondary growth. Two-year height varied from 7.1 cm. (Prince Edward Island, Canada) to 21.6 cm. (South Carolina). In general, the fastest growing trees were from regions with long frost-free periods in southern and central states, thus height was negatively correlated with latitude. Two-year height was correlated positively (in decreasing degree) with 1-year height, date of terminal bud set, needle length, tendency for secondary growth, seed weight, and bluish foliage color. Diameter at two years ranged from 3 mm. to 5 mm. and was strongly correlated with height. Bluish-green foliage in summer was most common among seedlings from Ohio and other locations in the central range. Needle-length varied from 5.5 cm. (Manitoba) to 10 cm. (North Carolina) and was inversely correlated with latitude.

The correlations between 2-year heights in Maryland and 1-year heights of the same sources grown in Australia, Germany and Pennsylvania were statistically significant, but not particularly strong (r = .37 to .59). This may be due to actual site-genotype interaction or to differences in experimental technique.

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Seed Orchard Designs for Sites with a Constant Prevailing Wind

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(Received for publication January 31, 1967)

Most East African softwood planting areas lie in the intertropical convergence zone of the monsoon wind system. Concequently many sites receive light winds which blow remarkably constantly from the East. At Muguga, Kenys, for example, winds from a westerly direction were recorded on 218 afternoons in a total of 3581 afternoons, over a period of ten years, (*Fig.* 1). Similar constant wind directions have been recorded from other forest stations and elsewhere in East Africa (E. A. Met. Dept., 1964).

Current thought on the design of clonal seed orchards favours the "polycross" design (see, for example, FAULKNER, 1965) in which all clones are arranged in such a way that no ramet is neighbour to a ramet of its own clone and, it is hoped, every clone has an equal chance of pollination by every other clone in the orchard. The design of polycross orchards is often time consuming and computer Programmes developed to construct these laborious designs tend to be slow and expensive of machine time[2]).

Where polycross designs have been adopted, seed collected in bulk from the seed orchards is often assumed to be of the full polycross mixture with equal contributions of genes from all clones in the orchard. The early seed collected from an orchard is sometimes used in progeny trials in an attempt to obtain an early estimate of genetic gain achieved by the plustree selection Programme, but seed from this type of orchard can only be the full polycross mixture if a number of conditions are fulfilled. All clones in the orchard must be equally prolific in the production of seed and pol-

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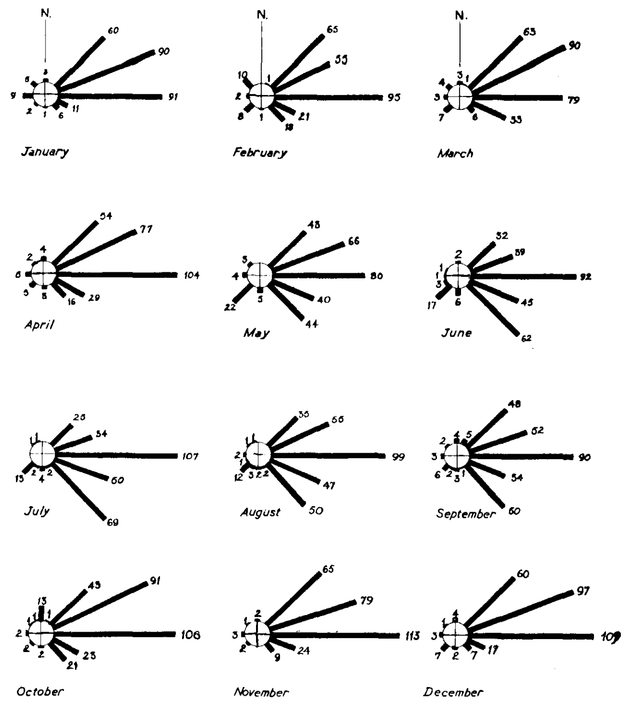

Fig. 1. — Wind direction at Muguga, Kenya, 10 years, 1956—1965. — Afternoon winds for ten years (totals, missing readings ignored):

N.	NNW.	NW.	WNW.	W.	WSW.	SW.	SSW.	S.	SSE
35	3	31	1	37	4	103	7	29	5

SE.	ESE.	E.	ENE.	NE.	NNE.	Total
358	377	1165	825	593	8	3581

len; all must be equally compatible as male and female parents, self fertilization must be negligible in amount, the clones must all flower about the same time and the pollen cloud must be evenly dispersed over the orchard. These conditions are often not fulfilled in polycross orchards and NAMKOONG *et al.* (1966) have discussed the errors involved in calculating genetic gain, when the conditions for full polycross seed have not been met to an unknown degree.

The parentage of wind pollinated seed can never be known with certainty and problems of varying fertility and compatibility amongst the clones are common to all seed orchards, but the problems of simultaneous flowering and inefficient mixing of the pollen cloud can sometimes be avoided. The requirement for efficient mixing of the pollen cloud can be circumvented in East Africa on sites with a constant wind direction.

It is a common observation in Kenya and in Zambia[3]) that the bulk of pollen shed by a tree drifts to leeward. This has been confirmed by measurement in the U. S. A. (SILEN, 1962; BOYER, 1966). Pollen may sometimes move upwind (WRIGHT, 1953) and be carried long distances in large turbulent eddies (LANNER, 1966), but on sites with a gentle wind of constant direction the great majority of female flowers will be pollinated by trees immediately upwind of them. The requirement of simultaneous flowering is met by *Cupressus lusitanica* trees in Kenya which produce female flowers successively near the tips of actively growing shoots, so that some receptive flowers are continuously available throughout the growing season. Pollen shedding takes place over a shorter period and different trees shed pollen at different times, but since all trees have some receptive female flowers whenever pollen is shed, by collecting cones set during a complete flowering season it may be assumed that all clones have been represented as male parents. If, therefore, it can be shown that the wind direction is constant throughout the flowering season, simple seed orchard designs which place each clone to leeward of every other clone an equal number of times should yield seed with a predictable chance of being the full polycross mixture.

With this possibility in mind an examination was made of the wind directions at Muguga, which are recorded twice daily. Of the two sets of data, the afternoon readings were preferred because it is often so calm in the early morning that ordinary weather vane directions may be unreliable and, further, it is not known at what time of day cypress flowers are most readily pollinated. Wind direction data collected for the ten-year period 1956—1965 show that the wind is almost constantly easterly. Afternoon readings during the two pollination seasons, March, April, May and August, September, October, show only very occasional westerly winds and the number of days of westerly winds is set out in *Table 1* and shown diagrammatically in *Figure 1*.

Thus there is an average chance of flowers being pollinated from the 'Wrong' direction of only $\frac{114}{1840}$ or 6.2 percent. Only in two months in ten years did the chance of unfavourable pollination exceed 1 in 5. Wind data for other sites in Kenya have been examined and similar constant directions found. At Kimakia forest station, for example, only 17 days of westerly winds were observed during the six pollination seasons between March 1963 and October 1965. The chances of unfavourable pollination were thus only $\frac{17}{552}$ or 3 percent.

In view of these results, seed orchards were laid out to take advantage of the nearly constant easterly wind direction.

Possible directional designs and their use in practice

In designing the orchards the three trees occupying the north east, east and south east positions from any given ramet were regarded as pollinators for that ramet. Some form of incomplete block design with three trees to a block was thus desirable. BOSE (1939) showed that balanced incomplete block designs with three plots to a block exist for all numbers of treatments of the form 6t + 3, and for many numbers of the form 6t, 6t + 1 and 6t + 4. HANANI (1961) generalised this result to show that there are balanced incomplete block designs with three plots to a block and any number of treatments. It thus remained to adapt these designs for seed orchards, using a layout with 3 rows and as many columns as needed.

In a seed orchard all possible pollinators of a given seed parent should occur the same number of times. If trees in the middle row of three are the only ones used as seed parents, the pollen parents must be so arranged that, with respect to any one seed parent, all the other clones must occur equally often in the columns to windward of it. When the total number of clones is 3t + 1 this may be achieved by having t columns of 3 trees each to pollinate the remaining

Table 1. — Days of westerly afternoon winds at Muguga 1956—65

	Mar.	Apr.	May	Aug.	Sept.	Oct.
Total days in 10 years	15	16	32	31	17	13
Max. No. of days in one year	5 (1964)	5 (1963)	9 (1959)	6 (1956)	6 (1961)	8 (1961)

[3]) T. F. GEARY, Forest Geneticist, Agricultural Research Council, Kitwe, Zambia. Personal Communication, 1965.

	I	G	E	C	A	L	J	H	F	D	B	M	K	I
→	L	J	H	F	D	B	M	K	I	G	E	C	A	L
	H	F	D	B	M	K	I	G	E	C	A	L	J	H
	K	J	I	H	G	F	E	D	C	B	A	M	L	K
→	M	L	K	J	I	H	G	F	E	D	C	B	A	M
	E	D	C	B	A	M	L	K	J	I	H	G	F	E
	G	I	K	M	B	D	F	H	J	L	A	C	E	G
→	C	E	G	I	K	M	B	D	F	H	J	L	A	C
	F	H	J	L	A	C	E	G	I	K	M	B	D	F
	J	K	L	M	A	B	C	D	E	F	G	H	I	J
→	B	C	D	E	F	G	H	I	J	K	L	M	A	B
	D	E	F	G	H	I	J	K	L	M	A	B	C	D

Seed to be collected from centre rows

Columns containing pollinators only

← Wind direction

Fig. 2. — Design of a seed orchard with 13 clones planted at Muguga, Kenya, on a site with a prevailing easterly wind.

clone, all combinations of seed and pollen parents thus occurring once. For 3t or 3t + 2 clones all combinations must occur 3 times; it can be arranged that each pollen parent occurs once each to the north east, east and south east of a given seed parent. Balanced incomplete block designs fulfilling these conditions have been found for all numbers of treatments up to 20, and for those of the form 3t + 1 up to 40 (Freeman, in press).

Two of these designs have been used for seed orchards at Muguga, and one is illustrated in *Fig. 2.* This design, like all those so far discovered, is cyclic, that is to say, one column is obtained from the next by adding a constant to the letters of the first column. For example, to get from DGC to FIE, in the top set of blocks, one takes the next letter but one in the alphabet; when one comes on to M, the 13tn letter, this is replaced by B in the next column. In *Fig. 2* there are some columns marked as containing pollinators only; this is inevitable, but the number of such columns can be minimised by using designs with the smallest possible number of cycles.

Discussion

On sites with a constant wind direction, these one-way designs have both practical and theoretical advantages. Since they are systematic and cyclic the clone layout may be readily designed. For prime numbers of clones of the form 3t + 1 (and certain other numbers) the plan can be simply written out: for other numbers a general computer programme is available.

The basic unit is columns of three so that the orchard can be planned in any shape from one long strip, parallel to the prevailing wind, three trees wide, to an almost square shape when the strip is divided into sections of equal length placed parallel with one another. Each division of the strip, however, requires the repetition of one group of three trees at the windward end of the section to provide a pollinator row, so that long narrow designs at right angles to the wind direction are wasteful of plants. Some clone numbers are more convenient than others and can be designed in one cycle, thus using fewer blocks and pollinator rows than designs with two or more cycles.

As compared with polycross designs these row and column designs do not reduce the number of ramets of each clone required and for some clone numbers more ramets are required than are usually included in polycross designs. Designs which make provision for thinning have not yet attempted because, with cypress, the size of trees can be easily controlled by pruning.

The theoretical advantage is that when seed is collected only from the middle rows it has (subject to the limitations discussed above) a calculable probability of being full polycross seed which can be used in a progeny trial with confidence. Seed from the outer two of the three rows should be similar to that obtained from a normally designed polycross orchard. The degree of confidence to be attached to the use of seed from the middle rows for progeny trials can be found by checking the wind direction recorded during the pollination season and the numbers of viable seeds obtained from each clone.

It should again be remembered that pollen dispersal is never fully predictable and so the parentage of wind pollinated seed can never be known with certainty, but with these designs the probability of full polycross parentage may be calculated more accurately than with polycross designs.

These designs were constructed for use in tropical conditions with a long pollination season and remarkably constant prevailing winds, but in temperate conditions, where the pollination season is shorter, they could be used where winds are constant for shorter periods. Indeed, on any site where the wind tends to blow from one direction during the pollination season they are probably more suitable than polycross designs. When planning seed orchards, therefore, tree breeders may be well advised to examine the wind directions recorded for their sites. When there is no tendency for the wind to blow from one directon at pollination time, polycross designs will be appropriate: when such a tendency is found, directional designs are to be preferred and will be increasingly suitable with increasing constancy of wind direction.

Acknowledgements

Thanks are due to the Physics Division, E. A. A. F. R. O., for making available original records of the wind direction. Some of the experimental designs were constructed by means of the ICT 1501 computer in Nairobi.

Summary

Some sites in East Africa have a constant prevailing wind. On such sites advantage should be taken of the steady

wind direction to lay out seed orchards so that all clones are placed to leeward of all other clones an equal number of times. Seed orchards must fulfil a number of conditions if the seed collected from them is to be of predictable parentage. With polycross designs, one such condition is that the pollen cloud must be evenly mixed over the orchard, which it can not be on sites with a constant prevailing wind. Polycross designs are thus unsuitable and directional designs are needed. With directional designs, if pollination is assumed to occur downwind of the male parent, seed collected from any one clone has a calculable probability of containing genes from all other clones in the orchard.

Lay-outs based on BOSE's balanced incomplete block designs for three treatments in a block are shown to be suitable and an example is given of an orchard for thirteen clones which has been planted at Muguga, Kenya. The basic unit is a long narrow strip parallel to the wind direction, in which the clones are arranged in columns of three, but it is possible to break the strip into blocks of convenient length to suit any shape of site available.

While these orchards were designed for Kenya conditions with constant winds and a long pollination season, they may be applicable to other sites with a steady prevailing wind, where polycross designs are less suitable.

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Micropulping Loblolly Pine Grafts Selected for Extreme Wood Specific Gravity

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(Received for publication February 24, 1967)

Introduction

Loblolly pine possessing high wood specific gravity is desirable as pulpwood because of its potentially high yield per volume, leading to a higher cellulose production per acre for the same growth rate. It also results in a more efficient use of machinery in the pulp mills. Loblolly pine of low wood specific gravity is desirable for its more favorable pulp and papermaking properties.

The relationship of wood specific gravity to pulp and papermaking properties is quite complex. Wood specific gravity is the average result of a great variety of properties such as specific gravity of the cell wall material, microporosity of the cell walls, proportions of springwood and summerwood, wall thickness and fiber dimensions within springwood and summerwood, and amount of extractives in the wood. To gain a complete understanding it is necessary to accumulate information on the relationship between each of these factors contributing to wood specific gravity and the various pulp and papermaking properties.

Considerable evidence has accumulated that wood specific gravity is strongly inherited. It is, therefore, expected that the associated pulp and papermaking properties are also under strong genetic control. This needs to be verified experimentally. In addition, quantitative information about the relationships is needed. Thus the objectives of the study described in this paper are:

1. To compare the pulp and papermaking properties of several clones selected for high wood specific gravity with several clones selected for low wood specific gravity.

2. To determine the relative importance of the various anatomical factors influencing wood specific gravity.

3. To determine the influence of these factors on pulp and papermaking properties.

4. To get some indication of the inheritance of these wood and pulp properties.

For a literature review of the variation and inheritance of wood properties, one is referred to GOGGANS (1961). Excellent literature reviews on the influence of wood properties on pulp and papermaking properties were made by DADSWELL, *et al.* (1959), BESLEY (1959), and DINWOODIE (1965).

In general, an increase in wood specific gravity has been associated with a decrease in bursting strength and an increase in tear strength. More recently, studies by BAREFOOT (1966) and WANGAARD (1966) indicated strong influence of some of the fiber dimensions on pulp and papermaking properties.

Material and Methods

1. Materials

Three loblolly pine clones selected for high wood specific gravity and three clones selected for low wood specific gravity were used in this study. From each clone four grafts were selected, resulting in a total of 24 trees. The trees were approximately 10 years old. The wood was collected in the form of increment cores with a diameter of 11 mm. taken

Tabele 1. — Standard micropulping conditions

Wood charge, moisture free basis, g.	20
Maximum temperature, °C.	172
Time to maximum temp., min.	120
Time at maximum temp., min.	90
Liquor ratio, ml./g. ovendry	12
Liquor analysis	
Active alkali, as NaOH, g./l.	40
Sulfidity, %	24,7

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