ATTRIBUTES OF THE FOUR-TREE-CLUSTER SEEDLING SEED ORCHARD DESIGN

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ABSTRACT -- Characteristics of the four-tree-cluster seedling orchard design are described. Examples are given of possible spacings which could be used and resulting selection differentials. Suggestions are made as to how seedling seed orchard goals are affected by using a four-tree-cluster design rather than a four-tree row-plot design having approximately the same initial number of trees/acre.

INTRODUCTION

Forest tree seed orchards can be established either by planting seedlings grown from seed collected from the chosen parent trees or by vegetative propagation of the parent trees. Orchards derived in those two ways are called seedling orchards and clonal orchards, respectively. While the ramets in a clonal orchard are exact copies of the parental genotypes, the trees in a seedling orchard, with the exception of selfs, received only half their genetic make-up from the known parent trees and as a result have a less certain pedigree. And unless the parent tree is homozygous at all loci, even selfs are not necessarily identical genetic copies of, the parental genotypes.

The initial spacing of seedling orchards is usually much closer than that of clonal orchards because the need for heavier roguing is anticipated (Giertych, 1975). Multiple-tree plots are commonly used to allow more effective within-family selection in seedling orchards; only one ramet is planted per location in a clonal orchard unless heavy mortality is expected.

The purpose of a seed orchard is to supply seed of improved genetic quality for the regeneration of forest stands (Barber & Dorman, 1964). Regardless of whether an orchard is of seedling or clonal origin, the design is usually intended to meet several objectives. Van Buijtenen (1971) summarized those general objectives as follows: 1) maximize the ratio of the

orchard pollen to outside Pollen; 2) provide an adequate supply of orchard pollen to ensure high seed set; 3) maximize the number of crosses occurring within the orchard; and 4) minimize the frequency of inbreeding. A number of additional factors should be considered when deciding whether to use clonal or seedling orchards.

SEEDLING VS. CLONAL ORCHARDS

Over the years, many breeders have insisted that seedling orchards are better than clonal orchards, or vice versa. A more objective viewpoint was expressed by Zobel and McElwee (1964), who stated that clonal orchards are not necessarily better than seedling orchards but that either may be more desirable depending on given conditions and the species involved.

Toda (1964) pointed out that cost and difficulty of establishment is an important consideration. He noted that the cheapest method of orchard establishment is usually the collection of open-pollinated seed from selected parents and planting of the resulting seedlings in an orchard. However, a clonal orchard can often be produced faster than a control-pollinated seedling orchard (Barber & Dorman, 1964).

Grafts of many species flower earlier than seedlings (Wright, 1964). Clonal orchards of such species provide seed at an earlier age, thus increasing the economic gain. But seedlings of other species produce seed as early or earlier than grafts, and in that case often yield as much gain in less time at a lower cost (Schreiner, 1961).

Namkoong (1969) suggested that if conditions exist which prohibit reliable phenotypic selection, the use of seedling orchards would probably be more cost efficient in the first generation. He would seem to favor seedling orchards for those species generally found in mixed, uneven-aged stands.

Another important factor favoring use of seedling orchards is the existence of important juvenile traits which can not be detected in the mature Phenotype. An example is the age of initiation of height growth in longleaf pine (Pinus palustris Mill.), a critically important trait. Seedling orchards are recommended for longleaf pine (Goddard et al, 1977).

Inbreeding may be of more concern in seedling

orchards than in clonal orchards (van Buijtenen, 1971). If open-pollinated seed is collected from widely-scattered selections, the degree of inbreeding which occurs in the resulting seedling orchard should differ little from that in a clonal orchard derived from the same selections. However, if controlled crosses are made using a polymix, half-sibs could be inadvertently planted in adjacent locations in the orchard. Even if a partial diallel is used, some of the resulting progeny will be at least half-sibs and could be full-sibs (Zobel & McElwee, 1964). Whether or not that is a problem depends on the degree of inbreeding which results and the extent to which that inbreeding is expressed as a depression of the genetic quality of the progeny.

Proponents of seedling orchards have claimed the use of those plantings for both test and orchard to be a major advantage. That is a valid claim in the case of black walnut (*Juglans niffa* L.), which is planted and managed on a production basis as an orchard (Masters & Beineke, 1973). But with many species it is difficult, if not impossible, to locate sites which are both appropriate for progeny testing and suitable for optimum seed Production (Zobel & McElwee, 1964). Suitable progeny test spacing is often too close for high seed production, as shown by Goddard (1964) in the case of slash pine (*Pinus elliottii* Engelm. var. *elliottii*). Cultural practices to encourage heavy seed Production may bias Progeny test results unless the same practices are used in production plantings (Barber & Dorman, 1964). Pressure to thin at an early age is often high in seedling orchards because of the close initial spacing (Zobel & McElwee, 1964), but unless juvenile:mature correlations are known to be high, progeny tests should not be thinned until they reach 1/2 to 2/3 normal rotation age (Toda, 1964).

The last major factor influencing the decision to establish seedling or clonal orchards is the magnitude of the genetic gain Possible through each approach. Assuming that selections of the same intensity are used, a clonal orchard may require fewer selections than an open-pollinated seedling orchard in order to produce progeny of the same average quality after roguing (Barber & Dorman, 1964). The relative value of a control-pollinated orchard is less certain and depends on the proven quality of the parents; an untested cross may turn out to be a good specific

combiner without being a good general combiner (McElwee, 1963).

There is no simple answer to the question of whether or not to use seedling orchards. The answer depends on the interplay of a number of characteristics of each species, some of which contradict each other. For instance, seedling orchards would be favored in a species having very low heritabilities. But if seedlings of that species do not flower until age 15 while grafts flower at age 5, a choice must be made as to which difficulty to avoid and which to accept.

ATTRIBUTES OF THE FOUR-TREE-CLUSTER DESIGN

The four-tree-cluster is similar to the progeny square described by Schreiner (1963) in that the seedlings are planted at the corners of a square rather than in a row-plot. But unlike Schreiner's design, the distance between adjacent seedlings of different families is greater than the distance between adjacent seedlings within a family plot. Figure 1 illustrates the general layout of a four-tree-cluster orchard.

Both within-cluster and between-cluster spacing can be varied depending on the desired selection differential, growing space requirements of the species of interest, and the necessity of access lanes for tractors, mowers, fertilizer spreaders, etc. Table 1 denotes numerical characteristics of a number of possible four-tree-cluster spacings.

FOUR-TREE-CLUSTER VS. FOUR-TREE ROW-PLOT

What are the Pros and cons of using a four-tree-cluster design rather than the more common four-tree row-plot? Consider the following two hypothetical orchards shown in Figures 1 and 2.

Figure 1 shows a portion of a four-tree-cluster orchard planted with 3 feet between seedlings within a plot and 8 feet between seedlings of adjacent plots. Initial stocking is 1440 trees per acre, and a minimum of 67 familier is required to provide at least 90 feet between different plots of the same source. A maximum of 240 families could be included if available land were limited to 10 acres but a minimum of 60 seedlings per family were desired. Possible selection differentials resulting from keeping the best tree Der

Table 1. Numerical characteristics of sample four-tree-cluster orchard spacings

Spacing (ft)	Trees per acre	Number of families	Selection differential[a/]
(2 X 2) X 4	4840	225[b/] - 807[c/]	.02[d/] - .01[e/]
(2 X 2) X 5	3555	165 -593	.03 - .01
(2 X 2) x 6	2722	127 -454	.04 - .01
(2 x 2) x 7	2151	100 -359	.05 - .01
(2 X 2) X 8	1742	81 -290	.06 - .02
(2 X 2) X 9	1440	67 -240	.07 - .02
(2 X 2) X 10	1210	56 -202	.09 - .02
(2 X 2) X 12	888	41-148	.12 - .03
(3 x 3) x 6	2151	100 -359	.05 - .01
(3 x 3) x 7	1742	81 -290	.06 - .02
(3 x 3) x 8	1440	67 -240	.07 - .02
(3 x 3) X 9	1210	56 -202	.09 - .02
(3 x 3) x 10	1031	48 -172	.10 - .03
(3 x 3) x 12	774	36 -129	.14 - .04
(4 x 4) X 8	1210	56 -202	.09 - .02
(4 x 4) x 10	888	41 -148	.12 - .03
(4 x 4) x 12	680	32 -113	.16 - .04
(4 x 4) x 15	482	22 - 80	.23 - .06

a/ assuming best individual per plot is kept for best 20 families

b/ minimum number of families to ensure at least 90 feet between relatives

c/ maximum number of families for which at least 60 progeny per family could be planted on a 10-acre site

d/ based on minimum number of familie

e/ based on maximum number of families

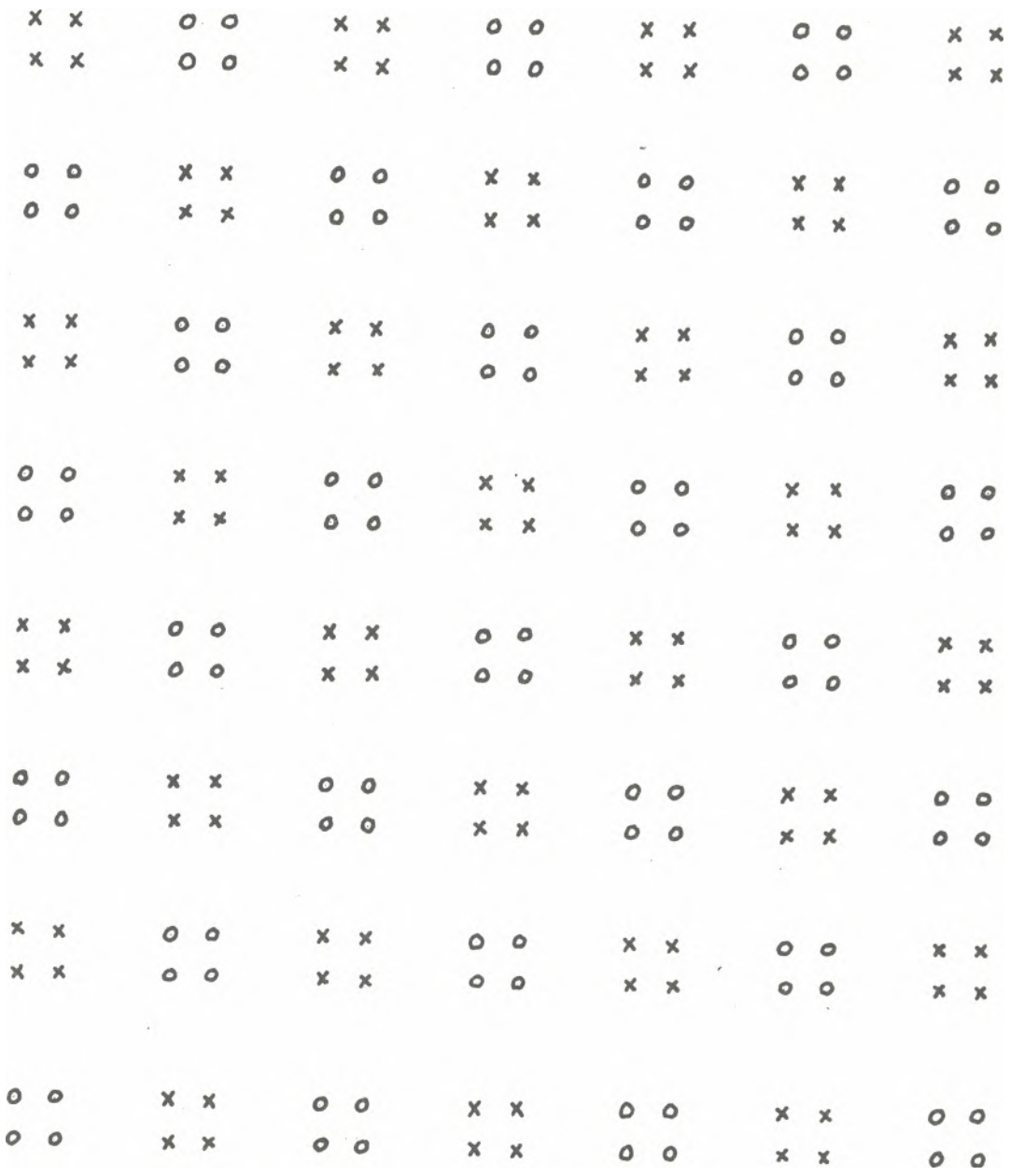

Figure 1. (3' X 3') X 8' Four-tree-cluster orchard

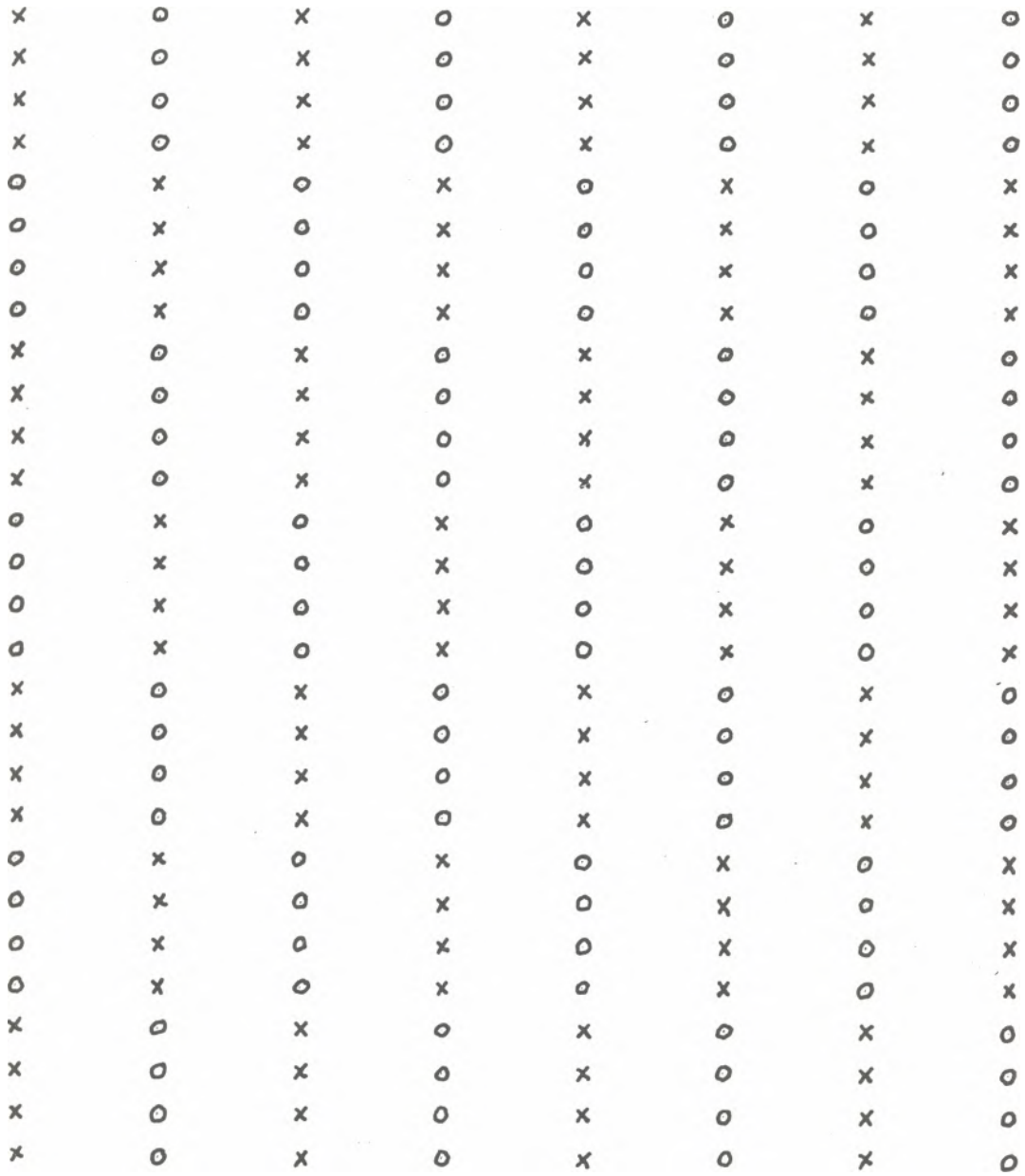

Figure 2: 3' X 1' Row-plot orchard

plot of the best 20 families would range from .02 to .07.

Figure 2 shows a portion of a row-plot orchard planted at a spacing of 3 feet by-10 feet. Initial stocking is 1.452 trees per acre, and a minimum of 68 families is required to provide at least 90 feet between different plots of the same source. A maximum of 242 families could be included if available land were limited to 10 acres but at least 60 seedlings per family were desired. Possible selection differentials resulting from keeping only the best individual per plot of the best 20 families would range from .02 to .07.

At first glance there would seem to be little difference between the two orchards since they have essentially the same total number of trees per acre, number of families, and possible selection differential. But other differences could have a considerable effect on the overall value of the respective designs.

In Figure 2, sup[p]ose that adjacent trees of different families happen to be the best individuals of the respective plots. Roguing down to the best tree per plot in that instance would leave trees only 3 feet apart --- much too close for adequate crown development. Keeping an alternate tree in one or both plots would allow more room for crown development but lower the selection differential attained.

In the four-tree-cluster design shown in Figure 1, the choice of which tree to keep in a plot would have much less of an effect on final spacing because adjacent trees of neighboring plots are 8 feet apart. Thus the necessity of choosing an alternate tree to keep should not occur as often in the four-tree-cluster orchard, and the actual selection differential attained should be closer to the theoretical maximum allowed by the initial stocking.

But that is not the only way in which a row-plot design compares poorly with a four-tree-cluster. In both the University of Florida and N. C. State University tree improvement cooperatives, it has been noted that the differences between faster- and slower-growing families tend to become exaggerated following crown closure in row-[p]lot progeny tests. The implication is that the faster-growing families tend to suppress their slower-growing neighbors. That can

cause the faster-growing families to appear better than they actually are and the slower-growing ones worse. Although the bias caused by interfamily competition probably has little effect on the distinction between the best and worst families, it could possibly reverse the rankings of families with intermediate values.

Initial planting spacing in row-plot orchards is often much closer in the drill than that of either production plantations or progeny tests. Thus the effects of interfamily competition are potentially quite damaging and increase as roguing is delayed after crown closure occurs.

In a four-tree-cluster orchard, crown closure occurs within the family plot before it occurs between adjacent plots. Thus at least for the first few years, each tree is competing mainly with its siblings, which are theoretically more similar than seedlings of different families. Within-family selection should be better than in a row-plot because of more uniform competition, and between-family selection should be better because suppression of trees in adjacent plots is reduced.

After roguing down to the best tree per plot, the four-tree-cluster orchard shown in Figure 1 would tend to look like that shown in Figure 3. The space between adjacent trees of neighboring plots would vary from 8 to 14.3 feet in both directions.

Similar roguing in the row-plot orchard shown in Figure 2 would result in a pattern like that shown in Figure 4. In the rows, spacing between trees would vary from 3 to 21 feet, while the spacing between trees of neighboring plots across the rows would vary from 10 to 13.5 feet. Both Figure 3 and Figure 4 are based on probability; for instance, the probability of adjacent trees being kept in the same row in Figure 4 is 1/4 X 1/4 or 1/16.

Actual planting of a four-tree-cluster would be somewhat more complicated than that of a row-plot orchard but that minor difficulty can be overcome with a little preplanning. A polyethylene or polypropylene rope could be marked with plastic flagging at intervals equal to the distance between the centers of adjacent clusters (11 feet in the case of the orchard shown in Figure 1). A lightweight wooden or aluminum

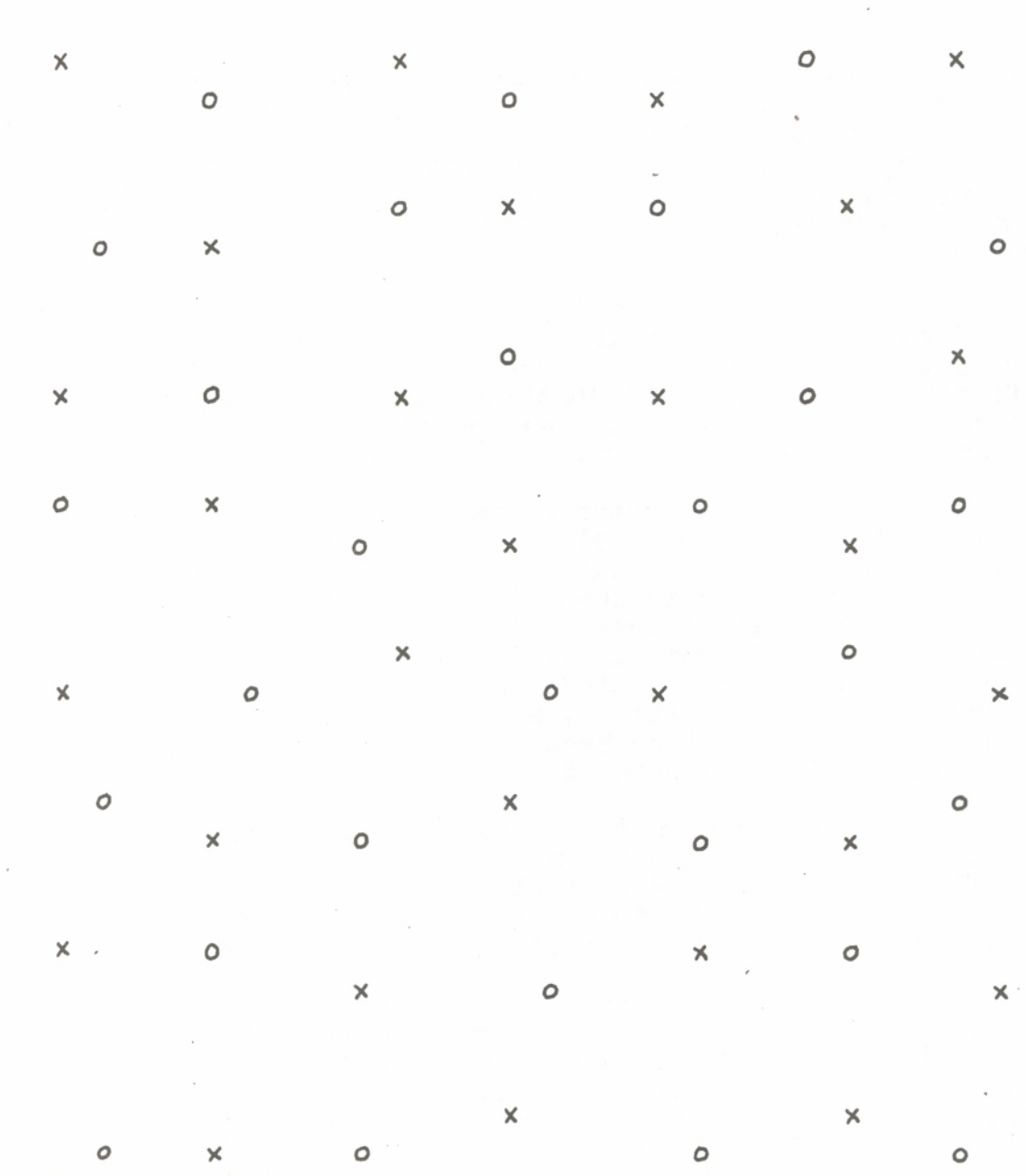

Figure 3. (3' X 3') X 8' Four-tree-cluster orchard after roguing to the hest tree per plot

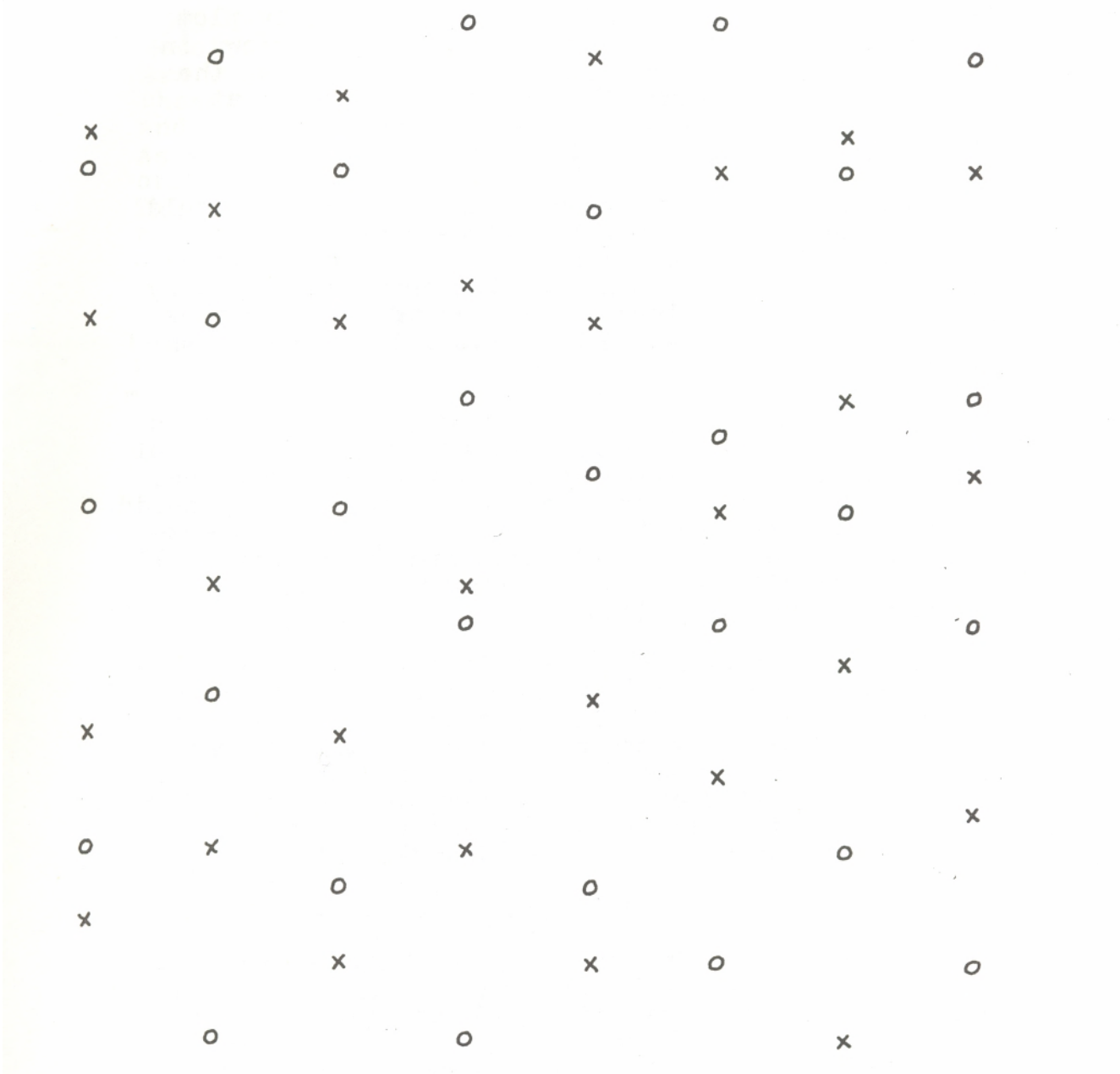

Figure 4. 3' X 10' Row-plot orchard after roguing to the best tree per plot

frame could then be used to outline the family plot (a 3-foot square in the case of the orchard shown in Figure 1). After stretching out the rope along the ground, the frame would be placed on top of it at each flag and one seedling from the same family planted at each corner of the frame.

Orchard mapping, tagging, and measurement should actually be easier in the four-tree-cluster design since there is no doubt where one family plot stops and another starts. In a row-plot orchard it is very easy to become disoriented, particularly if the tree identities are only shown on a map and not marked on the ground.

Equipment access should be a major consideration in any seed orchard. In many areas, intensive control of groundcover vegetation is essential both to reduce competition for the young orchard and to simplify seed collection. Fertilization and treatment with insecticides are usually desirable and often necessary. All of these activities require a certain amount of room in which to maneuver equipment.

Vehicular access is generally limited to only one direction in a row-plot orchard until after the first roguing. Even after roguing, access across the rows may be difficult in spots because of occasional pairs of closely spaced trees. However, access is equally good in both directions in a four-tree-cluster, and the extent of that access can be easily adjusted by selecting an appropriate spacing between clusters.

CONCLUSIONS

The four-tree-cluster is a flexible seedling orchard design which should be used more often. It may favor orchard characteristics over progeny test characteristics to some extent, but that is no problem since all seedling orchards should be backed up with separate progeny tests whenever possible.

There is at least one species for which the four-tree-cluster is not suitable; namely, black walnut. Allelopathy problems make the single-tree plot at wide spacing the only reasonable design to use for that species.

Longleaf pine is a Prime example of a species well-suited to the four-tree-cluster. Existing sites

for mass selection are often understocked and have usually been repeatedly high-graded. Juvenile traits are very important but can not be detected in mature phenotypes. Juvenile:mature correlations for growth and other important traits are essentially unknown. As a result, complete removal of families from the orchard would seem inadvisable until at least age 2n. The four-tree-cluster allows a nearly uniform spacing to be maintained even after roguing to the best tree per plot.

In general, the four-tree-cluster would seem to be well-suited to any species susceptible to heavy juvenile losses to disease pathogens and found in mixed, uneven-aged stands.

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