The Effect of Spacing, Fertilization, and Cultivation on Flowering and Seed Production in Loblolly Pine

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INTRODUCTION

The objectives of this study were:

1. To determine the best way to handle a seed orchard so as to produce the earliest, heaviest and most substained yield of seed.

2. To determine the economic feasibility of seed orchards.

3. Of secondary importance, to produce in quantity seed of drought resistance stock and to test these for their genetic worth.

The study was set up in 1954, by Zobel and Cech when virtually nothing was known about the management of seed orchards. From 1956, till 1960 the project was continued by Brown, and carried on since that time by the author. The study set out specifically to determine the effect of cultivation, fertilization, spacing and physiological age of the scion material on flowering and seed production. The literature on the subject was reviewed by Matthews (1963), Richardson (1962) and Zobel (1958).

MATERIALS AND METHODS

The materials in the orchard consist entirely of loblolly pine selected for drought resistance. The great majority of these selections were made in the "Lost Pine" areas in Bastrop and Fayette County. A few selections from Leon County and Anderson County were also included. The orchard was established over the period from 1954 through 1960. The bulk of the material was established during the period from 1954 through 1957. The soil is an extremely deep sand. The drought of 1956 and 1955 affected the orchard rather severely and caused growth during these years to be very slow. The experiment was basically set up as a

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factorial design. The following factors were tested:

1. Disking versus mowing.
2. Three levels of fertilization:
   a. Unfertilized control.
   b. A low level of fertilization consisting of two hundred pounds of phosphorous and potassium per acre plus two applications of nitrogen, each at a rate of a hundred pounds per acre and
   c. A high level of fertilization consisting of SOO pounds of P and K per acre, plus two applications of nitrogen each at a rate of 300 pounds per acre.

The fertilizer requirements were determined each year from the soil analyses of samples taken each fall. Phosphorous was given in the form of 45% super phosphate in a quantity sufficient to bring the calculated amount of phosphorous up to the prescribed level. The same procedure was followed for potassium, which was administered in the form of muriate of potash. The full amount of nitrogen was given at each application as ammonium nitrate.

3. A 30T x 30' spacing versus a 20' x 20' spacing.
4. Grafts from physiologically young material compared to grafts from physiologically mature material. The physiologically juvenile grafts were obtained from open pollinated progenies of the ortets from which the clones of mature material were derived. The orchard was not laid out according to a regular statistical design although all 24 possible treatment combinations are present. They were, however, arranged to make comparisons of most treatments feasible and a good many of combinations of treatments. An important consideration in the design was also the convenience of applying the treatments. The experimental layout is shown in Figure 1. All treatment combinations are replicated twice except the six combinations involving juvenile grafts at the 30' x 30' spacing.

The following observations were made:

1. Number of pollen clusters per graft.
2. Number of female flowers 27 per graft.
3. Number of cones per graft.

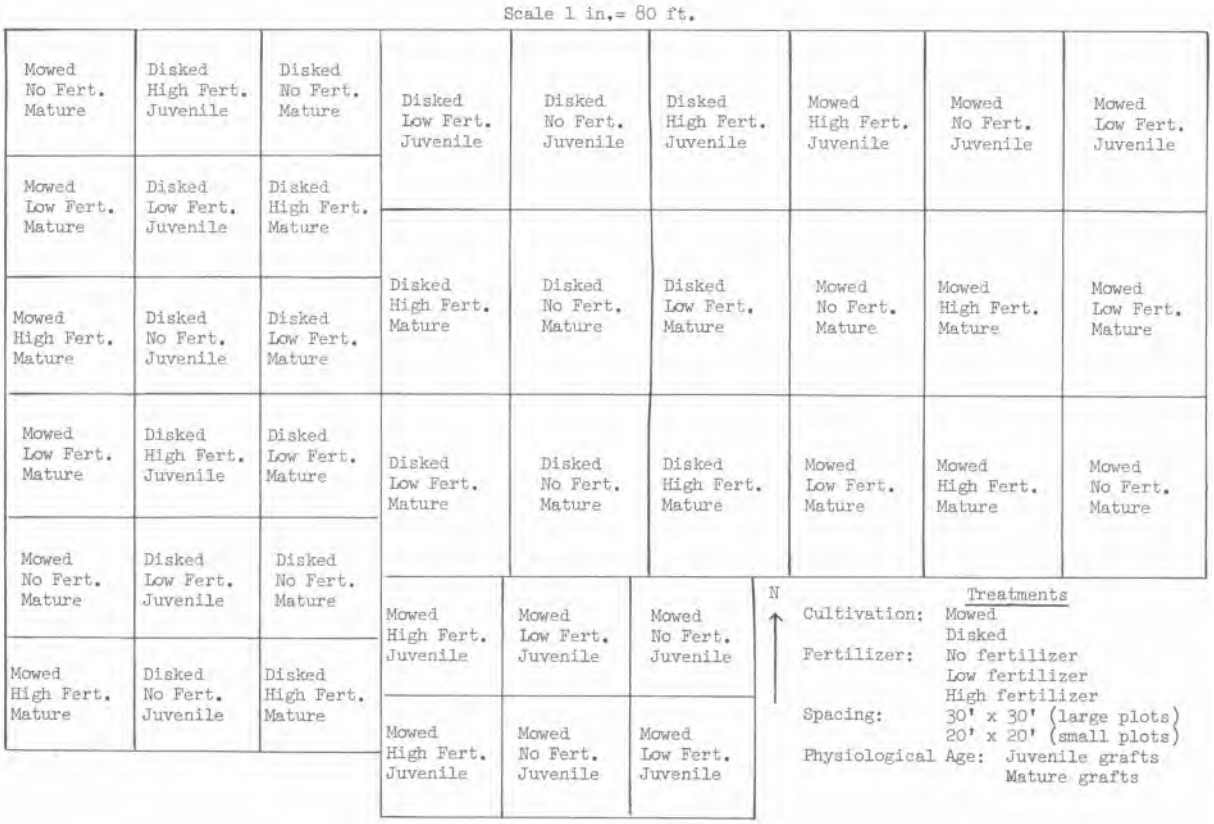

FIGURE 1. FIELD LAYOUT OF EXPERIMENTAL ORCHARD

2/ Although botanically incorrect, the term flower has been colloquially accepted and has been used throughout this paper instead of the term strobilus.

4. Total number of seeds per graft.
5. Number of sound seeds per graft.

This paper is based on the data from 1962 and 1963.

RESULTS

Due to the unequal number of grafts in the various blocks, the different ages of the grafts and the missing replication an analysis of variance by the usual method is virtually impossible. Two approaches were taken in comparing the various treatments:

1. By grouping the data according to grafts of the same age and comparing blocks containing sufficient numbers for a statistical analysis.
2. By making an over all analysis following the method of fitting constants described by Li (1964).

Comparisons using part of the data. The results of the comparisons are given in Table 1.

Cultivation had a significant effect on the 1962 female flower production and both the male and female flower production in 1963. In all cases flower production was increased by disking.

Statistically significant effects of fertilization on male and female flower production could be demonstrated in 1962 and 1963. Fertilization apparently increases the number of female flowers, and decreases the amount of male flowers.

The number of ways in which spacing could be compared was very limited. It could be shown however, that spacing significantly increased male flower production.

It was impossible to compare the juvenile and mature grafts in this manner, since the

Table 1. Comparisons between various treatments after grouping data according to age of graft. The values given are averages per graft.

Treatments	1962 pollen clusters	1962 female flowers	1962 cones	1962 total seed	1962 sound seed	1963 pollen clusters	1963 female flowers	1963 cones	1963 total seed	1963 sound seed	Remarks
Mowed	272	131	13	480	424	476	77	22	610	151	
Disked	221	135	14	514	413	500	113	25	1843	1040	Group 1
Control	363	104	11	484	258	730**	65	29	841	553	Planted in 1954
Low fertilizer level	192	134	14	324	396	420	76	18	1237	734	30' x 30' spacing
High fertilizer level	176	164	16	710	626	290	153	23	1693.	517	Juvenile scions
Control	435	90	2	7	6	388*	74	4	403	296	Group 2
Low fertilizer level	242	69	12	475	449	209	34	12	415	52	Planted in 1954 Disked
High fertilizer level	208	125	14	733	653	162	52	2	12	4	20' x 20' spacing Juvenile scions
Control	71	12	1	30	24	178	20	3	22	131	Group 3
Low fertilizer level	130	40	2	91	79	127	29	2	223	12	Planted in 1955 Mowed
High fertilizer level	115	50	1	9	7	179	25	2	50	16	20' x 20' spacing Juvenile scions
Mowed	12	7	.3	20	17	64	22	--	--	--	
Disked	24	11	-	--	--	112	56	--	--	--	Group 4
Control	3	3	.08	7	5	55	18	--	--	--	Planted in 1957
Low fertilizer level	40	10	.20	8	6	126	55	--	--	--	30' x 30' spacing
High fertilizer level	18	18	.14	13	13	109	63	--	--	--	Mature scions
Mowed	9	4**	.1	68	63	49*	19*	--	--	--	
Disked	13	13	1	40	31	83	42	--	--	--	Group 5
30' x 30' spacing	19**	9	.1	9	7	91*	41	--	--	--	Planted in 1957
20' x 20' spacing	6	9	1	82	71	52	25	--	--	--	Mature scions
Control	291*	71	5	137	109	454*	54*	14	451	306	
Low fertilizer level	189	79	9	347	307	263	45	10	600	286	Pooled Data
High fertilizer level	167	114	11	495	438	195	78	9	597	182	

* The treatment effect in this group is significant at the 5 percent level.
** The treatment effect in this group is significant at the 1 percent level.

great majority of the juvenile grafts were established before the mature grafts.

Analysis using the method of fitting constants. The nature of this type of analysis is very similar to a multiple regression analysis and is particularly suited for data in which the number of observations is unbalanced. It has the additional advantage of allowing the use of a number of variables as covariates. The effect of such variables can be accounted for in the analysis of variance. In this instance, the year in which the graft was planted was used as such a variable, thus adjusting all data to the same year of planting. The results are summarized in Table 2. For the purpose of comparison the actual averages are given in Table 3.

A significant effect of cultivation could be demonstrated on the female flowers, number of cones, total amount of seed, and the number of sound seed produced. In every case the disking treatment showed an increase over mowing.

A significant effect of fertilization could be shown on male flower production, female flower production, and seed production in 1962. No effect could be demonstrated In the 1963 cone and seed data. Fertilization had a depressing effect on male flower production and increased the other factors.

Spacing had a significant effect on male flower production, female flower production, cone production, and seed production. In all cases production in the 30' x 30' spacing was highest.

Physiological age had a significant effect on male flower production and on the 1963 cone and seed production.

DISCUSSION

As shown in Table 2 disking has a considerable stimulating effect on flower and seed production as compared to mowing. An objection sometimes raised to the practical application of disking is the possibility of increased danger of infection by Fomes annosus. In our ex-

Table 2. Adjusted averages of significantly different treatments.

Treatments	1962 pollen clusters	1962 female flowers	1962 cones	1962 total seed	1962 sound seed	1963 pollen clusters	1963 female flowers	1963 cones	1963 total seed	1963 sound seed	Number of grafts in each group
Mowed							39	5	164	56	230
Disked							54	11	523	276	243
Control		35		126	99	214	36				168
Low fertilizer level		45		187	164	164	44				153
High fertilizer level		65		390	341	130	60				152
30' x 30' spacing		64	7	344	291	224	66	14	594	290	173
20' x 20' spacing		32	3	125	111	115	27	2	94	42	300
Juvenile	126					209		15	607	300	217
Mature	56					130		2	80	32	256

Table 3. Overall averages of treatments.

Treatments	1962 pollen clusters	1962 female flowers	1962 cones	1962 total seed	1962 sound seed	1963 pollen clusters	1963 female flowers	1963 cones	1963 total seed	1963 sound seed	Number of grafts in each group
Mowed	71	37	4	213	187	137	32	3	93	29	230
Disked	94	47	5	188	159	153	48	8	353	180	243
Control	91	31	3	118	94	178	33	4	148	93	168
Low fertilizer level	86	43	5	188	166	150	41	8	237	108	153
High fertilizer level	70	54	6	304	267	104	47	4	304	121	152
30' x 30' spacing	102	69	8	375	318	222	69	12	492	237	173
20' x 20' spacing	72	27	2	99	87	101	23	2	74	31	300
Juvenile	152	64	6	253	221	224	47	11	470	227	217
Mature	24	23	3	156	132	79	34	1	20	4	256

perience no adverse effect of disking on the condition of the trees has been apparent. As a matter of fact survival has been slightly better in the disked than in the mowed blocks. Another more serious objection is the danger of erosion. On many types of soil this poses a serious problem, and makes the use of disking as a method to stimulate seed production highly questionable.

Fertilization had a stimulating effect on female flower production and seed production, but a depressing effect on male flower production. Increased female flower production as a result of fertilization has been reported most recently by Goddard (1965). It is interesting to note that in 1963 the per cent sound seed in the highly fertilized blocks was considerably lower than in the controls, while the difference was much less pronounced in 1962. This is particularly meaningful if one remembers that in the spring of 1962 a severe frost did considerable damage to the pollen. This could have made the general availability of pollen so low that the reduction in the amount of male flowers in the highly fertilized blocks might have been a critical factor.

The 30' x 30' spacing seems to be much preferable over the 20' x 20' spacing. In 1962 the seed production was approximately equal on a per acre basis. In 1963, however, the seed production in the wide spacing was approximately three times as high on a per acre basis as in the 20' x 20' spacing. Visual observation of the orchard also indicates that the 20' x 20' spacing is becoming much too close.

The comparison between juvenile and mature materials was one of the most difficult to make, since the juvenile materials were predominantly established in the first three years of the experiment while the mature materials were established in the subsequent years. The statistically significant difference in pollen production appears to be rather typical. Juvenile grafts have been observed to produce abundant pollen year after year. The difference in cone and seed yields between the two groups, however, appears to be abnormally strong in 1963 and was rather contrary to expectation. The most likely explanation is that the mature grafts were more severely affected by the freeze because the flowers generally develop more rapidly than the flowers of the juvenile materials. Also the effect of the difference in age might not have been completely removed by the covariance analysis.

The study confirms the impact of cultural treatments on seed production although a good many points need clarification.

With respect to disking, it would be desirable to determine whether the effect is due to root pruning, the reduction of competition with ground cover, or both. The results might suggest better means of obtaining the same effect.

With regard to fertilization the effect of individual elements needs further study. An experiment established by Brown in 1958 on the effects of P and N is a step in this direction.

SUMMARY

1. Disking stimulates both seed and flower production. Erosion can often be a serious deterrent to its practical application.

2. Fertilization with a complete fertilizer stimulates female flower production, but has a depressing effect on male flower production. Seed production is increased.

3. A 30' x 30' spacing is preferable to a 20' x 20' spacing both with respect to flowering, and seed production on a per acre basis.

4. Juvenile grafts tend to produce more male flowers. No significant difference could be shown between the female flower production of juvenile and mature grafts. No conclusions can be drawn from the seed production in 1963 since mature and juvenile grafts were probably affected differently by the damaging freeze in the spring of 1962.

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