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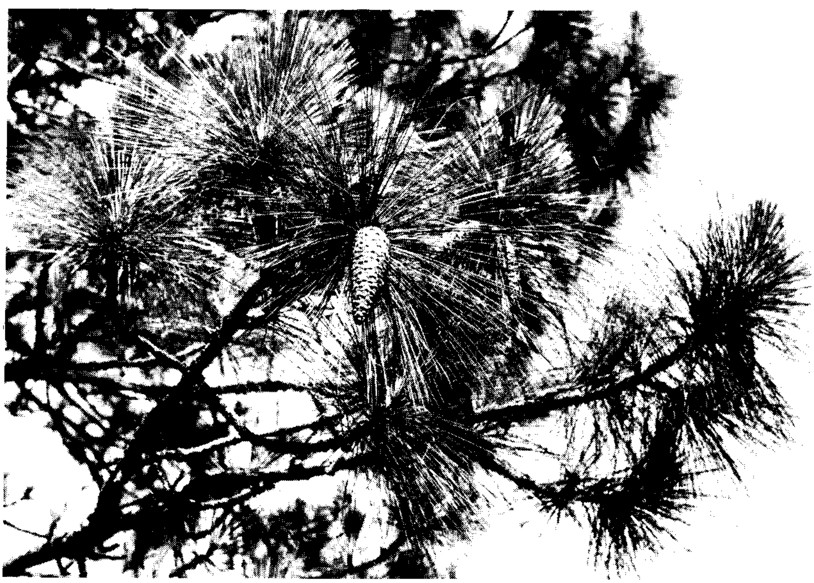

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Cone and Seed Characteristics Of Fertilized and Unfertilized Longleaf Pines

B. F. McLemore[1]

Fertilizing longleaf pines (Pinus palustris *Mill.) increased cone yields and seed size but did not affect number* of *seeds per cone, percentage of empty or wormy seed, cone size, initial viability, or keeping quality of seed. Cones per tree, sound seeds per cone, percentage of empties, seed weight, and cone size are characteristics* of *individual trees. Germinability is not associated with individual trees, nor with seed size, cone size, seeds per cone, or cones per tree. There is no consistent relationship between numbers of cones per tree and seeds per cone.*

Additional keywords: *Pinus palustris,* germination, seed yields.

In agricultural crops the addition of needed fertilizers increases both the quality and quantity of seed, and there is evidence that certain nutrients, especially phosphorus, are translocated from other plant parts into the maturing seeds (Lo&wing 1942, Williams 1946) . The amount of food in the endosperm is important in determining viability during storage. On consideration of these factors, it seemed possible that summer fertilization might benefit longleaf pine seed trees. A study was therefore made to determine if annual applications of a complete fertilizer, plus trace elements, would affect the quantity and quality of fresh seed and the keeping quality of stored seed. Secondary objectives were to collect cone and seed data useful in the management of seed orchards.

METHODS

In early July of 1957, 44 second-growth longleaf pines were selected in central Louisiana (Rapides Parish) . Diameters ranged from 29.5 to 45.2 cm and averaged 38.1 cm, while heights were approximately 20 meters. The trees had large crowns and were about 45 years old. Topography in the area is undulating to gently rolling. Soil is Ruston fine sandy loam with good surface and internal drainage.

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Trees were paired on the basis of their size, proximity, crown volume, and general appearance. Competing hardwoods were removed, and one tree from each pair was randomly selected for five annual applications of fertilizer:

Mineral	*Concentration and source*	*Effective amount*
		Kg
N	33 % Ammonium nitrate	1.5
P_2O_5	20 % Superphosphate	1.5
K_2O	60 % Muriate of potash	1.5
Trace elements		[2]0.5

The fertilizer for each tree was mixed thoroughly and placed in 75 to 100 holes, made with a planting dibble, around the outer edge of the crowns. It was applied between July 21 and August 1 of each year from 1957 through 1961.

To eliminate differences in viability that might be attributed to maturity, cones were collected just as they were ready to open-when their specific gravities were in the 0.70's or low 0.80's. Although collections were made from each tree in 1955, counts were omitted because a hurricane had dislodged many cones. Annual counts were subsequently made from 1958 to 1967.

Four apparently sound, mature cones were picked at random from each tree yearly to determine numbers of full, empty, and wormy seed. Lengths and diameters of these sample cones were recorded from 1961 to 1964.

For the years 1957-1962, all seeds were extracted in a small kiln at approximately 35° C. After being dewinged by hand rubbing and cleaned to 100 percent soundness, they were dried at 35° C to a moisture content of approximately 9 percent. The paired design of the study was maintained throughout drying. Seed from each tree was subdivided into five 200-seed samples for germination tests after 2, 4, 7, and 10 years of storage at 2" C. There was insufficient seed from some trees for testing after the longest periods of storage.

Weight of 200 sound, ovendry seeds was measured for each tree from 1959 through 1967.

Paired "t" tests were used to analyze differences (0.05 level of significance) in cone and seed yields and germination percentages between fertilized and check trees. The arcsin $\sqrt{\text{proportion}}$ transformation was used for all analyses involving germination percentages. Correlation coefficients were computed to evaluate relationships between various cone and seed parameters throughout the study.

RESULTS AND DISCUSSION

Seed Germination

Fertilization had no effect on initial germination, except in 1960 when the controls had a small, unimportant superiority (table 1). Viability was 90

2 Total amount of a commercial preparation containing 7.8% CuO, 18.4% MnO, 4.5% ZnO, 2.9% Fe_2O_3, and 5.3% B_2O_2.

Table 1.—*Viability of longleaf seed by year of collection and length of storage*

Year and treatment	Initial germination	Germination after storage for—			
		2 years	4 years	7 years	10 years
	Percent				
1957					
Fertilized	89	88	63	50S	24S
Check	91	86	66	63S	40S
1958					
Fertilized	89	95	92	90	84
Check	91	94	94	90	86
1959					
Fertilized	94	92	91	84	93
Check	93	93	92	86	94
1960					
Fertilized	93S[1]	91	91	81	69
Check	96S	91	91	85	60
1961					
Fertilized	74	79	86	76	8"
Check	78	84	86	83	87
196"					
Fertilized	91	85	95	92	86S
Check	93	85	96	94	91S

[1] S denotes significant difference (0.05 level) in germination between seed from fertilized and check trees.

percent or greater in all years except 1961, when it averaged 76 percent.

Viability of stored seed from fertilized and check trees differed only for the 1957 crop after 7 and 10 years and for the 1962 crop stored 10 years (table 1) . In these three instances, normal germination from check trees was significantly higher than that from fertilized trees; the explanation is unknown. When total germination (normal plus abnormal) was evaluated, however, differences were not significant. The 1957 crop deteriorated more than any others, perhaps because 2 months elapsed between harvesting of cones and storage of seed. In other years this period ranged from 2 to 4 weeks. Previous research has shown that there is a loss in viability during storage when cones (and presumably undried seed, as in this study) are held for 60 days (McLemore 1961) .

Seed collected in 1960 declined in viability when stored for 10 years, but differences due to fertilization were not significant. For the other 4 years, decreases in viability after 10 years were small. This result substantiates previous findings that longleaf seed can be held for at least 10 years (Barnett and McLemore 1950) .

The 1957 and 1962 crops decreased approximately the same amount during the first 2 years of storage---about 6 percentage points. Analysis indicated that differential performance by individual trees was not a factor. This evidence was strengthened by results obtained from 1957 and 1960 seed stored 10 years. Thus, good or poor storability characteristics are not traits of seed from individual trees.

The data did not bear out Tourney and Korstian's (1942) observation that high-quality seed is usually associated with large crops. Germination percentages were not correlated with numbers of cones per tree, sound seeds per cone, percentages of empty seed, seed weights, cone lengths, or cone diameters.

Similarly, seed weights were not related to germinalion percentages after various periods of storage.

Cone and Seed Production

Cones *per tree.*—Cone yields varied widely between trees and years. Although overall production was generally higher for fertilized trees, the difference was significant in only 3 of 10 years—1960, 1963, and 1964 (table 2) . When all data for the f-year period from 1959 through 1964 were considered, the fertilized trees produced significantly more cones than the check trees. These results agree with findings by Allen (1953) and Shoulders (1968) .

The 1959 crop was the first that could have been influenced by fertilization in 1957, but cone yields did not differ significantly. The 1960 crop was the largest during the 11-year period, and fertilized trees produced 55 percent more cones than check trees. As the last application of fertilizer was made in August 1961, primordia may have been stimulated in 1962. Thus, the 1964 cone crop should have been the last to be affected if carryover effects are discounted. This supposition was strengthened by data from 1965-67, when yields were no longer significantly different.

The study supported Croker's (1964) finding that some longleaf trees consistently produce more cones than others. When comparisons were made of yields from individual trees for each year with the IO-year average for that tree, the r values were significant in 7 of the 10 years for fertilized trees and in 9 of 10 years for check trees.

Wenger (1955) reported that large cone crops of loblolly pine (*Pinus taeda* L.) may reduce the number of flower buds formed during the late summer and early fall, thus curtailing the number of cones produced 2 years later. In comparisons of cone yields between alternate years for the present study, correlation coefficients were generally low and showed significance in only two instances for fertilized trees and in only one for check trees. The general lack of correlation in cone crops from individual trees between alternate years, coupled with the consistent correlations between single years and overall averages, substantiates Wenger's findings.

Seeds per cone.—Fertilization had no effect on number or percentage of seeds per cone-sound, empty, wormy, or total-in any year of observation (table 2). The average of sound seeds per cone for the 44 study trees ranged from 16 in 1966 to 99 in 1967.

Table 2.-*Summary of cone and seed data from fertilized and check trees, by year of collection*

Year and treatment	Cones per tree	Total seed/cone	Sound seed/cone	Empty seed/cone	Wormy seed/cone	Empty seed	Wt. 200 oven-dry seed	Cone length	Cone diameter
	Number					*Percent*	*Grams*	*Millimeters*	
1957									
Fertilized	.	114	82	25	7	22	...	. .	...
Check	. .	114	84	22	8	20	. .	. .	...
1958									
Fertilized	127	67	51	15	1	24	. .	...	...
Check	183	67	50	15	2	24	.	. .	...
1959									
Fertilized	217	109	78	23	8	21	19.2S		.
Check	158	107	78	21	8	20	17.3s	.	.
1960									
Fertilized	517S[1]	121	94	24	3	20	16.2	.	. .
Check	333s	120	96	21	3	18	15.7	.	
1961									
Fertilized	271	52	37	11	4	23	16.5S	153	51
Check	198	54	39	10	5	19	14.9s	150	51
1962									
Fertilized	146	103	72	22	9	22	19.2s	173	59
Check	108	99	72	18	9	20	17.9s	167	53
1963									
Fertilized	374s	77	60	16	1	22	16.2	156	50
Check	217S	74	56	16	2	23	16.1	158	52
1964									
Fertilized	2648	63	44	18	1	29	17.1	151	51
Check	158S	63	48	13	2	22	16.6	156	52
1965									
Fertilized	35	77	59	14	4	19	18.4S		.
Check	60	80	59	16	5	21	16.7S	.	
1966									
Fertilized	18	64	18	36	10	54	17.6		...
Check	5	56	13	34	9	56	17.1		.
1967									
Fertilized	251	126	99	24	3	19	16.4		. .
Check	274	124	99	21	4	17	15.3	. .	...

[1] S denotes significant difference (0.05 level) between fertilized and check trees.

As with cones per tree, there was a definite relationship in seed yields from year to year for individual trees. When numbers of sound seeds per cone from individual trees in adjacent years were compared, correlations were significant in 9 of the 10 pairs of years tested. Thus, trees that yield large or small numbers of seeds per cone in one year can he expected to yield proportionately in the future.

Although number of seeds per cone varied widely between years, the percentage of empty seeds remained fairly constant except in 1966, when the average for all trees was 55 percent. For the other 10 years, percentages ranged from 18 to 26 and averaged 21 (table 2) .

Since the annual variation in percentages of empty seed was usually small but differences between trees were g-rent, it appears that some trees consistently have high-or low—percentages of empties. As an example, values from two fertilized trees were:

Crop year	*Tree* 15	*Tree 22*
	— — Percentage of empties — —	
1957	4	48
1958	3	30
1959	6	47
1960	5	46
1961	9	38
1962	7	43
1963	11	26
1964	10	59
1965	4	42
1966	43	62
1965	6	23
Average	10	42

In further appraisal, correlation coefficients were computed for individual trees in consecutive years. As was expected, *r* values were high and significant for all years, including 1966, with no differences between fertilized and check trees. This result verifies that percentage of empty seeds is a characteristic of individual trees. The reason is conjectural; fertility cannot explain the variation. DeBarr and Ebel (1974) reported, however, that feeding by the seedbug *Leptoglossus corculus* caused high percentages of empty seed in shortleaf (*Pinus echinata* hfill.) and loblolly pine cones. This predator also feeds on longleaf seed. Differences between trees in susceptibility to the pest may explain the large variation in percentage of empty seeds between trees, Another explanation may be degree of self-pollination. Snyder and Squillace (1966) reported that self-fertilization reduces the yield of sound seed as compared to cross-fertilization, and Bramlett and Popham (197 1) developed a model to express the probability of unsound seed as a function of the number of fertilizations in each ovule and the number of lethal alleles carried by the selfed parent. Although Franklin (1969) reported that selfing of loblolly pine depresses germinability, no relationship was found in the current study between the proportion of empty seed and germinability. Finally, when numbers of cones per tree were compared with percentages of empty seed over the 10-year period, no relationship was apparent.

Correlations between cones per tree and seeds per cone were signicant for fertilized trees in 4 of the 10 years, but in no years for check trees. Perhaps of greater interest is the relationship between years in number of cones and in seed count per cone. Cone production in 1960 exceeded that of any other year, and yields of sound seeds per cone then were surpassed only in 1967. In 1966, by contrast, the number of cones was less than in any other year and yields of sound seeds per cone were also far below average. Aside from these 2 years, no relationship between the cone crop and seed yield was apparent. In the following tabulation, average cone yields per tree are ranked in descending order:

Year	*Cones per tree*	*Sound seeds per cone*
1960	425	95
1963	296	58
1967	262	99
1961	234	38
1964	211	46
1959	188	78
1958	155	50
1962	127	72
1965	48	59
1966	12	16

The computed *r* value of 0.612 from data in the tabulation was not significant. Wahlenberg (1946) reported that yield of sound longleaf seed per bushel of cones is less in a light than in a heavy cone crop. Wakeley (1954) noted that longleaf may average 50 to 60 sound seeds per cone in good seed years and half as many in poor years. From the data presented here, it appears that the observations of these authors are true only for unusually large or small crops.

Wormy seed.--From 2 to 9 percent of the seeds were infested by larvae of the seedworm *Laspeyresia ingens* each year except in 1966. In that year of low cone and seed yields, damage from the pest rose to 20 percent. Fertilized and check trees suffered equally in all years. Merkel (1967) found that individual slash pines differ in susceptibility to the seedworm *Laspeyresia anaranjada,* but no consistent preference was shown for any particular tree in this study.

On a IO-year average, number of wormy seeds per cone from individual trees was negatively correlated with average number of cones per tree-the greater the number of cones per tree, the smaller the number of wormy seeds per cone. Also significant were the positive correlations between number of wormy seeds per cone and total seeds per cone, and between numbers of wormy and sound seeds per cone. Finally, there was no apparent relationship over a period of 9 years between percentage of wormy seed and seed weights.

Seed weight.--Seed size, as well as shape and coloration, is uniform for individual trees but varies widely between trees. The weight of 200 sound, ovendry seeds from each tree was determined annually from 1959 through 1967. Seeds from fertilized trees were significantly heavier than those from check trees in 4 of the 9 years-1959, 1961, 1962, and 1965 (table 2) . In 1960, 1963, and 1964, production of cones from fertilized trees was significantly greater than from check trees. Moreover, these were the only years in which significant differences occurred in cone production. It is believed that the reason for lack of significance in seed weights for these 3 years lies in the difference in cone production, since number of cones per tree was negatively correlated with seed weight in 3 years for fertilized trees and in 4 years for check trees. Although heritability, cone size, and fertilization effects are undoubtedly contributing factors, it is concluded that trees with large numbers of cones tend to have light seeds.

Correlations between numbers of sound seeds per cone and seed weights for the 9-year period were not significant for either fertilized or check trees. Moreover, no relationship was apparent between seed weights and percentages of empty or wormy seeds.

Seed weight of individual trees, fertilized or check, was remarkably uniform from year to year, r values ranging from 0.596 to 0.926. Thus, seed from individual trees tends to be consistently large or small. The smallest seeds observed in the study averaged 16,233 per kilogram at 10 percent moisture, while the largest averaged 7,570.

Size of cones.-Cone size was not affected by fertilization. Cone dimensions of individual trees were fairly uniform from year to year (table 2). Correlations of cone lengths and diameters between adjacent years for individual trees were significant in all instances.

Although cones from individual trees are remarkably uniform in size and shape, there is great variation between trees. Correlations between cone length and number of sound seeds per cone were significant for 4 years in which data were available. Cone diameter and sound seeds per cone were significantly correlated in only 2 of the 4 years, but the 4-year average was significant. Veracion (1964) has reported significant correlations between cone size and numbers of seeds per cone for *Pinus insularis,* while Lee and Luo (1957) found positive correlations between size of cones and the number, size, and weight of China fir seeds.

Cone length was not correlated with seed weight. On the other hand, the relationship between cone diameters and seed weights was significant in 3 of the 4 years for fertilized trees and in 1 year for check trees, indicating a trend for thick cones to yield large seed.

Tree Growth

Diameter (b.h.) of all trees was measured in 1957 and 1962. Fertilized trees averaged a 48-mm increase over the 5-year period, while the increase for check trees was 41 mm-the difference not significant. Height measurements were not taken.

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