Selfing vs. Outcrossing Under Artificial Conditions in Pinus elliottii Engelm.

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The increase in self-pollination expected to occur in tree-seed orchards consisting of a limited number of clones has been a source of concern among foresters for several years (KLAEHN, 1953; STERN, 1959). This concern is warranted, and justly based on the results of numerous studies which have shown inbreeding to bave a depressing effect on progeny growth rates and other characters. Among the pines this inbreeding depression has been reported for eastern white pine (Pinus strobus L.) (JOHNSON, 1945), western white pine (P. rnonticola DOUGL.) (BINGHAM and SQUILLACE, 1955), Scotch pine (P. *silvestris* L.) (EHRENBERG *et* al., 1955; JOHNSON, 1945; SARVAS, 1962), and slash pine (P. elliottii ENGELM.) (MERGEN, 1954; SQUILLACE and KRAUS, 1963 a). Early results have indicated that the deleterious effects of selfing may be negligible in red pine (P. resinosa AIT.) (FOWLER, 1962).

In recent years several studies have been made in the Naval Stores and Timber Production Laboratory (formerly Lake City Research Center), Olustee, Florida, to investigate the problems of selfing and its effects in slash pine. A previous report indicated that considerable variation occurs among individual slash pines in the degree of natural selfing (SQUILLACE and KRAUS, 1963 b). Of 11 trees tested, 2 were estimated to be moderately self-fertile (23 and 27 percent selfing), and the remainder showod selfing of 5 percent or less. The present paper covers the relative yield of selfed seedlings under controlled selfing and under matings where outcross and self-pollens were mixed. The "selective fertilization" technique employed was similar to that used for western white pine by SQUILLACE and BINGHAM (1958), and BARNES et al. (1962).

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Materials and Methods

The data utilized in this study were obtained from various matings made in different years on seven slash pine trees (*table* 1). Four of these trees (1, 10, 11, and 27) were high-gum-yield selections which had been selfed and outcrossed with at least two other trees. The three other trees (29, 193, and 194) were used in the selective fertilization tests and were notable for their possession of atypical heritable traits. Tree 29 is distinguished by its production of yellow oleoresin, a trait apparently due to a rare recessive gene or genes. Trees 193 and 194 are both virescent chlorophyll mutants; however, the mode of inheritance of this trait has not yet been accurately determined[2]). Although knowledge of the mode of inheritance is incomplete, these traits were useful as gene markers for the present study.

[2]) KRAUS, J. F., and SQUILLACE, A. E.: Inheritance of yellow oleoresin and virescent foliage in slash pine. 1963. *(In press.)*

Table 1. — Seed yield and germination in self- vs. cross-pollinations and relative yield of self-pollinated seedlings.

Tree number	Year of pollination	Seed yield per cone		Seed germination		Seedling yield per cone		Relative yield of seedlings from self-pollination
			Average cross	Self	Average cross	Self	Average cross	
		Number		Percent		*Number*		Percent
1	1956, 1957	7	17	6	39	0.4	6.6	6
10	1947	29	45	22	56	6.4	25.2	25
11	1957, 1958	3	5	3	55	0.1	2.8	4
27	1958	42	23	7	44	2.9	10.1	29
29	1960	3	52	54	76	1.6	39.5	4
193	1958, 1960	10	15	42	78	4.2	11.7	36
194	1960	12	46	70	88	8.4	40.5	21
Mean								18

Table 2. — Results of the selective fertilization tests.

Mating	Strobili pollinated	Cones collected	Sound seed yield per cone	Average seed weight	Speed of germination	Aberrant seedlings[1])	Average seedling heights	Seedling basis
	Nurnber			*Mg.*	Percent		*Cm.*	Nurnber
29 X 29	18	15	3	41.4	67	100	13.9	15
29 × pm	10	7	52	49.9	73	0	20.5	271
29 × (pm + 29)	11	9	39	47.1	79	7	20.2	249
193 X 193[2])	9	7	10	31.9[3])	43	74	12.7	27
193 × pm	6	5	15	31.0	87	0	24.3	60
193 × (pm + 193)	6	4	13	27.1	—	35	—	34
194 X 194	5	5	12	29.7	98	78	17.2	41
194 × pm	2	2	46	33.7	99	2	19.3	81
194 × (pm + 194)	2	2	45	31.1	91	4	19.5	85

[1]) For matings on tree 29 aberrant seedlings are "yellow oleoresin", and for trees 193 and 194 they are "virescent".
[2]) Includes seed from controlled pollinations made in 1958 and 1960.
[3]) Based only on seed obtained from 1960 pollinations.

The matings were made in the spring of 1960 *(table 2)* using essentially the same techniques employed in western white pine. The polymix (pm) consisted of equal volumes of pollen from 21 trees. The polymix plus self consisted of equal volumes of polymix-pollen and self-pollen.

The viability of the pollens of trees 29, 193, and 194 was not tested in crosses with other trees; ideally this should be done since low viability of these pollens could produce results interpretable as low self-fertility. However, the relative yields of selfed seedlings from trees 1, 10, 11, and 27, which were crossed with other trees, are of a magnitude similar to those found in 29, 193, and 194. This indicates that self-fertility of slash pine generally is maintained at a moderate to low level.

The cones resulting from the controlled pollinations were collected in the fall of 1961. The seed were extracted, and the chaff plus most of the empty seed were removed in an air column winnower. Sound seed yield per cone and average seed weight were determined.

The seed were sown in the spring of 1962 in row plots, randomized and replicated three times. Data were recorded on the total number of seed germinating, the speed of germination (14th day / 24th day germination), and the number of virescent chlorophyll-deficient seedlings. The number of seedlings yielding yellow oleoresin was determined in November 1962. Heights of the seedlings were measured in January 1963. Seed lot 193 X (pm + 193) was not sown in the replicated design; therefore, speed of germination and seedling height for this cross have been omitted from the data.

Results

Self-Fertility

All of the trees tested were partially self-fertile when pollination was controlled, but considerable variation existed between trees *(table 1)*. This is not surprising; similar results have been obtained for Scotch pine (EHRENBERG and SIMAK, 1956), and western white pine (BINGHAM and SQUILLACE, 1955).

The self-fertility of the trees studied was compared using an index based on relative yield of self-pollinated seedlings (BINGHAM and SQUILLACE, 1955). Trees 1, 11, and 29 rate low in self-fertility relative to the other four trees. On the average, relative seedling yields upon selfing of slash pine were only 18 percent of the outcross seedling yields *(table 1)*, a considerably lower figure than the 51 percent reported for western white pine.

The exact causes of the low self-fertility cannot be determined from results of this study. Low seed germination was one factor *(table 1)*. The production of fewer sound seed per cone was another, but why fewer sound seed are produced is un-certain. It could be due to inhibition of pollen tube growth by female tissue, to embryo mortality following fertilization, or other factors. Empty seed were not counted in the present study, but selfing of western white pine usually resulted in the production of large numbers of empty seed compared to outcrossing (BINGHAM and SQUILLACE, 1955). SARVAS (1962, pp. 122—142) showed that the main factor in the production of empty seed following self-pollination is embryo mortality resulting from an increase in the number of homozygous recessive lethal genes. It is possible that embryo mortality was a major cause of low seed yields in selfed slash pine progenies.

Selective Fertilization

Regardless of the causes of the reduced seed yield resulting from controlled selfing, crosses using a mix of self- and outcross pollens (50 : 50) should yield fewer selfed seedlings than outcross seedlings. This is true even if no real competition of pollen tubes or embryos occurs. Ovules pollinated with self-pollen yield more nonviable seed than those pollinated with outcross pollen, and lower seedling yields per cone are obtained from controlled selfing. Thus, fewer seedlings would be expected to result from selfing than from outcrossing when mixed pollen was used.

To assess the outcome of selective fertilization tests, should one compare the results with expectation of equal numbers of selfs vs. outcrosses (50 : 50) or with an expectation based upon the relative self-fertility (under controlled selfing) for the tree being tested? If a significant difference occurs from the 50 : 50 expectation, we can say that one or the other type of pollen was more effective, but it does not necessarily mean that competition occurred between pollen tubes or zygotes. On the other hand, if a significant difference is found using the expectation based on relative self-fertility, we can assume a real competition occurred. This latter comparison is the important one. We know, or can determine, the relative yield of selfed seedlings by our selections, but the important question is whether the yield of selfs will be reduced when self- and outcross pollens occur together, as in seed orchards.

Usage of the term "selective fertilization" is broad enough to cover all types of "discrimination" discussed. However, in presenting our results we shall employ both types of expectations and interpret the data as discussed above, without the need for specific terminology.

Expectations based on relative self- and cross-fertility were determined as follows. For tree 29 the seedling yields from selfing and from outcrossing were 1.6 and 39.5 seedlings per cone, respectively. Expectation of the percent of selfs in a mixed mating would be $\frac{1.6}{1.6 + 39.5} = 3.9$ percent (or a ratio of 3.9 : 96.1 selfs vs. outcrosses). In using this formula we assume that: (1) pollen viabilities are not changed by mixing pollens, (2) all pollen types are equally distributed among the ovules, and (3) relative self- and cross-fertility data obtained in the unmixed matings are good estimates of post-fertilization development in the mixed matings.

For trees 193 and 194 the expected percent of selfs in mixed matings was similarly computed to be 26.4 and 17.2 percent, respectively.

Crosses with Tree 29:

Results of this test showed a majority of outcrosses over selfs when self- and outcross pollens were mixed *(table 2)*. Progeny of the 29 × 29 mating all yielded yellow oleoresin. None of the progeny resulting from outcrossing showed this trait. In the mixed mating (29 × [pm + 29]), 7 percent of the seedlings produced yellow oleoresin. This indicates that this proportion of the mixed progeny were selfs. According to a chi-square test the ratio of selfs vs. outcrosses, 7 : 93, obtained for the gene marker data was significantly different from a 50 : 50 expectation. The preponderance of outcrosses probably was not due to chance. However, the ratio obtained was not significantly different from the expectation based on relative self-fertility, 3.9 : 96.1 ($X^2 = 1.42$, $P = < 0.25$). Thus, in this test outcrossing predominated in the mixed mating, but there was little or no evidence of actual competition among pollen tubes or embryos. The interpretation is that the presence of outcross pollens did not reduce the self-seedling yield below what could be expected when self-pollen is alone. Of course, tree 29, being relatively self-sterile, is not a "problem tree" from the standpoint of use in seed orchards.

The gene marker was considered to be rather accurate for determining the extent of selfing in the mixed-mating, but it is interesting to examine the utility of the other traits studied to estimate the degree of selfing. For example, seed yield was apparently a fairly good indicator; the yield of 29 × (pm + 29) was much closer to the outcross than to the self. The same was true for seedling height and seed weight, whereas, speed of germination gave an anomalous result.

Crosses with Tree 193:

In this test the mixed mating (193 × [pm + 193]) resulted in approximately equal numbers of selfs and outcrosses. About 35 percent of the seedlings of the mixed mating were virescent, contrasted with 74 and 0 percent for the self- and outcross matings, respectively. Thus, $\frac{35}{74-0}$, or 47.3 percent of the seedlings in the mixed progeny were estimated to be selfs. The ratio 47.3 : 52.7 was not significantly different from either the 50 : 50 or 26.4 : 73.6 expectations. In the latter case X^2 was 0.64, P = <0.50. The total number of seedlings in the mixed mating was only 34 — had there been a larger number the deviation from the latter expectation might have been significant. In this moderately self-fertile tree the presence of outcross pollen did not reduce the yield of selfs below what was expected from straight selfing. In fact, self-pollen may have been more competitive than outcross pollen.

Seed yield per cone was in agreement with the above result, but seed weight was not. Complete data on speed of germination and seedling height were not available to judge the utility of these traits.

Crosses with Tree 194:

The mixed mating here indicated a predominance of outcrosses over selfs. The mixed mating yielded 4 percent virescent seedlings whereas the self- and outcross matings yielded 78 and 2 percent, respectively. The percent of selfs in the mixed progeny was estimated to be $\frac{4}{78-2}$, or 5.3 percent. The ratio of selfs to outcrosses 5.3 : 94.7, in the mixed progeny was significantly different from both 50 : 50 and 17.2 : 82.8 ratios. The latter test suggests that outcross pollen was somewhat more competitive than self-pollen. The interpretation is that tree 194, although moderately self-fertile, would likely yield fewer selfs in a clonal orchard than it yields under controlled selfing.

Seed yield and seedling height were in agreement with the gene marker results whereas seed weight was not. The utility of speed of germination could not be judged because its magnitude under selfing and outcrossing did not differ greatly.

Discussion

The results of this study indicate that a situation similar in some respects to that existing in western white pine is present in slash pine. Individual trees of both species differ in their capability for self-fertilization, and no tree yet tested has proved completely self-sterile. In addition, there is general agreement with the conclusion reached by SARVAS (1962, p. 127) that decreased seed yields from self-pollination are probably more often the result of post-fertilization competition than to competition prior to fertilization. The significance of these findings in slash pine seed orchard establishment seems clear: (1) some inbreeding is likely to occur in all seed orchards, regardless of the number of clones used; (2) the larger the number of clones used the less will be the degree of inbreeding; and (3) the relatively low level of self-fertility may not justify testing all selections for self-fertility to discard the most self-fertile trees.

If it seems desirable to have information on the relative self-fertility of selected trees or clones already in seed orchards, the testing need not be an arduous task. The data for slash pine (SQUILLACE and KRAUS, 1963 a), western white pine (BARNES *et al.*, 1962; BINGHAM and SQUILLACE, 1955), Scotch pine (JOHNSON, 1945; EHRENBERG *et al.*, 1955; EHRENBERG and SIMAK, 1956; SARVAS, 1962), and red pine (JOHNSON, 1945) all show that selfing causes a noticeable decrease in seed yield. Exceptions to this rule have been reported for eastern white pine (JOHNSON, 1945), and red pine (FOWLER, 1962). Each selected tree should have sufficient female strobili control-pollinated with self-pollen, and also with a mixture of outcross pollens, to yield 5 to 10 cones per cross. Comparison of the sound seed yields per cone should permit the identification of the highly self-fertile individuals.

Assuming that 7 percent is a reasonable estimate of the average degree of natural selfing in slash pine (SQUILLACE and KRAUS, 1963 b), it is interesting to speculate on the probable extent of selfing in clonal seed orchards.

Total selfing in a clonal orchard can be thought of as due to two sources, actual selfing of individual ramets and matings among ramets of the same clone. The factors affecting the yield of selfs following pollination would depend on the self-fertility of the clone and competition between self- and outcross-pollen.

If a clonal orchard contains many clones, (say 100 or more), the situation would be similar to existence under natural stand conditions. Total selfing could be expected to average 7 percent (assuming no effects from difference in spacing of trees). On the other hand, in an orchard containing fewer clones, there will be an additional component of selfing because of matings among ramets of the same clone, as noted above. This additional component would be a function of the number of clones, the self-fertility of the clones, and pollen competition. With no difference in effectiveness of self- vs. outcross-pollen, a 20-clone orchard could contain a maximum of 5 percent "additional selfing" because theoretically one-twentieth of the windborne pollen would be "self-pollen" in respect to any particular ramet. Thus, total selfing would be 7 + 5 = 12 percent. However, it was shown that "self-pollen" was less effective than "outcross pollen" and that mixing of the two types apparently did not greatly change the result. If self-fertility is only 18 percent, as found in this study, selfing from matings among ramets would be approximately 1 percent (18 percent of 5 percent). Total selfing would be 8 percent in the 20-clone orchard.

According to this analysis the degree of selfing in a clonal orchard of at least 20 clones would, on the average, probably yield only slightly more selfs than are obtained under natural stand conditions. Elimination of relatively self-fertile clones may even result in fewer selfs than are obtained in natural stands. An opportunity to eliminate many of these selfs occurs when the seedlings are graded prior to outplanting. Culling small seedlings should greatly reduce the number of selfs outplanted.

Furthermore, because of the non-random structure of natural stands, clonal orchards could have an advantage.

The inbreeding coefficient of progenies produced in the orchard would average less than of progenies produced in natural stands. This presumes the selected ortets were not all from the same stand. Just how great or important inbreeding due to non-random structure is in natural stands is unknown.

Determination of the actual amount of selfing occurring in a seed orchard has not yet been possible with the material available to most foresters. Hypothetical computations of the number of clones necessary to assure good cross pollination require that certain assumptions be made concerning the production and distribution of pollen. These assumptions are principally that all or most clones produce pollen yearly, that the pollen produced is distributed uniformly over the orchard, and that pollen flight and female strobilus receptivity coincide. However, observations have shown that in some years a preponderance of the pollen may be produced by a small number of clones in the orchard (Lücke, 1962).

Marker stocks have been used in orchard grass (*Dactylis glomerata* L.) to determine the percent of outcrossing occurring in recombination blocks (Cuany, 1958). A similar determination is possible in slash pine. Slash pine clones carrying genes for virescence, yellow oleoresin, and albinism are available[3]) (Squillace and Kraus, 1963 b). These clones could be planted along with clones of superior trees in a seed orchard, permitting an empirical estimate of the degree of selfing. Even though the natural self-fertility of the clones may differ, the relative increase in selfing could be established by comparison with the frequency of natural selfing found in the original ortet, or with a known value for the species. The marker clones could later be rogued from the orchard.

Summary

Self-fertility expressed as percentage yield of seedlings from self-pollinations vs. outcrosses averaged 18 percent and ranged from 4 to 36 percent for seven slash pine trees. Controlled crosses on three trees used self-pollen, outcross pollen, and a mix of equal volumes of self- and outcross pollens. The three trees had gene markers for yellow oleoresin or virescent foliage. The ratios of selfed vs. outcross seedlings obtained were compared both to the ratios expected on the basis of estimated self-fertility and to the 50 : 50 ratio expected with complete self-fertility. In two trees outcrossing was equal to or greater than expected on the basis of estimated self-fertility. In the third tree self-pollen may have been more effective than outcross pollen. The results are discussed in relation to clonal seed orchards of slash pine. The conclusion is drawn that selfing between ramets of a clone will add to the selfing that normally occurs within a ramet. The magnitude of the added selfing will depend on the number of clones in the orchard and on their self-fertility. Roguing of self-fertile clones may not be necessary.

Zusammenfassung

Titel der Arbeit: *Selbstung und Fremdung unter künstlichen Bedingungen bei Pinus elliottii Engelm.*

Die Selbstfertilität, ausgedrückt als Zahl der nach Selbstbestäubung erhaltenen Sämlinge in Prozent der Zahl nach Fremdkreuzung erhaltenen betrug im Mittel 18% und reichte von 4 bis 36% bei sieben Bäumen von *P. elliottii*. Kontrollierte Kreuzungen an drei Bäumen erfolgten mit Eigenpollen, Fremdpollen und einem Gemisch aus gleichen Anteilen beider. Die drei Bäume trugen Markierungsgene für gelbes Harz oder vireszente Benadlung. Die Verhältniszahlen von Selbstungs- bzw. Fremdungsnachkommen wurden mit den Werten verglichen, die auf Grund der geschätzten Selbstfertilität und auf Grund des Verhältnisses 50 : 50 bei voller Selbstfertilität zu erwarten waren. Bei zwei Bäumen war der Anteil der Fremdung gleich oder größer, als nach der geschätzten Selbstfertilität zu erwarten war. Beim dritten Baum dürfte Eigenpollen wirksamer als Fremdpollen gewesen sein. Die Ergebnisse werden im Zusammenhang mit Klonsamenplantagen von *P. elliottii* diskutiert. Es wird geschlossen, daß Selbstung zwischen den Klonteilen eines Klons zu dem Betrag an Selbstung hinzutreten wird, der normalerweise in einem Klonteil auftritt. Das Ausmaß der so hinzukommenden Selbstung wird von der Anzahl der Klone in der Plantage und ihrer Selbstfertilität abhängen. Entnahme selbstfertiler Klone dürfte nicht notwendig sein.

Résumé

Titre de l'article: *Auto- ou hétérofécondation artificielle chez Pinus elliottii Engelm.*

L'autofertilité exprimée en pourcentage de production de semis obtenus par auto-pollinisation par opposition à l'hétérofécondation était en moyenne de 18% avec des valeurs extérieures de 4 à 36% pour 7 individus de *Pinus elliottii*. Sur trois des arbres, on a effectué des croisements contrôlés avec du pollen de l'arbre lui-même, du pollen d'autres arbres et un mélange en volume égal de ces deux types de pollen. Les trois arbres avaient des gènes marqueurs pour l'oléorésine jaune ou le feuillage virescent. Les proportions de semis obtenus par autofécondation par rapport à ceux obtenus par hétérofécondation ont été comparées à celles attendues, basées sur l'autofertilité estimée et au rapport 50/50 correspondant à une autofertilité complète. Chez deux des arbres, l'hétérofécondation était égale ou supérieure à celle attendue basée sur l'autofertilité estimée. Chez le troisième arbre, son propre pollen a été sans doute plus efficace que celui d'autres arbres. Les résultats sont examinés en liaison avec les vergers à graines de clones de *P. elliottii*. On peut tirer la conclusion que l'autofécondation entre les individus d'un clone augmentera l'autofécondation qui se produit normalement à l'intérieur d'un même arbre. L'amplitude de ce supplément d'autofécondation dépendra du nombre de clones dans le verger et de leur autofertilité. L'élimination des clones fertiles peut ne pas être nécessaire.

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[3]) See footnote 2.

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Beobachtungen zur individuellen Widerstandsfähigkeit der Kiefer gegen Lophodermium pinastri-Befall[1])

Kurze Mitteilung

(aus dem Botanischen Institut der Universität des Saarlandes)

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(Eingegangen am 3. 8. 1963)

Im Rahmen der Resistenzzüchtung gegen *Lophodermium pinastri* fanden von 1954 bis 1960 Individualselektionen statt, die zum Auffinden zahlreicher widerstandsfähig erscheinender Kiefern führten (SCHÜTT 1957). Im Verlauf der Selektionsarbeiten fiel auf, daß Kiefern mit mehr als einem Gipfeltrieb oft schwächere Befallssymptome zeigten als normal verzweigte Bäume. So ist es nicht verwunderlich, daß ein relativ hoher Anteil der als widerstandsfähig selektionierten Kiefern zwieselt oder mehrgipfelig ist.

Um zu prüfen, ob diese Feststellung auf Zufällen beruht oder ob sie endogene Ursachen hat, pfropften wir aus einer 7jährigen Kieferndickung im Forstamt Trittau von vier Verzweigungsgruppen jeweils 20 Kiefern ab, pflanzten die Pfropflinge ins Freiland und setzten sie drei Jahre lang gelenkten *Lophodermium*-Infektionen aus. Während der Vegetationsperioden 1960, 1961 und 1962 fanden Befallsbonitierungen nach einem bewährten, sechsstufigen Schema statt, bei dem 0 = befallsfrei und 5 = totaler Nadelverlust bedeuten. Die Befallsdaten wurden nach Nadeljahrgang, Insertionshöhe und Befallsjahr getrennt ausgewertet und die Differenzen mit dem von SCHMIDT (1962) empfohlenen τ-Test nach LORD statistisch geprüft.

Die erwähnte Einteilung in „Verzweigungsgruppen" lehnt sich an die von SCHLÜTER (1956) aufgezählten Ursachen für das Entstehen von Triebanomalien an.

Gruppe 1 enthält normal verzweigte Individuen mit einer Terminal- und höchstens fünf Lateralknospen am Endtrieb. Johannistriebbildungen[2]) kommen nicht vor.

Gruppe 2 besteht aus Kiefern mit mehr als zwei Leittrieben, wofür die Ursache allerdings nicht mehr zu erkennen ist. Dafür in Frage kommen: *Tortrix*-Befall, Johannistriebe, genetische Anlage zur Mehrgipfeligkeit, mechanische Beschädigungen u. a.

Die Kiefern der *Gruppe 3* haben wesentlich mehr Knospen am Gipfeltrieb als gewöhnlich (8—11) und ihre Terminalknospe ist nur schwach ausgebildet. Bei einigen Fällen dieser Gruppe könnten auch gestauchte Johannistriebe zur Vielknospigkeit geführt haben.

Die *Gruppe 4*, schließlich, enthält Kiefern mit deutlich ausgebildeten Johannistrieben, ohne daß bereits Vielgipfeligkeit zu erkennen wäre.

[1]) Herrn Professor Dr. W. LANGNER danke ich für die Erlaubnis zur Veröffentlichung der an seinem Institut gewonnenen Ergebnisse.

[2]) Die Begriffe „Johannistrieb" und "Prolepsis" werden synonym gebraucht (BÜSGEN 1917).

Von den drei Gruppen mit Verzweigungsanomalien steht demnach lediglich für die Gruppe 4 eine alleinige Ursache (Johannistriebbildung) fest. Für die Anomalien in der Gruppe 3 können mindestens zwei, für die der Gruppe 2 sogar noch mehr Ursachen verantwortlich sein.

Die folgende Aufstellung enthält eine Zusammenfassung der Befallsbonitierungen für einjährige und zweijährige Nadeln zu vier Bonitierungszeitpunkten. Die statistische Sicherung bezieht sich auf die Befallsdifferenzen zur Gruppe 1:

Befallsstärke am	Gruppe I (Normale)	II (Vielgipfel.)	III (Vielknosp.)	IV (Proleps.)
28. 6. 1960	6,27	5,84*	6,13	5,64**
26. 7. 1961	9,16	8,55	9,02	7,74**
30. 10. 1961	16,37	16,26	16,54	15,08*
20. 8. 1962	13,56	13,87	13,69	12,95

Es tritt klar hervor, daß sich die Kiefern mit Johannistrieben (Gruppe 4) durch signifikant geringeren Befall von den normalen Pflanzen der Gruppe 1 abheben. Die deutlichsten Differenzen herrschen im Juli des zweiten Befallsjahres. Ende Oktober des gleichen Jahres sind die Unterschiede bereits geringer und im August 1962 sind sie nicht mehr zu sichern.

Diese Tendenz tritt in schwächeren Befallsjahren stärker bei den zweijährigen als bei den einjährigen Nadeln und stärker in den unteren als in den oberen Regionen hervor. Bei starkem allgemeinem Befall verlagert sich die Differenzierung hingegen auf die jüngeren und höher inserierten Nadeln.

Darüber hinaus sind in allen drei Untersuchungsjahren gesicherte Befallsunterschiede zwischen den Gruppen 3 und 4 festzustellen. Offenbar werden vielknospige und normale Kiefern gleich stark befallen, während vielgipfelige (Gruppe 2) durch etwas geringeren und proleptische Pflanzen (Gruppe 4) durch deutlich geringeren Befall hervortreten. Eine Erklärung dafür bietet vielleicht der unterschiedliche Anteil proleptischer Pflanzen in den einzelnen Gruppen; denn Gruppe 4 hat ausschließlich, Gruppe 2 einige, Gruppe 3 wenige und Gruppe 1 keine Johannistriebbildungen.

Zumindest für die beiden ersten Befallsjahre ist aus diesen Resultaten eine Verbindung zwischen Prolepsis und Befallsstärke in dem Sinne zu erkennen, daß Kiefern mit Johannistrieben signifikant weniger befallen werden als nor-