POLLINATION STUDIES AND YIELD TESTS

WITH

THE CASTOR PLANT, *RICINUS COMMUNIS*, LINN.

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By

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INTRODUCTION

The seed from which castor oil is extracted comes from the castor plant, *Ricinus communis* Linn., (Fig. 1) which is a perennial, monoecious non-legume and is native of Africa or India. In Oklahoma and in other parts of the United States subject to freezing temperatures, it behaves as an annual. The plant has large, alternate, palmately-lobed leaves, grows 4 to 8 feet high, and once flowering commences, continues to produce spikes until frost. The flowers are unisexual and are grouped on an elongated axis, the pistillate florets being borne at the top of the inflorescence, the staminate florets below (Fig. 2).

During the last decade of the nineteenth century, castor seed was produced commercially in Oklahoma, but competition from petroleum products and seed from foreign sources eliminated them except for brief periods during World War I and World War II. Castor seed is produced for commercial purposes in India and Brazil, but due to these sources being undependable, extracting companies in America desire a stable supply in this country.

Castor oil is used in the manufacture of hydraulic fluids, plastics, artificial leather, linoleum, oil cloth, nylon, soap, emulsion breakers, inks, perfume aromatics, toilet creams, hair dressings, medicinal oils, leather preservatives, rubber substitutes, and hydrated oil for paints and varnishes. Extracts from the leaves and stems have insecticidal value and the stems are a source of pulp and cellulose for use in the manufacture of cardboard, newsprint and other paper materials. Increasing uses of the oil are being developed.

The present castor plant varieties require at least 160 days growing season and 15 inches of rainfall during that period. In areas of higher rainfall which have long periods of high humidity, the plant is attacked by gray mold, Sclerotinia ricini Godfrey, which destroys the inflorescence (2).[1] Alternaria ricini (Yoshii) Hansford, attacks the inflorescences and capsules in all areas although less frequently in areas of low rainfall and low humidity (2). Castor plants cannot be grown on soil infested by Texas root rot, Phymatotrichum omnivorum (2).

It has been found that the castor plant grows best and produces a maximum of disease-free seed in the central section of the United States where the average annual rainfall ranges from 15 to 35 inches and high humidity periods are short. This region includes Oklahoma, Kansas, Arkansas, Missouri, northern Texas and Mississippi, western Kentucky and Tennessee, southern Illinois, and southeastern Nebraska.

At the present time, the crop must be hand-harvested as the type of plant of the adapted varieties does not lend itself to efficient machine harvesting.

The problem of the plant breeder is to develop higher yielding varieties that can be machine-harvested. To accomplish this task, it is essential that a careful study of the growth habits and breeding behavior of this crop be made. In solving this problem, a knowledge of the pollination habits of the plant and the effect of temperature, humidity, and wind on pollination are of prime importance.

The objectives of this investigation were to determine the time of day of pollination, the number of days that the staminate florets shed pollen, the relative amounts of pollen dispersed in the air at various distances from their source, and the relative yields of several of the better strains of castor plants under conditions at Stillwater, Oklahoma.

/1 Figures in parenthesis refer to "Literature Cited", p. 32.

Fig. 1.--Castor plants growing on the Oklahoma Experiment Station, Stillwater, Oklahoma, 1947.

Fig. 2.--A close view of a spike and two young spikes of the castor plant.

REVIEW OF LITERATURE

Jones and Newell (3) give a comprehensive review of literature concerning pollination cycles, mostly with grasses. They report that temperature has a decided influence on the time of day of blooming. Fewer florets bloom when the temperature is lower than the minimum for complete blooming, and a lower temperature delays blooming for several hours or even until another day. Also, blooming is delayed by fog, heavy dew, rain, and high humidity. Shading delays the time of blooming, but if there is sufficient heat, a cloudy sky has no noticeable effect. Weather conditions of the previous day also have an influence on the time of the first blooming and the most frequent blooming during the day.

Sando, according to Vinall and Hein (10), and Stephens and Quinby (6) agree that relative humidity does not influence the time of blooming.

Jones and Newell (3) state that when the meteorological conditions were optimum for blooming, the daily pollination periods occurred regularly at the same time of day for each grass throughout its seasonal pollination cycle. It seemed to them that the time of day of blooming of grass florets is the result of the interaction of inherent and external factors.

White (12) observed at the Brooklyn Botanical Gardens, that male flowers of the castor plant usually mature and shed pollen in early morning and Peat (4), working in the British West Indies, indicated that the female florets open in the morning.

Putt (5), in 1939, exposed sets of 8 microscope slides vertically and horizontally at 4 elevations in a sunflower nursery and in 2 blocks of grasses that were known to be wind pollinated as a means of comparing the relative amounts of pollen dispersed in the air by these crops. The sunflower pollen was frequently found in clumps of 5 or more grains, a fact that indicated to Putt that it was not normally wind-borne.

White (12), working at the Brooklyn Botanical Gardens, observed that progenies of castor plants of different varieties grown close together indicated very little cross-fertilization, "probably not more than 5%, even under the most favorable conditions." He attributed this to an abundance of the plant's own pollen near the female flowers, and the sheltering effect of the foliage against air currents bearing foreign pollen.

In contrast, under conditions in Illinois, Domingo (1) found 36% crossing between adjacent plants in the same row and between plants in adjoining rows. This difference could be the result of a greater air movement in Illinois (11).

An isolation distance of 7.33 rods was found by Peat (4) to be sufficient to prevent crossing in the British West Indies, while Weibel and Woodworth (11) at Illinois, state that plantings separated by as little as 10 rods showed no evidence of out-crossing.

Jones and Newell (3) studied the amount and distance of pollen dispersal under field conditions for 7 species of cross-pollinated forage grasses and cereal crops by means of microscope slides exposed at heights of 2.5, 5.0, and 10.0 feet in the center of the field and at distances of 5, 15, 25, 40, and 60 rods from the field. The dispersal of the pollen of all the grasses followed approximately the same general trend. Gravity and dispersion decreased the pollen load as it was blown from the field. It appeared that at 25 rods from the field considerable quantities of pollen remained dispersed in the air. The amount of pollen was not reduced to small quantities until 40 rods were reached. At 60 rods, they caught about 1% as much pollen as was caught at the field source. One per cent of pollen would be sufficient to effect considerable fertilization in the absence of competition, but when considered as a contaminant, the odds are approximately 100 to 1 in favor of a field's own pollen (3). The data from their investigations suggested to them that an isolation distance of 60 rods or greater would give better chances of maintaining genetic identity than lesser distances.

Only 4 of the varieties and selections in these experiments have been tested before. They are Conner, Doughty 11, and U.S. 4 from which strains number 71 and number 93 were selected.

The results of the first cooperative regional castor plant tests (7), conducted by stations in 16 midwestern, southern, and southwestern states in 1941, showed that Doughty had the highest yield in 18 of 38 tests while Conner was superior in 16 of 61, and U.S. 4 in 9 of 53. Fifty varieties and selections were grown in 63 separate tests by these stations. In many instances, the Conner stands were poor because of low seed viability and weak seedlings. These 3 varieties yielded well in all tests, U.S. 4 being second in 16, Doughty second in 7, and Conner second in 9.

In Oklahoma, where 7 varieties were tested in 1941 (7), yields of Doughty exceeded those of Conner in 7 of 12 tests with both having about the same yield at Cherokee. One of the 3 varieties was highest in each test, Doughty having the top yield in 5, Conner in 4, and U.S. 4 in 3. U.S. 4 had the second highest yield in 4 tests, and Doughty in 3. Conner and U.S. 4 were each lowest in 1 of the 12 tests, but Doughty never ranked below fifth.

Six varieties, Conner, Doughty, U.S. 4, U.S. 7, Kentucky 38, and Kansas Common, were tested at 61 locations throughout the southern half of the United States in 1942 (8). The mean yield of Conner was 941 pounds of hulled seed per acre; of U.S. 4, 936 pounds; and of Doughty, 829 pounds. The mean yield of Conner was either the highest or within range of error (5% level) of the highest at 42 stations; U.S. 4 at 36; and Doughty at 25.

The 1942 experiments in Oklahoma (8) showed that Conner was significantly higher in yield (5% level) than Doughty at Watonga and Stillwater, and higher than U.S. 4 at Watonga. At Ardmore, there was no significant difference between U.S. 4 and Doughty but both had significantly higher yields than Conner. The yields of U.S. 4 and Conner were practically the same at Stillwater and the 3 varieties showed no significant differences at Lawton.

In 48% of the cooperative regional tests in which it occurred in 1943 (9), Conner yielded either highest or within the 5% range of error of the highest while Doughty was in this position in 31% of the experiments. At Stillwater, Conner had a significantly higher yield in 1 of 3 tests. U.S. 4 was not tested in 1943.

At Beltsville, Maryland, yields of selections number 71 and number 93 exceeded those of Conner. /2

MATERIALS AND METHODS

Studies of the time of day, number of days of pollen shedding, and pollen dispersal were conducted at the Oklahoma Experiment Station, Stillwater, Oklahoma in 1947 and 1948.

To determine the time of pollination, microscope slides with approximately 1 square inch coated with vaseline were exposed in the center of the castor plant field at heights of 2 and 5 feet during early June when the plants were approximately 2 feet high. The slides were placed in holders that were attached to weather vanes at an angle of 45 degrees (Fig. 3). Exposure of the slides by this method kept them turned into the wind and at

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/2 Personal correspondence, May, 1947, with Dr. W. E. Domingo, Agronomist, Baker Castor Oil Company.

an angle that would catch pollen whether blown through the air or falling as a result of gravity. Observation of the staminate flowers and of slides exposed for periods of 5 to 6 hours revealed that no appreciable shedding of pollen occurred between 9:00 p.m. and 4:00 a.m. After determining the general time of day when pollen was shed and after uniform pollination commenced, an intensive study was made for 4 days. The slides were exposed for 30-minute periods throughout the day between 4:00 a.m. and 9:00 p.m. After 9:00 p.m., slides were left exposed until the following day so that counts could be made for 24-hour periods. Each slide was labeled as to date and time, and kept in a slide box until they could be examined. The total number of pollen grains observed on 20 random low-power microscope fields (41.22 sq. mm. area) on each slide was converted to number per square inch and the average for the 2 heights of collection was used in these investigations as a measure of the amount of pollen shed. Temperature and humidity for all the pollination studies were recorded by means of a hygro-thermograph. The average wind velocity was obtained by observing an anemometer and general light intensity was determined by visual observation.

Castor pollen was easily distinguished from pollen of other families of plants, dust particles, and rust spores which were the main contaminants. No information describing pollen of castor plants or related plants could be found. Pure pollen was collected and studied under the microscope so that positive identification could be made during the study. The pollen grains of the castor plant are ovoid in shape and average 0.38 mm. long and 0.23 mm. wide. They have a smooth yellow to yellow-green exine with an indentation running lengthwise of the pollen (Fig. 4).

Fig. 3.--A weather vane used in the pollination studies with microscope slide holder attached.

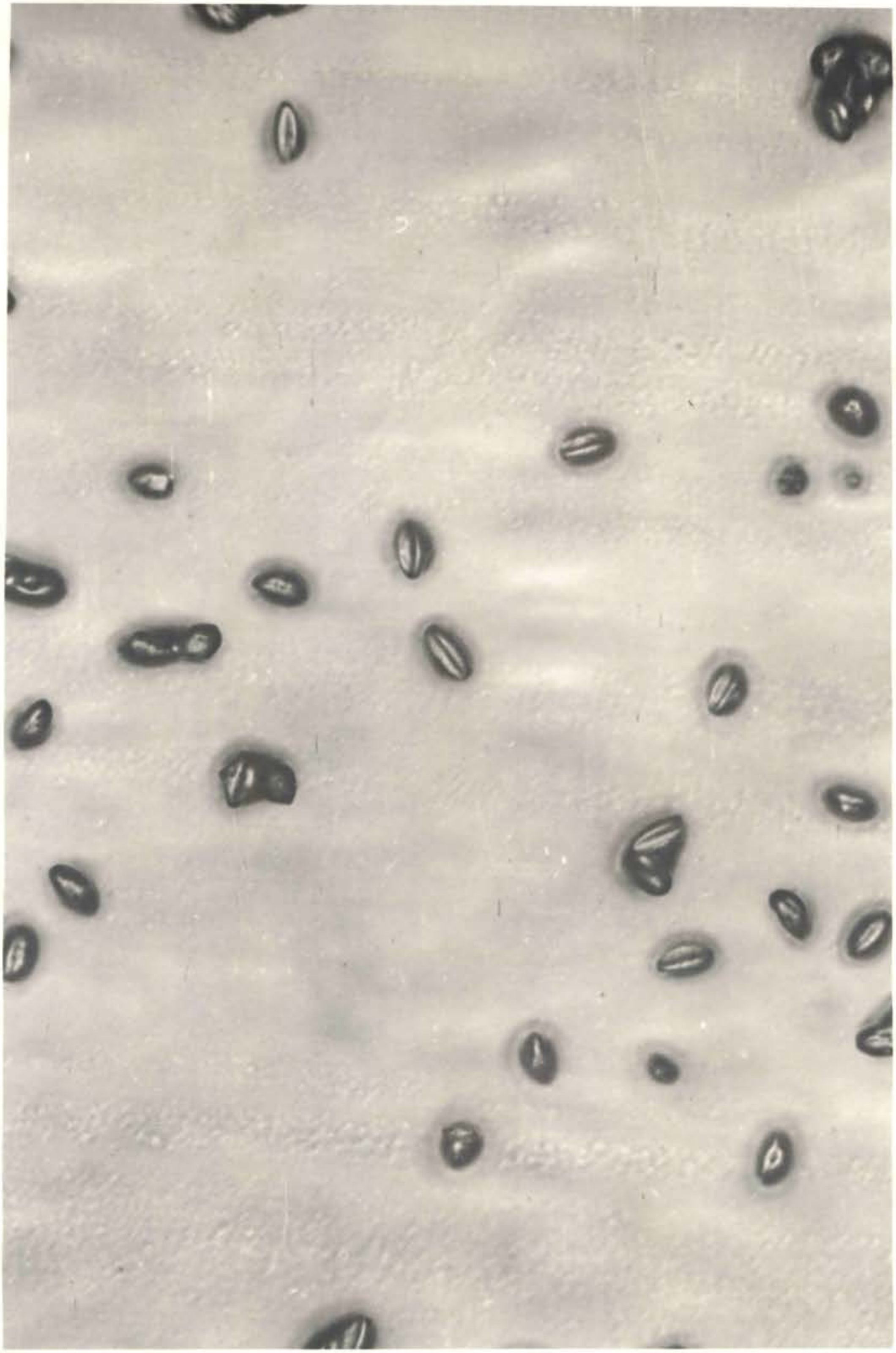

Fig. 4.--Pollen grains of the castor plant (greatly enlarged).

For the pollen dispersal study, slides coated with vaseline were exposed during 6 days of active, uniform pollination. The slides were exposed at 2, 5, and 10 feet in the same manner as in the time of pollination study and then collected and labeled as to distance and direction from the field and height of exposure. Points about the field where slides were exposed are designated as stations. Stations were set up at distances of 5, 15, 25, 40, and 60 rods to the north, northeast, and northwest of the field and 1 station was located in the center of the field as a check. Check stations were also located 5 rods to the east, west, and south and also at 15 to the south of the field, but the slides were exposed at heights of 2 and 5 feet only. The slides were exposed to the north of the field since the prevailing winds are from the south.

The length of time that the staminate flowers of a single castor plant inflorescence shed pollen was obtained by tagging a number of inflorescences of selection number 227 on the day that the first staminate flower began to shed pollen. The inflorescences were examined daily until all the flowers had shed. Twenty-one inflorescences were tagged in 1947 and 25 in 1948. Also, the number of staminate flowers on each raceme was counted in 1948.

Two castor seed yield tests were conducted at the Oklahoma Experiment Station, Stillwater, Oklahoma in 1947.

One test was conducted on bottom land having Yahola clay soil (Fig. 5). The plot consisted of 3 replications, 50 feet long. Eight selections, B-211, B-221, B-222, number 71, number 93, Wieman, Brawley Conner, and Maryland Conner, were randomly assigned in each replication.

Fig. 5.--A general view of one of the castor plant variety tests from which yield data were obtained.

Selections B-211 and B-221 were harvested from outstanding plants found growing as ornamentals in California. The seed of selection B-222 was imported from Mexico and represents some of their best material. Lots number 71 and number 93 are pure-breeding selections from U.S. 4. They are low-growing plants having many small spikes. Wieman was developed by a rancher in the Imperial Valley of California where it seems to do well. Maryland Conner is seed of Conner that was produced in Maryland. Seed of Brawley Conner was obtained from plants grown in the Imperial Valley from Maryland Conner seed.

Two replications were planted May 28 and the third, May 29. The seed was planted in 42 inch rows with the hills spaced 2 feet apart. Due to a limited quantity of seed, selections B-211, B-221, and B-222 were planted in a single row per replication while the other varieties were planted in 2 rows per replication. After the plants became well established, each hill was thinned to 1 plant. Wieman was used for border in each replication.

The second experiment was conducted on an upland plot having Kirkland silt loam soil. Five varieties, Conner, Wieman, Doughty 11, number 71, and number 93, were assigned randomly in each of 5 replications. Each variety was planted in two 42 inch rows, 10 hills per row, 2 feet apart in each replication. Three seeds were planted in each hill and later thinned to 1 plant. Normal cultural methods were used as needed in these 2 tests.

All rows in both experiments were harvested after frost by stripping the capsules off the spikes by hand (Fig. 2). The capsules were allowed to dry and then hulled with a hand-huller. The seed was cleaned to remove the hulls and immature kernels. The clean, mature seed was weighed in grams per plot and the weights converted to pounds per acre for the analysis of variance.

RESULTS AND DISCUSSION

Time of Day of Pollen Shedding

Preliminary studies with the castor plant had shown that it was advisable to begin exposure of the slides at 4:00 a.m. to get a complete picture of the time of day of pollen shedding. The staminate flowers were observed to begin opening the evening and night before the anthers dehised the following morning.

This study was made June 4, 8, 11, and 13, 1948. The relative humidity was approximately 100% until 6:30 a.m. on the last 3 days while on June 4, it remained above 80% until that time. There was a sharp drop in the relative humidity each morning immediately after it had reached its peak. Pollen shedding began 0.5 to 1.5 hours (7:00 - 8:00 a.m.) after the humidity had reached its peak, the humidity being approximately 70% on 3 of the 4 mornings. On June 8, the second day of the study, evidence of shedding was found when the humidity was 94%. The shedding peak was found to occur at approximately 60% on 3 of the 4 days, June 11 being the day that the peak was reached at a low relative humidity of 30%. The main pollinating period ended at a humidity of about 40% on 3 of the 4 days. After much fluctuation, the period on June 11 ended at 25%.

Each day this study was conducted, shedding began at a temperature near 75° F. and the main peak was attained between 80 and 86° with it ending around 90°.

The time of peak pollination was between 9:00 and 9:30 a.m. on 2 of the days. One day, it was 1 hour later due, perhaps, to a low temperature of 60 degrees early that morning. This was the lowest temperature recorded during the study. The first day, a peak was reached between 8:00 and

8:30 a.m. and a second peak was reached between 10:30 and 11:00 a.m.

Light intensity seemed to have no apparent bearing on pollen shedding. The first day and the last day were clear while 2 days were partly cloudy.

No doubt, the wind had some influence on the time that part of the pollen was shed. On June 4 between 4:00 a.m. and 12:30 p.m., the wind velocity averaged 10.5 miles per hour. Practically all of the pollen was shed during this period. The wind diminished during the afternoon, but between 5:00 and 7:00 p.m., it rose to an average velocity of 12 miles per hour. This may account for the abrupt rise in shedding between 5:30 and 6:30 p.m. on that date. A strong wind for a short period of time at 3:45 p.m. on June 8, appeared to have caused the peak that occurred at that time. During the last 2 days of the study, the wind was of moderate velocity with no irregularities occurring.

The overall picture, shown in Table 1 and illustrated in Figure 6, indicates that in general, pollination began about 7:30 a.m., reached its peak at 9:30 a.m., and fluctuated moderately from 11:00 a.m. until 8:00 p.m.

Table 1.—The average number of pollen grains caught on 1 square-inch areas of microscope slides exposed in the center of a castor plant field at heights of 2 and 5 feet during 30-minute periods of the day in 1948.

Time of Day	Number of pollen grains per square inch				
	June 4	June 8	June 11	June 13	Average
4:00- 4:30 am	8	0	0	0	2
4:30- 5:00	0	0	0	0	0
5:00- 5:30	0	0	0	0	0
5:30- 6:00	0	8	0	0	2
6:00- 6:30	0	0	0	0	0
6:30- 7:00	0	0	0	0	0
7:00- 7:30	8	16	0	0	6
7:30- 8:00	24	24	8	56	28
8:00- 8:30	72	24	64	88	62
8:30- 9:00	56	56	16	88	54
9:00- 9:30	40	128	24	104	74
9:30-10:00	8	32	24	32	24
10:00-10:30	24	8	128	16	44
10:30-11:00	72	24	8	24	32
11:00-11:30	16	16	32	16	20
11:30-12:00	0	16	0	16	8
12:00-12:30 pm	8	0	24	32	16
12:30- 1:00	0	0	64	16	20
1:00- 1:30	0	0	0	8	2
1:30- 2:00	0	0	0	40	10
2:00- 2:30	0	8	0	40	12
2:30- 3:00	0	16	16	0	8
3:00- 3:30	0	8	0	0	2
3:30- 4:00	0	64	8	8	20
4:00- 4:30	0	8	8	0	4
4:30- 5:00	0	0	0	8	2
5:00- 5:30	0	8	0	0	2
5:30- 6:00	16	8	16	0	10
6:00- 6:30	16	0	0	0	4
6:30- 7:00	0	0	0	0	0
7:00- 7:30	0	0	24	0	6
7:30- 8:00	0	0	0	0	0
8:00- 8:30	0	0	0	0	0
8:30- 9:00	0	0	0	0	0
Total	368	464	464	592	474

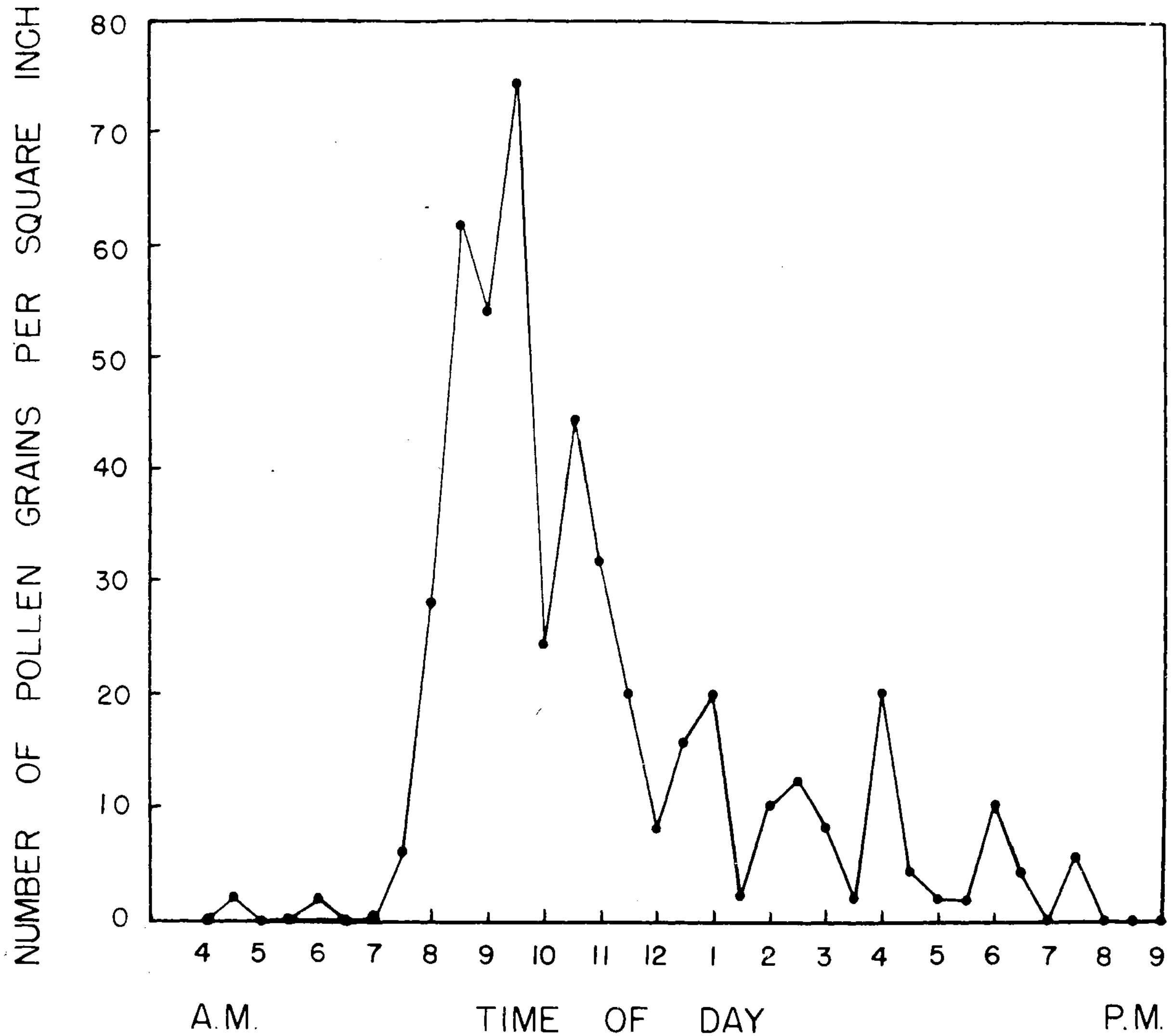

Fig. 6.--The average number of pollen grains caught on 1 sq. inch areas of microscope slides in the center of a castor plant field during 30-minute periods for 4 days in 1948.

Pollen Dispersal

The data obtained from the pollen dispersal study are shown in Table 2. The average number of pollen grains caught daily for 6 days at the 3 heights, 2.0, 5.0, and 10.0 feet, in the center of the field was 387 per square inch. Using 387 as 100%, the 81 pollen grains caught 5 rods north of the field represent 21% of the pollen dispersed. An average of 31 grains at 15 rods was 8% while 4% was caught at 25 rods and 2% at 40 rods. The 5 grains caught per square inch at 60 rods were approximately 1% of the number caught in the center of the field. These data are presented graphically in Figure 7.

South winds prevailed during the study so that the greatest amount of pollen was caught at all heights on the slides exposed to the north of the field. Pollen was found on the slides exposed northeast and northwest of the field which was probably due to eddies and shifts of the wind characteristic of this region. A tendency for the wind to shift to the southwest resulted in more pollen being dispersed to the northeast than to the northwest. This may also account for the similarity in amount of dispersal to the east and northeast at 5 rods. No pollen was found on the slides exposed 60 rods northeast and northwest, and only a small amount at 60 rods north of the field. There was a rapid drop in the average number of pollen grains at all station heights as the distance from the field increased which indicates that castor pollen may be classed among the heavier types of pollen found in various species of plants. The slides exposed at 5 and 15 rods south of the field were found to be free of pollen. The quantity of pollen dispersed by the castor plant is small when compared with most grasses. The amount of pollen that falls in the immediate area of the plant was not determined but considering the 805 grains caught at the same height as the plant, it would seem to be large. These facts suggest that an isolation distance of 60 rods in all directions is sufficient to prevent contamination in a breeding plot when its own pollen is present.

Some vertical dispersion was indicated by there being about the same amount of pollen at all heights as the distance from the field increased. Near the field more pollen was caught at 2 feet which was the approximate height of the plants.

Table 2.—Average daily number of pollen grains caught on 1 square inch areas of microscope slides exposed at various elevations and distances from the castor plant field on 6 days during June, 1948.

Distance (rods) and direction from the field	Elevation (ft.) 2.0	5.0	10.0	Average
Center	805	280	75	387
5 N	107	80	56	81
NE	21	37	40	33
NW	5	8	0	4
Average	44	42	32	39
W	8	0	—	4
E	29	48	—	38
S	0	0	—	0
15 N	37	27	29	31
NE	8	24	24	19
NW	5	3	11	6
Average	17	18	21	19
S	0	0	—	0
25 N	24	13	11	16
NE	3	3	0	2
NW	5	8	8	7
Average	11	8	6	8
40 N	5	13	3	7
NE	3	3	3	3
NW	0	0	0	0
Average	3	5	2	3
60 N	3	3	8	5
NE	0	0	0	0
NW	0	0	0	0
Average	1	1	3	2

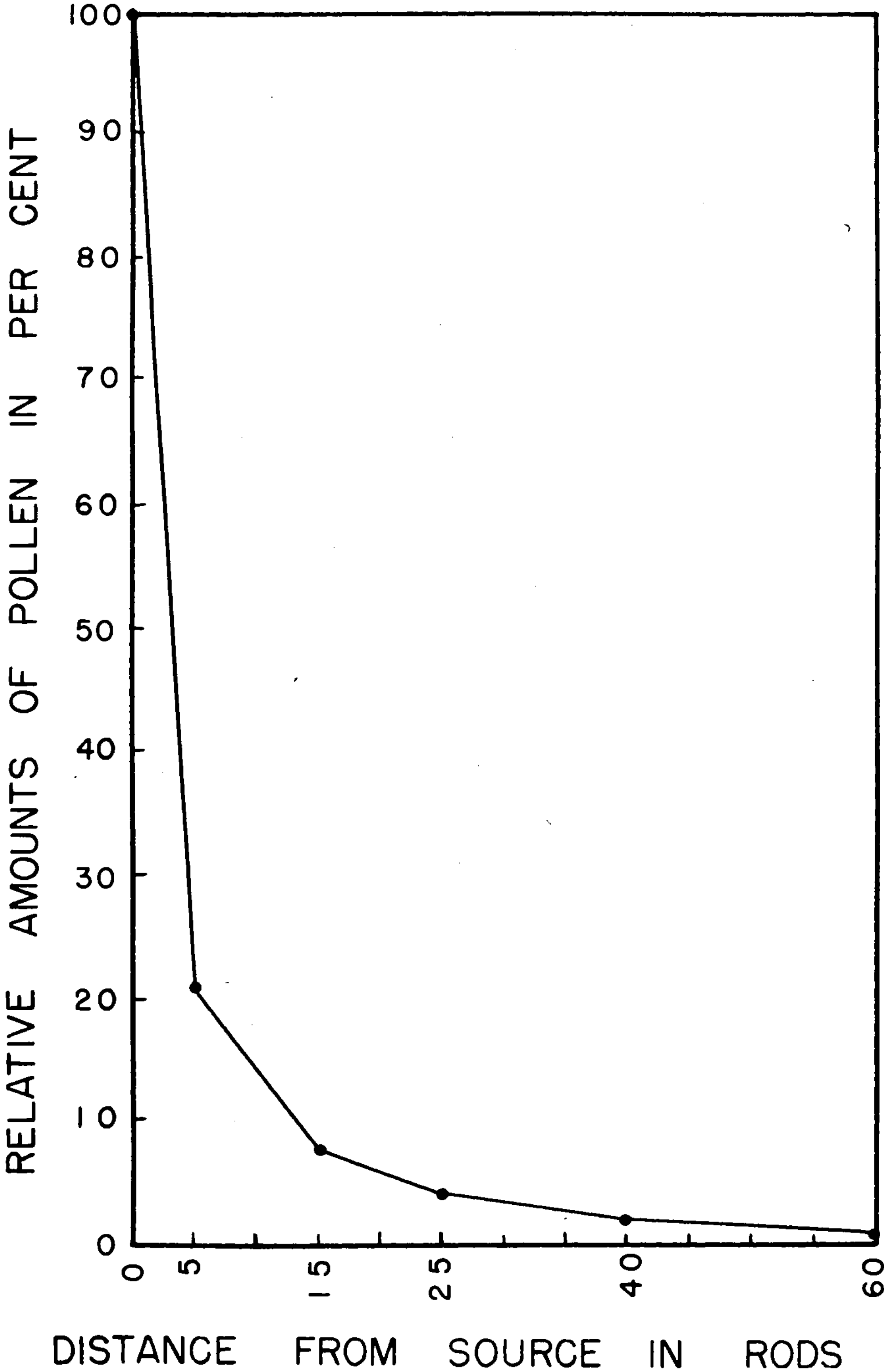

Fig. 7.—The relative amounts of pollen at various distances from the field in the direction of greatest concentration (north). Calculations are based on a 6 day average of pollen dissemination in 1948.

Length of Time the Staminate Flowers on a Spike Shed Pollen

The castor plants begin to produce inflorescences at approximately the eighth node and continue to produce them until frost. The data (Table 3) obtained in August, 1947 show the number of days that a single inflorescence sheds pollen to vary from 13 to 18. The temperatures during this study were high and the relative humidities were low. The average number of days that the 21 racemes studied in 1947 shed pollen was 15.67 with a standard deviation of 1.46. The fiducial interval that a raceme was found to shed pollen was 14.70 to 16.64 days (1% level).

The data obtained in 1948 are given in Table 4. The temperature during this time varied from the low 70's F. during the night to the low 90's during the day. The relative humidity was approximately 100% during the early morning hours, gradually declining to 20-30% during the afternoon. The last 3 days of the study were rainy and very little pollination occurred. The 25 inflorescences studied in 1948 shed pollen for an average of 16.32 days with a standard deviation of 1.93. The number of days varied from 14 to 21. A fiducial interval of 15.24 to 17.40 days (1% level) was obtained.

To determine the relationship of the number of staminate flowers and the length of time a raceme sheds pollen, a correlation was calculated. The data for this study are shown in Table 10 (Appendix). The number of flowers varied from 33 which required 18 days to complete blooming to 68 that needed only 14 days to finish blooming. A correlation figure of -0.18 was obtained. This suggests that there is no relationship between the number of staminate flowers and the length of time of blooming.

Table 3.—The number of days required for a single castor plant inflorescence to completely shed its pollen, 1947.

Inflorescence number	Date shedding commenced	Date shedding ceased	Number of days (X)
1	August 15	August 29	14
2	August 13	August 31	18
3	August 15	August 29	14
4	August 14	August 28	14
5	August 14	August 29	15
6	August 14	August 30	16
7	August 13	August 29	16
8	August 13	August 30	17
9	August 14	Sept. 1	18
10	August 14	August 31	17
11	August 13	August 31	18
12	August 13	August 28	15
13	August 13	August 28	15
14	August 13	August 28	15
15	August 14	August 31	17
16	August 14	August 28	14
17	August 13	August 26	13
18	August 13	August 29	16
19	August 14	August 30	16
20	August 13	August 29	16
21	August 14	August 29	15
Total			329
Mean			15.67

Standard deviation = 1.46

Standard deviation of the mean = 0.3395

Estimate of the mean (1% level) = $\bar{x} \pm {}_{.01}t_{20}\, s_{\bar{x}}$ = 15.67 ± 0.9659

Fiducial interval (1% level): 14.70 to 16.64 days

Table 4.—The number of days required for a single castor plant inflorescence to completely shed its pollen, 1948.

Inflorescence number	Date shedding commenced	Date shedding ceased	Number of days (x)
1	June 5	June 22	17
2	June 4	June 21	17
3	June 5	June 22	17
4	June 5	June 21	16
5	June 4	June 18	14
6	June 5	June 21	16
7	June 4	June 19	15
8	June 4	June 18	14
9	June 5	June 19	14
10	June 3	June 20	17
11	June 4	June 22	18
12	June 4	June 20	16
13	June 5	June 20	15
14	June 5	June 19	14
15	June 5	June 20	15
16	June 5	June 19	14
17	June 5	June 20	15
18	June 5	June 19	14
19	June 5	June 22	17
20	June 5	June 23	18
21	June 5	June 23	18
22	June 5	June 23	18
23	June 5	June 24	19
24	June 5	June 24	19
25	June 5	June 26	21
Total			408
Mean			16.32

Standard deviation : 1.93.

Standard deviation of the mean : 0.3860.

Estimate of the mean (1% level) : $\bar{x} \pm {}_{.01}t_{24}\ s_{\bar{x}}$: 16.32 ± 1.0796.

Fiducial interval (1% level): 15.24 to 17.40 days.

Variety Yield Tests

The yields in pounds per acre for the 5 varieties of castor plants grown on upland are shown in Table 8 (Appendix). Number 71 had the highest yield with 897.5 pounds and number 93 was second with 753.2. Wieman produced 409.3 pounds, the lowest of the 5 varieties.

An analysis of variance was calculated on the seed yields (Table 5). No significant difference among the replications were shown by the analysis indicating that the testing block was homogeneous.

The analysis showed a highly significant difference (1% level) among the 5 varieties. A significant mean difference of 255.1 pounds was calculated for the 1% level. This would seem to indicate that number 71, number 93 and Conner had significantly larger yields than Wieman, and numbers 71 and 93 had significantly higher yields than Doughty. These statements are supported by four orthogonal comparisons shown in Table 6. The first comparison, high yield versus low yield, showed 71 and 93 having highly significantly greater yields than the other 3. There was no difference between the yields of the 2 high varieties nor was there any between the yields of the 2 low varieties. There was, however, a significant difference at the 5% level between Conner yields and those of the 2 lower yielding varieties.

The yields of the 8 varieties and selections grown on bottomland are shown in Table 9 (Appendix). Again, 71 had the highest yield but the analysis of variance of this block (Table 7) indicated no significant differences among the varieties. The yields were much lower than expected due probably to late planting, tight soil, and droughty conditions during the growing season. The analysis showed the testing block to be uniform, contrary to its general appearance during the experiment.

Table 5.—An analysis of variance of the yields of 5 varieties of castor seed grown on upland at Stillwater, Oklahoma, 1947.

Source	D F	SS	MS	F
Replications	4	86 718.78	21679.69	1.1373
Varieties	4	706 887.28	176721.82	9.2706**
Error	16	305 000.23	19062.51	
Total	24	1 098 606.29		

Least significant difference - 255.1 pounds.

** Significant difference at the 1% level.

Table 6.—An orthogonal comparison of the yields of 5 castor plant varieties grown on upland at Stillwater, Oklahoma, 1947.

Comparison	Variety and Total Yield				
	#71 4487.73	#93 3766.21	Conner 3467.59	Doughty 2746.13	Wieman 2046.38
1. High vs. Low	+3	+3	-2	-2	-2
2. High vs. High	+1	-1			
3. Medium vs. Low			+2	-1	-1
4. Low vs. Low				+1	-1

Source	DF	SS	MS	F
Replications	4	86 718.78	21 679.69	1.1373
Varieties	4	706 887.28	176 721.82	
1	(1)	452 828.67	452 828.67	23.75**
2	(1)	52 059.11	52 059.11	2.73
3	(1)	153 034.49	153 034.49	8.03*
4	(1)	48 965.01	48 965.01	2.57
Error	16	305 000.23	19 062.51	
Total	24	1 098 606.29		

* Significant difference at the 5% level.

** Significant difference at the 1% level.

Table 7.—An analysis of variance of the yields of 8 varieties of castor seed grown on bottom land at Stillwater, Oklahoma, 1947.

Source	DF	SS	MS	F
Replications	2	11 019.16	5 509.58	0.3842
Varieties	7	221 431.65	31 633.09	2.2058
Error	14	200 767.71	14 340.55	
Total	23	433 218.52		

SUMMARY AND CONCLUSIONS

This investigation was conducted with the castor plant to determine the time of day of its pollination, the relative amounts of pollen dispersed in the air at various distances from their source, the number of days that the staminate florets shed pollen, and the relative yields of several of the better strains grown under conditions at Stillwater, Oklahoma.

The staminate flowers opened during the evening and night before the anthers dehised. Pollen shedding commenced 0.5 to 1.5 hours after the relative humidity had reached its peak, the humidity being approximately 70% on 3 of the 4 mornings and the temperature near 75° F. The shedding peak occurred at about 60% humidity on 3 of the 4 mornings and at a temperature between 80 and 86 degrees. The main pollinating period ended at a humidity of about 40% on 3 of the 4 days and at a temperature of approximately 90°. Pollination began about 7:30 a.m., reached its peak at 9:30 a.m., and fluctuated moderately from 11:00 a.m. until 8:00 p.m.

Based on the 387 pollen grains caught per square inch in the center of the castor plant field as 100%, 21% as much pollen was caught 5 rods north of the field; 8% at 15 rods, 4% at 25 rods, 2% at 40 rods north, and 1% at 60 rods. A rapid drop in the average number of pollen grains at all station heights indicates that castor pollen is heavy but some vertical dispersion is indicated. No pollen was found south of the field. An isolation distance of 60 rods in all directions appears to be sufficient to prevent contamination in a breeding plot when its own pollen is present.

The staminate flowers on a raceme shed pollen 15.67 ± 0.97 days (1% level) in August, 1947 and 16.30 ± 1.08 days (1% level) in June, 1948. A correlation coefficient of -0.18 was found between the number of staminate florets and the length of time required for the raceme to completely shed its pollen.

Varieties number 71 and number 93 had highly significantly greater yields than Conner, Doughty, and Wieman on upland. Conner yielded significantly better than Doughty and Wieman. The test on the bottomland plot showed no significant difference among the varieties.

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A P P E N D I X

Table 8.--Yields in pounds per acre of 5 varieties of castor seed grown on upland at Stillwater, Oklahoma, 1947.

Variety	Replications I	II	III	IV	V	Mean
Number 71	805.49	1128.93	817.93	933.00	802.38	897.55
Number 93	743.29	774.39	821.04	712.19	715.30	753.24
Conner	895.62	584.68	566.02	889.46	531.81	693.52
Doughty 11	475.83	525.59	653.10	677.98	413.63	549.23
Wieman	435.40	255.02	693.53	363.87	298.56	409.28

Table 9.—Yields in pounds per acre of 8 varieties of castor seed grown on bottom land at Stillwater, Oklahoma, 1947.

	Replications			
Variety	I	II	III	Mean
Number 71	291.91	560.78	58.71	303.80
Number 93	186.56	69.14	167.08	140.93
Brawley Conner	327.30	456.80	110.57	298.22
Maryland Conner	127.85	108.10	85.05	107.00
Wieman	68.31	110.29	327.85	168.81
B 211	105.90	24.69	82.86	71.15
B 221	87.25	21.40	65.85	58.17
B 222	32.37	30.73	68.59	43.90

Table 10.--A correlation of the number of staminate flowers and the length of time required for a raceme to completely shed its pollen, 1948.

Raceme number	Number of days X	Number of flowers Y	Deviations from the mean x	y	Deviations squared x^2	y^2	Product of deviations xy
1	14	54	-2.32	6.76	5.3824	45.6976	-15.6832
2	14	68	-2.32	20.76	5.3824	430.9776	-48.1632
3	14	47	-2.32	-0.24	5.3824	0.0576	0.5568
4	14	38	-2.32	-9.24	5.3824	85.3776	21.4368
5	14	63	-2.32	15.76	5.3824	248.3776	-36.5632
6	14	42	-2.32	-5.24	5.3824	27.4576	12.1568
7	15	37	-1.32	-10.24	1.7424	104.8576	13.5168
8	15	50	-1.32	2.76	1.7424	7.6176	-3.6432
9	15	48	-1.32	0.76	1.7424	0.5776	-1.0032
10	15	40	-1.32	-7.24	1.7424	52.4176	9.5568
11	16	53	-0.32	5.76	0.1024	33.1776	-1.8432
12	16	43	-0.32	-4.24	0.1024	17.9776	1.3568
13	16	56	-0.32	8.76	0.1024	76.7376	-2.8032
14	17	47	0.68	-0.24	0.4624	0.0576	-0.1632
15	17	35	0.68	-12.24	0.4624	149.8176	-8.3232
16	17	48	0.68	0.76	0.4624	0.5776	0.5168
17	17	55	0.68	7.76	0.4624	60.2176	5.2768
18	17	39	0.68	-8.24	0.4624	67.8976	-5.6032
19	18	40	1.68	-7.24	2.8224	52.4176	-12.1632
20	18	33	1.68	-14.24	2.8224	202.7776	-23.9232
21	18	45	1.68	-2.24	2.8224	5.0176	-3.7632
22	18	46	1.68	-1.24	2.8224	1.5376	-2.0832
23	19	56	2.68	8.76	7.1824	76.7376	23.4768
24	19	53	2.68	5.76	7.1824	33.1776	15.4368
25	21	45	4.68	-2.24	21.9024	5.0176	-10.4832
Total	408	1181	0.00	0.00	89.4400	1786.5600	-72.9200

r: -0.18

Typist: Mary Wallace Spohn