SUGAR-BEET POLLEN GERMINATION IN RELATION TO ENVIRONMENTAL CONDITIONS

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In the domestic production of sugar-beet seed, low viability has in certain years in one district or another presented a serious problem in this rather new enterprise. The low quality seed 1/ is characterized by a failure of embryo development. Field observations, together with consideration of weather records and anomalous environmental conditions, have not, in the absence of recognizable abnormalities in the floral structures, revealed the factors concerned in the interference with normal seed development.

In 1936, pollen germination tests with sugar beets at Fort Collins, Colorado, under rather hot, dry conditions showed that a large number of free-blooming plants produced pollen either very low in viability, or sterile 2/. These observations took on special significance when it was found that the seed crop in Colorado in that season had extremely low viability, the seed yields being, in general, below average. Since the data, although extensive, covered only a limited period, it seemed advisable to conduct further studies throughout a blooming season to determine general relation of pollen viability to seed quality.

EXPERIMENTAL WORK

Fall-planted sugar beets being grown for seed production in experimental plots at the New Mexico Agricultural Experiment Station were used. Fifty plants were chosen as they were coming into bloom, care being taken to select not only those that were growing vigorously but also small and stunted ones. Pollen was collected individually from the plants selected soon after the first flowers began to open, additional daily sampling being continued until the plants were nearly mature (April 26 to May 23). The duration of blooming period varied among the plants, the large plants usually having a longer season than the small ones. High winds which sometimes came up rather suddenly and scattered the pollen before all samplings of a given day were completed, are responsible for the occasional breaks in a series of observations.

In 1938 and 1939, similar tests were carried out but the pollen collections were made only during the height of the blooming period.

1/Sugar-beet seed, in commercial usage, refers to the nutlike fruits or fruit clusters that arise as the flowers mature. Commonly two or more flowers grow together at their bases and form a hard, irregular, dry glomerule or seed ball, the perianths hardening and drying down on the ovaries. The true seed is a small, shiny lentil-like structure with a curved embryo enclosing a perisperm. Development of the seed ball to normal size may proceed irrespective of fertilization. Seed balls low in vitality commonly show empty ovaries except for the brownish, dried-up integuments of the unfertilized ovules.

2/Unpublished data from tests conducted in cooperation with H. E. Brewbaker.

Viability tests were made by using artificial media, such as employed by the writer in earlier experiments 3/. It was found best to pour the Petri dishes just before use. Since the sugar concentration of the media was rather high (40%), the latter had to be handled while still hot in order to obtain a thin agar film. To prevent water condensation in the form of small droplets over the layer of agar, the dishes with the freshly poured agar were allowed to cool before the covers were applied. The prepared Petri dishes were taken to the field between 8:30 and 9:30 in the morning, depending upon temperature and wind conditions. Pollen samples were obtained by holding the open Petri dish beneath a branch of the seed bush and shaking the bush slightly. The exposed plates were kept at a temperature of approximately 30°C. There appears to be no well-defined temperature level for best germination. Pollen tubes develop almost as rapidly at summer room temperature as at the lower temperatures in the beet field during the blooming season. At temperatures above 30°C., there is always danger of the formation of water droplets from condensation on the concentrated sugar medium, with detrimental effects on the growing pollen tubes. The pollen was left to germinate until about 4:00 in the afternoon, when the plates were examined and the germination graded as follows: 0, no germination; 1, very poor germination; 2, poor germination; 3, fair germination; 4, good germination; 5, excellent germination.

The records for the germination tests, together with the climatological data for the sampling period, are summarized in table 1.

DISCUSSION

The daily pollen germination records for the entire group of plants and the seasonal, individual records deserve consideration. From the first-named approach, any correlations of pollen viability prevailing with climatic conditions should be revealed, as well as indicating the relative amount of fertile pollen available for open pollination of the flowers. The individual plant behavior should indicate both the amount and constancy of germination to be expected within the population, information of value in breeding and genetics investigations.

The daily germination record for 1937 shows that, with the exception of two days, there was no great variation, at least not important enough to affect materially the pollen supply for good seed setting. To be sure, the daily mean was almost always below the theoretical average, but this fact should have little practical significance because the amount of pollen produced is relatively large. The situation was somewhat different for May 13 and 18, for which the mean ratings were 0.56 and 0.11, respectively. If these ratings are accepted as typical for the field at large, the probability is that on these two days the pollen supply was not adequate. May 14 and 19, however, brought an ample supply of pollen; and since the stigma of the beet flower is believed to remain normally receptive for several days, the flowers that failed to pollinate on the days of poor pollen supply were pollinated on the succeeding day.

The mean daily germination record (table 1) for 1938 and especially for 1939 was much higher than for the preceding year, even if we allow for the fact that samples were taken mostly during the height of the blooming period.

3/Artschwager, E. and Starrett, R. C. The time factor in fertilization and embryo development in the sugar beet. Journ.Agr.Research 47:823-843. 1933.

The daily pollen supply was exceptionally good, and only a few cultures showed no germination.

A comparison of germination averages for individual selections in 1937 discloses an appreciable difference in performance. One plant gave an exceptionally low average of 0.94. Its seasonal record shows that on several days the pollen did not germinate at all; this would probably result in spotty seed setting under isolation. Under ordinary field conditions, failure on the part of a few individuals to produce viable pollen should not affect seed setting unless poor pollen production and low receptivity on the part of the stigma are associated phenomena. However, such a combination is probably rare, if found at all, since all the plants studied during the season of 1937 produced good seed. Relatively poor pollen was produced in 1937 by 8 out of 50 plants. The daily germination ratings for these were consistently low, although there was some viable pollen in all Petri-dish cultures, except on occasional days. On days when the performance of the high-and medium-rating individuals was above average, the poor pollen producers generally showed also a higher rating, indicating that the factors that influence pollen viability in general have a favorable effect on poor pollen producers. Five plants had a high-germination rating and one had a consistently high record, although its mean was slightly depressed because of the zero ratings for May 13 and 18.

The individual performance during 1938 and 1939 was much better than for the previous season and extremely low ratings were absent. Many plants showed a consistently high rating while a few were always low. It is evident that there is a range in capacity to produce viable pollen among individuals and that environmental conditions rather strongly influence the situation.

Studies of the plates showed that high-germination ratings commonly were associated with high-germination energy. With collections of this type, the pollen grains germinated almost immediately after being sown on the agar, and the pollen tubes were always very long. In certain of the plants selected, the pollen tubes frequently burst, a phenomenon that was found to be more pronounced on some days than on others. Bursting of emerging pollen tubes may be associated with some change in the osmotic concentration of the pollen grains for which the 40% sucrose agar employed in these test plates was no longer suitable. If pollen grains show the same differential reaction on the surface of the stigma, varieties in which this condition is pronounced must be grouped under poor or unreliable pollen producers unsuitable for inbreeding work.

Size of plant or vigor was apparently not associated with capacity for pollen production, since some small, stunted individuals produced pollen with as good a germination rating as tall, strong plants. On the other hand, pollen quality seemed to be a characteristic of the individual. This may be illustrated by contrasting two individuals of the 1937 series. These plants were adjacent in the field and both were unusually small. The mean germination rating of one was 2.88; for the other, 2.00.

The effect of irrigation on pollen viability is difficult to determine, for during the blooming season the fields are irrigated each week and the soil moisture is naturally not depleted. No consistent differences in daily germination ratings that might be attributed to irrigation effects were observed. From the data in table 1, it appears that for 1937 and 1938 high relative humidity of the air, within the limits shown for these tests, is not necessarily associated with poor pollen germination. Pollen viability and

morning humidity (8:00 a.m.) did not show significant correlation; pollen germination and evening humidity (8:00 p.m.) showed a small but significant positive correlation of 0.14.

No very definite correlations of pollen germination with environmental factors were found, nor could comparisons of behavior on selected days be used to indicate effects of specific climatic factors. For example, pollen germinations for May 13, 1937 were very poor (0.56); both temperature and relative humidity were average, but exceptionally strong winds prevailed. The weather on the preceding day was normal, with average wind movement. On May 17 and 18, 1937, the weather was also normal except for slightly elevated temperatures. The average pollen germination ratings for these two days were 2.63 and 0.11, respectively. The poor germinations on May 13 and 18 could not be assigned to any unusual weather conditions. In general, lower night temperatures, within the limits of the exposures given seemed to favor pollen germination, since pollen viability and night temperatures (minimum temperatures cf. table 1) show a correlation of 0.28, significant at 1 percent point.

The analysis of pollen germinations for 1937, 1938 and 1939 shows that daily fluctuations of the mean germination rating existed, as well as differences in individual performance. These three seasons were good seed years, the 1938 and 1939 crops being, in general, of better quality judging by average size of seed ball and smaller percentage of the crop rejected as screenings. The 1939 crop, although of fine quality, was light due to poor stand resulting from a heavy freeze early in November and again late in spring when development of seed stalks was well under way. During the blooming season the weather of these years was devoid of extremes. In 1937, the rainfall was less than normal and temperatures, on the whole, were favorable. Unusually high winds were limited to a few days. The weather in 1938 and 1939 just before the blooming season was favorable to the development of seed stalks. During blooming, untoward climatic conditions lasting any considerable period did not occur.

With the 1936 observations in mind, it seems that, although germination of sugar-beet pollen is subject to external influences, failure of pollination, which is to be attributed solely to poor pollen, is to be expected only if unusual conditions are continuous and prolonged. It is recognized that rain may affect pollen directly, causing it to burst, but under the conditions in New Mexico rainy periods are probably not of long enough duration to be a serious factor. From the 1937, 1938, and 1939 tests, it appears that, regardless of temporary fluctuations and poor performance of some individuals, there is always enough pollen in the air to assure pollination of opening flowers. The relatively long receptive period of the embryo sac, as demonstrated with emasculated flowers, would indicate that untoward effects on pollen would be remedied on succeeding days.

Unfavorable weather conditions may also produce ill effects on the female part of the flower. The egg cell is well protected and not very subject to injury by abnormal environmental conditions. The writer's experience in heat-treatment experiments in which, following differential heat exposures, the floral parts were examined cytologically showed that injuries to pollen mother-cells, the stigma, and integuments of the ovule near the micropyle occurred with high heat exposures 4/ had no apparent effect on the egg cell.

4/ Branches with flowers in all stages of development were immersed for five minutes in water at 43 C. and exposures for 15 minutes at 42° C. were used.

High winds associated with high temperatures were not shown to have detectable effects on pollen germination; on the other hand, such weather combinations could have ill effects on the stigmatic surface or more exposed parts of the pistil, bringing about such deterioration as would interfere with pollen germination, growth or penetration.

It probably will be found that the unusual climatic factors associated with low seed viability produce their ill effects on both pollen and pistil, the probabilities being that pistillate parts are frequently more decisively concerned than the pollen.

SUMMARY

Sugar-beet pollen germinates readily on an agar medium containing 40% sucrose and 1½% agar. Individual selections show great variation in seasonal performance, indicating that among beet plants there are good and poor pollen producers. Selections with a high germination rating usually have a high germination energy, giving rise to growing pollen tubes almost immediately after the pollen is sown on the culture medium. The daily germination record of all the individuals also shows variation but there is little correlation between environmental anomalies and germination behavior. Usually there is enough pollen available each day to effect fertilization of the opening flowers even if the germination average is below normal.

Poor pollen and poor seed setting may be associated phenomena if unfavorable weather which is known to reduce pollen viability, continues for several days; this holds true provided the receptivity period of the embryo sac is short, so that belated fertilization of flowers is unlikely. Often poor seed-setting is directly traceable to injury to the female part of the flower, especially the stigma which is sensitive to hot, windy weather. Good pollen germination throughout the season usually indicates a good seed crop, while consistently poor germination suggests the presence of some unknown environmental anomaly which prevents proper fertilization and seed setting through a harmful influence on the development of one or both essential parts of the flower, or of the young embryo in its initial stages of development.

Table 1. —Germination ratings and meteorological data by days, 1937-39.

Date	Number of Observations	Frequencies of Germination Ratings							Meteorological Data						
									Temperatures			Humidity			
		None 0	Very poor 1	Poor 2	Fair 3	Good 4	Very Good 5	Mean	Max.	Min.	Mean	8:00 AM	8:00 PM	Rain 1/	Wind total miles
1937															
April 26	10	-	1	7	2	-	-	2.1	82	41	61.5	31	16		120
27	10	-	1	6	2	1	-	2.3	79	42	60.5	12	12		297
28	5	-	1	-	2	2	-	3.0	72	42	57.0	36	25		232
29	12	-	3	1	4	3	1	2.58	72	38	55.0	22	21		188
30	28	1	6	11	8	2	-	2.14	72	36	54.0	34	22		142
May 1	23	-	4	5	9	4	1	2.69	76	32	54.0	33	20		96
2	-	-	-	-	-	-	-	-	83	41	62.0	36	25		133
3	29	-	1	7	15	6	-	2.89	77	45	61.0	48	33		262
4	30	1	4	6	11	7	1	2.73	77	53	65.0	50	34	+	270
5	29	1	2	7	10	6	3	2.93	79	57	68.0	42	32	+	257
6	39	2	11	9	10	6	1	2.23	81	50	65.5	75	29	-	184
7	38	1	17	9	4	6	1	2.00	84	45	64.5	62	25		93
8	39	3	3	6	9	14	4	3.00	89	44	66.5	43	21		98
9	40	3	13	14	5	5	-	1.90	82	51	66.5	46	39		183
10	49	1	9	11	12	15	1	2.69	82	49	65.5	49	21		126
11	50	-	3	18	11	15	3	2.94	85	38	61.6	30	16		140
12	50	-	2	13	22	13	-	2.92	89	43	66.0	45	17		122
13	50	39	1	5	3	2	-	.56	83	57	70.0	44	25		334
14	44	-	5	12	18	7	2	2.75	90	54	72.0	56	21		144
15	39	-	3	11	14	11	-	2.84	95	54	74.5	41	23		110
16	-	-	-	-	-	-	-	-	96	57	76.5	31	31		135
17	27	-	3	10	8	6	-	2.63	95	50	77.5	37	22		108
18	27	24	3	-	-	-	-	.11	93	63	78.0	37	33		151
19	25	-	-	6	11	8	-	3.08	90	55	72.5	55	27		128
20	11	-	-	2	9	-	-	2.82	90	51	70.5	41	19		103
21	21	-	-	3	5	10	3	3.62	90	46	68.0	41	17		94
22	10	-	-	1	5	4	-	3.30	86	51	68.5	31	24		329
23	11	-	-	2	6	3	-	3.10	82	65	73.5	74	46		228
Total	746	76	96	182	215	156	21								

1/ Too small for recording.

Table 1. (Con'td.)

Date		Number of Observations	Frequencies of Germination Ratings							Meteorological Data					
										Temperatures			Humidity		
			None 0	Very poor 1	Poor 2	Fair 3	Good 4	Very good 5	Mean	Max.	Min.	Mean	8:00 AM	8:00 PM	Rain 1/	Wind total miles
1938																
May	11	40	-	9	14	14	3	-	2.27	85	45	65.0	55	14		120
	12	40	1	5	11	17	3	3	2.62	86	42	64.0	61	20		110
	13	40	-	1	7	16	12	4	3.27	89	53	71.0	38	25		97
	14	40	-	-	8	14	10	8	3.45	93	50	71.5	32	21		191
	15	-	-	-	-	-	-	-	-	93	59	76.0	46	17		204
	16	40	-	2	6	16	12	4	3.25	87	62	74.5	27	21		150
	17	40	-	1	7	16	11	5	3.30	85	52	68.5	41	20		154
	18	40	-	1	15	12	9	3	2.95	79	62	70.5	42	68	+	157
	19	-	-	-	-	-	-	-	-	82	47	64.5	52	22		119
	20	38	-	-	6	13	16	3	3.42	89	44	66.5	39	20		120
	21	38	-	1	9	17	7	4	3.10	89	43	66.0	30	42	+	146
	22	-	-	-	-	-	-	-	-	82	53	67.5	38	18		205
	23	39	-	2	9	11	11	6	3.25	82	46	64.0	40	31		181
	24	43	-	-	4	17	13	9	3.63	86	63	74.5	42	21		193
	25	44	-	-	7	15	17	5	3.45	93	48	70.5	42	13		94
	26	-	-	-	-	-	-	-	-	93	55	74.0	34	17		109
	27	42	-	-	10	13	13	6	3.36	97	50	73.5	38	16		92
	28	44	-	1	11	15	14	3	3.16	94	53	73.5	27	18		135
	29	41	-	1	6	17	10	7	3.39	93	51	72.0	27	21		171
	30	42	-	-	14	21	7	-	2.83	92	45	68.5	42	17		139
	31	41	-	-	4	22	13	2	3.32	95	52	73.5	39	27		106
June	1	41	-	-	11	17	13	-	3.05	94	52	73.0	39	22		214
	2	38	-	2	8	19	5	4	3.03	97	65	81.0	41	21		350
	3	-	-	-	-	-	-	-	-	96	57	75.5	37	16		128
	4	-	-	-	-	-	-	-	-	92	62	77.0	44	54		153
	5	-	-	-	-	-	-	-	-	96	60	78.0	45	31		132
	6	24	-	2	2	14	5	1	3.04	98	65	81.5	41	23		147
Total		795	1	28	169	316	204	77								

1/ Too small for recording.

Table 1. (con'td)

Date	Number of Observations	Frequencies of Germination Ratings							Meteorological Data					
									Temperatures			Humidity		
		None 0	Very poor 1	Poor 2	Fair 3	Good 4	Very good 5	Mean	Max.	Min.	Mean	8:00 AM	8:00 PM	Rain 1/ Wind Total miles
1939														
May 8	9	-	-	4	4	1	-	2.66	85	51	68	27	12	110
9	48	-	8	12	14	8	6	2.83	89	43	66	29	12	93
10	48	2	13	11	8	4	10	2.60	90	44	67	32	12	102
11	50	1	4	8	8	11	18	3.78	86	48	67	33	14	125
12	50	1	7	7	11	13	11	3.22	85	45	65	25	14	44
13	50	-	5	10	18	13	4	3.02	72	52	62	52	35	180
14	-	-	-	-	-	-	-	-	80	47	64	63	27	170
15	50	-	-	4	8	18	20	4.08	83	52	68	48	18	135
16	50	1	4	13	15	5	12	3.10	83	43	63	30	18	181
17	52	-	4	5	11	14	18	3.71	86	49	68	34	14	95
18	51	-	4	4	13	18	12	3.59	91	46	69	35	11	45
19	50	1	6	13	16	12	2	2.76	93	47	70	31	11	143
20	-	-	-	-	-	-	-	-	93	43	68	38	13	100
21	-	-	-	-	-	-	-	-	92	45	69	25	15	118
22	-	-	-	-	-	-	-	-	92	45	69	21	26	128
23	44	-	6	10	11	10	7	3.05	89	50	70	23	8	137
24	36	-	6	8	9	9	4	2.92	83	47	65	30	14	175
25	-	-	-	-	-	-	-	-	82	48	65	24	6	137
26	38	-	3	2	7	14	12	3.79	86	51	69	22	12	112
27	32	-	1	5	10	12	4	3.40	92	45	69	22	11	73
28	-	-	-	-	-	-	-	-	93	48	71	31	20	248
29	31	5	7	2	8	7	2	2.35	85	58	72	47	22	† 174
30	-	-	-	-	-	-	-	-	83	60	72	21	38	187
31	31	3	8	8	7	2	3	2.19	89	62	76	56	20	101
June 1	-	-	-	-	-	-	-	-	90	53	72	38	14	93
2	30	8	4	2	8	5	3	2.23	95	53	74	27	15	170
Total	750	22	90	128	186	176	148							

1/Too small for recording.