DIFFERENCES IN SEEDLING VIGOR OF CORN AT A COOL TEMPERATURE

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DIFFERENCES IN SEEDLING VIGOR OF CORN

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DIFFERENCES IN SEEDLING VIGOR OF CORN AT A COOL TEMPERATURE

INTRODUCTION

For many years corn has been one of the leading crops in the state of Oklahoma. In 1909 there was a total of 5,939,000 acres harvested in Oklahoma; however, in the past few years, the corn acreage has declined until in 1956 there were only an estimated 318,000 acres harvested.[1] Although there are several reasons that account for this declining corn acreage in the state, one of the most important is the unfavorable weather conditions. July and August in Oklahoma are usually hot and dry, accompanied by low humidity, which is very unfavorable for the proper development of the corn plant. These hot, dry days in the summer cause a high transpiration rate and will often cause reduced seed set if they occur during the pollination period. By planting the corn early in the spring, it is possible to get a large percent of the corn plant developed before the hot, dry period begins. At this time of year, early planting presents a problem in that the soil temperature is still cool and not conducive to rapid germination of the corn seed.

Corn planting usually begins about March 20 in southeast Oklahoma and around April 1 in the Stillwater area. The mean air temperature for the Stillwater area is 50° F. in March and 60.9° F. in April. Although no exact data are available for soil temperature, there is good indication

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[1]Oklahoma Crop and Livestock Reporting Service.

that the soil is just warm enough to allow a very slow germination; and it generally takes about 14 days for the seedlings to emerge when planted in early April in the Stillwater area. Quick emergence from the soil will not only hasten development of the plant, but will also give added assurance of obtaining a uniform stand in the field; therefore, a corn variety which has good seedling vigor at these cool temperatures would be an extremely desirable corn variety for Oklahoma conditions.

The purposes of this study were to devise a method for measuring seedling vigor and to establish the presence or absence of genetically controlled differences in seedling development at a cool temperature.

REVIEW OF LITERATURE

There has been a great deal of interest in the "cold-test" germination of corn in recent years, and several reports have been published with emphasis on disease resistance to the soil-borne fungi. The techniques used for the "cold-test" germination are basically the same. Various factors, such as seed injury, maturity, physical qualities and genetic differences are used in selecting the seed to be tested. These seed are then placed in moist soil known to be contaminated with soil-borne diseases. The seed and moist soil are placed in a cool temperature, 50° F. or less, for a variable number of hours or days. After being chilled for the prescribed period of time, the seed are then removed to a warm temperature which permits germination; and the number of sprouted seed are counted to ascertain the germination percentage.

Hoppe (3) described a successful method of "cold-testing" corn by the rolled-towel method to study disease resistance to soil-borne diseases. He found a successful test could be conducted by taking some soil known to be contaminated with the disease to be studied and rolling it up with the corn seed.

Several factors have been studied in connection with disease resistance in the "cold-test" of corn. Tatum and Zuber (9) found that mechanical injury to the pericarp resulted in a low germination when subjected to the "cold-test" treatment. The more serious injuries were those which provided the most direct means for the pathogen to enter the embryo. Wortman and Rinke (10) selected kernels by visual examination for mechanical

injury caused from processing equipment, and these were then germinated by the "cold-test" method using corn-field soil. They found that injury over the germ caused the greatest reduction in stands; also, the removal of the tip cap from the seed caused a significant reduction in the emergence of the seedlings.

Rush and Neal (6) studied five hybrids that were harvested at ten-day intervals. The grain was dried and germination tests made by the "cold-test" method. They found that, in general, with increased maturity there was an increase in germination of the seed at low temperatures, and seed-coat injury did not seem to be the major factor in determining stands. Hooker (2) studied the effects of seasonal conditions on the "cold-test" germination of corn. He found that seed produced in warm temperatures with ample moisture during June, July, and August followed by a cool, but dry, September and October produced better stands than seed produced in a cool, but dry, or a cool and wet season. The level of soil nitrogen did not appear to be a factor in determining resistance to the Pythium debaryanum disease.

Neptune and Rossman (4) by the "cold-test" method demonstrated that one and two year old seed did not produce as good a stand as new seed, and some hybrids appeared to have inherent ability to germinate better in cold, wet soils than others. Pinnell (5) studied the ability of corn to germinate in wet field soil at low temperatures under both field and laboratory conditions. He found wide differences among inbreds, and some hybrids appeared to have inherent ability to produce better stands at cool temperatures than others, although, there seemed to be little or no relation between the performance of an inbred as a female in crosses and its performance as a male in crosses.

Goodsell, Huey, and Royce (1) tested seed stored in air, carbon

dioxide, and nitrogen at different temperature levels and different moisture content. Corn stored in carbon dioxide or nitrogen differed very little in germination by the "cold-test" method from corn stored in air, with one exception. At the higher moisture levels and storage temperatures, the one hybrid which was classified as weak was slightly more susceptible to "cold-test" pathogens than seed of the strong hybrid. Under all conditions "cold-test" germination was significantly lower after one-half to one year of storage.

Tatum (8), in further studies with "cold-test" reaction in corn seed, soaked various lots of seed in water and the amount of turbidity was assumed to reflect differences in the amounts of solid materials diffusing from the seed. "Cold-test" germinations were made on these seed and the results compared to the turbidity readings. A highly significant correlation between the two sets of values was found. The seed that had the greatest concentration of leached material also resulted in the lowest germination by the "cold-test" method.

There appear to be several factors that control the germination of corn by the "cold-test" method, but there is little information to suggest which is the most important.

Smith (7) earlier had studied the chlorophyll formation of two inbred lines when germinated at 17° C. and found that chlorophyll formation was partially inhibited in one inbred line, while correspondingly a normal green color was produced in the other.

MATERIALS AND METHODS

Preliminary observations used to establish the scoring technique for comparing the material were made on inbred and single cross corn from several different years' production. The seed selected for the major portion of this work was from the varieties Mickles Yellow Dent and 110 Day. Seed of the two varieties used for the germination test were produced in 1955 in the same field. From 17 ear-to-row plantings of the Mickles Yellow Dent variety, the five best ears were selected from each row, making 17 families with 5 ears each or a total of 85 ears. The 85 ears selected were shelled by hand and germination tests made from the seed of these ears. The seed from the 110 Day variety were selected by the same method. For the Mickles Yellow Dent variety, 100 seed were used for the germination test; however, only 50 seed were germinated from the 110 Day variety since previous work with Mickles Yellow Dent indicated that a 50-seed test was adequate. Only sound mature kernels were used and germinated by the rolled-towel method. No soil was used for these tests. Standard germination paper toweling, 10 inches by 15 inches, was moistened; and 50 seed were placed between four of the moist paper towels. The toweling and seed were then rolled and a sheet of wax paper wrapped around each roll to prevent excessive evaporation. These rolls were then placed in a Stults Junior Da-Lite seed germinator for 14 days. The temperature maintained in the germinator was a constant $55^{\circ} \pm 2^{\circ}$ F. At the end of the 14-day period, the seed were removed from the germinator and were scored in the following manner:

For plumule development, four possible scores were used:

1. No plumule growth.

2. Some plumule development with growth up to one-fourth of an inch.

3. Plumule development one-fourth to one-half of an inch.

4. Plumule development over one-half of an inch.

The roots were given a possible score of six classes as follows:

1. No root development.

2. Weak primary root with no adventitious root development.

3. Weak primary root and weak adventitious root development.

4. Vigorous primary root with little or no adventitious root development.

5. Weak primary root development with vigorous adventitious root development.

6. Vigorous primary and adventitious root growth.

There were 24 possible combinations for a seed score since each seed was scored independently for root and plumule development. Primary emphasis was given to the rate and type of root development with a higher value given for vigorous adventitious roots than for well elongated primary roots. Figure 1 shows the possible scores for both root and plumule. The first number is the root score and the second number is the plumule score. The upper row i.e. 1-1, indicates neither root nor plumule growth. The center row shows the three possible scores for plumule growth with no root growth on these seed. The lower row shows the five scores possible for root development with no plumule growth. Normal classes with both root and shoot growth are not shown.

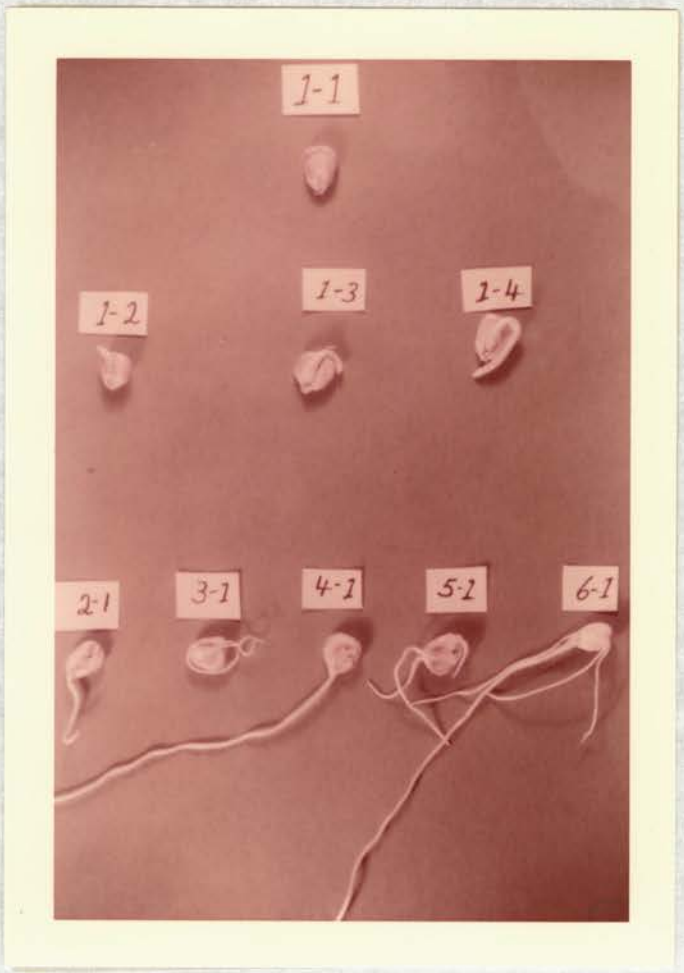

Figure 1. Colored photograph illustrating some of the possible scores for root and plumule development.

RESULTS AND DISCUSSION

In the first tests that were made with the inbred and single cross material, a wide variation was found between some of the lines. One inbred line known to have a weak root system in the field also had a very low root score when germinated at a cool temperature. The seed from this inbred produced mostly adventitious root development and generally had a very weak primary root. The single cross seed used that had this inbred line as one parent also had a low root score. With an increase in age of the seed there was also a general reduction in vigor of the seedlings when germinated at this cool temperature.

Early in the preliminary work, it was noted that various selections had a typical type of root development and these observations were verified throughout the entire experiment. Some ears produced very characteristic root development in that they would produce little or no adventitious roots during the germination period even though a strong primary root developed. The number of adventitious roots produced would vary to a certain extent with different selections.

Figure 2 shows a portion of the 50-seed test upon removal from the germinator after the 14-day period. Note the strong primary and secondary root growth as well as good plumule elongation. This selection had a very high score for both root and plumule growth. Figure 3 shows an exceptionally weak root development and practically no adventitious root growth; however, the plumule growth is reasonably good. This does not mean that initial plumule and root growth are completely independent, but

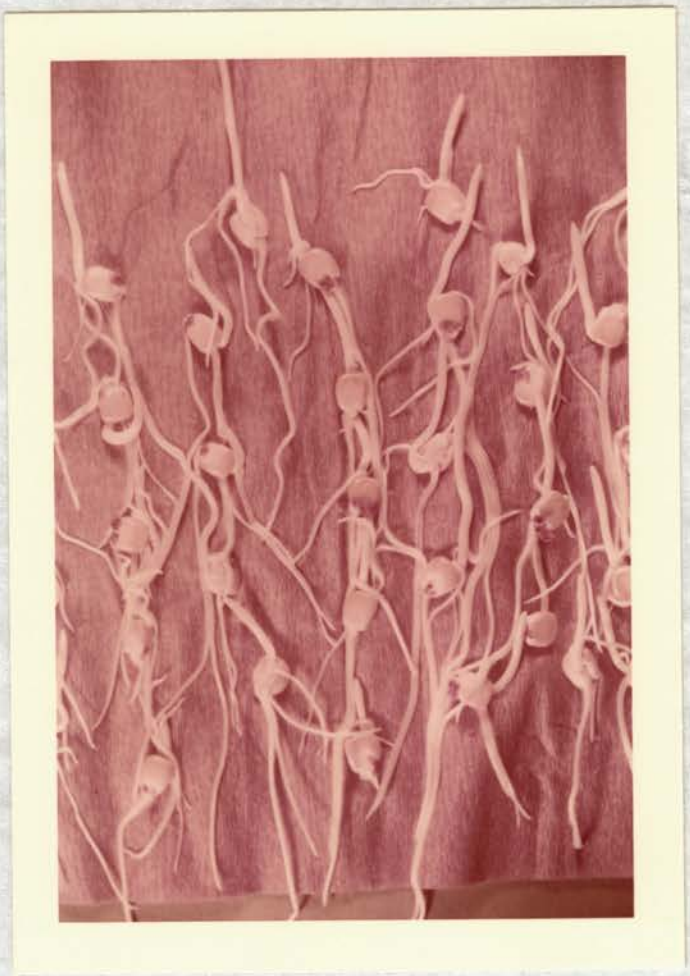

Figure 2. Seedlings from one ear of 110 Day variety germinated for 14 days at 55° F. Most seedlings show vigorous development.

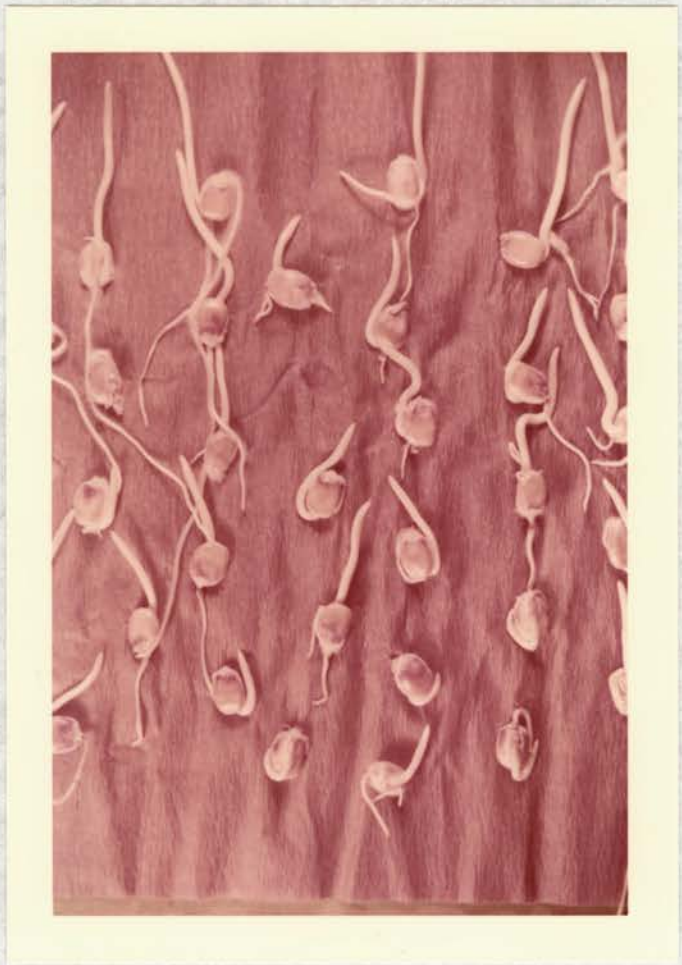

Figure 3. Seedlings from one ear of 110 Day variety germinated for 14 days at 55° F. Most seedlings show exceptionally weak root development with generally good plumule elongation.

does suggest a certain degree of independence between the two.

Data from certain selected ears are shown in Table I to illustrate a uniform sample, a highly variable sample, and a sample from an ear with average distribution of seedling score. The three-part number designation at the top of the table is the complete identification for an individual ear. The first part of the number is the variety designation; the second part of the number is the family; and the third part is the progeny ear number. Ear 15-1-3 from 110 Day and ear 11-10-4 from Mickles Yellow Dent illustrate the better scores. Selections 15-6-2 and 11-9-2 show about the maximum amount of spread in frequency for both varieties. Selections 15-19-1 and 11-16-5 are about average in the frequency distribution of these varieties.

Tables II and III present the scores recorded for the different ears of the two varieties. The column "Progeny Ear" is divided into five sections representing the five ears comprising each family. The scores for the five ears were averaged and are shown as the mean value for each family.

From the total scores for the individual ears and the sum of the five ears from the same family, an analysis of variance was calculated, Tables IV and V. A significant variation was found in the Mickles Yellow Dent variety for both root and plumule scores with a significantly greater variation among families than within families. This would indicate that selection for seedling vigor in this variety could be made on a progeny basis. In the analysis of variance of the 110 Day variety, there was no significant difference among families, which would suggest that selection for seedling vigor at cool temperatures in this variety would be difficult because of greater uniformity for this characteristic than in the Mickles Yellow Dent variety.

TABLE I

FREQUENCY OF SEEDLING CLASSES FROM SELECTED EARS OF THE TWO VARIETIES

SCORE R-P[1]	MICKLES YELLOW DENT			110 DAY		
	11-10-4	11-9-2	11-16-5	15-1-3	15-6-2	15-19-1
1-1		9	1		2	2
1-2						
1-3		3			1	
1-4						
2-1						
2-2		1				
2-3		2			1	
2-4					5	
3-1						
3-2						1
3-3		2	1		6	
3-4					3	
4-1						
4-2						
4-3		8	4			1
4-4		2	2		12	9
5-1						
5-2						
5-3						
5-4		7			4	
6-1						
6-2						
6-3		12	6		1	3
6-4	50	4	36	50	15	34
Total Seed	50	50	50	50	50	50
Average Root Score	6.0	3.9	5.5	6.0	4.1	5.2
Average Plumule Score	4.0	2.9	3.7	4.0	3.7	3.7

[1]The R-P represents root and plumule, respectively.

TABLE II

AVERAGE ROOT AND PLUMULE SCORE FOR EACH EAR AND MEAN OF THE FIVE EARS FROM EACH FAMILY FOR THE MICKLES YELLOW DENT VARIETY

FAMILY	PROGENY EAR					FAMILY MEAN
	1 R - P[1]	2 R - P	3 R - P	4 R - P	5 R - P	R - P
11-1	2.8-2.4	2.9-2.5	3.6-2.8	4.6-3.6	3.8-3.1	3.5-2.9
11-2	5.9-3.8	5.4-3.6	4.6-3.0	5.1-3.3	3.8-3.1	5.0-3.4
11-5	4.7-3.1	5.3-3.7	5.6-3.6	5.0-3.9	4.5-3.4	5.0-3.6
11-6	5.4-3.8	5.7-3.8	4.3-3.1	5.3-3.7	5.2-3.2	5.2-3.5
11-8	5.5-3.7	5.6-3.5	5.0-3.8	5.5-3.6	3.1-2.8	4.9-3.5
11-9	5.5-3.4	3.9-2.9	5.1-3.3	5.6-3.5	4.7-3.6	5.0-3.3
11-10	5.8-3.8	4.6-3.2	5.0-3.4	6.0-4.0	4.0-3.2	5.0-3.5
11-11	5.6-4.0	6.0-4.0	5.7-3.6	5.3-4.0	4.3-3.3	5.4-3.8
11-12	6.0-4.0	5.9-3.9	5.9-4.0	5.3-3.7	5.0-3.6	5.6-3.8
11-13	5.2-3.9	5.7-3.9	5.9-4.0	5.6-3.9	5.6-3.9	5.6-3.9
11-14	5.7-3.8	4.6-3.3	5.4-3.9	5.4-3.9	4.4-2.9	5.1-3.6
11-15	5.6-3.9	5.9-4.0	5.9-4.0	5.0-4.0	5.3-3.9	5.5-4.0
11-16	5.8-3.9	6.0-3.9	4.6-3.8	5.3-3.8	5.5-3.7	5.4-3.8
11-17	5.5-3.9	5.5-3.9	4.8-3.8	5.7-3.6	3.9-3.4	5.1-3.7
11-18	5.6-3.9	5.9-4.0	5.3-3.9	5.7-3.9	5.4-3.6	5.6-3.8
11-19	2.7-3.0	3.3-2.5	4.9-3.3	3.9-2.5	3.9-2.7	3.7-2.8
11-20	5.7-3.7	5.0-3.5	4.4-3.2	4.5-3.2	4.0-2.8	4.7-3.3

[1]The R - P represents root and plumule, respectively.

TABLE III

AVERAGE ROOT AND PLUMULE SCORE FOR EACH EAR AND MEAN OF THE FIVE EARS FROM EACH FAMILY FOR THE 110 DAY VARIETY

FAMILY	PROGENY EAR					FAMILY MEAN
	1 R - P[1]	2 R - P	3 R - P	4 R - P	5 R - P	R - P
15-1	5.8-4.0	6.0-4.0	6.0-4.0	5.6-3.8	5.7-4.0	5.8-4.0
15-2	4.9-4.0	4.4-3.7	3.4-3.3	5.4-3.9	5.7-3.8	4.7-3.7
15-4	5.7-4.0	4.4-3.8	5.8-4.0	4.9-3.9	5.0-3.6	5.2-3.8
15-5	5.3-3.4	5.6-3.9	4.1-3.3	5.5-3.9	5.3-3.7	5.1-3.6
15-6	5.7-3.9	4.1-3.7	5.8-3.8	5.7-3.7	4.7-3.3	5.2-3.7
15-8	5.4-3.6	5.8-3.9	5.7-3.9	5.6-3.9	5.6-4.0	5.6-3.8
15-9	5.2-3.4	5.8-3.9	4.6-3.8	5.4-3.7	5.8-3.9	5.3-3.8
15-10	4.9-3.8	4.7-3.8	5.2-3.8	5.1-3.4	6.0-4.0	5.2-3.7
15-11	4.9-3.6	5.3-3.8	5.2-4.0	5.6-3.9	5.6-3.9	5.3-3.9
15-13	4.9-3.8	5.8-3.9	5.1-3.3	5.5-4.0	5.4-3.9	5.3-3.8
15-14	6.0-4.0	6.0-4.0	5.0-3.7	5.8-3.9	5.4-3.9	5.6-3.9
15-15	5.8-4.0	5.7-3.9	5.6-3.9	5.6-3.8	5.0-3.9	5.5-3.9
15-16	6.0-4.0	4.0-3.9	6.0-4.0	3.7-3.2	5.8-4.0	5.1-3.8
15-17	5.7-3.7	5.1-3.6	5.5-3.9	5.3-3.5	5.2-3.9	5.4-3.7
15-18	5.8-3.9	5.4-3.5	5.9-3.9	6.0-3.8	3.5-2.9	5.3-3.6
15-19	5.2-3.7	5.6-3.7	5.4-4.0	5.2-3.7	5.7-3.9	5.4-3.8
15-20	5.9-3.9	4.5-3.2	5.3-3.8	5.4-3.6	5.8-3.8	5.4-3.7

[1]The R - P represents root and plumule, respectively.

TABLE IV

ANALYSIS OF VARIANCE OF SEEDLING SCORES FOR ROOT AND PLUMULE DEVELOPMENT FOR THE MICKLES YELLOW DENT VARIETY

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	
		ROOTS	PLUMULE
Families	16	8,739.7**	2,744.2**
Ears Within Families	68	2,072.2**	469.3**
Between Samples	85	141.0	87.8

** Exceeds the 1 percent level of signifiance.

TABLE V

ANALYSIS OF VARIANCE OF SEEDLING SCORES FOR ROOT AND PLUMULE DEVELOPMENT FOR THE 110 DAY VARIETY

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	
		ROOTS	PLUMULE
Families	16	660.5	119.3
Ears Within Families	68	891.6	129.6

Ears showing slow germination and others showing rapid germination with cool temperature conditions were again sampled and tested under standard germination procedure. While the results were, in general, parallel, the duration of the germination period was more critical under standard germination conditions than at the cool temperatures. An attempt was made to determine the number of hours the seedlings had been subjected to degrees over 50° F. since it had been previously found that very little growth occurred at 50° F. At a germination of 55° average for 14 days the seed would have received a total of 1,680 degree-hours above 50° F. Comparing this with a standard germination test of 68° F. for 16 hours and 86° F. for 8 hours the seedlings would have accumulated in three days 1,728 degree-hours above 50° F. To give an accurate comparison, however, the seed should be pre-soaked to their maximum moisture content before beginning the test. Although no definite conclusions could be drawn, it was observed that the same lines of corn were generally at about the same stage of development after 3 to 4 days in the alternating 68 to 86° F. temperature as they were after 14 days when germinated at 55° F.

It would appear that this method or a modification of it has promising possibilities in a selection program for seedling vigor and type of seedling development. Whether it is necessary to run the test at 55° F. for 14 days is a question that remains unanswered. It is possible by increasing the temperature and reducing the number of days, the time required to conduct the test could be shortened. In scoring the plumule it would probably be wise to add two more scores of five and six in order to more accurately measure the growth of the plumule over one-half of an inch.

SUMMARY

A study was conducted on different ear selections of corn to measure seedling vigor at a cool temperature and the possibility for improvement of this characteristic by a progeny selection program. Disease resistance was not a factor under consideration here. Ear-to-row selections from the varieties Mickles Yellow Dent and 110 Day were used for the primary part of the study. One hundred seed from each selected ear of Mickles Yellow Dent and fifty seed from each selected ear of 110 Day were germinated by the rolled-towel method and placed in the germinator at 55° F. for 14 days. The seedlings were then scored for both root and plumule development.

The total score for the ears from the same parents was also determined. Primary emphasis was on the rate and type of root development.

1. From the Mickles Yellow Dent variety a highly significant variation was found between families and a less significant variation within families.

2. This would indicate that a breeding program designed to improve seedling vigor at a cool temperature might be practical for this variety.

3. From the analysis of variance for 110 Day the variation between families was not significant.

4. The 110 Day variety is apparently more uniform for seedling vigor, and it would be difficult to improve this characteristic by a progeny selection program.

5. There was not a complete correlation between high root score and

high plumule score indicating a certain degree of independence between these separate but essential seedling structures.

6. The technique used for this study has possibilities in screening breeding material for the selection of seedling vigor at cool temperatures. It is possible that increasing the temperature would shorten the time required to conduct the test.

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