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A STUDY OF THE EFFECTS OF TEMPERATURE AND
OTHER FACTORS UPON THE GERMINATION OF
CERTAIN VARIETIES OF SWEET CORN

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ABSTRACT

A series of trials were conducted during 1950 and 1951 to study the effects of temperature, as well as the effects of the nature of the germinating medium and of the duration of exposure, upon the germination of three open-pollinated and one hybrid varieties of sweet corn. The results indicated that germination of sweet corn seed was seriously inhibited by temperatures of 10°C. or lower, with no apparent difference between the effects of the lower temperatures. Germination in soil was lower than in sterile vermiculite, particularly at low temperatures, indicating that soil pathogens play an important role in limiting germination in cold soil. The duration of exposure was an important limiting factor only at the lower temperatures. Although significant varietal differences were observed, they could not be attributed to any differences in cold resistance, but must be considered as being related to the viability, and possibly to the maturity, of the individual seed lots used.

THE UNIVERSITY OF ALBERTA

A STUDY OF THE EFFECTS OF TEMPERATURE AND OTHER
FACTORS UPON THE GERMINATION OF CERTAIN VARIETIES
OF SWEET CORN

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INTRODUCTION

Sweet corn is one of the most important of the canning crops grown in Southern Alberta. The acreage producing sweet corn is increasing annually, and is expected to increase sharply with the completion of the St. Mary's Irrigation Development. It has also become increasingly apparent that, in the near future, more canneries will be erected and go into production, in the area served by irrigation. In addition, the canning firms are considering the installation of quick freezing equipment to satisfy the ever increasing demand for fresh frozen fruit and vegetable products. This part of the processing industry is still in its infancy and will, as it expands, require the production of an increasing volume of sweet corn.

Growers and research workers alike have often observed that stands of sweet corn are poor in seasons when cold, wet soil conditions prevail during the germination period. These observations have led canning company fieldmen, farmers, and research workers to ask, "Why should this be so?" "Is the ability of the seed to germinate inhibited or destroyed by low soil temperatures?" "Or, are attacks by soil pathogens,* upon the elongating coleoptiles, responsible for the reduction of the final stands in the field?"

The species Zea mays L. is known generally to be a "warm season" plant, and thus its development is best under condi-

* This term, as used in this thesis, refers to soil-borne pathogens.

tions of high summer temperatures. The reasons underlying poor germination at low temperatures are, however, little understood. The project, reported herein, was initiated to study the effects of exposure to low soil temperatures, in several media, upon the germination of certain varieties of sweet corn. It was hoped that the information gained would be useful in answering the above questions.

LITERATURE REVIEW

Meyer and Anderson (15) define germination of seeds as the resumption of active growth on the part of the embryo, resulting in the rupture of the seed coats and the emergence of the young plants. Environmental conditions conducive to normal germination include adequate moisture and oxygen, as well as a "suitable" temperature. The germination is also affected by varietal differences in vigor and speed of germination, by inherent differences in embryo development, by the viability of the seed itself, and by the presence of insects and pathogenic micro-organisms in the soil. The above authors observe that the initiation of growth is essentially enzymatic in nature. Moisture and temperature are, therefore, important factors since both are required in optimum degree for the activation of enzymes. Seeds of most species of plants will germinate over a wide range of temperatures but maximum germination is obtained at some intermediate (optimum) temperature. Meyer and Anderson (15) state

that corn will germinate through a range of temperatures from 5° or 10°C. to 45°C. with an optimum of approximately 30°C., whereas wheat has a range from 0°C to 35°C. with an optimum between 15° and 20°C.

Early work on the effect of temperature on the germination of members of the grass family were conducted on wheat, oats, and barley - species which are known to tolerate relatively low soil temperatures. Investigations, conducted by Wilson (22), Wilson and Hottes (23), and Bell (1), all conclude that small grain cereals will germinate satisfactorily at low temperatures (0° to 10°C.) with an optimum near 15° to 20°C. Wilson and Hottes (23) observed that above the optimum temperature the decrease in percentage germination of wheat was accompanied by an increased percentage of damage due to fungal activity. Coffman, as cited by Wilson and Hottes(23), observed that small grains will germinate at the temperature of melting ice.

Jones (11) studied the effect of temperature on the germination of rice which, like sweet corn, is a warm season crop. He observed that some varieties germinated quite well after exposure in a moist condition to temperatures of 0°, 2°, and 5°C. for periods up to 36 days.

Robbins and Petsch (18) studied the relationship of moisture content of the seeds and high temperature to the germination of corn (flint and dent varieties were used). They observed that as the moisture content of the seed increased the percentage germination lowered markedly under low or high temperature

conditions. This is shown graphically in Figure 1. Low temperature data were obtained from the studies of Kiesselbach and Ratcliff as reported by Robbins and Petsch (18). The low temperature data show a similar trend to that of high temperature data.

Haskell (4) exposed selected flat and round seeds of each of six single-cross hybrids and one double-cross sweet corn hybrid to a temperature of 10°C . for eight days. Germination was completed in a warm greenhouse. Although round seeds were heavier than the flat seeds there was no significant difference between germination rates. He suggested a differential behavior between hybrids.

Haskell (5) seeded five inbred lines of sweet corn in flats of field soil, recently under corn. One series of flats was placed in a cold room at 10°C ., and the other series in another cold room at 5°C . The soil was kept moist as required. At intervals of from two to thirty-two days flats were removed from the cold rooms and germination rates were determined in a warm greenhouse. He observed that germination percentages were lower for the 10°C . temperature than for the lower temperature, and that the percentage became lower as the period of exposure lengthened regardless of germinating temperature. He states that the difference between the effects of the two temperatures suggest that the loss in germinability is due in part to cold, and in part to the penetration of soil pathogens into the slowly developing seedling. He believes the pathogens to be partly inhibited

Fig. 1. Relation of water content to temperature required to kill 75 percent of Dent corn grains: Reid's Yellow Dent exposed two hours for temperatures above zero; Hogue's Yellow Dent exposed 24 hours for temperatures below zero. (From Robbins and Petsch)

at 5°C., and, therefore, more active at 10°C. In conclusion, he states that the 5°C. treatment gives a truer picture of the resistance of the inbreds to cold, but that the 10°C. treatment is more critical and selective to other detrimental influences.

Haskell (6) continuing his investigations, soaked the seeds of four sweet corn inbreds in water for periods varying from 0 to 60 hours, and then exposed them for eight days at temperatures of 5°C. and 15°C. He noticed that pre-soaking the seeds did not alter their behavior to cold treatment although germination at the higher temperature was more rapid after pre-soaking.

Haskell (7) seeded five inbred lines of sweet corn and one strain of hybrid dent corn in sand and soil, and exposed them to temperatures of 5°C. and 10°C. for varying periods of time. Germination was completed in a warm greenhouse. From the results the investigator made the following conclusions: (a) The longer the period of exposure, the greater was the number of pre-emerged seedlings killed off; (b) Strains reacted differently to cold treatment; (c) Genetical constitution, temperature, exposure time, and the nature of the germinating medium all significantly affect the final germination; and (d) As an aid to plant breeding, the controlled cold treatment offers a suitable method for artificially selecting hardier strains of sweet corn.

Haskell (8), in a field trial, seeded six varieties at 28 day intervals beginning on March 1. He observed that as the

sowing dates became later the interval to flowering became shorter, and that maturity was directly proportional to flowering time. The size of ears was not materially affected by sowing date, although later sowings gave ears with higher numbers of rows. The earlier sowings produced plants which were shorter, with more tillers, and which produced slightly higher plant yields.

Haskell and Singleton (9) seeded a number of inbred lines and hybrids of sweet and field corn in flats which were exposed to 10°C. for 32 days, and then transferred to a warm greenhouse for completion of germination. The same lines were seeded outdoors in early April. In all cases, outdoor germination percentages were much higher than those from the cold rooms. Sweet corn lines were as cold hardy as the lines of field corn. The field corn hybrids germinated better than their parent lines, illustrating a possible effect of heterosis on cold hardiness. They conclude that the cold treatments can be used advantageously to supplement field trials for cold hardiness.

Mather and Haskell (14) observed, in England, that corn varieties germinate differently according to date of seeding. They selected hardy plants which survived early March sowing and, as the selected lines became hardier, selections were made from February sowings. Two sweet corn varieties and one dent variety increased their ability to germinate from February sowings, while Peruvian derivatives of sweet corn, used in the test, did not. The selected lines are to be tested for combining ability, and used as a basis for obtaining cold hardy sweet corn hybrids for the British Isles.

Pinnell (17), on the basis of 10 years' laboratory and field tests, concluded that double-cross corn hybrids germinated best at low temperatures, followed by single-cross hybrids and inbred lines in order. He observed that wide differences in the germination of inbred lines appeared to be heritable in crosses, and that the female parent was more important than the male parent in determining seedling stands of single- and double-cross hybrids, indicating that this may be due to a form of cytoplasmic inheritance.

Vander Meulen and Henke (21) found cold testing of corn to be valuable in determining the effects of fungicides used for seed treatment. Fungicides, at best, protect good seed from destructive pathogens when germination is delayed due to cold, wet soils. Cold testing also emphasizes the importance of proper methods of seed production, handling, processing, and storage since mechanical damage would result in poor germination under adverse growing conditions by permitting soil pathogens to penetrate the seed coat easily.

Dickson and Holbert (2) found that corn seedlings grown at low temperatures (8° - $20^{\circ}\text{C}.$) are low in soluble carbohydrate building substances, and that the cell walls are composed largely of pentosan yielding substances. On the other hand, seedlings grown at high temperatures ($24^{\circ}\text{C}.$ and above) have large reserves of soluble carbohydrate building substances, and the cell walls are composed of cellulose impregnated with suberin. The latter are highly resistant to fungal penetration, while in the

former fungi are able to obtain nourishment directly from the cell wall and thus gain entry into the seedling.

Tatum and Zuber (20) reviewed the separate works of Meyer, Koehler, and Tatum, all of whom observed that germination of corn seed was reduced when any amount of pericarp damage was present. Tatum had believed that minor injuries over the germ were as serious as more obvious damage to other parts of the kernel. Tatum and Zuber (20) found that low temperature alone did not decrease germination in sterilized soil, indicating that soil pathogens were responsible for the reduction in germination. They emphasized the need for more careful handling of the seed.

Lehenbauer (12) held corn seedlings at constant temperatures and concluded that the minimum growth temperature for corn was near 12°C. to 14°C.

Erwin (3) observed that sweet corn seed germinated promptly when the soil temperature is approximately 12.78°C. (55°F.), provided that other conditions were optimum.

Rush and Neal (19) of Wisconsin, obtained corn seed which had been harvested at 10 day intervals, and exposed it to a temperature of 10°C. in soil for 14 days. They found that stands improved with the increase in maturity of the seed. On the other hand, seed harvested after a frost gave significantly lower germination under cold test conditions than unfrosted seed which was not as advanced in maturity. These workers concluded that seed coat injury did not appear to be of major significance in deter-

mining the stands of corn at low temperatures, and that Arasan treated seed gave better stands than untreated seed of the same maturity.

Magoon and Culpepper (13), after a series of experiments conducted at different locations throughout the United States, concluded that the minimum air temperature required for development of sweet corn fell within a range of 50°F. to 60°F. (10°C. to 15.6°C.) and that this requirement varied with varieties and with strains within varieties. These investigators observed that the minimum soil temperature fell approximately 5°F. (2.78°C.) lower than the minimum air temperature.

Mortimer (16), in studying the germinating ability of 36 reciprocal single crosses under adverse conditions found that 55.5 per cent of the single crosses showed significant differences between reciprocals, with the maternal parent playing the primary role in determining the differences. This agrees with the conclusions of Pinnell (17), already cited.

MATERIALS AND METHODS

Four factors relating to the germination of sweet corn were considered in this study. These are reviewed briefly in the following paragraphs.

(1) Temperature

Controlled temperature chambers were available at the Science Service Laboratories, Lethbridge, Alberta for the field

trial carried out in 1950, and at the Food Processing Laboratory of the Experimental Station, Lethbridge, Alberta for the field and greenhouse trials undertaken in 1951. In both units, temperatures of 5°C., 10°C., and 15°C. were maintained throughout the period of exposure. At the University of Alberta during the winter of 1950-51 the above temperatures could not be duplicated, and the trial was carried out using temperatures of 35°F. (1.7°C.), 50°F. (10°C.), and 65°F. (18.3°C.).

(2) Germinating Medium

The seed was sown in 3 different media, (a) Lethbridge brown silt-loam from the horticultural area of the Experimental Station, (b) Parkland black loam* from the Parkland Farm of the University of Alberta, Edmonton, Alberta, and (c) Vermiculite, an inert mineral substance (heat expanded particles of mica) sold under the trade name of "Zonolite". Neither of the soils had been used for the growing of corn for a number of years.

(3) Duration of Exposure

The seed was exposed in each of the above media and at each of the above temperatures for periods of 10, 20, and 30 days duration.

(4) Varieties

Each of 3 open-pollinated sweet corn varieties (Altagold, Dorinny, and Golden Early Market) and 1 sweet corn hybrid (Carmelcross) were subjected to all combinations of the above factors.

* Malmo silty clay loam.

In the controlled temperature chambers, the seed was sown in the flats and covered with approximately one inch of the appropriate medium. The media were kept moist as required. Seeding was done at 10 day intervals so that all exposure periods would be completed at the same time, e.g. the 30 day exposure was sown first, followed 10 days later by the 20 day exposure, etc.

After the exposures were completed the flats were removed from the controlled temperature chambers and transferred to the field or to a greenhouse for completion of germination. When transferred to the field, the seeds were removed from the flats and set into the soil at approximately the same depth as they were in the flats.

Experimental Design

The trials were set up in a split plot design, with 4 replications. Each replication consisted of 9 whole plots (each flat made up a single whole plot) made up of all combinations of the 3 temperatures and the 3 media, as follows:

T ₁ M ₁	T ₂ M ₁	T ₃ M ₁
T ₁ M ₂	T ₂ M ₂	T ₃ M ₂
T ₁ M ₃	T ₂ M ₃	T ₃ M ₃

The position of these whole plots was at random within each replication, whether in the greenhouse or in the field. The whole plots were also randomized in the controlled temperature chambers.

Each of the whole plots consisted of 12 sub-plots (rows) made up of all combinations of the 3 exposure periods and the 4 varieties, as follows:

E_1V_1	E_2V_1	E_3V_1
E_1V_2	E_2V_2	E_3V_2
E_1V_3	E_2V_3	E_3V_3
E_1V_4	E_2V_4	E_3V_4

The position of the sub-plots within each whole plot was at random, with a different randomization in each case. Each sub-plot (row) consisted of 25 seeds. In order to facilitate setting out, the sub-plots were transferred to the field in the same rotation as they appeared in the flats. The sub-plots, in the field, became single 25 foot rows spaced 3 feet apart, and with the seeds placed at intervals of approximately 1 foot.

The arrangement of the whole plots within one replication in the field is shown diagrammatically in Figure 2, while the arrangement of the sub-plots within a single whole plot is illustrated in Figure 3.

Methods of Collecting Data

According to Meyer and Anderson (15), germination is completed with the rupture of the seed coat and the emergence of the young plant. For the purpose of this study, germination was considered to be complete when one prominent seedling leaf had emerged from the coleoptile, above the surface of the medium.

Fig. 2. Plan of one replication showing the arrangement of the whole plots.

Fig. 3. Plan of one whole plot showing the arrangement of the subplots (the same arrangement as in the flats).

In the greenhouse trials, counts of all the emerged seedlings were made when it had been ascertained that no further germination would take place. The vigor of the seedlings was also recorded.

For the field trials, seedling counts were made before the material was transferred to the field and again when it was certain that no more seeds would germinate. It may be noted here that the germination of seed exposed at 15°C. was almost complete when the transfer to the field was made. It was, therefore, necessary to transplant all the emerged seedlings. As a result, considerable losses were incurred and final stands were often lower than the initial germination. The final stands and the initial germination were compared and the higher figure of the two was taken to be the final germination.

Data were also collected regarding the maturity of the numerous sub-plots. These data were based upon the dates on which 50 per cent of the plants had completed silking.

No yield data were collected because of frost damage to the entire plot area before the varieties had matured sufficiently.

Methods of Analysing the Data

The data were analysed to determine the effects of the different factors by means of the analysis of variance. The significance of all main effects was determined and Least Significant Differences were calculated where the F values obtained were significant.

Separate analyses were computed for the separate trials. The results of the trials could not be combined because of certain dissimilarities, namely, the greenhouse trials were exposed at different temperatures and only one field trial was successfully carried out, due to weather conditions that are discussed later.

All data were recorded as percentages and it was necessary to transform them using the angular transformation (percentage = $\sin^2 \theta$) as laid out by Hayes and Immer (10). The relationship of angles (in degrees) to percentages is illustrated in Appendix V.

Climatic Influences

In 1950, the transfer to the field was made into relatively dry soil under warm weather conditions. The entire plot area was sprinkled with approximately one inch of water immediately after the transfer to the field had been completed, giving excellent conditions for the completion of germination.

In 1951, on the other hand, the transfer was made under decidedly adverse soil and weather conditions. The soil was very wet and low temperatures persisted for an extended period. On the fourth day after the transfer was made (June 26) a heavy snowfall occurred. The plots were left for approximately one month and after close observation it was considered that the cold and snow had nullified the effect of the previous temperature treatments, as no treatment differences were apparent. As a result of this careful inspection, it was decided to abandon the trial.

Greenhouse temperatures were relatively low during the time that the seeds were undergoing completion of germination. As a result, germination was rather slow. The temperatures could not be altered because of the presence of other plants which would not tolerate the higher temperatures.

RESULTS

The results of this project fall logically into 3 separate phases, namely the Field Trial 1950, Greenhouse Trial 1950-51, and the Greenhouse Trial Fall 1951. Each of these phases will be discussed individually.

Field Trial 1950

General views of the plot area are shown in Figures 4, 5, and 6.

Under near ideal soil and weather conditions, germination progressed rapidly after the seed had been transferred to the field. On the other hand, plants which had been transplanted showed very little progress for about 10 days, after which time growth was quite rapid. Plants, from the lower temperature treatments, were generally shorter than those from the 15°C. treatment. There was no consistent difference in the number of tillers per plant and the smaller plants appeared to be as healthy as the larger plants.

At silking time no consistent differences in maturity could be detected between treatments within varieties. There were

Fig. 4.

Fig. 5.

Fig. 6.

Figures 4-6. General views of the plot area. Field Trial 1950.

Note that extensive gaps appear in certain plots - these represent treatments where germination was seriously inhibited

Table 1. Mean Germination rates (in degrees) for all combinations of temperatures, media, duration of exposure, and varieties. Each figure is the mean of four replications. Field Trial 1950.

MEDIA

Variety	No. of Days Exposed to Controlled Temperature	Vermiculite			Parkland Soil			Lethbridge Soil		
		5°C.	10°C.	15°C.	5°C.	10°C.	15°C.	5°C.	10°C.	15°C.
Altagold	10	58.93	65.35	66.80	49.03	44.95	38.08	47.50	50.85	56.53
	20	59.58	62.00	62.55	50.95	14.85	48.50	52.13	58.83	46.80
	30	40.38	43.20	56.33	23.05	2.88	35.93	20.33	14.95	45.00
Carmelcross	10	63.93	60.73	62.53	40.43	27.03	40.98	39.45	35.33	45.40
	20	60.85	54.63	66.18	12.55	10.20	33.70	15.75	27.78	38.43
	30	43.83	38.50	58.83	15.08	5.08	35.20	14.95	29.83	33.50
Dorinny	10	63.48	64.40	60.08	37.80	30.88	38.00	38.58	41.40	50.23
	20	58.55	50.30	67.60	20.98	13.85	35.23	10.98	24.78	44.03
	30	40.95	38.58	52.18	12.75	0.00	29.20	6.65	16.18	31.55
Golden Early Market	10	59.40	68.50	64.03	20.20	6.98	26.08	23.05	29.43	29.13
	20	42.13	43.20	67.45	7.98	2.88	18.70	0.00	13.85	33.55
	30	27.98	30.38	57.93	2.88	0.00	18.35	0.00	2.88	14.95

however, normal variations between early and midseason varieties. No yield data were realized.

Table 1 lists the mean germination rates for all treatments (converted from percentages to degrees). Each figure is the mean of 4 replications. An analysis of variance (Appendix I) was computed for the complete data, and certain treatment effects were observed to be significant.

The rate of germination of sweet corn was significantly affected by the temperatures to which the seed had been exposed, as illustrated in Table 2.

Table 2. Mean germination rates (in degrees) for each of the temperature treatments. Field Trial 1950.

<u>Temperature</u>	<u>Germination Rate</u>
5°C.	31.74 degrees
10°C.	30.70 degrees
15°C.	44.69 degrees

Least Significant Difference = $\pm$ 9.77 degrees

F value = 9.79 ∇

∇ Exceeds the 5 per cent level of significance

The mean germination rate at 5°C. and 10°C. were both significantly lower than that at 15°C., but there was no basis for assuming any real difference between the effects of the two lower temperatures. The influence of temperature on the stands of the plants in the field is illustrated in Figures 7 to 15.

The nature of the germinating medium also significantly affected the rate of germination (Table 3). Germination

Fig. 7

Fig. 8

Fig. 9

Figures 7 - 9. The effect of temperature upon the stands of sweet corn sown in vermiculite. Field Trial 1950.

Fig. 10

Fig. 11

Fig. 12

Figures 10 - 12. The effect of temperature upon the stands of sweet corn sown in Parkland Soil. Field Trial 1950.

Fig. 13

Fig. 14

Fig. 15

Figures 13 - 15. The effect of temperature upon the stands of sweet corn sown in Lethbridge Soil. Field Trial 1950.

in both Parkland and Lethbridge soils was significantly lower than in Vermiculite. There was no indication of any real difference between the effects of the two soil types upon germination.

Table 3. Mean germination rates (in degrees)
for each media. Field Trial 1950

Medium	Germination Rate
Vermiculite	55.05 degrees
Parkland Soil	25.10 degrees
Lethbridge Soil	29.00 degrees

Least Significant Difference = $\pm$ 9.77 degrees
F value = 46.57 ~~¶¶~~

~~¶¶~~ Exceeds the 1 per cent level of significance

The significance of the first order interaction between temperatures and media indicates a differential effect of temperature from one medium to another. The combined effect of the two factors is shown graphically in Figure 16, photographically in Figures 7 to 15, while Table 4 lists the means of the combined treatments.

Table 4. Mean germination rates (in degrees) for all combinations of temperatures and media. Field Trial 1950

Medium	Temperature		
	5°C.	10°C.	15°C.
Vermiculite	51.63	51.63	61.83
Parkland Soil	22.81	13.28	33.14
Lethbridge Soil	20.80	27.20	39.09

F value = 2.85 ~~¶~~

~~¶~~ Exceeds the 5 per cent level of significance

It may be observed in Table 4 and Figure 16 that the germination rate dropped to a greater extent from 15°C. to 10°C., and 5°C. in soil than it did in Vermiculite. It is interesting to note, at this point that the germination in Parkland Soil was lower at 10°C. than at 5°C.

Germination was significantly affected by the duration of exposure, as illustrated in Table 5. The 30-day exposure produced a significantly lower germination rate than the 10-day exposure. The germination rate for the 20-day exposure period was intermediate between the longer and shorter exposures but did not differ significantly from either.

Table 5. Mean germination rates (in degrees) for the different durations of exposure. Field Trial 1950

Number of Days Exposed	Germination Rate
10	45.68 degrees
20	35.39 degrees
30	26.11 degrees

Least Significant Difference = $\frac{1}{2}$ 11.53 degrees
F value = 11.53 ∇

∇ Exceeds the 5 per cent level of significance

Table 6. Mean germination rates (in degrees) for all combinations, duration of exposure and temperature. Field Trial 1950

Number of Days Exposed	Temperature		
	5°C.	10°C.	15°C.
10	45.03	43.82	48.16
20	29.55	29.76	46.88
30	20.74	18.51	39.09

F value = 11.69 $\nabla\nabla$

$\nabla\nabla$ Exceeds the 1 per cent level of significance

Fig. 16. The combined effect of temperatures and media upon the germination rate of sweet corn. Field Trial 1950.

Fig. 17. The combined effect of the duration of exposure and temperature upon the germination rate of sweet corn. Field Trial 1950.

The significance of the interaction between the duration of exposure and temperature indicates that the effect of temperature was differentially affected by the duration of exposure. The mean germination rates are tabulated in Table 6, and the effect is illustrated graphically in Figure 17. The graph shows how germination at 15°C. was only slightly reduced as the duration of exposure increased, whereas germination at the two lower temperatures was reduced sharply under similar conditions.

Table 7. Mean germination rates (in degrees)
for varieties. Field Trial 1950.

Variety	Germination Rate
Altagold	42.77 degrees
Carmelcross	37.42 degrees
Dorinny	36.26 degrees
Golden Early Market	26.37 degrees

Least significant Difference = $\pm$ 7.49 degrees
F value = 10.07 ~~44~~

~~44~~ - Exceeds the 1 per cent level of significance

The differences in the germination rates of the varieties could be observed visually in the field. The analysis of variance bore this out as illustrated in Table 7. Golden Early Market germinated at a significantly lower rate than the other three varieties. Altagold germinated significantly better than Golden Early Market but no actual difference was detected between Altagold, Carmelcross, and Dorinny.

The first of these is the fact that the
  
 principles of the system.

A differential effect of media upon the germination of the varieties is indicated in the significance of the interaction between varieties and media. The relationship is illustrated graphically in Figure 18, and the mean germination rates are listed in Table 8. As may be observed in Figure 18, all varieties germinated very well in Vermiculite, while in the two soils germination is reduced in varying degrees according to variety.

Table 8. Mean germination rates (in degrees) of varieties as affected by the germinating medium. Field Trial 1950

Variety	Vermiculite	Parkland Soil	Lethbridge Soil
Altagold	57.21	32.02	39.22
Carmelcross	56.64	24.47	31.16
Dorinny	55.10	24.27	29.37
Golden Early Market	51.22	11.56	16.32

F value = 4.81 ~~¶¶~~

~~¶¶~~ Exceeds the 1 per cent level of significance

Table 9. Mean germination rates of sweet corn in different media for varying durations of exposure. Field Trial 1950

Medium	Duration of Exposure (days)		
	10	20	30
Vermiculite	63.16	57.88	44.08
Parkland Soil	33.39	20.86	15.03
Lethbridge Soil	40.56	27.24	19.22

F value = 2.93 ~~¶~~

~~¶~~ Exceeds the 5 per cent level of significance

Figure 18. The effect of medium upon the rate of germination of four varieties of sweet corn. Field Trial 1950.

Figure 19. The combined effect of medium and duration of exposure upon the germination of sweet corn. Field Trial 1950.

The interaction between durations of exposure and media was significant to the five per cent level indicating that the effect of media was altered somewhat by the duration of exposure. Figure 19 shows that the germination rate in Vermiculite fell more slowly than in soils as the duration of exposure was increased to 20 days. However, when the duration of exposure was increased, still further, to 30 days the germination rate in Vermiculite fell more rapidly. The mean rates are presented in Table 9.

The interaction between varieties and temperatures was not significant indicating that the varieties were not differentially affected by temperature. This is well illustrated in Figure 20 where it can be seen that the curves for varieties are nearly parallel to one another. There was, therefore, no difference in the response of the varieties to the different temperatures.

Fig. 20. The effect of temperature upon the germination of four varieties of sweet corn. Field Trial 1950.

Fig. 21. The effect of temperature upon the germination of four varieties of sweet corn. Greenhouse Trial 1950-51.

Table 10. Mean germination rates (in degrees) for all combinations of temperatures, media, duration of exposure, and varieties. Each figure is the mean of four replications. Greenhouse Trial 1950-51

MEDIA

Variety	No. of Days Exposed to Controlled Temperature	Verniculite						Parkland Soil			Lethbridge Soil		
		35°F.	50°F.	65°F.	35°F.	50°F.	65°F.	35°F.	50°F.	65°F.	35°F.	50°F.	65°F.
Altagold	10	29.60	59.55	61.08	18.93	14.10	55.28	25.45	15.90	65.88			
	20	8.63	57.55	73.03	2.88	16.98	51.70	0.00	18.80	57.13			
	30	0.00	48.50	74.25	0.00	0.00	49.63	0.00	2.88	41.95			
Carmelcross	10	40.90	72.45	74.78	17.55	23.30	63.43	28.93	25.70	66.85			
	20	21.88	75.08	74.58	0.00	18.38	60.20	9.85	7.95	52.80			
	30	7.95	69.68	79.18	0.00	15.70	66.50	0.00	7.95	52.10			
Dorinny	10	22.65	42.08	54.48	8.20	8.63	47.28	16.98	19.33	57.18			
	20	5.75	28.30	59.63	0.00	4.10	36.48	0.00	5.75	44.33			
	30	0.00	21.30	53.88	0.00	5.75	49.70	0.00	2.88	41.53			
Golden Early Market	10	40.28	61.05	68.68	17.13	14.68	56.58	27.20	16.50	57.60			
	20	22.83	50.18	73.28	0.00	14.95	49.73	2.88	13.28	57.30			
	30	7.95	45.55	67.90	0.00	5.08	49.05	0.00	0.00	46.10			

Greenhouse Trial 1950-51

As previously noted, this trial was conducted at temperatures of 1.7°C., 10°C., and 18.3°C. The analysis of variance was computed in the same manner as for the 1950 Field Trial, and is shown in Appendix II. Table 10 lists the mean germination rates for all treatments, each figure being the mean of the four replications.

Temperatures were again found to cause highly significant differences in the germination rates of sweet corn. Table 11 shows that the germination rates for 1.7°C. and 10°C. were significantly lower than that for 18.3°C., but did not differ significantly from one another.

Table 11. Mean germination rates (in degrees)
for temperatures. Greenhouse Trial 1950-51

<u>Temperature</u>	<u>Germination Rate</u>
1.7°C.	10.68 degrees
10.0°C.	25.22 degrees
18.3°C.	58.08 degrees

Least Significant Difference = $\pm$ 22.63 degrees
F value = 18.70 ~~we~~

~~we~~ Exceeds the 1 per cent level of significance

Differences in germination rates between the different media did not prove to be significant in this trial ($F = 5.10$).

The significance of the interaction between temperature and media indicated that media altered the effects of temperature in a differential manner, as shown in Table 12 and in Figure 22.

Fig. 22. The combined effect of temperatures and media upon the germination rate of sweet corn. Greenhouse Trial 1950-51.

Fig. 23. The combined effect of duration of exposure and temperature upon the germination rate of sweet corn. Greenhouse Trial 1950-51.

Table 12. Mean germination rates (in degrees) for temperatures and media. Greenhouse Trial 1950-51

Medium	Temperature		
	1.7°C.	10°C.	18.3°C.
Vermiculite	17.37	56.20	67.89
Parkland Soil	5.39	11.63	53.40
Lethbridge Soil	9.27	11.41	52.96

F value = 20.52 ~~vv~~

~~vv~~ Exceeds the 1 per cent level of significance

Figure 22 illustrates that germination at 1.7°C. and 18.3°C. are proportional in their relationship, but that at 10°C. germination was much higher in Vermiculite than in the two soils.

The duration of exposure, in itself, did not significantly affect germination although there was a differential effect of the duration of exposure upon activity of temperatures, as indicated by the significance of the interaction between duration of exposure and temperature. As shown in Figure 23, the duration of exposure did not greatly affect the germination rates at 18.3°C., and only slightly decreased the rates at 10°C. However, at 1.7°C. the germination rate was reduced sharply as the duration of exposure was increased. Mean germination rates for the combined factors are listed in Table 13.

Table 13. Mean germination rates (in degrees) for all combinations, duration of exposure and temperature
Greenhouse Trial 1950-51

Number of Days Exposed	Temperature		
	1.7°C.	10°C.	18.3°C.
10	24.40	31.10	60.75
20	6.22	25.94	57.51
30	1.33	18.62	55.98

F value = 5.45 *

* Exceeds the 1 per cent level of significance

Significant differences were found between the germinating ability of the varieties included in the trial as shown in Table 14.

Table 14. Mean germination rates (in degrees) for varieties. Greenhouse Trial 1950-51

Variety	Germination Rate
Altagold	31.47 degrees
Carmelcross	38.21 degrees
Dorinny	23.56 degrees
Golden Early Market	32.06 degrees

Least Significant Difference = $\pm$ 4.49 degrees

F value = 17.09 **

** Exceeds the 1 per cent level of significance

Applying the least significant difference to Table 14 it is observed that Carmelcross germinated significantly better than the other three varieties, and that Dorinny had a significantly lower rate of germination than all other varieties.

 

There was no real difference between the germinating ability of Altagold and Golden Early Market.

In this trial, as in the 1950 field trial, no significance ($F = 1.11$) was obtained for the interaction between varieties and temperatures. It is clearly illustrated in Figure 21 that the effects of the temperature treatments upon the different varieties were almost identical.

Greenhouse Trial - Fall 1951

This greenhouse trial was conducted under identical temperature conditions to the 1950 field trial, except that germination was completed in a greenhouse. The mean germination rates for all treatment combinations are listed in Table 15, and the completed analysis of variance is tabulated in Appendix III.

The effects of the various treatments are illustrated photographically in Figures 28 - 34. The plants from the 15°C. treatment were severely etiolated and were not photographed.

As in the two previous trials, temperatures were responsible for highly significant differences in the germination rates of sweet corn. In Table 16 it may be observed that both the 5°C. and 10°C. temperatures produced significantly lower germination rates than did the 15°C. temperature, while no real difference could be detected between the effects of the two lower temperatures.

 

Table 15. Mean germination rates (in degrees) for all combinations of temperatures, media, duration of exposure, and varieties. Each figure is the mean of four replications. Greenhouse Trial - Fall 1951.

MEDIA

Variety	No. of Days Exposed to Controlled Temperature	Vermiculite			Parkland Soil			Lethbridge Soil		
		50C.	100C.	150C.	50C.	100C.	150C.	50C.	100C.	150C.
Altagold	10	60.73	76.05	74.25	46.75	56.48	74.10	43.85	30.35	69.40
	20	52.78	65.25	84.25	24.95	28.03	59.68	27.18	33.13	56.93
	30	37.15	70.63	71.65	5.75	44.45	59.48	19.38	45.10	58.25
Carmelcross	10	63.63	63.20	74.83	29.68	13.85	56.38	26.08	13.63	59.08
	20	45.53	49.10	76.73	13.28	11.50	43.85	9.18	15.08	33.13
	30	27.05	73.35	70.68	0.00	9.18	37.45	2.88	22.75	47.90
Dorinny	10	46.73	53.95	63.03	19.93	15.18	42.70	22.48	17.13	45.05
	20	25.70	47.30	61.38	10.83	13.28	34.35	19.18	13.83	34.98
	30	2.88	52.08	62.80	0.00	19.33	31.60	4.10	13.95	36.23
Golden Early Market	10	66.55	62.95	76.98	35.43	22.40	56.38	29.75	24.95	58.83
	20	37.83	55.25	67.60	14.25	23.65	46.13	24.83	14.83	47.90
	30	38.53	65.53	71.30	5.75	23.53	46.15	0.00	28.60	49.68

Media, too, produced highly significant differences in the rates of germination. As illustrated in Table 17, germination rates were significantly lower in Lethbridge and Parkland Soils than that obtained for Vermiculite. There was no apparent difference between the effects of the two soil types.

Table 16. Mean germination rates (in degrees) for all temperature treatments. Greenhouse Trial - Fall 1951

Temperature	Germination Rate
5°C.	26.07 degrees
10°C.	35.25 degrees
15°C.	56.69 degrees

Least Significant Difference = $\frac{1}{2}$ 12.19 degrees
F value = 25.59 ~~44~~

~~44~~ Exceeds the 1 per cent level of significance

Table 17. Mean germination rates (in degrees) for all media. Greenhouse Trial - Fall 1951

Medium	Germination Rate
Vermiculite	58.20 degrees
Parkland Soil	30.54 degrees
Lethbridge Soil	29.27 degrees

Least significant Difference = $\frac{1}{2}$ 12.19 degrees
F value = 27.69 ~~44~~

~~44~~ Exceeds the 1 per cent level of significance

Table 18. Mean germination rates (in degrees) for all temperature and media. Greenhouse Trial - Fall 1951

Medium	Temperature		
	5°C.	10°C.	15°C.
Vermiculite	42.09	61.22	71.29
Parkland Soil	17.03	21.74	49.02
Lethbridge Soil	19.07	22.78	49.77

F value = 40.76 ~~44~~

~~44~~ Exceeds the 1 per cent level of significance

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The interaction between temperature and media was again highly significant, indicating a differential effect of temperature in different media. In Table 18 and Figure 24 it may be observed that the germination rate dropped more markedly from 15°C. to 10°C. in the two soils than in the Vermiculite medium.

The duration of exposure, alone, was not found to have any significant effect upon the germination rate (Table 19), but its interaction with temperature was highly significant, indicating that the duration of exposure affected the reaction of the seed to the temperature treatments. Table 20 and Figure 25 illustrate how germination at 5°C. dropped sharply as duration of exposure lengthened, while at 10°C. germination dropped slightly after 20 days exposure and then increased rather sharply after 30 days exposure.

Table 19. Mean germination rates (in degrees) of duration of exposure. Greenhouse Trial - Fall 1951

Number of Days Exposed	Germination Rate
10	46.41 degrees
20	36.75 degrees
30	34.87 degrees

F value = 1.69

Table 20. Mean germination rates (in degrees) for all combinations of duration of exposure and temperature Greenhouse Trial - Fall 1951

Number of Days Exposed	Temperature		
	5°C.	10°C.	15°C.
10	40.80	35.84	62.58
20	25.46	30.84	55.90
30	11.95	39.06	53.60

F value = 29.03 ~~44~~

~~44~~ Exceeds the 1 per cent level of significance

Fig. 24 . The combined effect of temperatures and media upon the germination rate of sweet corn. Greenhouse Trial - Fall 1951.

Fig. 25. The combined effect of duration of exposure and temperature upon the germination rate of sweet corn. Greenhouse Trial.- Fall 1951.

Significant differences were also observed between the germinating ability of the four varieties in the trial (Table 21). Altagold germinated significantly better than any of the other three varieties, while Dorinny germinated at a significantly lower rate than the other three. No difference between the germination rates of Carmelcross and Golden Early Market could be established.

Table 21. Mean germination rates (in degrees)
for varieties. Greenhouse Trial - Fall 1951

Variety	Germination Rate
Altagold	50.22 degrees
Carmelcross	36.64 degrees
Dorinny	30.00 degrees
Golden Early Market	40.49 degrees

Least Significant Difference = $\pm$ 6.58 degrees
F value = 19.62 ~~44~~

~~44~~ Exceeds the 1 per cent level of significance

Table 22. Mean germination rates (in degrees) of varieties
at all temperatures. Greenhouse Trail - Fall 1951

Variety	Temperature		
	5°C.	10°C.	15°C.
Altagold	35.39	47.72	67.55
Carmelcross	24.41	30.21	55.56
Dorinny	16.86	27.34	45.79
Golden Early Market	27.88	35.72	57.88
F value = 1.00			

The effect of temperature upon the germination of the four varieties of sweet corn are illustrated in Table 22 and in Figure 26. The insignificant F value indicates that the

varieties responded similarly to temperature treatment. The graph in Figure 26 bears this out more emphatically.

The nature of the germinating medium significantly influenced the germination of the different varieties. Table 23 and Figure 27 shows that the reduction in germination in soils, as compared to vermiculite, was greatest for the variety Carmelcross and least for Altagold. Germination of Carmelcross was reduced by nearly two-thirds, that of Altagold by approximately one-third, and those of Dorinny and Golden Early Market by approximately one-half.

Table 23. Mean germination rates (in degrees) of varieties as affected by the germinating medium
Greenhouse Trial - Fall 1951

Variety	Medium		
	Vermiculite	Parkland Soil	Lethbridge Soil
Altagold	65.86	42.18	42.62
Carmelcross	60.48	23.91	25.52
Dorinny	46.20	20.80	22.99
Golden Early Market	60.25	30.18	31.04

F value = 3.49 *

* Exceeds the 5 per cent level of significance

In order to better evaluate the effects of temperature upon the germination of sweet corn, a separate analysis of variance was computed for the data obtained for the seed germinated in Vermiculite. The complete analysis of variance is tabulated in Appendix IV.

Fig. 26. The effect of temperature upon the germination of four varieties of sweet corn. Greenhouse Trial - Fall 1951.

Fig. 27. The effect of medium upon the germination rate of four varieties of sweet corn. Greenhouse Trial - Fall 1951.

Temperature again caused significant differences in the germination of sweet corn. Mean germination rates for the different germinating temperatures are listed in Table 24. Applying the least significant difference it is observed that germination was significantly reduced with each decrease in germination temperature.

Table 24. Mean germination rates (in degrees) for sweet corn germinated in vermiculite at different temperatures
Greenhouse Trial - Fall 1951

Temperature	Germination Rate
5°C.	42.09 degrees
10°C.	61.22 degrees
15°C.	71.28 degrees

Least Significant Difference = $\frac{1}{2}$ 4.26 degrees

F value = 145.81 ~~vv~~

~~vv~~ Exceeds the 1 per cent level of significance

Varieties differed significantly ($F = 40.47$ ~~vv~~) in their germinating ability, and, as before, the germination at the different temperatures was differentially affected by the duration of exposure, ($F = 25.59$ ~~vv~~). The interaction between varieties and temperatures was again insignificant ($F = 2.18$) verifying the observation that the varieties did not react differently to temperature treatment.

Note: In each of Figures 28 to 33 the quaduplicate rows of varieties appear in the following rotation: Front row (1 to 4) - Altagold, Carmelcross, Dorinny, Golden Early Market exposed for 30 days; and Altagold and Carmelcross exposed for 20 days. Back row (1 to 4) - Dorinny, Golden Early Market exposed for 20 days; and Altagold, Carmelcross, Dorinny and Golden Early Market exposed for 10 days.

Fig. 28

Fig. 29

Figures 28 and 29. The germination of sweet corn seed in Vermiculite, showing the effects of temperature and duration of exposure after seven days in the greenhouse Greenhouse Trial - Fall 1951. Fig. 28 exposed at 5°C. and Fig. 29 at 10°C. Note also varietal effects (see footnote p. 46).

Fig. 30

Fig. 31

Figures 30 and 31. The germination of sweet corn seed in Parkland Soil, showing the effects of temperature and duration of exposure after seven days in the greenhouse. Greenhouse Trial - Fall 1951. Fig. 30 exposed at 5°C. and Fig. 31 at 10°C. Note also varietal effects (see footnote p. 46).

Fig. 32

Fig. 33

Figures 32 and 33. The germination of sweet corn seed in Lethbridge Soil, showing the effects of temperature and duration of exposure after seven days in the greenhouse. Greenhouse Trial - Fall 1951. Fig. 32 exposed at 5°C. and Fig. 33 at 10°C. Note also varietal effects (see footnote p. 46).

DISCUSSION OF RESULTS

The germination of sweet corn was significantly reduced by the lowering of the soil temperature from 15°C. to 10°C. There was, however, no significant reduction in germination when the temperature was reduced from 10°C. to 5°C. or 1.7°C. It is apparent, therefore, that the minimum temperature, at which germination and growth of sweet corn will take place actively, is above 10°C. and below 15°C. Similar observations were recorded by Lehenbauer (12), Erwin (3), and Magoon and Culpepper (13). The results of this experiment indicate that the temperature range used was too wide to determine a minimum growth temperature, although the lower temperatures might be used satisfactorily in evaluating the cold hardiness of inbred lines of sweet corn, as recommended by other workers (5, 7, 9, 16, 17, 18). Further studies are planned in which a range of temperatures between 10°C. and 15°C. will be used to determine the minimum growth temperature of sweet corn. In the 1950 Field Trial, it was observed that the mean germination rate at 10°C. was slightly lower than the mean germination at 5°C. (Figure 16 and Table 2). This relationship was most pronounced in the case of seed germinated in Parkland Soil (Table 4). Haskell (5) recorded similar results. As an assumption, one might feel that the Parkland Soil supported the largest population of harmful parasitic organisms, and these might logically be more active at the higher temperature. The greenhouse trials failed to confirm the above observations, resulting in rather inconclusive results on this point.

That the nature of the germinating medium affected the germination of sweet corn, as reported by Haskell (7), was confirmed in the trials reported in this paper. Germination in the soils was much lower than it was in sterile vermiculite. This was particularly true at the two lower temperatures, as illustrated in Figures 16, 22, and 24. These observations suggest strongly that the reduction of germination in soils at low temperatures is, as reported by Haskell (5), due partly to the direct effects of cold and partly to the detrimental effects of soil pathogens. The seed exposed to the 10°C. temperature showed a greater incidence of moulded kernels than did the seed exposed to 5°C. Where only the germination in vermiculite was considered (Table 24) germination was reduced progressively as temperatures became lower, with greatest reduction from 10°C. to 5°C. It is, therefore, logical to assume (as indicated earlier) that the reduction in germination at 5°C. is due, largely, to the destruction of the embryo by direct effect of cold, and at 10°C. by the penetration of soil pathogens into the damaged seeds and slowly developing coleoptiles.

Since the duration of exposure to controlled temperatures was found to be significant in only one trial, it must be assumed that it was not important, in itself, in determining stands. It did, however, appear to bear a significant relation to stands at the lower temperatures, as illustrated in Figures 17 and 25, where marked decreases were observed as the duration of exposure lengthened. Haskell (5, 7) recorded similar results.

Other workers (5, 7, 9, 16, 17) have reported that inbred lines and hybrids react differently to cold treatment, with some inbreds being more cold resistant than others. They observed, too, that the hybrids generally possessed greater cold resistance than their parent lines. In this project, significant differences were obtained between varieties in all trials. The same varieties did not always occupy the same position in relation to high or low germination. When compared under the different temperature treatments, it was observed that all varieties reacted similarly to each temperature within a trial (Figures 20, 21, and 26). It appears logical to conclude that varieties differed only as the relative germinating ability of the lots of seeds differed. The differences could be explained on the basis of maturity, as has been discussed by Rush and Neal (19). The similarity of the reactions of all varieties to temperature treatment may be due, to some extent at least, to the fact that all were varieties requiring a relatively short growing season. A late season variety, such as Iochief, Lincoln, or Lee, may have reacted differently to cold treatment.

On the basis of the maturity data obtained from the 1950 Field Trial, it was not possible to distinguish any differences in maturity as affected by germination, temperature and/or duration of exposure, within a variety. There was some variation in date of silking but this was not consistent for each treatment. It seemed reasonable to assume that sweet corn germinated at 15°C. would mature earlier than that germinated at the lower temperatures because plants were better developed at

planting out time. These plants suffered a severe setback, as mentioned earlier, and at silking time were at the same stage of maturity as those germinated at the lower temperatures. If the seed had been sown in plant bands it is probable that the transfer might have been made without serious injury to the seedlings, thus making for a more reliable field trial.

The plants grown from seed germinated at 15°C. were somewhat taller than those germinated at the lower temperatures. Similar differences were observed by Haskell (8) who noted also that the taller plants produced fewer tillers and lower plant yields than the shorter plants. In the project, reported herein, there was no apparent difference in the number of tillers on the plants from the different temperature treatments. Unfortunately, no harvest was realized and no comparison could be made of the effect of temperature treatment upon yield.

SUMMARY

1. A series of trials were conducted during 1950 and 1951.
The effects of the following factors, upon the germination of three open-pollinated varieties (Altagold, Dorinny, and Golden Early Market) and one hybrid (Carmelcross) of sweet corn, were studied:
 - (a) Controlled temperatures - $5^{\circ}\text{C}.$, $10^{\circ}\text{C}.$, and $15^{\circ}\text{C}.$ (except in one trial when $1.7^{\circ}\text{C}.$, $10^{\circ}\text{C}.$, and $18.3^{\circ}\text{C}.$ were used);
 - (b) Germinating media - Vermiculite, Parkland Soil, and Lethbridge Soil;
 - (c) Duration of exposure - 10, 20, and 30 days.
2. Each trial was laid out as a split-plot factorial.
3. The percentage data were transformed by means of the angular transformation and were analysed statistically.
4. Highly significant differences were observed between the highest temperature treatment and the lower ones in each trial. This was more pronounced in soils and under different durations of exposure.
5. Germination was significantly better in Vermiculite than in either of the soils used.
6. The duration of exposure was important only at the two lower temperatures of each trial, when increased exposure caused significant reductions in germination.
7. The germination rates of the different varieties differed significantly, but all reacted similarly to temperature treatment.

CONCLUSIONS

The following observations have been made on the basis of the results obtained from the experiments described elsewhere in this thesis:

1. Temperatures of 10°C . or lower caused significant reductions in the germination of sweet corn. There was no apparent difference between the effects upon germination of 10°C . and of the lower temperatures studied.
2. Germination in soil was significantly lower than in sterile vermiculite, particularly at the lower temperatures, indicating the importance of soil pathogens in limiting the stands of sweet corn at low temperatures. This could be overcome, to some extent, by seed treatment.
3. The overall effect of duration of exposure did not appear to be important in determining the stands of sweet corn. However, when considered in relation to temperature, the duration of exposure had a highly significant effect, causing markedly reduced germination at the lower temperatures but not at 15°C .
4. Varieties were found to differ significantly in their ability to germinate. None showed any differential effect due to temperature treatment or to duration of exposure. The differences observed must be considered to be related to the viability and to possible differences in maturity of the several seed lots used.

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APPENDIX IANALYSIS OF VARIANCE - FIELD TRIAL 1950

Variance due to	D.F.	Sums of Squares	Mean Square	F.
<u>WHOLE PLOTS:</u>				
Replicates	3	1821.69	607.23	1.93
Temperatures	2	17508.35	8754.17	9.79 *
Media	2	83255.67	41627.84	46.57 **
T x M	4	3574.20	893.72	2.85 *
Error (a)	24	7526.24	313.59	

SUB-PLOTS:

Exposures	2	27642.17	13821.09	11.53 *
Varieties	3	15222.33	5074.11	10.07 **
E x V	6	733.80	122.30	1.17
E x T	4	4796.46	1199.11	11.69 **
E x M	4	1227.12	306.78	2.93 *
V x T	6	355.74	59.29	0.57
V x M	6	3024.39	504.07	4.81 **
E x V x T	12	762.62	63.55	0.61
E x M x T	8	769.58	96.20	0.92
E x V x M	12	1404.70	117.06	1.12
V x T x M	12	1343.66	111.97	1.07
E x V x T x M	24	2513.33	104.72	1.56 *
Error (b)	297	19957.74	67.20	

* Exceeds the 5 per cent level of significance
 ** Exceeds the 1 per cent level of significance

Calculations of Least Significant Differences:

$$L.S.D. = \frac{2(s^2)}{K} (t_{.05})$$

L.S.D. (Temperature and Media) = (3.52)(2.776) = $\pm$ 9.77 degrees
 L.S.D. (Exposures) = (4.08)(2.776) = $\pm$ 11.33 degrees
 L.S.D. (Varieties) = (3.06)(2.447) = $\pm$ 7.49 degrees

APPENDIX IIANALYSIS OF VARIANCE - GREENHOUSE TRIAL 1950-51

Variance due to	D.F.	Sums of Squares	Mean Square	F.
<u>WHOLE PLOTS:</u>				
Replicates	3	46.74	15.58	0.35
Temperatures	2	169861.07	84930.54	18.70 ***
Media	2	46360.64	23180.32	5.10
T x M	4	18167.24	4541.81	20.52 ***
Error (a)	24	5312.87	221.37	

SUB-PLOTS:

Exposures	2	13519.90	6759.95	5.27
Varieties	3	11691.06	3897.02	17.09 ***
E x V	6	609.43	101.57	1.28
E x T	4	5134.75	1283.69	5.45 *
E x M	4	1479.35	369.84	1.56
V x T	6	1523.39	253.90	1.11
V x M	6	3572.39	595.40	2.61
E x V x T	12	955.02	79.59	1.80 *
E x M x T	8	1883.54	235.44	5.32 ***
E x V x M	12	612.14	51.01	1.15
V x T x M	12	2738.19	228.18	5.16 ***
E x V x T x M	24	1140.43	47.52	1.07
Error (b)	297	13146.39	44.26	

~~*~~ Exceeds the 5 per cent level of significance
~~***~~ Exceeds the 1 per cent level of significance

Least Significant Differences:

L.S.D. (Temperatures) = $(8.151)(2.776) = \pm 22.63$ degrees
 L.S.D. (Varieties) = $(2.06)(2.179) = \pm 4.49$ degrees

APPENDIX IIIANALYSIS OF VARIANCE - GREENHOUSE TRIAL FALL 1951

Variance due to	D.F.	Sums of Squares	Mean Square	F.
<u>WHOLE PLOTS:</u>				
Replicates	3	32.82	10.94	0.52
Temperatures	2	71145.36	35572.68	25.59 ***
Media	2	76972.30	38486.15	27.69 ***
T x M	4	5560.24	1390.06	40.76 ***
Error (a)	24	818.43	34.10	
<u>SUB-PLOTS:</u>				
Exposures	2	11046.59	5523.30	1.69
Varieties	3	23145.96	7715.32	19.62 ***
E x V	6	260.48	43.41	0.39
E x T	4	15089.59	3272.40	29.05 ***
E x M	4	255.62	63.41	0.59
V x T	6	679.68	113.28	1.00
V x M	6	2559.15	393.19	3.49 *
E x V x T	12	381.71	31.81	0.28
E x M x T	8	1722.45	215.31	1.99
E x V x M	12	1375.42	114.62	1.02
V x T x M	12	1720.39	143.37	1.27
E x V x T x M	24	2705.44	112.73	6.65 ***
Error (b)	297	5033.93	16.95	

* Exceeds the 5 per cent level of significance
~~***~~ Exceeds the 1 per cent level of significance

Least Significant Differences:

$$\begin{aligned} \text{L.S.D. (Temperatures and Media)} &= (4.59)(2.776) = \\ &\quad \pm 12.19 \text{ degrees} \\ \text{L.S.D. (Varieties)} &= (2.69)(2.447) = \pm 6.58 \text{ degrees} \end{aligned}$$

APPENDIX IVANALYSIS OF VARIANCE - VERMICULITE DATA
GREENHOUSE TRIAL FALL 1951

Variance due to	D.F.	Sums of Squares	Mean Square	F.
<u>WHOLE PLOTS:</u>				
Replicates	3	48.55	16.18	0.22
Temperatures	2	21121.60	10560.80	145.81 ***
Error (a)	6	454.59	72.43	
<u>SUB-PLOTS:</u>				
Exposures	2	3667.66	1833.83	1.14
Varieties	3	7655.46	2544.49	40.47 ***
E x V	6	762.75	127.13	2.02
E x T	4	6434.33	1608.58	25.59 ***
V x T	6	824.17	137.36	2.18
E x V x T	12	1348.33	112.36	1.79
Error (b)	99	6224.47	62.87	

~~***~~ Exceeds the 1 per cent level of significance

Least Significant Differences:

$$\begin{aligned} \text{L.S.D. (Temperatures)} &= (1.74)(2.447) = \frac{1}{1} 4.26 \text{ degrees} \\ \text{L.S.D. (Varieties)} &= (1.87)(1.987) = \frac{1}{1} 3.71 \text{ degrees} \end{aligned}$$

APPENDIX VTHE TRANSFORMATION OF PERCENTAGE DATA TO DEGREES ‡

$$\text{Percentage} = \sin^2 \theta$$

Per cent	Degrees	Per cent	Degrees	Per cent	Degrees
0	0.0				
1	5.7	36	36.9	71	57.4
2	8.1	37	37.5	72	58.1
3	10.0	38	38.1	73	58.7
4	11.5	39	38.6	74	59.3
5	12.9	40	39.2	75	60.0
6	14.2	41	39.8	76	60.7
7	15.3	42	40.4	77	61.3
8	16.4	43	41.0	78	62.0
9	17.5	44	41.6	79	62.7
10	18.4	45	42.1	80	63.4
11	19.4	46	42.7	81	64.2
12	20.3	47	43.3	82	64.9
13	21.1	48	43.9	83	65.6
14	22.0	49	44.4	84	66.4
15	22.8	50	45.0	85	67.2
16	23.6	51	45.6	86	68.0
17	24.4	52	46.1	87	68.9
18	25.1	53	46.7	88	69.7
19	25.8	54	47.3	89	70.3
20	26.6	55	47.9	90	71.6
21	27.3	56	48.4	91	72.5
22	28.0	57	49.0	92	73.6
23	28.7	58	49.6	93	74.7
24	29.3	59	50.2	94	75.8
25	30.0	60	50.8	95	77.1
26	30.7	61	51.4	96	78.5
27	31.3	62	51.9	97	80.0
28	31.9	63	52.5	98	81.9
29	32.6	64	53.1	99	84.3
30	33.2	65	53.7	100	90.0
31	33.8	66	54.3		
32	34.4	67	54.9		
33	35.1	68	55.6		
34	35.7	69	56.2		
35	36.3	70	56.8		

‡ Extracted from Hayes and Inner (10)

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