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Effect of Low Temperature on the Germination of Artificially Dried Seed Corn

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AGRICULTURAL EXPERIMENT STATION

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SUMMARY

Soil pathogens were primarily responsible for the reduction in emergence of corn seedlings following the cold treatment. The susceptibility of the seedlings to soil pathogens was much greater when the seedlings were exposed to a soil temperature of 5° C. for 7 to 14 days than when they were held continuously at 20° C.

Seedling emergence was in inverse relation to kernel moisture content at time of harvest. Artificial drying of the seed intensified this effect, particularly in nonsterile soil.

Treatment of the seed with Arasan prior to planting completely eliminated the effect of soil pathogens on seedling emergence either with or without the cold treatment.

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CONSIDERABLE interest has developed in recent years in improving the germinability of seed corn in cold soils. With the advent of artificial drying this problem has become even more important. In preliminary tests at the Nebraska Agricultural Experiment Station to compare the ability of hybrids to emerge from soil after having been exposed to a temperature of 5° C. for 14 days, the results indicated that the conditions under which the seed was produced, harvested, and processed might influence the susceptibility to cold. It therefore seemed desirable to determine the influence of the condition of the seed on emergence following the cold treatment before making further comparisons of hybrids.

Tatum (*19*), Haskell (*4*), and Haskell and Singleton (*6*) have discussed the various methods used, and problems arising in connection with cold treatments. Haskell (*4*) concluded that germination, as measured by the emergence of the plumule, decreases as the duration of the exposure to the cold increases. Magoon and Culpepper (*16*) and Kiesselbach and Ratcliff (*9*) discuss several additional factors that are important in determining the ability of seeds to germinate and produce strong plants at low temperatures. Tatum (*19*) found that differences between inbred strains were erratic and the effects seemed to be due to seed conditions in the samples used rather than to genetic resistance or susceptibility. Haskell and Singleton (*6*) report that the cold resistance of seeds is primarily determined by the genetic constitution of the embryo.

Haskell (*4*), Haskell and Singleton (*6*), Ho (*7*), Magoon and Culpepper (*16*), and Tatum (*19*) suggest that organisms are the most im-

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portant factor in reducing emergence following exposure to cold. Haskell and Singleton (*6*), Pinnell (*18*), and Tatum (*19*) found that there are also significant heritable differences in cold susceptibility between inbred and hybrid lines of corn but there is some question whether this is susceptibility to cold injury or susceptibility to organisms under the influence of cold temperatures. Magoon and Culpepper (*16*) have shown that the minimum temperature for physiological activity of corn is considerably above the temperature used in the cold treatment. Haskell (*4*) presents evidence that the cold treatment interferes with the germinating ability of the seed and also renders the seedlings more susceptible to soil pathogens. Haskell and Singleton (*6*) suggest that the more important factors in cold resistance may be the "ability to resist attacks by different pathogenic organisms and the ability of the protoplasm to freeze without damage to vitality." Dickson, Eckerson, and Link (*1*) suggest that the effect of low temperatures in increasing the susceptibility of corn seedlings to certain soil pathogens is primarily on the metabolism of the host plant with the result that at low temperature the cells of the maize seedlings are unable to accumulate materials which offer resistance to fungus penetration.

The effect of artificial drying of seed corn on the emergence of seedlings at low temperatures has not been given adequate consideration in the literature. Harrison and Wright (*3*) report that artificial drying at 40° to 44° C. did not injure the germination, seedling growth, and field performance of corn at ordinary temperatures. Kiesselbach (*10*) found that artificial drying at 41.6° C. caused no injury to corn with an original moisture content of 49 per cent or lower but when the moisture content was 55 per cent the percentage of germination and vigor of the sprouts were both materially reduced in the rag doll. Drying at 44.9° C. caused no injury when the original moisture content was 38 per cent, but with 50 per cent moisture, germination was reduced. McRostie (*17*) obtained results that were very similar, except that with 55 per cent kernel moisture there was no injury when drying was at 40.6° C. With 30 per cent moisture, no injury occurred even with a drying temperature of 54.4° C. Dimmock (*2*) also found that the moisture content of the kernel and the drying temperature are important factors in determining the amount of injury that may result. He concluded that a temperature of 42.2° C. ± 2.7° C. is safe for drying corn containing up to 35 per cent moisture in the kernels at harvest, such corn being considered as having reached normal maturity. However, when the kernel moisture exceeds 40 per cent, drying at this temperature is injurious. In general, the kernel with the lower moisture content will endure a higher drying temperature.

MATERIALS AND METHODS

Ten ears of the single cross WF9 x M14 were collected at weekly intervals during the growing seasons of 1948 and 1949, beginning three weeks after pollination at each of three locations—Lincoln, North Platte, and Scottsbluff, Nebraska. The corn at North Platte and Scottsbluff was grown in irrigated fields. The ears from these locations were left in the husks, placed in a cardboard box and packed with paper to reduce bruising, and sent by overnight express to Lincoln for drying.

Each collection was divided into two equal samples, then one was dried naturally and the other artificially. Natural drying consisted of placing the ears on a rack in an open room at 25° to 30° C. until the moisture content reached approximately 12 per cent. Artificial drying was done in a 4 x 4 ft. chamber at a temperature of 40° C. ± 2° C. The temperature was maintained by a flow of hot air through the chamber. Heat was supplied by two electric heating units equipped with a fan and thermostat. The ears were placed on a rack in the chamber to facilitate air circulation and were left until the moisture content was reduced to approximately 12 per cent. After drying, the ears were kept in an open room at 20° to 30° C. for two weeks, then placed in cold storage at 5° C. with those dried naturally. The corn was carefully shelled by hand and kernels showing visible injury were discarded. The seed from each sample of five ears was composited.

Wooden flats 18 x 15 x 6 inches were filled to a depth of 4 inches with composted soil consisting of 3 parts sod soil and 1 part sand. An effort was made to keep the soil uniformly wet by careful watering. The seed was planted 1½ inches deep and the flats were held in the greenhouse at a temperature of 20° C. for 72 hours. At the end of this period the seed had germinated and the radicle was ½ to 1 inch long, depending on the condition of the seed. The flats were then placed in a refrigerated room at 5° C. for a specified period of time, after which they were returned to the greenhouse at 20° C. for three weeks when emergence records were taken.

A cold treatment of 14 days was used with the seed collected in 1948. However, with the seed collected in 1949, complete pre-emergence loss occurred with the 14-day exposure to cold, and it was necessary to reduce the exposure to seven days to permit evaluation of the various factors under test.

This change in length of exposure to cold was necessary because of differences in the soil during the two years. When seed collected during 1948 and 1949 was germinated in the same soil under similar conditions, comparable emergence was obtained. Undoubtedly the number and types of organisms present in the two soils varied considerably.

RESULTS

The results of the tests conducted over the two-year period with seed produced at Lincoln are summarized in tables 1 and 2. The data obtained with seed produced at the North Platte and Scotts Bluff Substations were very similar; thus they are not included. The emergence data show the effects of (1) organisms in the soil, (2) exposure to low temperatures, (3) artificial drying at 40° C., and (4) moisture content of the seed at time of collection.

Effect of Soil Organisms and Temperature on Emergence

The importance of soil pathogens in causing stand reductions in cold soils may be seen by examining figure 1. A high percentage of emergence was obtained in sterile soil. In nonsterile soil there was a substantial reduction in emergence from nearly all except the most mature collections of seed. The reduction was greatest from the seed that was most immature at harvest and progressively less with increased maturity of the seed when collected.

This would indicate that the reduction in emergence is due almost entirely to the microorganisms contained in the soil. However, there are undoubtedly many factors that predispose the young corn seedlings to the attack of these organisms, and the most critical appears to be the soil temperature during the early growth stages. When other factors were comparable, emergence was lower after the seedlings were exposed to a soil temperature of 5° C. than when they were held continuously at 20° C. The effect was very marked in nonsterile soil with seed produced in both 1948 and 1949 (columns 5, 6, 9 and 10, tables 1 and 2). Reduction was greatest with the more immature seed. In sterile soil there was only a slight reduction in emergence following the cold treatment.

Effect of Artificial Drying on Emergence Following the Cold Treatment

Emergence from artificially dried seed in sterilized soil held continuously at 20° C. was similar to that from naturally dried seed, except with the very immature lots (columns 4 and 8, tables 1 and 2). The same was true following the cold treatment in sterilized soil (columns 3 and 7). In nonsterile soil, emergence from artificially dried seed produced in 1948 was greatly reduced in comparison with that from naturally dried seed following the cold treatment (columns 5 and 9), and with all except the mature collections held at 20° C. continuously (columns 6 and 10, table 1). The results from seed produced in 1949 were different in that no reduction occurred when the seedlings were grown continuously at 20° C. However, following the cold treatment a very significant reduction in emergence occurred when compared with the emergence from naturally dried seed (columns 5, 6, 9 and 10, table 2).

These results further indicate that the soil pathogens are the most important factor in reducing stands following the cold treatment.

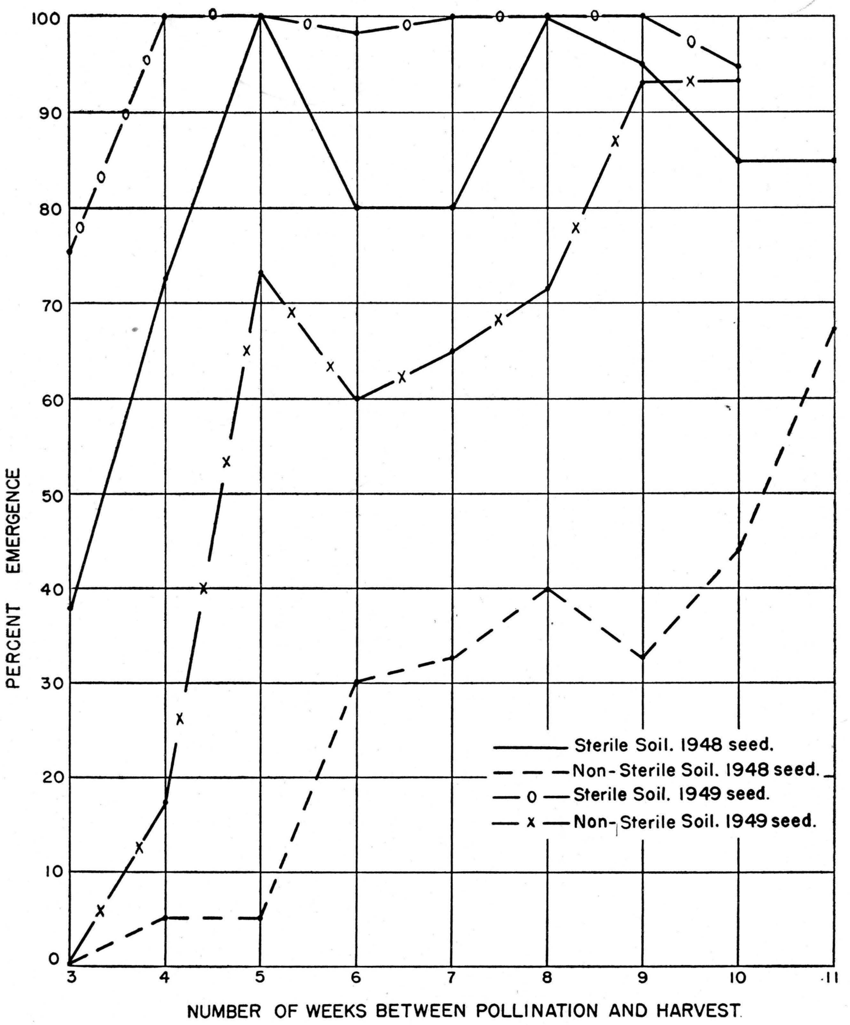

FIGURE 1.—Effect of soil pathogens on emergence of seedlings from naturally dried seed corn after subjection to the cold treatment. Seed produced at Lincoln, Nebraska.

There are also indications that the ability of corn seeds to produce seedlings is reduced when the seed is artificially dried, as shown by comparing the data in columns 5 and 9, tables 1 and 2. Numerous workers (*2, 3, 4, 5, 6, 7, 8, 10, 12, 13, 16, 17, 19*) have shown that this ability is affected by a number of factors, particularly the maturity

TABLE 1.—Effect of artificial drying of seed corn on seedling emergence in sterile and nonsterile soil at various temperatures. Seed produced at Lincoln, Nebraska, 1948. Fifteen replications of 25 seeds each in each treatment.

Weeks after polli-nation	Kernel mois-ture	Emergence as influenced by manner of drying seed							
		Natural				Artificial			
		Sterile soil at temperature of		Nonsterile soil at temperature of		Sterile soil at temperature of		Nonsterile soil at temperature of	
		5° C	20° C	5° C	20° C	5° C	20° C	5° C	20° C
1	2	3	4	5	6	7	8	9	10
No.	%	%	%	%	%	%	%	%	%
3[1]	75	37.5	45.0	0.0	17.5	2.5	7.5	0.0	0.0
4	69	72.5	92.5	5.0	60.0	27.0	17.5	0.0	5.0
5	59	100.0	95.0	5.0	95.0	65.9	65.0	0.0	35.0
6	48	80.0	87.5	30.0	82.5	80.0	92.5	11.2	52.5
7	52	80.0	97.5	32.5	95.0	56.5	72.5	11.2	37.5
8	42	100.0	100.0	40.0	97.5	43.5	37.5	16.2	35.0
9	36	95.0	100.0	32.8	100.0	90.6	95.0	31.5	77.5
10	23	85.0	100.0	44.3	100.0	85.9	95.0	43.4	97.5
11	18	85.0	95.0	67.2	97.5	85.0	92.5	41.6	95.0
	Mean	70.5	90.2	28.5	82.7	56.3	63.7	17.2	48.3

[1] First collection made on August 23, 1948.

TABLE 2.—Effect of artificial drying of seed corn on seedling emergence in sterile and nonsterile soil at various temperatures. Seed produced at Lincoln, Nebraska, 1949. Twelve replications of 20 seeds each in each treatment.

Weeks after polli-nation	Kernel mois-ture	Emergence as influenced by manner of drying seed							
		Natural				Artificial			
		Sterile soil at temperature of		Nonsterile soil at temperature of		Sterile soil at temperature of		Nonsterile soil at temperature of	
		5° C	20° C	5° C	20° C	5° C	20° C	5° C	20° C
1	2	3	4	5	6	7	8	9	10
No.	%	%	%	%	%	%	%	%	%
3[1]	73	75.0	70.0	0.0	13.4	95.0	90.0	3.3	60.0
4	62	100.0	98.4	16.7	96.7	95.0	90.0	16.7	93.4
5	51	100.0	100.0	73.3	100.0	95.0	98.4	10.0	81.7
6	45	98.4	95.0	60.0	98.4	98.4	100.0	33.3	96.7
7	50	100.0	98.4	65.0	100.0	100.0	100.0	35.0	93.3
8	28	100.0	100.0	71.7	98.4	98.4	100.0	75.0	98.4
9	22	100.0	100.0	93.4	100.0	100.0	98.4	83.3	100.0
10	14	95.0	100.0	93.4	100.0	100.0	100.0	73.3	100.0
	Mean	96.1	95.2	57.9	88.3	97.8	97.1	41.2	90.4

[1] First collection made on August 17, 1949.

of the seed at the time of drying and the temperature maintained during the drying process. Since seed maturity has been shown to be important and since it has become a common practice with hybrid seed producing companies to artificially dry seed corn, it seemed desirable to study further the effect of the cold treatment on emergence following the drying of seed at different stages of maturity.

Effect of Kernel Maturity on Seedling Emergence

No results have previously been reported on the susceptibility of artificially dried corn harvested in various stages of development to soil pathogens following the cold treatment. The results presented in tables 1 and 2 show that susceptibility increased with decreasing maturity as measured by time of collection and moisture content. There were indications that susceptibility increased more rapidly above a moisture level of about 30 per cent than below. This might be expected in view of the fact that physiological maturity of the kernel occurs at slightly above that figure. A high percentage of emergence was obtained with naturally dried seed in continuously warm soil in both years when the kernel moisture at harvest was around 60 per cent but was markedly reduced when it was around 70 per cent. It made only slight difference whether or not the soil had been previously sterilized. However, with artificially dried seed produced in 1948, emergence, at continuously warm temperatures, was low until the seed had reached physiological maturity.

The indications are, therefore, that with artificial drying, the ability of corn seed to produce seedlings will vary greatly from year to year, particularly when the seed is harvested and dried before it has become physiologically mature. The ability of the seed to produce a strong and vigorous seedling is reduced by artificial drying and the seedlings are more susceptible to soil pathogens, particularly in cold soils.

Effect of Seed Treatment on Emergence

Since reduced emergence following cold treatment appeared to be caused by pathogenic microorganisms in the soil, tests were conducted to determine if seed treatment prior to planting would be beneficial. Seed from each of the three locations was shaken with Arasan dust in a paper bag. The excess dust was screened off and the seed was planted, germinated and subjected to the cold treatment as previously described. The results were similar with seed from all locations; thus only the data obtained from seed produced at Lincoln in 1949 are reported in table 3. They indicate that seed treatment is advisable with seed dried naturally as well as artificially, even when the moisture content of the corn at the time of harvest is as low as 28 per cent.

There was a high percentage of emergence from even the most immature seed when treated.

Since the above results were obtained following only a seven-day exposure to the cold treatment, the data in table 4 are presented to show the effect of seed treatment following a severe cold treatment of 14 days duration. This treatment almost entirely eliminated the seedlings from untreated seed collected in 1949 whether dried naturally or artificially. However, when the seed was treated with Arasan before planting, a high percentage of emergence was obtained from the naturally dried seed even when harvested three weeks after pollination. With the artificially dried seed, on the other hand, a low

TABLE 3.—Effect of dusting artificially dried seed corn with Arasan on seedling emergence in nonsterile soil following the cold treatment for 7 days. Seed produced at Lincoln, Nebraska, 1949. Ten replications of 15 seeds each in each treatment.

Date collected	Weeks after pollination	Kernel moisture	Emergence as influenced by manner of drying seed: Natural		Artificial	
			Untreated	Treated	Untreated	Treated
	No.	%	%	%	%	%
8/17	3	73	0.0	80.0	3.3	90.0
8/24	4	62	16.7	100.0	16.7	96.7
8/31	5	51	73.3	100.0	10.0	100.0
9/8	6	45	60.0	96.7	33.3	93.3
9/14	7	50	65.0	91.7	35.0	90.0
9/21	8	28	71.7	100.0	75.0	98.4
9/28	9	22	93.4	100.0	83.3	100.0
10/7	10	14	93.4	100.0	73.3	100.0
	Mean		57.9	96.0	41.1	96.0

TABLE 4.—Effect of dusting artificially dried seed corn with Arasan on seedling emergence in nonsterile soil following the cold treatment for 14 days. Seed produced at Lincoln, Nebraska, 1949. Six replications of 20 seeds each in each treatment.

Date collected	Weeks after pollination	Kernel moisture	Emergence as influenced by manner of drying seed: Natural		Artificial	
			Untreated	Treated	Untreated	Treated
	No.	%	%	%	%	%
8/17	3	73	0.0	86.7	0.0	8.7
8/24	4	62	0.0	56.7	0.0	8.7
8/31	5	51	0.0	76.7	0.0	26.7
9/8	6	45	3.3	86.7	0.0	40.0
9/14	7	50	0.0	86.7	0.0	83.3
9/21	8	28	3.3	93.3	0.0	80.0
9/28	9	22	10.0	96.7	10.0	73.3
10/7	10	14	33.3	100.0	13.3	86.7
	Mean		6.2	85.3	2.9	50.9

percentage of emergence was obtained from the immature treated seed, although it was better than from the untreated samples. Emergence was good from the mature artificially dried seed after treatment but still not as good as from the mature naturally dried seed similarly treated.

These results further substantiate the conclusion that soil pathogens are primarily responsible for reduced emergence following the cold treatment, and emphasize the importance of seed treatment, particularly in connection with the practice of artificial drying.

DISCUSSION

Soil-borne pathogens are primarily responsible for the failure of seedlings to emerge from the soil following the cold treatment. This agrees with the views expressed by Magoon and Culpepper (*16*), Tatum (*19*), Leach (*14*), Haskell (*4*), Haskell and Singleton (*6*), and Ho (*7*). Many factors, however, affect the degree to which the pathogens attack the seedlings. The types and concentration of organisms as well as the other soil factors are undoubtedly very important. This was indicated when it was necessary to reduce the length of the cold treatment with the 1948 seed when compared with that produced in 1949. No attempt was made to use the same soil each year, although the soil type was similar; thus there were undoubtedly differences in the types and numbers of organisms present.

There is also the possibility that the different environmental and soil conditions under which the corn was produced during the two seasons may have altered the susceptibility, since it was shown that the susceptibility of the seedlings is related to the seed. However, there was only a small difference in the susceptibility of seed produced at Lincoln, North Platte, and Scottsbluff, where the altitude is 1,230, 2,805, and 3,950 feet, respectively. The soil types were Waukesha silty clay loam, Hall silt loam, and Tripp fine sandy loam, respectively. If variations in the environment under which the seed was produced will cause an effect on the susceptibility of the seedlings, it would seem that the differences in altitude and soil type at the three locations are sufficient to produce noticeable differences in seedling reaction.

Low soil temperatures have been shown by Dickson *et al.* (*1*) and Ho (*7*) to favor the attack on maize roots by soil pathogens. Dickson *et al.* (*1*) explain this as an effect on the metabolism of the host seedling. However, the effect observed in the studies reported here was on the seed as much as on the seedling. Hoppe, Holbert, and Dickson (*8*) report that the effect of environment on the maturation of the mother plant greatly affects the disease reaction of the seedlings to *Gibberella zeae*. Resistance increased with the maturity of the parent seed. Koehler, Dungan, and Burlison (*12*) found that seedling vigor was much better from seed harvested in the more mature stages and that field stand varied directly with the vigor of the seed planted even though the seed showed 100 per cent germination. These reports are in agreement with the data reported here which indicate that the resistance of the seedlings to soil pathogens increased with the maturity of the seed.

The increased susceptibility of seed corn to soil pathogens following artificial drying is not understood. Dimmock (*2*) studied the physiological differences associated with immaturity and artificial drying of seed corn and reported that artificial drying induces numerous changes including lowered diastase activity, slightly retarded emergence from mature seed and greatly retarded emergence from immature seed, and depressed sprouting of plumules and development of secondary roots from immature seed. He also found that lines and hybrids differ in the amount of injury resulting from artificial drying. From these results it appears that several physiological factors may be involved in the increased susceptibility of artificially dried seed. In addition, mechanical injuries to the pericarp have been shown by Koehler *et al.* (*11, 12, 13*) to increase the seedling loss in nonsterile soil. Dimmock (*2*) has shown that artificial drying slightly increases blistering of the pericarp. The importance of these injuries in the cold tests has not been adequately determined. However, in the experiments reported here, an attempt was made to minimize the effect of injuries by allowing the seed to germinate before being exposed to the cold treatment.

The value of seed treatments for stand improvement of corn has been recognized for some time and recently reviewed by Leukel (*15*). It is thus not surprising that coating the seed with Arasan protected the seedlings from the soil organisms in the cold treatment. The seed treatment provided nearly complete protection, even with the very immature seed.

No attempt was made to compare lines and hybrids of varying genetic constitution, such as has been done by Tatum (*19*), Haskell and Singleton (*6*) and Pinnell (*18*). However, the data permit the conclusion that the seed of different hybrids must be produced and processed in a comparable manner in order to make accurate comparisons of their cold susceptibility.

LITERATURE CITED

1. Dickson, J. G., Eckerson, S. H. and Link, K. P.
1923. THE NATURE OF RESISTANCE TO SEEDLING BLIGHT OF CEREALS. Proc. Nat. Acad. Sci. 9: 434-439.

2. Dimmock, F.
1947. THE EFFECTS OF IMMATURITY AND ARTIFICIAL DRYING UPON THE QUALITY OF SEED CORN. Canad. Dept. Agr. Tech. Bul. 58.

3. Harrison, C. M. and Wright, A. H.
1929. SEED CORN DRYING EXPERIMENTS. Jour. Amer. Soc. Agron. 21: 994-1000.

4. Haskell, Gordon.
1948. EFFECT OF LOW TEMPERATURE ON THE GERMINATION OF INBRED LINES OF SWEET CORN. Science 107: 150.

5. Haskell, Gordon.
1949. PRESOAKING AND COLD HARDINESS IN MAIZE. Plant and Soil I (4): 342-345.

6. Haskell, G. and Singleton, W. R.
1949. USE OF CONTROLLED LOW TEMPERATURE IN EVALUATING THE COLD HARDINESS OF INBRED AND HYBRID MAIZE. Agron. Jour. 41: 34-40.

7. Ho, W.
1944. SOIL INHABITING FUNGI ATTACKING THE ROOTS OF MAIZE. Ia. Agr. Exp. Sta. Res. Bul. 332.

8. Hoppe, P. E., Holbert, J. R. and Dickson, J. G.
1932. THE RELATION OF MATURITY OF SEED TO SEEDLING BLIGHT SUSCEPTIBILITY IN DENT CORN. (Abst.) Phytopath. 22: 12.

9. Kiesselbach, T. A. and Ratcliff, J. A.
1920. FREEZING INJURY OF SEED CORN. Nebr. Agr. Exp. Sta. Res. Bul. 16.

10. Kiesselbach, T. A.
1939. EFFECT OF ARTIFICIAL DRYING UPON THE GERMINATION OF SEED CORN. Jour. Amer. Soc. Agron. 31: 489-496.

11. Koehler, Ben.
1946. HEMP SEED TREATMENTS IN RELATION TO DIFFERENT DOSAGES AND CONDITIONS OF STORAGE. Phytopath. 36: 937-942.

12. Koehler, B., Dungan, G. H. and Burlison, W. L.
1934. MATURITY OF SEED CORN IN RELATION TO YIELDING ABILITY AND DISEASE INFECTION. Jour. Amer. Soc. Agron. 26: 262-274.

13. Koehler, B. and Dungan, G. H.
1940. DISEASE INFECTION AND FIELD PERFORMANCE OF BIN- AND HANGAR-DRIED SEED MAIZE. Jour. Amer. Soc. Agron. 32: 768-781.

14. Leach, L. D.
1947. GROWTH RATES OF HOST AND PATHOGEN AS FACTORS DETERMINING THE SEVERITY OF PRE-EMERGENCE DAMPING-OFF. Jour. Agr. Res. 75: 161-179.

15. Leukel, R. W.
1948. RECENT DEVELOPMENTS IN SEED TREATMENT. Bot. Rev. 14: 235-269.

16. Magoon, C. A. and Culpepper, C. W.
1932. RESPONSE OF SWEET CORN TO VARYING TEMPERATURES FROM TIME OF PLANTING TO CANNING MATURITY. U. S. D. A. Tech. Bul. 312.

17. McRostie, G. P.
1949. SOME FACTORS INFLUENCING THE ARTIFICIAL DRYING OF MATURE GRAIN CORN. Agron. Jour. 41: 425-429.

18. Pinnell, Emmett L.
1949. GENETIC AND ENVIRONMENTAL FACTORS AFFECTING CORN SEED GERMINATION AT LOW TEMPERATURES. Agron. Jour. 41: 562-568.

19. Tatum, L. A.
1942. THE EFFECT OF GENETIC CONSTITUTION AND PROCESSING METHODS ON THE ABILITY OF MAIZE SEED TO GERMINATE IN COLD SOIL. Ia. St. College Jour. Sci. 17: 138-140.