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Sweet Corn Seed Studies

BY A. T. ERWIN AND E. S. HABER

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

C. F. CURTISS, DIRECTOR

VEGETABLE CROPS

Ames, Iowa
SUMMARY AND CONCLUSIONS

Sweet corn seed matures at a slower rate than field corn. Due to its sugary character and high moisture content it is readily subject to damage in handling and to mold invasion.

In a study of various methods used to hasten the curing of the seed in the field:
1. Topping proved ineffective.
2. Opening the husks materially hastened the rate of drying of the ears.

The following conclusions were reached regarding the kiln drying of sweet corn seed:

Air warmed to a temperature of 100° F. can be used in drying seed corn carrying a high moisture content, without impairing its vigor.

A forced circulation and a relatively low humidity must be maintained.

A high temperature combined with high humidity is detrimental in that drying is checked and mold invasion is encouraged.

The moisture content of sweet corn seed can be reduced from 50 to 15 percent in approximately 72 hours at a temperature of 100° F. and a change of air once per minute.

Immature seed equaled the mature in percent germination, although the seedlings were not as vigorous. The immature seed showed a tendency towards earliness and yielded slightly less.

The most vigorous seedlings gave the largest yield.
Sweet Corn Seed Studies

BY A. T. ERWIN AND E. S. HABER

Sweet corn is the most important canning crop grown in Iowa. The average annual pack in this state for the past five years is approximately 2,500,000 cases. High grade seed, both as to canning quality and vitality, is of primary importance to the canning industry. Due perhaps to its sugary character, sweet corn is more difficult to cure than field corn. Also, it is a plant of less vigor and more subject to diseases. Greater care is therefore required in curing and handling the seed.

This study was undertaken to secure information regarding:

1. Methods of hastening the curing of sweet corn seed in the field by topping the plants, by opening the husks and by curing in the shock.
2. The kiln drying of sweet corn seed.
3. The influence of immature seed.
4. Relation of vigor of germination to yield.

Comparative Rate of Curing of Sweet Corn and Field Corn

Sweet corn growers in general have the idea that sugar corn is slower in drying out and more difficult to cure than field corn. As a preliminary to the other investigations, the following study was made to determine the comparative rate of maturing of sweet and field corn.

Reid's Yellow Dent, a standard variety of field corn, and Stowell's Evergreen, which occupies the same relative position for sweet corn in this state, were used in this experiment. The two varieties were planted on May 16 on adjoining plots. Beginning September 1, by which time both varieties were well dented, samples were gathered and moisture determinations made at 15-day intervals. The results are indicated in table I.

On September 1 the difference in moisture content was 18 percent. The date of planting, May 16, was late for field

<table>
<thead>
<tr>
<th>Date</th>
<th>Dent</th>
<th>Evergreen</th>
<th>Difference</th>
</tr>
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<tbody>
<tr>
<td>Sept. 1</td>
<td>35%</td>
<td>58%</td>
<td>18%</td>
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<tr>
<td>Sept. 15</td>
<td>28%</td>
<td>41%</td>
<td>13%</td>
</tr>
<tr>
<td>Sept. 30</td>
<td>17%</td>
<td>22%</td>
<td>5%</td>
</tr>
<tr>
<td>Oct. 15</td>
<td>15%</td>
<td>17%</td>
<td>2%</td>
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</tbody>
</table>

http://lib.dr.iastate.edu/bulletin/vol21/iss250/1
TABLE II. RATE OF DRYING OF EAR ON TOPPED AND CHECK PLOTS
Percent of moisture in corn at different dates after topping as compared with percent not topped.

<table>
<thead>
<tr>
<th>Date</th>
<th>Topped</th>
<th>Check</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-1</td>
<td>54.5</td>
<td>54.5</td>
<td>0</td>
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<tr>
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<td>54.5</td>
<td>52.9</td>
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<td>10-14</td>
<td>50.1</td>
<td>49.2</td>
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</tr>
<tr>
<td>10-21</td>
<td>46.1</td>
<td>51.0</td>
<td>-4.9</td>
</tr>
<tr>
<td>10-31</td>
<td>44.4</td>
<td>45.1</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

corn; otherwise the difference in the degree of maturity of September 1 would probably have been even greater. In other words, sweet corn seed gives off its moisture more slowly than field corn, due perhaps to sweet corn's sugary character.

**Does Topping the Stalks Hasten the Curing of the Seeds?**

In certain sections of New England where sweet corn seed is produced commercially, the practice of topping the plants is followed. The stalk is cut off at the first joint above the ear when the kernel has reached the early denting stage. The supposition is that topping hastens the curing of the seed by increasing transpiration, and the method used involves the reduction of the leaf area.

In garden practice, the foliage is pruned to check rather than hasten transpiration. For the purpose of determining the influence of topping on the curing of the ear the following experiment was made:

Alternate rows of Stowell's Evergreen, Country Gentleman and Crosby were topped in the customary manner. Moisture determinations were made at stated intervals from composite samples from the topped rows and check plots to determine which dried faster.

The results for the three varieties run fairly parallel. The average moisture determinations for Stowell's Evergreen for one month following topping are shown in table II.

For the first month after topping, which extends beyond the time when seed may with safety be left out of doors, the average difference between the two plots in the rate of drying is insignificant.

From a physiological standpoint, any beneficial effects from topping are not readily explained. It is thru the foliage that transpiration, or the giving off of moisture, takes place. Therefore, the more foliage the greater the transpiration. In point of fact, however, the curing of the ear comes at a stage in the life cycle of the plant when its vital processes are ebbing and rapidly ceasing to function. Any differences due to topping are, therefore, probably due to more complete admission of sunshine and an improved circulation of air rather than to any response of the plant to this pruning.
Keisselbach (14) found in the case of Hogue's Yellow Dent field corn that transpiration from the plant reached its maximum in the ninth week from planting time. This corresponds very closely as to age of plant with the early denting stage of late varieties of sweet corn. After the ninth week he found a rapid reduction in transpiration, indicating a decline in the vital forces of the leaf.

The value of the green stover provided would in a measure offset the cost of topping. (From the standpoint of curing the seed, however, the results do not compare with those for the husked ears discussed later.) Whatever merit the plan may possess seems to be based upon an early supply of green stover rather than value as a seed treatment. A grower in this state who tried topping reports that in a cold, wet season the ears of the topped plants showed a tendency to sour. We have not experienced this difficulty.

**Influence of Topping on Yield**

Does the removal of the upper portion of the stalk interfere with the filling out of the ear? Kent and Patrick (13) in studying the comparative value of fodder cut at different stages, states that "the corn plant first elaborates material and then uses this material largely in forming the ear. The full formation or complete ripeness of the ears results in considerable loss of nutrient material in the stalk and blade, the loss being 17 percent in dry matter." Duncan (5) simulated foliage injury from hail to the corn plant by means of wire brushes, used at various stages of growth. He found that when such injury occurred at the late milk and soft dough stages, which would approximate the canning stage in sweet corn, the yield was reduced from 6 to 8 bushels per acre. In the instance of sweet corn this transference of food material from the stalk to the ear is mainly in the form of dextrin and starch.

From the topped plots, 100 representative ears of Stowell's Evergreen were gathered and a corresponding number from the check plots. The average ear weight of Stowell's Evergreen from the topped plots was 145.9 grams and from the check plots 152.2 grams, or a difference of 6.3 grams. This variation of approximately 4 percent in the weight of the corn is suggestive but not significant. Tracy and Lloyd (23) found that the removal of the tops after field corn had become well glazed showed a marked decrease in yield, for which the value of the tops did not compensate. Similarly Hunt (12) reports that the yield of ears was reduced by topping the stalks when the kernels were dented. When the topping was done at the beginning of the canning stage the tendency towards "chaffiness" seemed to be more pronounced on the Ames plots.
Does the presence of the husk tend to check evaporation and hence delay the curing of the ear? For the purpose of securing information on this point, alternate rows were husked, but the ears were left attached to the stalk. This was done at the early denting stage. Moisture determinations were made from composite samples from the husked ears and from the check rows at stated intervals. Stowell's Evergreen was used for this study because it is the leading variety grown in this section and also the most difficult to cure. The results for the autumn of 1925, which are in general typical of the other years, are presented in graphic form in fig. 1.

Under favorable weather conditions for curing, the husked
ears dried out more rapidly than the check plot. On the fifth week (see fig. 1), for example, the moisture content of the husked ears was approximately 20 percent and 44 percent for the check plot.

In the fall of 1927 a number of rows of Country Gentleman were stripped on September 12. Six weeks later moisture determinations from the husked rows gave an average moisture content of 12.9 percent and for the check rows 26.4 percent. It would therefore seem that the husk, which is virtually

Fig. 2. Left ear stripped completely; middle ear stripped half way; right ear check. Photo taken 10 days after stripping. Note that the kernels are well dented on the upper half of the middle ear while those toward the butt of the ear are still in the milk stage. The benefits from stripping are largely lost unless the husk is peeled back and the butt fully exposed.
a wrapper provided by nature to protect the kernel while young and tender, retards the curing of the ear, and that the ears which are exposed to the sun and air by peeling back the husk dry more rapidly.

It was also found that the rate of drying is influenced materially by weather conditions. In a number of instances moisture determinations following a rain showed actual increase, indicating that the seed had re-absorbed a quantity of moisture. This was particularly noticeable on the check plots, due to the retentive effect of the husk. The retention of moisture at the curing stage is a vital consideration, however, particularly from the standpoint of seed infection.

Durrell (7) found "the retention of moisture at the butt of the ear to be an important factor in diplodia infection." In fact, in many seasons it is the retention of moisture rather than low temperature that is the primary cause of bad seed. Under such conditions draining the ear by opening up the husk no doubt can be followed to advantage.

Reports from growers indicate that in fields adjoining timber the stripped ears may be damaged, especially by blackbirds and crows. We have experienced some damage in the open, when only a few rows were husked. On the other hand, in a patch of a few acres or more, the damage from this source was negligible.

Data secured from growers indicate that it requires from 10 to 12 man-hours to peel back the husks on one acre.

The benefits from stripping the ears are contingent upon favorable weather, sunshine and wind. In other words, in cool, wet autumns, the particular conditions under which we need assistance, this method is not effective. It was also noted that the character of the husk varies for different varieties. With the Buena Vista, for example, the husk is long and tends to fold down close over the tip of the ear. In Country Gentleman, the edges of the inner husks are folded and wedged in more or less between the rows.

It is important that the husking be thoroughly done. The ear must be completely stripped, otherwise the upper half of it may be well dried and the lower hardly dented. The center ear in fig. 2 forcibly illustrates this.

**Rate of Curing in the Shock**

It is an old New England practice to shock sweet corn intended for seed and allow it to stand for several days, then husk and harvest the seed. Vincent and Longley (24) similarly recommends for the plains region: "The stalks should be cut and placed in small shocks. As soon thereafter as the stalks become well wilted, which usually occurs in from three to six days, the ears should be husked and dried in an airy place."
Studies were made to determine the actual rate of curing of the seed of shocked corn in comparison with that left in the field. Country Gentleman was the variety used. The seed was planted on May 22, 1924. The first determinations were made October 20, and continued to November 28. It will be noted from table III that check plots had become constant by November 4 and also that the check shows as low moisture content on November 1 as does the shocked corn on November 28. In other words, it required 28 additional days for the shocked corn to reach the 16 percent line.

In a comparison of shocked corn with topped corn, the Rhode Island Experiment Station (19) reports a yield of 1,521 pounds of hard ears and 127 pounds of soft ears from the topped plot, and 1,385 pounds of hard corn and 367 pounds of soft corn from the shocked plot, indicating that a more complete maturity was attained in the field than in the shock.

As would be expected, the conditions for drying were more favorable for the check plot than in the shock. The difference was most pronounced during the first two weeks, gradually fading from that time on. The ears in the shock retained moisture reabsorbed from rains longer than the check plot. In case of a severe frost, of course, the ears in the shock would receive protection. On the whole, the plan of shocking corn intended for seed seems to have little merit for this region.

Kiln Drying of Sweet Corn

It is a well recognized fact that the average germinative quality of commercial sweet corn seed is below that of field corn. The seed is more difficult to cure than field corn, the plant is less vigorous and hence more susceptible to adverse conditions and mold invasion. The "throwout" at shelling time is frequently heavy, making the final cost of the seed excessive. For these reasons the kiln drying of sweet corn seed offers a number of advantages.

The kiln drying of seed may be defined as the evaporation of the surplus moisture within the seed by means of a current of air, the temperature, humidity and flow of which are under control.
The factors involved in the kiln drying of sweet corn seed are initial moisture content of seed, temperature, humidity, air velocity and duration of drying period.

Moist seeds are more susceptible to injury from heat than dry seeds. The moisture content of the seeds to be dried is therefore a first consideration. Waggoner (25) found that radish seeds are resistant to heat in inverse proportion to their moisture content.

Huelson (10) dried two lots of sweet corn at 100°F. The one containing an initial moisture content of 69 percent was seriously damaged, whereas the lot containing 44 percent moisture gave a high germination and good vigor.

Since immature sweet corn seed may be injured by heat it is essential that the temperature be governed by the maturity of the seed. When the initial moisture content is high, the drying should start at a lower temperature and the temperature may be stepped up as the drying of a given lot progresses.

The drying out of the seed involves the evaporation of water or a change from a liquid to a vapor. Heat hastens this process, whether it be supplied naturally or artificially. The heat required is expressed in terms of British Thermal Units or B. T. U.* Specifically, if the grower has a sample of sweet corn containing 40 percent moisture which is to be dried to 15 percent and the corn is brought into the drier at a temperature of 60°F. and dried at 90°F., 28,643 B. T. U. are required to do the work. In other words, approximately 1,145 B. T. U. are required to evaporate 1 pound of water from the seed. It may be noted that the cellular structure of the pericarp tends to retard drying, and the rate of evaporation is therefore less than from an open vessel.

In taking up this vapor, heat is absorbed and becomes latent, resulting in a chilling effect and a drop in temperature. The amount of evaporation taking place is gauged by the drop in temperature, and to offset this there must be a continuous supply of heat.

According to Appleman and Easton (1), "The rate of ripening in sweet corn, within a wide range of temperature, appears to adhere rather strictly to Van't Hoff-Arrhenius' principle.' According to this principle the rate of ripening is increased from two to three times for each increase of 18°F.

The cheapest form of heat both as to initial cost and operation is secured by direct radiation, such as a warm air furnace. In many cases, however, it is possible to connect to a steam plant which is required for other work. Indirect heating, such as steam, provides more moderate temperatures, and in

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*1074 B. T. U. are required to transform 1 pound of water from a liquid to a vapor at 90°F.
a large room the distribution of the heat can be better controlled.

Oil burners may be used for both systems. The cost for oil is greater than for coal, but this is partially compensated for by the elimination of a fireman.

Closely associated with temperature is the humidity factor. The water vapor in the air is expressed as relative humidity. The vapor-holding capacity of the air is determined by the temperature and dew point. For example, if we have a temperature of 81° F., a dew point temperature of 68° F., and a relative humidity of 64 percent, by raising the temperature to 104° F., the dew point temperature remaining constant, the relative humidity is reduced to 32 percent. In other words, by increasing the temperature 22° F, the moisture-holding capacity of the air is increased 100 percent.

Expressed conversely, the rate of evaporation decreases as the humidity increases. An instrument for measuring the humidity of the drying room is essential. Various forms of hygrometers, such as the wet and dry bulk hygrometer and hydrodeik are available at a small cost.

The hygrometer should be located in the far corner of the drying room and not in close proximity to a ventilator. It should be read frequently during the drying period. A decided increase in humidity means a check in the rate of drying and suggests closer attention to heating and ventilation. Dripping window panes in mild weather are even a more positive index of a highly humid atmosphere and suggest a condition that needs immediate attention.

The air flow or velocity performs two functions in the kiln drying. It conducts the heat from the heating system to the corn; second, it absorbs and removes the water vapor which the heat has evaporated.

The capacity of the drier is determined by the volume of heated air which is brought in contact with the corn and the temperature maintained. The air flow is therefore a vital factor. In the earlier types of driers natural drafts were employed. This was based upon the principle that warm air is lighter than cold, hence tends to rise. In practice this plan has proven seriously defective in corn driers. Friction is developed in passing the air over the corn, resulting in a low and uneven velocity. This in turn results in the uneven drying of the seed. Dead air pockets are a fertile breeding ground for mold infection which is the most serious source of loss during the curing period. High temperatures combined with high humidity form an ideal combination for the growth of dry rot organisms. A forced circulation is therefore an essential part of the kiln drier equipment.

The fan is either located near the heating plant, in which
case it drives the air, or it is located at the farthest end of the drier and pulls it thru.

The use of a fan not only improves the circulation but also increases the efficiency of the heating system.

Willard, Kratz and Day (27) state that, "Results in practice indicate that the efficiency of the heating surface may be increased and the capacity of the furnace materially raised by the use of a fan to give a positive circulation of air over the heating surface. At an equivalent register temperature of 196° F. it was found possible to force the furnace to a capacity of 328,000 B. T. U. per hour and maintain the register temperature. The corresponding capacity under natural circulation was 114,000 B. T. U. It is therefore possible to increase the B. T. U. capacity 2.88 times."

Baker (2) advises that with "forced air thru the furnace there would be in the hot air chamber a light excess of pressure in place of a slight vacuum which at present exists, and the resulting improved circulation thus corrects the faulty distribution of heat. Another decided advantage would be the delivery of warm air instead of hot air."

This feature of the equipment is stressed by the authors because the use of heat without a forced circulation has not been a success and the loss from moldy seed in stagnant corners has in some cases been excessive. Even a very simple fan equipment will aid materially. In one instance under observation, where there had been trouble with dead-air pockets, an opening was cut thru the wall on the side near the stove; into this cold-air inlet an ordinary house fan was placed so as to drive the current of air over the stove. An opening was also made in the far end of the attic providing a warm air outlet. The circulation of air was greatly improved by these changes, and the rate of drying rendered practically uniform throughout the room.

In the tests on air velocity made by the authors, it was found that the factors of moisture content of the seed, humidity of the outside air and outside temperatures are so interrelated as to make it impossible to lay down definite rules. When the velocity was slowed down too much, the moisture laden air was not carried off properly. Under these conditions the air tended to chill at the top layer of corn, depositing a film of moisture on the seed. In general, the air replacement of once per minute may be regarded as maximum for seed which is very moist and a proportionate reduction for drier seed.

The manufacturers will furnish information regarding the volume of air their fans are capable of moving and other information along this line. The velocity of the air can be determined by means of an atmometer.

Closely allied to the subject of air velocity is that of ven-
If the drying room were a sealed chamber the air would ultimately reach the saturation point and drying would cease. On the other hand, if the heated air is passed over the corn but once, an excessive amount of heat would be wasted with the exhaust air because the volume of air required for the absorption of the moisture is much less than that needed to convey the heat required for evaporation. The happy medium is therefore a combination of re-circulation and ventilation. This involves the re-use of a portion of the warm air to which is added sufficient fresh air to lower the humidity of the resultant heated mixture of air to approximately the same humidity as the air was before it passed over the corn previously. This requires the adjustment of intake and exhaust dampers so as to maintain a relative humidity within the drier which will give the most rapid drying consistent with fuel economy.

Another type of equipment which is being used successfully by some of the canners is the "tunnel drier" which is patterned after the tunnel fruit driers used on the Pacific coast. A portion of the warehouse, the long way of the building and parallel to the wall, is closed off by means of a removable partition forming a long narrow passage or tunnel, perhaps 7 by 8 feet, and as long as the building. The fan and furnace are located at the air intake end of the tunnel and the air outlet at the opposite end. The corn is placed in a series of trays with a wire mesh bottom. The trays are tiered, with an adequate opening between, on hand trucks. The trucks enter the tunnel at the end farthest from the furnace. Each time a truck load enters the tunnel those already in are pushed forward one truck length. The loading is so timed that each truck is allowed an allotted time to pass thru the tunnel. Once the tunnel is filled the process becomes continuous. As a new load enters all of the trucks are moved forward one length and the first one is pushed out of the tunnel thru a series of air locks. The truck load of dried corn is then wheeled to the store room where the trays are either stacked or dumped. This plan has certain advantages. It is elastic in that the tunnel space can be used for other purposes the remainder of the year. It also solves the expense of re-handling and loss from shelling incident to re-handling.

Since the corn enters at the farthest end from the heating system, the drying of a given lot starts at a lower temperature. As the moisture content lowers, the corn becomes more resistant to heat, and as the trucks move forward towards the heating unit the temperature is increased.

When conditions are such that the surface evaporation from the tissue exceeds the rate of diffusion of moisture at the surface, the pericarp becomes hard and dry and tends to reduce
drying. This is known as "case hardening," and is a condition which can be overcome by lowering the temperature.

Results of Kiln Drying Experiment

The following experiment in the drying of sweet corn seed in quantity was conducted in cooperation with a grower. The husked ears were placed in a series of bins approximately 5 feet square, with a false slatted bottom. By means of a fan the air was driven thru a series of ducts into the bottom of each bin. The fan operated at a speed of 700 r. p. m. and had a displacement of 70 cubic feet per minute. The following are the averages for a series of runs. Corn with an initial moisture content of approximately 25 percent and carried at a temperature of 80° F. was reduced to 14 percent in 48 hours. Another series of runs was made on corn containing from 40 to 45 percent moisture at a temperature of 95° F.; these were reduced to a 15-percent moisture content in 72 hours. In a third series, representing corn in the early denting stage, the moisture content ranged from 55 to 65 percent. The drying period was 96 hours at 95° F.

The germinative quality in all of these samples was classed as good, the range being from 94 to 97 percent.

One criticism of this method of curing is that the corn does not dry out evenly. The lower strata receive the most heat and dry first, and the top layer last. Consequently, by the time the top layer has been reduced to a sufficient degree of dryness, the lower portion has been reduced unnecessarily low in moisture content. In one lot, for example, when the top stratum was reduced to 15 percent dryness, the center was 11 percent and the lower third 8 percent, thus leaving a spread of 7 percent between the top and bottom. Wright (28) describes a modification of this system in which the current of warm air is forced up thru the corn for 24 hours, then down thru the corn for the same period. In this manner the rate of drying is more nearly equalized thru the bin, which is a decided advantage.

In the experience of the authors, corn which contained only a limited amount of excess moisture could be dried satisfactorily in bins as above described. On the other hand, in handling wet corn in this fashion, a considerable percentage of the kernels were damaged by rupturing the pericarp. This in turn led to mold invasion. Bin drying is an economical method, but its use for drying sweet corn is limited. In the case of late maturing varieties, such as Stowell's Evergreen, it is necessary to use ear hangers in the bad seed years, for the reason mentioned above.

In the foregoing studies no effort was made to determine
the upper limits of temperature that can be used in drying without impairing the seed. Sweet corn carrying a high moisture content is probably more readily injured by a high temperature than that which is more mature. Duncan and Marston (6) found that corn in the milk and soft dough stage when kiln-dried at 112°F. showed a lower germination than corn dried in the hard dough stage at the same temperature. The moisture content in this case is not stated, but sweet corn in the milk stage will commonly run 65 to 70 percent. Huelson (10) concludes "that sweet corn with about 40 percent moisture on the dry basis may be kiln-dried at temperatures not exceeding 100°F., provided there is a proper circulation of air. The length of exposure at this temperature may vary from 48 to 72 hours without injury."

These figures would seem to be well within the limits of safety. As previously noted, we have, at a slightly lower temperature, 95°F., handled corn containing 50 percent moisture and secured a good germination. On the other hand, a drying temperature much above 100°F. for corn carrying a high moisture content seems open to serious question.

Frost injury to sweet corn seed is governed by the moisture content. Kiesselbach (14) found that field corn containing 35 percent moisture was hurt by a killing frost and germinated only 80 percent. In this connection it may be noted that sweet corn is killed at approximately 28°F. The average date for killing frost (18) for central Iowa (Des Moines) is October 10. A study of the records on moisture content for Stowell's Evergreen indicates that at the time killing frost may be expected, this variety is still carrying a high water content and therefore is liable to frost injury.

At the close of the first week in October, in Stowell's Evergreen on the Station field, for example, the moisture content in 1921 was 16 percent, while for the years 1925, 1926 and 1927 it has run around 50 percent. Suffice it is to say that much of the time late varieties of sweet corn carry a sufficiently high moisture content to subject the seed to injury from either frost or mold invasion. Early harvesting and the use of artificial heat are means of avoiding this loss.

It should be emphasized that the moisture content rather than any exact date is the best guide as to when sweet corn seed should be harvested. Samples should be gathered and moisture determinations made at intervals in the fall. From such records the grower is able to judge accurately the seasonal conditions. The Brown-Duvel (3) moisture tester is a useful and inexpensive instrument and easily operated.

Temperature is the dominant factor governing the ripening of sweet corn. Appleman and Easton (1) reports that "a late crop of corn required 15 days for the same period of ripening
that required only 6 days for an early crop, a time ratio of 2.5,"" and concludes that the rate of ripening in sweet corn, within a wide range of temperature, appears to adhere strictly to Van't Hoff-Arrhenius' principle, the application of which means that the rate of ripening in sweet corn increases from two to three times every 18° F. change in temperature, within certain limits. These limits in the case of sweet corn, according to Appleman and Easton (1), are from 40° to 99° F. A study of the temperature factors for the bad seed corn or "soft corn" years in this state verifies this principle.

Records for a series of years, for a given variety, as to when it reached the canning stage, give an index as to the rate of maturity for the corresponding years. At one of the leading factories in central Iowa, the average opening date for a 10-year period for the packing of Stowell's Evergreen is August 21. The earliest opening date within this decade was August 10. The latest was September 4 in 1924. Using 55° F. as the base, the normal total of effective heat units for the months of May to August, inclusive, is 1,850.4° F., according to the United States Weather Bureau. The actual total of effective heat units for the same months for 1924 was 1,483.3° F., or a deficiency of 367.5° F. effective heat units. The reason for the late maturity of the 1924 crop is obvious.

On account of being handled before fully ripe, the pericarp or seed coat of the kernel of sweet corn is easily damaged, affording entrance for molds. An examination of ears husked in the field and thrown into a wagon box and re-handled in the customary manner of handling field corn, shows a considerable percentage of damage and consequent loss from harvesting immature seed in this fashion. When the corn was snapped and husked immediately before being hung, the loss from this source was inappreciable. A good plan is to harvest the corn in crates. Tomato crates are convenient for this purpose.

**Relation of Moisture Content to Viability**

It is a well recognized fact that by lowering the moisture content the seed is protected from the invasion of mold and other organisms and is also able to withstand lower temperatures without injury. On the other hand, when considered from the standpoint of viability, is the seed apt to become too dry? In other words, from the standpoint of moisture content, what is the safety line below which desiccation becomes detrimental to germination? To determine this, six thermostatically controlled ovens were installed. These were operated for 72 hours at the temperatures indicated below. The initial moisture content was 14.4 percent and the germination 96 percent. The results are indicated in table IV.
TABLE IV. RELATION OF MOISTURE CONTENT TO VIABILITY

<table>
<thead>
<tr>
<th>Degrees Temp.</th>
<th>Moisture content</th>
<th>Percent germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>95°</td>
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<td>94</td>
</tr>
<tr>
<td>105°</td>
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<td>94</td>
</tr>
<tr>
<td>115°</td>
<td>4</td>
<td>87</td>
</tr>
<tr>
<td>125°</td>
<td>3.2</td>
<td>87</td>
</tr>
<tr>
<td>130°</td>
<td>3</td>
<td>77</td>
</tr>
<tr>
<td>140°</td>
<td>2.2</td>
<td>9</td>
</tr>
</tbody>
</table>

It will be noted that the germination is the same up to a temperature of 105° F. and a moisture content of 4.4 percent. In the next series of 115° F. and a moisture content of 4 percent there is a rather definite break in germination. These results suggest that a moisture content as low as 5 percent and a temperature of 100° F. are within the limits of safety for the period indicated above. In practice, there is nothing gained by reducing the moisture content below 15 percent. At this stage of dryness the invasion of molds is inhibited and the seed will withstand low temperatures. Any further reduction of moisture means a loss in weight with nothing to be gained.

Influence of Using Immature Sweet Corn Seed

A number of the sweet corn packers make it a practice to save for seed the ears off the picker belt which are too mature for canning. These ears are in the early dough stage and are just beginning to dent.

This study was undertaken to determine the value of immature sweet corn seed as compared with mature seed from the standpoint of vigor, season of maturity and productiveness.

Schmidt (21) found that the producing power of Golden Bantam corn, with respect to the number of ears, green weight of ears and dry weight of stalk and husk, varied in the same order as did the weight of the seed planted. Germination took place more rapidly in light than in heavy seed, but a greater proportion of the plants from heavy seed produced ears than from the light seed.

Crocker* states, "A good many rose growers claim that they get quicker germination from immature than from mature seeds. We now have a set of experiments going on this question and find that of the rose seeds grown on the same bush, those collected and put in a germinator at maturity germinate quicker than those collected and put in a germinator a month sooner. I seriously doubt whether there is any ground for the statement regarding rose seeds. We have found in *Betula lenta* that the fully matured seeds germinate much better than those collected a month earlier.

*Letter to the writer dated 12-13-26 from Dr. William Crocker, Boyce Thompson Institute.
"Of course, we are handling mainly seeds in connection with forestry and horticulture, but we have handled a great many different kinds of these seeds and are convinced in every case that the mature seeds are the better seeds. This is markedly the case for bittersweet (Celastrus scandens) which the nurserymen are now beginning to grow for market. As nearly as I can make out, this idea of immature seeds is based on those that will not stand drying to any great degree, such as the silver maple."

Shamel (22) in the case of tobacco tests of light and heavy seed, found that the best developed and most vigorous plants are always produced from heavy seed, while light seed produced small, irregular and undesirable plants. The plants from the heavy seed grew more rapidly than those from the light and reached the transplanting stage from 7 to 9 days earlier.

Webber and Boykin (26) found in the case of cotton that there was an increase of 10.9 percent in yield from the use of heavy seed.

Goff (8) reports, in an experiment covering five years with a variety of flint corn, that "very immature seed gave smaller yields of corn and stalks and a slightly earlier maturity than fully mature seed." Kiesselbach (15) in a two-year test with field corn found, "that carefully cured corn selected midway between silking and maturity may possess both high germinative and yielding ability. Corn selected at five weekly intervals before ripe, yielded in no case more than 2 percent less than fully matured seed. Even tho viability and yield may not be impaired by immature selection, thorough field curing of seed should be practiced as far as possible, since difficulty of curing and preservation are thereby greatly reduced. The above test does not include the effect of unfavorable growth conditions in some seasons. It is possible that small, immaturely harvested seeds would be handicapped under unfavorable climatic or seedbed conditions." Burlison (4) concluded that "corn selected after it is well dented is just as good from the standpoint of productivity as seed selected after it is completely matured."

**PLAN OF THE EXPERIMENT**

Stowell's Evergreen was selected for the study, since it is the variety most widely planted in this state. Two lots of seed were saved each year from the same stock for the three-year period. The one lot, known as immature seed, was harvested in the early dough stage, which corresponds to the early denting ears saved by the canners, and carefully cured. The second lot matured on the stalk. It was harvested previous to killing.
frosts and dried in a heated room. One-twentieth-acre plots in triplicate of each series were planted each year.

GERMINATION OF MATURE AND IMMATURE SEED*

A composite sample consisting of 500 seeds of each lot was tested for germination at planting time. The average germination for the mature seed for the five-year period was 96 percent and for the immature 92 percent. This difference, tho not marked, is in favor of the mature seed. Both lots show a higher germination than the best grades of commercial seed. It would therefore seem that from the standpoint of germination, a reasonably high degree of germination may be secured from both mature and immature seed, provided the seed is harvested early and properly cured.

Notes were also taken on the comparative rate of germination of the mature and immature seed. Generally speaking, the results favored the mature seed. For example, lot A, the mature seed, showed 81 percent germination by the fourth day, and the immature 52 percent. By the close of the sixth day, the rate of germination on the two lots was practically the same.

COMPARATIVE WEIGHT PER BUSHEL OF MATURE AND IMMATURE SEED

It is generally recognized that immature seed is likely to be "chaffy" and lighter than mature seed. For the purpose of determining the differences in this respect, weights were taken of a measured bushel of mature and immature seed at various times. Previous to such weighings, moisture determinations were made and both lots reduced to the same degree of dryness. The average weight of a measured bushel of shelled corn (Stowell's Evergreen) at 16 percent moisture, was 48.65 pounds for the mature and 43.65 pounds for the immature. This difference of approximately 10 percent was clearly discernible without the aid of scales.

These data indicate that weight per bushel and maturity of seed are definitely correlated. The lighter weight is apparently due to a difference in the quantity of food materials stored in the endosperm. Under favorable conditions, the quantity may be sufficient even in the immature seed to supply the needs of the young plant until it has formed roots and begins to feed upon the soil. On the other hand, under adverse conditions the heavier seed may have a decided advantage. The larger amount of stored food in the kernel gives the seedling a better start in the spring and often results in a more vigorous and productive plant.

*Acknowledgement is due R. A. Rudnick, formerly Assistant Chief in Vegetable Crops, who assisted in this phase of the work.
COMPARATIVE VIGOR

Two lots of 300 seeds each of immature seed and an equal number of the check were germinated in flats of pure sand in the college greenhouse. Certain differences were clearly discernible. For the mature, the stems were heavier, the plants taller and the foliage of a deeper shade of green. In the immature lot the leaves were of a yellowish green, and the plants were uniformly smaller. Fig. 3, showing typical seedling specimens of each lot, discloses these differences quite clearly. The modal height at the end of 14 days for the 600 plants from the immature was 7.25 inches and for the mature 9.20 inches, respectively.

EARLY MATURITY

The stages of development in sweet corn are more difficult to measure accurately than in the case of fruits, for example. However, the tasseling period covers but a comparatively short time and is definitely correlated with the maturing of the fruit, hence, affords a good opportunity for observing comparative differences in season. The field notes from this experiment (taken in the large) seems to indicate that the use of immature

![Fig. 3. The comparative vigor of corn plants grown from immature and mature seed. From the mature seed, the stems were heavier, the plants taller and the foliage of a deeper shade of green. In the immature lot the leaves were of a yellowish-green, and the plants were uniformly smaller.](image)
Fig. 4. Photo of Stowell’s Evergreen taken July 29, of typical plants showing comparative rate of development from immature and mature seed. Specimen on the right, from immature seed, is in full tassel, and silks have also appeared, while the one on the left from mature seed shows tassels just appearing above sheath and the ear beginning to develop.

Seed tends to develop earliness. On July 5, 1922, for example, 13 percent of the plants on the immature plot were in tassel as compared with 8.3 percent of those on mature. One week later, July 12, the plants on the immature plot were noted; 100 were in full tassel, whereas on the mature plot the tassels on the majority of the plants were just protruding beyond the leaf sheath. On July 19, 48.6 percent of the plants of immature seed showed an ear and 3 percent of the mature seed. The accom-
TABLE V. COMPARISON OF RATE OF MATURING FROM MATURE AND IMMATURE SEED

<table>
<thead>
<tr>
<th>Kind of seed</th>
<th>Percent</th>
<th>Percent</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pre-milk</td>
<td>milk</td>
<td>early dough</td>
</tr>
<tr>
<td>Immature</td>
<td>13.8</td>
<td>63.8</td>
<td>22.4</td>
</tr>
<tr>
<td>Mature</td>
<td>65.1</td>
<td>34.9</td>
<td>00.0</td>
</tr>
</tbody>
</table>

panying illustration (fig. 4), photo for which was taken July 29, shows the comparative rate of development of the two plots rather clearly.

Moisture determinations from a composite sample of kernels of each lot taken August 24 showed 54.1 percent for the corn from immature seed and 63.7 percent for that from mature seed.

Corresponding determinations made September 1 showed 50.5 percent and 49.7 percent, respectively, indicating that the two lots had practically reached a common level as regards moisture content.

Of the immature plot, 25 percent were in full tassel five days in advance of those on the mature plot. There is a definite correlation between early blooming and the canning stage, the interval being approximately 30 days for Stowell's Evergreen in this locality. In determining the canning stage as indicated by the nail test, it was estimated that the immature plot averaged from three to five days earlier than the mature.

The produce of 100 hills from each plot was harvested on August 13 and the ears classified as in either the pre-milk, milk or dough stage. Table V shows the average percentage of the ears in each class for the three-year period.

It will be noted from table V that when 64 percent of the plants from the immature seed had reached the milk or canning stage, but 35 percent of the plants from the mature seed had reached a corresponding degree of development.

The modal height of 500 plants on each plot was determined for 1924 as shown in table VI.

YIELDS

Table VII gives a summary of the yield for the five-year period. The corn was harvested at the canning stage and

TABLE VI. COMPARATIVE MODAL HEIGHT OF PLANTS FROM MATURE AND IMMATURE SEED

<table>
<thead>
<tr>
<th>Date</th>
<th>Mature seed modal height</th>
<th>Immature seed modal height</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-5-21</td>
<td>30.5&quot;</td>
<td>83.5&quot;</td>
</tr>
<tr>
<td>7-12-21</td>
<td>56.9&quot;</td>
<td>63.1&quot;</td>
</tr>
<tr>
<td>7-19-21</td>
<td>79.9&quot;</td>
<td>87.3&quot;</td>
</tr>
<tr>
<td>7-27-21</td>
<td>98.5&quot;</td>
<td>90.7&quot;</td>
</tr>
<tr>
<td>8-3-21</td>
<td>91.3&quot;</td>
<td>91.2&quot;</td>
</tr>
</tbody>
</table>
Table VII. Comparative Yield from Mature and Immature Seed—Stowell’s Evergreen

<table>
<thead>
<tr>
<th>Year</th>
<th>Mature</th>
<th>Immature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1919</td>
<td>8,880</td>
<td>8,120</td>
</tr>
<tr>
<td>1920</td>
<td>6,500</td>
<td>5,814</td>
</tr>
<tr>
<td>1921</td>
<td>4,918</td>
<td>4,434</td>
</tr>
<tr>
<td>1922</td>
<td>9,340</td>
<td>8,490</td>
</tr>
<tr>
<td>1923</td>
<td>9,100</td>
<td>8,440</td>
</tr>
<tr>
<td>Average for 5 years</td>
<td>7,749</td>
<td>7,059</td>
</tr>
</tbody>
</table>

Weighed with the husks on in conformity with “snap corn” delivered to the canning factories.

The average difference in yield of snap corn was 8.9 percent. It is significant that this difference is in line with the yields for Early Evergreen as compared with Stowell’s Evergreen. Early strains, in general, are less productive than late varieties. In using picker-belt seed, the canner is selecting for propagation the earliest strain, as evidenced by the fact that these ears have reached the denting stage while the others are still in the milk stage. He is therefore unconsciously selecting for an early type of corn.

**Conclusion**

Under favorable conditions mature and immature seed germinate equally well.

The immature seed is lighter. The mature seed shows more vigor and appears to withstand adverse conditions better. The immature seed is somewhat earlier.

The mature seed represents a later strain and produces the heavier crop, the difference being 10 percent. In favorable seed years the practice of saving immature seed is not to be recommended. In backward years it may be advisable, as such seed is likely to be superior to that exposed to the weather when containing a high moisture content.

**Relation of Germinative Vigor to Yield**

Do the readings secured from the germinator, as to weak and strong germination, bear a definite relation to yield? Discarding of ears showing weak germination as represented by seedlings with weak and slender sprouts, including those showing no plumule or stem sprout, is advised by Huddleston (9) and others, who recommend for planting, only ears with kernels showing strong, clean stem and root systems.

The present study was undertaken to determine the actual field performance of weak and strong types of seedlings.

*Average difference for five-year period equals 690 pounds per acre in favor of mature seed.*
As a preliminary to the experiment, germination tests were made from each ear, and those showing infection from diplodia or other organisms were discarded, thus reducing the comparison solely to physical vigor.

At the end of five days' run on the germinator, 900 seedlings were selected and divided into three equal lots in accordance with the following classification—plot I of weak germination and showing no plumule; plot II, weak, but having a plumule; plot III, strong germination. Fig. 5 shows representative specimens of each group.

This study differs from other experiments along this line in that the seedlings classified on the germinator as strong or weak were taken directly to the field and transplanted. Each plot was made up, therefore, of a uniform lot of seedlings of known characteristics from the standpoint of vigor rather than representing a certain percentage of strong and weak kernels.

The seedlings were taken to the field and set out singly in rows 3 feet 6 inches apart and 18 inches spacing within the row. The soil was prepared in a "garden-fine condition," and the plots were watered following the transplanting. The transplanting was done May 18, and 10 days later a stand count was made with the following results. Plot I, 60 percent stand; Plot II, 75 percent stand; Plot III, 75 percent stand.

Height measurements were taken throughout the active growing period as indicated by table VIII.

These figures (table VIII) show a slight difference in favor of Plot III for the first six weeks, but taken as a whole the difference in height growth for the three plots is not significant.

**PROPORTION OF PLANTS IN EACH GROUP FORMING SUCKERS**

Suckering or the development of tillers is regarded by many authorities as an index of vigor. A count was therefore made.

<table>
<thead>
<tr>
<th>Plot</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot I</td>
<td>2</td>
<td>4</td>
<td>20</td>
<td>38</td>
<td>29</td>
<td>7</td>
</tr>
<tr>
<td>Plot II</td>
<td>3.5</td>
<td>5</td>
<td>22</td>
<td>41</td>
<td>25</td>
<td>4.5</td>
</tr>
<tr>
<td>Plot III</td>
<td>3.5</td>
<td>4.5</td>
<td>23</td>
<td>40.5</td>
<td>24</td>
<td>4.5</td>
</tr>
</tbody>
</table>
on June 30 as to the number of suckers formed per plant. Table IX shows the percentage of the plants which formed one sucker, two suckers, etc.

Theoretically, the stand on none of the above plots seems very high. However, they are in line with what is commonly found under field conditions. Robinson and Bryan (20) report that where four kernels per hill were planted, there was an average of slightly above three plants per hill of field corn at harvest.

In all three groups, the highest percentage of plants is found in the three-sucker-per-plant class, otherwise the differences are not significant. It has been suggested that suckering is an index of vigor, but this theory is not borne out in this experiment. Furthermore, it may be noted that sweet corn, tho a less vigorous plant than field corn, suckers much more than the latter.

EARLINESS

Is there a difference in maturity between weak and strong seedlings? A count was made 60 days from the time of transplanting to determine the comparative rate of advancement for the three groups. Of the plants in plot III, 35 percent showed ears as compared with 27 percent for plot II and 29 percent for plot I. At the 90-day interval from planting time, a count was made of the number of ears showing denting. Eleven percent of the plants of plot III had dented ears and none in either plot I or II. It was also noted at harvest time that the ears on plot III averaged more mature, suggesting that, other factors being equal, the strong, vigorous plant moves along thru its cycle most rapidly and is the first to complete its work.

YIELD PER ACRE

The following are the yields of mature husked ears of Stowell’s Evergreen corn from the respective plots: Plot I,
Hughes (11) found that the planting of ears with 16 percent weak kernels results in a decrease of 3.4 bushels per acre. It should be observed that these two experiments are not parallel in one important respect. In the experiment reported by the authors, the entire plot was made up of weak or strong plants and hence uniform in character. The conditions were also more nearly ideal than occur under ordinary field conditions. The plants were evenly spaced, singly; and there was not the competition between strong and weak plants that may exist in the hill. The seed used in this experiment was of our own growing, and had been harvested early and was protected from de-vitalizing factors. The question as to what is a weak kernel is still a moot one. Hughes suggests that in cases where all of the kernels from a given ear germinate more slowly than the average for other ears, it is a question of tardy germination rather than weak vitality and it is very doubtful whether there is any such thing as “weak” vitality in corn, aside from those ears in which the germ has been injured by such agencies as freezing, molding and heating. It is generally agreed that the vitality of the kernel may be lowered thru the above-mentioned agencies. The question still remains as to whether plants may be constitutionally weak. In the instance of plot I, for example, is the apparent absence of a plumule due to an inherent weakness, or is it simply slower in development? If chargeable to some form of injury, it evidently reaches back into the formative period of the germ. So far as known, no studies have been made to determine the cause of cripples (plants lacking a plumule)—whether this is a genetic factor or due to environment.

The yield above reported indicates that the strongest plants on the germinator produced the most, and the plants showing weak germination, including those having no plumule are capable of producing an average crop under favorable conditions.

The strongest plants moved along thru their life cycle more rapidly than the weak ones. This proved true as measured by time of tasseling, denting and maturity. On the other hand, Hughes (11) has shown that a wide variation exists in interpreting the standards of vigor in germination tests and that severe reading of the germination test does not increase the yield sufficiently to counteract the expense of testing and loss of seed corn discarded.
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(27) Willard, A. C., Kratz, A. P. and Day, V. S.  
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