ELECTRICAL PROPERTIES OF SEED ASSOCIATED WITH VIABILITY AND VIGOR

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By

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Abstract

Seed of different viability and vigor have different intercellular contact and chemical composition which account for distinguishable differences in electrical properties. The electrostatic separator which affects seed according to their electrical conductivity and capacitance has been used to upgrade seed by separating the high and low quality seed.

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INTRODUCTION

Many factors affect the performance and productivity of crops. Farmers have control over some of the factors while others, such as temperature and rainfall, are not yet susceptible to control. Of those factors over which a farmer has some control, the quality of the seed to be planted is the most important. Seed of low viability and low vigor perform poorly even under ideal planting conditions, while seed of high viability and high vigor can perform well under relatively unfavorable conditions.

Variability among individual seed of a lot exist due to varying conditions under which the seeds were produced and variation in deterioration of the seeds. At any one time an individual seed drawn from a lot may range from a completely dead seed to a highly vigorous seed.

Once the proportion of non-germinable to germinable seed reaches the point where the lot does not meet acceptable marketing or legal standards for germination, the seedsman usually has three alternatives: (a) the lot can be removed from inventory and discarded; (b) it can be directed to feed or oil markets—provided the seed are suitable; or (c) it can be salvaged by blending with another lot (or lots) of higher quality. All of these alternative result in a loss of profit to the seedsman.

However, if the seedsman could remove the nonviable and nonvigor seed or even a portion of them from the lot, this would allow upgrading of the entire lot. This improvement would be passed on the farmer in a consistent supply of uniformly high quality seed. Since individual seed differ in viability and vigor it is reasonable to assume that they also differ in one or more physical properties which are indicative of the seed's viability and vigor. If a physical property such as size, density, color, or electrical characteristics is closely correlated with viability and vigor, then this property could be utilized to effect separation of the dete-riated seed and raise the quality of the entire lot.

Size and density have been used as indications of a seed's viability for many years. Color and electrical characteristics have recently shown promise as a good measure of seed's quality. Differences in seed quality result in differences in chemical composition, moisture distribution,
and inter-cellular contact. These differences can be indicated by electrical resistance, conductance, and capacitance. Therefore, there exists a strong possibility that one might use the electrical characteristics of a seed to measure its viability or vigor.

This paper attempts to summarize the work that has been done on the relation of certain electrical properties to seed viability and vigor and to point out how these properties could be better utilized as indicators of seed viability or vigor.

PREVIOUS WORK

Information on data on methodology for separating seed on a basis of viability and vigor are limited. In today's seed industry there are few applied methods for seed separation based on electrical properties. Many seed moisture indicators determine content by changes in the electrical resistance, conductivity, or capacitance across a sample of seed in a given volume.

Dexter (7) determined that live and dead corn seed differ in electrical characteristics and suggested that they might be separated on a basis of these differences. Holaday (9) has recently shown that heat damage in artificially dried corn could be determined by a combination of electrical measurement of the surface d.c. resistance and the electrical capacitance of the kernel.

In 1935 Burr and Northup (2) proposed a working hypothesis to the effect that the electrical signs to be found everywhere among living things indicate the existence of an underlying electrodynamic field whose characteristic forces impose patterns on the protoplasm.

In 1943 Burr (3) made a study of the electrical patterns in several pure line and hybrid strains of sweet corn. The corn seed used were from strains which have been under study for some time. These strains differed considerably in genetic constitution and in the degree of hybrid vigor shown in crosses between them.

The technique employed was developed by Burr in earlier work which consisted of determining the difference of potential between opposite ends and the longitudinal axis of the
was invariably positive and the opposite end negative. Contact with the system was made by silver-silver chloride electrodes and measurements made with microvoltmeter and gavano-meter. After more than 2000 measurements it was determined that there was a close relationship between the genetic constitution and the electrical pattern.

No less interesting than the electrical correlates of the pure strains was the relationship between the potential differences and hybrid vigor. The electrical studies showed a significant relationship between the potential difference and the degree of hybrid vigor; a relatively high potential difference indicated a high degree of hybrid vigor as manifested in the fields, while a lower difference indicated a lower degree of vigor.

In 1946, Nelson and Burr (11) attempted to correlate differences of potential across corn seed with viability. They hypothesized that each living corn seed is a physio-chemical system with an inherent electrical potential which is presumably the sum of E.M.F.'s of each individual cell, and as such the degree of magnitude of this force might be expected to show correlations with growth processes which are being initiated.

When E.M.F measurements were taken on the long axis, it was found that the micropylar end was nearly always negative to the germ end of the seed. Further, if an electrode was placed at the micropylar end, and the other electrode was shifted about the surface end of the seed, it was found that there was a regular pattern of equipotential lines over the surface (Fig.1).

We have attempted to make potential measurements on soybean seed and cottonseed using an electrometer, but to date we have been unable to obtain any consistent data. Static charge and methods of contacting the seed are our major instrumentation problems.

Recently Delouche (5) showed that crimson clover could be separated as to viability by using differences in density, color, and behavior in an electrostatic separator.

Delouche (5) used an electrostatic separation for the final separation of crimson clover seed. Taking advantage of differences in permeability, a difference in moisture content of viable and nonviable seed was induced by placing
Figure 1. Equipotential lines on the surface of a corn seed.
the seed in a single layer in contact with a moist paper or cloth surface for 10 minutes. After pre-conditioning, the seed were passed three times through a combination discharging, non-discharging electrical field. The seed were divided into four classifications: (a) seed lifted at 28,000 volts (b) seed lifted at 30,000 volts, (c) seed lifted at 32,000 volts, and (d) seed not lifted at 32,000 volts.

Germination percentages of seed from the various separates and a control sample are given in Table 1. The third pass pinned seed (poorest conductors) in every case had the highest germination percentage. Compared to the control, seed from this separate germinated 10 to 18 percent. Differences in germination between the poorest conductors (3rd pass pinned) and the best conductors (1st pass lifted) ranged from 26 to 38 percent. These results indicated that non-viable seed could be concentrated by use of an electrostatic separator.

TABLE 1. Viability of separates from five lots of crimson clover seed obtained after three passes through an electrostatic separator.

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Original</th>
<th>1st Pass Lifted</th>
<th>2nd Pass Lifted</th>
<th>3rd Pass Lifted</th>
<th>Pinned</th>
</tr>
</thead>
<tbody>
<tr>
<td>C10</td>
<td></td>
<td>80 (7)</td>
<td>60 (12)</td>
<td>74 (14)</td>
<td>90 (67)</td>
</tr>
<tr>
<td>%Germ.</td>
<td>80</td>
<td>64</td>
<td>60</td>
<td>74</td>
<td>90</td>
</tr>
<tr>
<td>%Seed</td>
<td></td>
<td>(7)</td>
<td>(12)</td>
<td>(14)</td>
<td>(67)</td>
</tr>
<tr>
<td>C11</td>
<td></td>
<td>72 (23)</td>
<td>68 (23)</td>
<td>67 (17)</td>
<td>88 (37)</td>
</tr>
<tr>
<td>%Germ.</td>
<td>72</td>
<td>56</td>
<td>68</td>
<td>67</td>
<td>88</td>
</tr>
<tr>
<td>%Seed</td>
<td></td>
<td>(23)</td>
<td>(23)</td>
<td>(17)</td>
<td>(37)</td>
</tr>
<tr>
<td>C12</td>
<td></td>
<td>76 (13)</td>
<td>63 (13)</td>
<td>74 (26)</td>
<td>90 (48)</td>
</tr>
<tr>
<td>%Germ.</td>
<td>76</td>
<td>52</td>
<td>63</td>
<td>74</td>
<td>90</td>
</tr>
<tr>
<td>%Seed</td>
<td></td>
<td>(13)</td>
<td>(13)</td>
<td>(26)</td>
<td>(48)</td>
</tr>
<tr>
<td>C13</td>
<td></td>
<td>82 (14)</td>
<td>72 (11)</td>
<td>79 (22)</td>
<td>92 (53)</td>
</tr>
<tr>
<td>%Germ.</td>
<td>82</td>
<td>60</td>
<td>72</td>
<td>79</td>
<td>92</td>
</tr>
<tr>
<td>%Seed</td>
<td></td>
<td>(14)</td>
<td>(11)</td>
<td>(22)</td>
<td>(53)</td>
</tr>
<tr>
<td>C14</td>
<td></td>
<td>68 (25)</td>
<td>52 (20)</td>
<td>68 (18)</td>
<td>86 (37)</td>
</tr>
<tr>
<td>%Germ.</td>
<td>68</td>
<td>56</td>
<td>52</td>
<td>68</td>
<td>86</td>
</tr>
<tr>
<td>%Seed</td>
<td></td>
<td>(25)</td>
<td>(20)</td>
<td>(18)</td>
<td>(37)</td>
</tr>
</tbody>
</table>
The basic purpose of seed testing is to determine the quality level of seed. The standard germination test determines the percent of seed which are capable of producing a normal seedling under ideal conditions. Obviously the conditions in the field are seldom ideal. Vigor tests are designed to determine the performance of seed under adverse conditions and to give a better indication of field emergence. The best known vigor test are the corn cold test, rapid aging technique and speed of germination test.

The corn cold test attempts to duplicate on a laboratory scale the cold wet conditions often encountered after corn is planted in the spring but before emergence. Cold test methods are not completely standardized. Soil gathered from a corn field and mixed with sand is used. The seed are planted in the soil and the soil is adjusted to 60% to 80% saturation. The tests are then held at 5°C for 5 to 10 days then transferred to 30°C, and percent seedling emergence determined.

The rapid aging technique subjects the seed to 100% relative humidity and 45°C for a predetermined period. At the end of the rapid aging period they are removed immediately and subjected to a standard germination test. Vigorous seed can stand the adverse storage conditions better and will retain a higher germination percent than will seed of low vigor. This of course assumes that the seed lots placed in rapid aging were of nearly the same germination percent before treating.

Speed of germination is a simple test which can give a quick estimate of comparative vigor of seed. It is run by planting the seed on towel oriented on an incline so that geotropism response will cause the roots to grow straight. After a predetermined period (usually 3 to 4 days) the length of each root is determined. The most vigorous seed will germinate faster.
FURTHER TESTS USING ELECTROSTATIC SEPARATION

Based on Delouche's results it was felt that the electrostatic separator has considerable potential as a practical, economical technique for upgrading germination of seed; therefore, further studies were run in this area.

The Principle of the Electrostatic Separations

Essentially the electrostatic separator operated on the basic principle that unlike electrical charges are attracted to each other. The seed are fed onto a grounded rotor into an electrical field set up by a highly charged large diameter electrode, a fine wire electrode or a combination of both electrodes. The mechanical arrangement of the two electrodes is given in Figure 2.

The attraction of seed with a static charge toward an electrode of the opposite charge is referred to as the "lifting effect" as in Figure 3. By use of this lifting effect seed which have a tendency to become charged with one or another definite polarity may be separated from each other even though their relative conductivity may be similar. This type of separation is sensitive to humidity and small temperature changes.

The current flow from the electrode to the grounded rotor is in the range of 0-20 microamps per five feet of rotor length when the wire electrode is pointed toward the grounded rotor. Then the seed receive a spray discharge of electricity causing some of them to momentarily retain the charge and to be pinned to the grounded rotor, the phenomenon is known as the "pinning effect" and is illustrated in Figure 4. As an example, if a mixture seed of various susceptibilities to surface charge is fed onto the spinning rotor and sprayed with high voltage discharge, the seed of relatively poor conductivity will assume a charge easily and be attracted to and pinned to the rotor. Seed of relatively high conductivity will not assume a charge easily and what little they do receive will readily leak off to the grounded rotor. These particles of higher conductivity therefore, when leaving the rotor, will follow a flight path approximately the same as if there were no charging effect at all.
Figure 2. The electrode assembly of the electrostatic separator.
Figure 3. The electrostatic separator producing an electrostatic field and causing a "lifting effect" on the seed.
Figure 4. The electrostatic separator producing a high tension field and causing a "pinned effect" on the seed.
Electrostatic separation makes use of the pinning effect to a very high degree and in some cases may combine both a strong pinning effect with some lifting effects. Figure 5 illustrates the relative position of the two electrodes which causes a combination pinning and lifting effect. The current flow from the wire electrode in this position is 0.25 to 1 milliamp per 5 ft. of rotor.

Experimental Procedure

Prior to all separation tests alfalfa seed were stored in rooms of constant temperature and relative humidity. From a given batch of seed approximately 100 gms. was removed for the control and approximately 400 gms. was removed to be run through the electrostatic separator. From the control sample approximately 60 gms. was used for a moisture determination, using the standard oven method, and 200 seed were used for a standard germination test. The remaining 4000 gms. were run through a precision divider resulting in two identical samples. Each sample was run through the separator which divided the seed into three groups (pinned, dropped, and lifted). The moisture content and standard percent germination was determined for each group. In some cases the number of seed in the pinned category was insufficient to make these determinations. When the moisture content and the percent germination were completed on the two identical samples, the results from each of the three separates were averaged for the two samples.

Similar tests were run using sorghum, cotton, and alfalfa seed, but in these test rapid aging vigor determinations were made in addition to the standard germination percentages.

Results

The results of seven tests of alfalfa seed are given in Table 2. You will note that in all seven tests the percent germination increases from "lifted" to "dropped" to "pinned" categories. In all but two tests the percent germination in the "pinned" and "dropped" categories were substantially increased over that in the "lifted" category for over 50% of the total seed in each test.
COMBINATION FIELD

FEEDER

PINNED

DROPPED

LIFTED

DIVIDERS

Figure 5. The electrostatic separator producing a combination filed and causing a combined "pinned and lifting effect" on the seed.
The results of separating the seed as to moisture content were not entirely consistent. However, in all but two tests the moisture content of the seed in the "lifted" category or seed with the lowest percent germination had a higher moisture content than those in the other two categories. This agrees with the hypothesis stated by Delouche (6) that the poorer quality seed have a higher permeability, and the seed would thus absorb a greater amount of moisture when stored under high humidity conditions such as these.

TABLE 2. Viability of separates from seven lots of alfalfa seed obtained from pinned, dropped, and lifted categories in electrostatic tests.

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Voltage</th>
<th>%Germ</th>
<th>%Moisture</th>
<th>%Seed</th>
<th>Electrostatic Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pinned</td>
</tr>
<tr>
<td>1</td>
<td>30,000</td>
<td>58.5</td>
<td>8.02</td>
<td>(54.71)</td>
<td>55.8</td>
</tr>
<tr>
<td>2</td>
<td>40,000</td>
<td>64.5</td>
<td>7.93</td>
<td>(44.21)</td>
<td>64.0</td>
</tr>
<tr>
<td>3</td>
<td>30,000</td>
<td>66.0</td>
<td>9.40</td>
<td>(0.80)</td>
<td>54.3</td>
</tr>
<tr>
<td>4</td>
<td>30,000</td>
<td>66.0</td>
<td>9.40</td>
<td>(1.06)</td>
<td>60.0</td>
</tr>
<tr>
<td>5</td>
<td>30,000</td>
<td>66.0</td>
<td>9.40</td>
<td>(1.30)</td>
<td>50.0</td>
</tr>
<tr>
<td>6</td>
<td>30,000</td>
<td>78.0</td>
<td>6.94</td>
<td>(17.02)</td>
<td>67.5</td>
</tr>
<tr>
<td>7</td>
<td>30,000</td>
<td>81.5</td>
<td>8.50</td>
<td>(3.43)</td>
<td>73.3</td>
</tr>
</tbody>
</table>
The viability and vigor of sorghum, cotton and alfalfa seed separated on the electrostatic separator is given in Table 3. You will note the following points of interest: (1) the germination and vigor of all seed in the pinned category were higher than the control; (2) the rapid aging tests resulted in a wider spread than the germination tests for sorghum and cotton; and (3) the germination percentages for cottonseed in the pinned and lifted categories were higher than those in the dropped category.

TABLE 3. Viability and vigor of separates from a sorghum seed, cottonseed, and alfalfa seed obtained from pinned, dropped, and lifted categories in electrostatic tests.

<table>
<thead>
<tr>
<th>Type</th>
<th>Voltage</th>
<th>Electrostatic Category</th>
<th>Control</th>
<th>Pinned</th>
<th>Dropped</th>
<th>Lifted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td>40,000</td>
<td>%Germ</td>
<td>83.0</td>
<td>88.5</td>
<td>87.0</td>
<td>86.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>%Rapid</td>
<td>44.0</td>
<td>47.5</td>
<td>45.0</td>
<td>41.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age</td>
<td></td>
<td></td>
<td>(13.78)</td>
<td>(36.89)</td>
</tr>
<tr>
<td>Cotton</td>
<td>43,000</td>
<td>%Germ</td>
<td>85.0</td>
<td>85.5</td>
<td>83.3</td>
<td>87.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>%Rapid</td>
<td>55.5</td>
<td>72.0</td>
<td>55.8</td>
<td>55.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age</td>
<td></td>
<td></td>
<td>(4.08)</td>
<td>(54.74)</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>30,000</td>
<td>%Germ</td>
<td>78.0</td>
<td>83.8</td>
<td>80.0</td>
<td>67.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>%Rapid</td>
<td>48.5</td>
<td>52.2</td>
<td>50.8</td>
<td>46.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age</td>
<td></td>
<td></td>
<td>(17.02)</td>
<td>(35.49)</td>
</tr>
</tbody>
</table>
Discussion

It was noted in the alfalfa tests that in some cases the control was higher in moisture than the separated seed and in other cases the control was lower in moisture. The tests were not run under controlled humidity conditions, therefore, the seed lost or gained moisture depending on whether the humidity was lower or higher than the equilibrium moisture content of the seed.

At this point we should stress that the reliability of the moisture content determinations is low when compared to the germination tests. To determine the percent germination, 200 seed from each of the two identical runs were tested for germination. Statistically, we have 400 seed which individually will either germinate or not germinate; thus, the average percent germination is highly reliable. On the other hand, we have no method of determining the moisture content of individual seed, but are required to determine it on a sample of seed. Therefore, the final average moisture content was derived from duplicate samples from the two identical runs or a total of only four tests.

One interesting observation in Table 4 is that the total percent germination of seed exposed to the electrical field obtained by summing the products of the percent germination and percent of seed in each category, was higher in most cases than that of the control. The total germination of the exposed seed and the control seed as given in Table 3 for 7 tests using alfalfa seed show that in 4 out of 5 tests using seed below 70 percent germination the overall germination was substantially raised by running the seed through the electrostatic separator one time. This suggests that the germination of lower quality alfalfa seed might possibly be increased by exposure to a discharging high voltage electrical field.

TABLE 4. Total germination of separated seed in seven electrostatic tests using alfalfa.

<table>
<thead>
<tr>
<th>Test</th>
<th>Control</th>
<th>Separated Seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>58.5</td>
<td>67.9</td>
</tr>
<tr>
<td>2</td>
<td>64.5</td>
<td>69.3</td>
</tr>
<tr>
<td>3</td>
<td>66.0</td>
<td>65.6</td>
</tr>
<tr>
<td>4</td>
<td>66.0</td>
<td>70.5</td>
</tr>
<tr>
<td>5</td>
<td>66.0</td>
<td>71.5</td>
</tr>
<tr>
<td>6</td>
<td>78.0</td>
<td>74.7</td>
</tr>
<tr>
<td>7</td>
<td>81.5</td>
<td>78.6</td>
</tr>
</tbody>
</table>
Harmond (9) exposed samples of various legume and grass seed to voltages up to 25,000 volts and found that there were no statistical differences in the percent germination before and after exposure; however, he did not give the original percent germination of the seed tested.

Of interest is the increase of germination of cottonseed for both the pinned and lifted categories over the dropped category. An earlier hypothesis (6) is that seed of low viability are more permeable to moisture and have a higher electrical conductance; therefore, they will lose their charge rapidly to the grounded rotor. Another hypothesis is that seed of low viability have lower capacitance than those of viable seed. The capacitance of a material is a measure of its ability to take on a charge in an electrical field (12). Either of these hypotheses would account for the pinned seed but not the lifted seed.

Seed are only lifted when the electrode is positioned so as to produce an electrostatic field as shown in Figures 3 and 5. The static charge and the density of a seed would determine if it is lifted and how much it is lifted. Low density is indicative of low quality seed. A static charge has been recorded on seed during potential measurements but it has not been determined if this charge is correlated to either vigor or viability.

RECOMMENDATIONS FOR FURTHER STUDY

Electrical properties appear to be closely related to the physiological status and balance of living components of seed, and thus, possibly good indications of a seed's viability and vigor. The problem is to determine which properties are the most reliable indicators and why. The "why" is the difficult part in most cases, and for this reason is often omitted. If we can answer "why" we can generalize our solution to other types of seed and altogether new and effective techniques of upgrading seed.

Further study using the electrostatic separator is warranted. More basic knowledge of the electrical properties of seed, such as resistance, capacitance and dielectric properties should furnish the answer to why the seed behave in a particular manner under the influence of a given electrical field. With these answers we will be in a better position to develop effective separation techniques based on differences in electrical properties of seed.
Burr's work on the existence of an electrical potential across a seed is of utmost interest. This work should be verified for other types of seed, and if the results are as successful, many new avenues to the separation of live and dead seed will be opened.

Any future studies should include not only percent germination, but also vigor and moisture content. Delouche (7) points out the importance of knowing the response of a lot of seed to the stress conditions it will face in the field, and this only shows up in vigor tests. We are well aware of the effect of moisture content and moisture distribution on electrical properties of hygroscopic material; therefore, any differences in electrical properties of seed may well be differences in the moisture distribution. This moisture distribution among and within an individual seed may be the key to a seed's viability and vigor.

SUMMARY

Physical properties indicate differences in the vigor and viability of seed. Some of these properties include size, density, color, and electrical properties. The electrical properties which have been used to measure the quality of seed and grain are conductance, resistance, capacitance and potential across individual seed.

The electrostatic separator has been used to separate seed as to viability, vigor, and moisture content by subjecting the seed to two different electrical fields. In one field a wire electrode discharges to a grounded rotor over which the seed are conveyed, and the other is an electrostatic field through which the seed pass. The separation is made by the differences in behavior of the seed passing through these fields. These differences are accountable by variations in electrical conductivity, capacitance, static charge, and density between individual seed.
REFERENCES


