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Seed Academy

# Bulk Electrical Conductivity Test for Corn

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## OVERVIEW & HISTORY

First proposed in 1925, the electrical conductivity (EC) test measures the biochemical characteristics of a seed lot to determine potential seed vigor characteristics. Less vigorous or aged seeds repair their internal membranes at a slower rate, resulting in more solutes leaking from the seed in comparison to more vigorous seeds with faster membrane repair processes. In the field, these solutes can attract and promote pathogen growth. These solutes include inorganic cations, and sugars among other biological compounds (Marcos-Filho, 2015). Fessel et al. (2006) found that the primary leachate is potassium ions. Sucrose, starch, oils, and complex proteins either are uncharged or tend not to be readily soluble in $H_2O$ within the 24-hour test and hence do not contribute to conductance. A high percentage of leaches come out of the seed in the first 6 hours of the test as the seed rapidly imbibes water (Hoegemeyer and Gutormson, 2000). Leakage is thought to be due to more permeable cell walls related to seed deterioration caused by frost events or aging of seed. Aging can occur when seed corn is being dried, especially when high moisture ear corn begins heating in the dryer, and is often due to poor ambient drying conditions or lack of air flow to keep the mass of ear corn cool. Seed size, soaking temperature and period, as well as mechanical damage can impact results (Fessel, 2006). Ratio of seeds to water cited varies between 1.2 ml water/seed (Hussein), 1.5ml/seed (Sena et al., Fessel et al.), 2 ml/seed (Aliloo & Shokati, Goggi et al.) and 5ml/seed (Ocvirk et al.). Gotardo et al. (2001) evaluated imbibition time and temperature and found that 18–24 hours at 25°C was the optimal test conditions for the maize bulk EC.

Good sampling is key for accurate EC results, as variation between replications can be large (Goggi et al., 2008). SoDak Labs utilizes four replicates of 50 seeds, 75ml water, at 25°C for a 24 hour incubation period as listed for corn (Zea mays L.) in Table 4.15 of the AOSA Seed Vigor Handbook (2009).


**FIGURE 1.** EC meter probe soaking in standard solutions.

## RELATIONSHIP TO VIGOR TEST, QUALITY AND FIELD EMERGENCE

In the Sena et al. (2017) study, the EC had significant correlations with the cold test and the low temperature germination test used (germination at 18°C). Ocvirk et al. (2014) also found EC to be significantly correlated with the coleoptile length in the cold test and the standard germination. Aliloo & Shokati (2011) found EC to be significantly correlated with field emergence. Hussein et al. (2012) found that as maize seed was aged via an accelerated aging process, the electrical conductivity increased, indicating that the EC test is capable of detecting deterioration due to aging and storage. In a study regarding storage temperature and seed deterioration, Fessel et al. (2006) found that the EC did detect seed deterioration in maize; however, it was not as sensitive as the cold test or accelerated aging to the decline in vigor during storage. This study did not observe significant deterioration in any of the test results in the 10°C storage treatment with any of the vigor tests used.

**FIGURE 2.** 50 corn seeds soaking in 75 ml of deionized water.

## RANKING SEED QUALITY USING BULK EC AS A VIGOR TEST

Sena et al. (2017) found that EC had the potential to be an efficient test to stratify and rank maize seed lots. Though it ranked lots slightly differently than the cold test, the rankings were similar to the field emergence test they performed.

## HISTORICAL AND RESEARCH DATA

To better understand the Bulk EC test in relation to other corn vigor tests, SoDak Labs has summarized historical data and collected data on farmer submitted samples. Historical data from Bulk EC tests on seed corn from 2016–2020 is presented in Table 1. Bulk EC quality ranges of 0–15, 16–20, 21–25, and 26–30 $\mu S\ cm^{-1}\ g^{-1}$ seed show good relation to seed quality as measured by warm germination at 25°C and tray cold tests. As EC value increases above 30 $\mu S\ cm^{-1}\ g^{-1}$, a drop occurs in tray cold test results from 91% to 87%, suggesting that 30 $\mu S\ cm^{-1}\ g^{-1}$ may be a level that indicates a seed quality concern.

**TABLE 1.** Six Bulk EC quality ranges of seed corn and corresponding quality responses for warm germination and tray cold tests. Results are averages for the quality range. Electrical conductivity results are expressed in µS $cm^{-1}$ $g^{-1}$, and warm germination and tray cold results are percentages. Tests dates from 09/2016 to 06/2021 and electrical conductivity results from 4,924 tests..

| Electrical Conductivity Range (µS $cm^{-1}$ $g^{-1}$ seed) | Seed Lots Testsed per Quality Range | Electrical Conductivity | Warm Germination | Tray Cold | |
|---|---|---|---|---|---|
| | | | Strong Normal Seedlings | Strong Normal Seedlings | UV/Slow Normal Seedlings |
| 0 – 15 | 4157 | 10 | 98 | 95 | 0 |
| 16 – 20 | 493 | 18 | 97 | 93 | 1 |
| 21 – 25 | 200 | 23 | 97 | 93 | 1 |
| 26 – 30 | 58 | 28 | 97 | 92 | 1 |
| 31 – 35 | 14 | 33 | 96 | 89 | 1 |
| >36 | 2 | 39 | 94 | 83 | 1 |

**TABLE 2.** Table 2 – Quality responses of 681 farmer submitted (2021) seed corn lots tested across three vigor tests and one mechanical damage test.

| Electrical Conductivity Range (µS $cm^{-1}$ $g^{-1}$ seed) | Seed lots tested per Quality Range | Percent of total samples | Average Electrical Conductivity (µS $cm^{-1}$ $g^{-1}$) | NPK Cold Tray Test % | | Saturated Cold % | | | | Pericarp Damage % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Normal | Slow Normal | Normal | Slow Normal | Abnormal | Dead | Severe & Medium | Light | None |
| 0 – 15 | 350 | 51 | 10 | 94 | 0 | 87 | 8 | 2 | 3 | 6 | 13 | 81 |
| 16 – 20 | 177 | 26 | 18 | 92 | 1 | 83 | 10 | 2 | 5 | 10 | 16 | 74 |
| 21 – 25 | 103 | 15 | 23 | 91 | 0 | 79 | 11 | 2 | 8 | 10 | 14 | 76 |
| 26 – 30 | 41 | 6 | 28 | 89 | 1 | 72 | 11 | 3 | 14 | 12 | 13 | 75 |
| 31 – 35 | 9 | 1 | 33 | 84 | 0 | 75 | 9 | 2 | 14 | 6 | 12 | 82 |
| >36 | 1 | 0 | 39 | 87 | 2 | 70 | 7 | 4 | 19 | 17 | 32 | 51 |

In 2021, SoDak Labs analyzed 681 farmer submitted seed corn lots for electrolyte leakage or membrane permeability (EC), pericarp damage (PD), and seedling vigor using a saturated cold test and NPK cold test. The NPK cold utilizes imbibitional chilling with aerobic conditions, and a "salt solution" (similar to a starter fertilizer) within the moistening agent. We grouped and averaged the data across six quality ranges to determine if there is a relationship between these seed quality indicators (Table 2). As EC values increased (lower EC values are desirable), the percent NPK cold and saturated cold strong normal decreased.

An average EC value of 10 equated to very high quality, 18 to high quality and 23 seemed to indicate acceptable quality when compared with saturated and NPK colds (Table 2). Only seven percent of the 681 seed lots had average EC values of 26 uS/cm/g or higher. NPK colds and saturated colds were 89% and 72% strong normals, respectively for this 7% of the 681 samples.

**TABLE 3.** Bulk EC levels and seed corn quality levels.

| uS $cm^{-1}$ $g^{-1}$ (leakage of charged ions) | Historical EC Data (2016–2021) from Table 2 | Percent of 681 samples tested in 2021 | Sena et al. (2017) Quality Rating |
|---|---|---|---|
| 0 – 15 | Very High | 51 | High |
| 16 – 20 | High | 26 | High – Medium |
| 21 – 25 | Acceptable | 15 | Low |
| 26 – 30 | Questionable | 6 | Low |
| 31 – 35 | Low | 1 | Low |
| >36 | Low | 0 | Low |

## CONCLUSIONS AND RATING QUALITY USING THE BULK EC TEST

Data from the literature review, SoDak historical data (Table 1) and research data from the 681 retail samples (Table 2) are incorporated into the Bulk EC quality ranking presented in Table 3. In general, an EC value of below 20 us/cm/g indicates high quality when compared to traditional vigor tests rankings by cold tests. An EC value of 21–25 seems to indicate acceptable quality. Values above 25 uS/cm/gram may have some field emergence concerns or represent seed treatment leachates from applied micro nutrients (charged ions) contributing to conductivity.

# Additional Research Studies

## Change in electrical conductivity over twenty-four hours

### OBJECTIVE

SoDak Labs research has shown water uptake by corn seed is very rapid during phase I of imbibition (Figure 3), followed by a slower increase in phase II. This initial increase may indicate that electrical conductivity can be measured earlier than the standard twenty-four hours, perhaps at 12 hours after the imbibition stage is completed.

### METHOD

To investigate a reduced hour Bulk EC test ten corn lots were selected that met industry standards for warm germination (93%), cold tray (85%), and saturated cold tray (75%). Four replicates of fifty seeds/seed lot were placed in 75 mL of deionized water. Samples were maintained at 20-25C for twenty-four hours with electrical conductivity (uS/cm) measured at two, four, six, eight, ten, twelve, eighteen and twenty-four hours. Results are reported as uS/cm/gram of seed.

The responses for each seedlot by hours of soaking are presented in Figure 4. It appears that leakage occurs rapidly with five seed lots reaching 50% of final 24 hour conductivity within first four hours of imbibition. However, leakage continued to slowly climb to 24 hours. For consistency in testing, it appears shortening the hours of soaking may not be practical.

### RAW VERSUS TREATED SEED

The impact of seed treatments on EC results is shown at sampling times 6 & 7 (Figure 5). EC testing post seed treatments showed a dramatic increase in EC values from sampling times 1–5 on raw yellow seed corn. Apparently, ions (such as zinc or other micronutrient ions) within the treatment slurry may contribute to conductance.

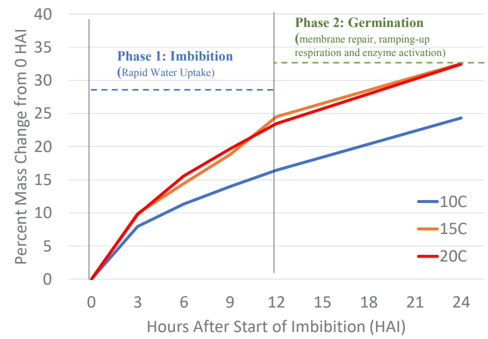


**FIGURE 3.** Water Uptake curve of corn seed between 0 and 24 hours after imbibition at 10C, 15C, and 20C embryo down on 100% saturated soil.

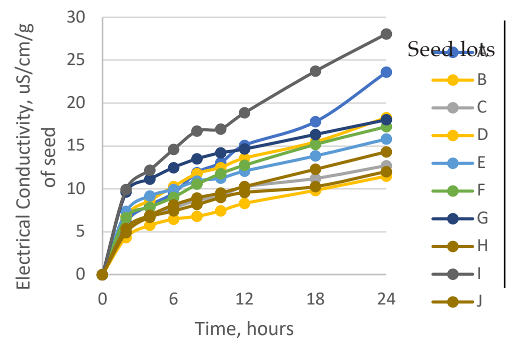


**FIGURE 4.** Electrical conductivity at 2, 4, 6, 8, 10, 12, 18 and 24 hours for ten corn seed lots.

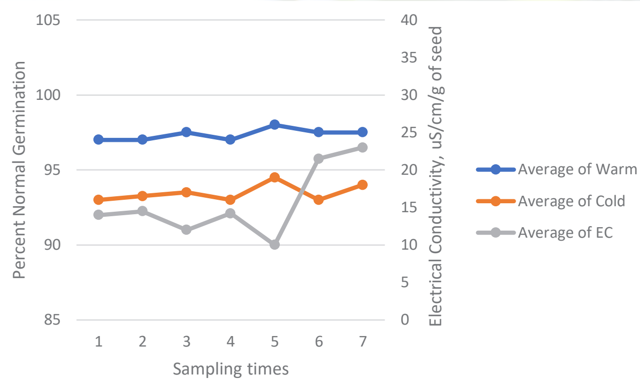


**FIGURE 5.** Bulk EC, warm germination, and tray cold readings from raw untreated seed corn (1–5) and then post seed treatment (6 & 7)


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### FOOTNOTES:


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