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Corn Pericarp Damage & Starter Fertilizers

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Introduction

Seed testing laboratories have seen an increase in the use of a corn pericarp damage examination during the past 10 years. This test has been given the name "Fast Green Test" based on the type of dye used to stain breaks in pericarp tissue of the seed. This increase in testing is related to agronomists recommending corn growers to test seed corn if starter fertilizers are placed within the furrow or near the furrow. The theory is fertilizer salt solution imbibition facilitated by pericarp damage enters the embryo and disrupts seedling development resulting in delayed or lack of seedling emergence. Seed lots with less pericarp damage are thought to tolerate in furrow or near furrow fertilizer placement. The concern laboratory staff express is that the pericarp damage evaluation can be subjective and damage ratings may not correlate well to actual emergence. To better understand this situation, SoDak Labs reviewed existing literature on starter fertilizer and corn germination.

Literature Review

OVERVIEW

Starter fertilizer placed with the seed have ben shown to reduce germination and/or delay emergence (Bates, 1971). Fertilizer so placed is referred to as direct seed contact, in-furrow, "pop-up," seed-row, and with seed application, among other terms. Toxicity can be caused by both osmotic stress and the more specific stress caused by the genesis of ammonia gas by ammonium fertilizers; thus, ammonium toxicity is a recognized phenomenon (Pan et al., 2016). The level of sensitivity to ammonium and salt stress varies by species and interacts with other forms of N available as well as other nutrients, particularly K (Britto & Kronzucker, 2002). While ammonium toxicity can occur at any developmental stage, most species are most sensitive during germination and seedling growth (Barker et al., 1970).

SOIL TYPE

Fine sand soil textures place seed at a higher risk than clay or silt loams for reduced germination and emergence due to seed-row fertilizer (Rehm & Lamb, 2009). Kaiser & Rubin (2013) found that this risk was approximately double in fine sand soil textures compared to clay or silt loams.

SOIL MOISTURE, TEMPERATURE, & PH

In low soil moisture environments, seed-row starter fertilizer may delay emergence beyond the delay expected due to low moisture (Rehm & Lamb, 2009). Drier soils with a high initial pH may see more free ammonia gas generated, and lower temperatures decreased nitrification and thus, the production of NH_3 (Creamer & Fox, 1980).

NUTRIENT FORMULATION

Significant consideration has been given to the method of determining the maximum safe formulation to place with the seed without impacting the emergence and growth of the seed and seedlings. Some approaches use the total salt index to determine risk of salt stress on the seeds, factoring the relative ability of nutrient components to increase the salt concentration in the soil solution, and including N, P, K, and S. Fluid fertilizers, already including water, generally place less osmotic stress on the soil solution in comparison to granular fertilizers (Mortvedt, 2001). However, some studies found that the total N applied was more important than the total N and K (Rehm & Lamb, 2009), which had been proposed in other studies. Phosphorous tends to have a lower impact on seed stress than N, K, or S (Mortvedt, 2001). Phosphorous also tends to increase plant mass, which could complicate evaluation of tests if they are based on seedling mass (Kaiser & Rubin, 2013).

FERTILIZER RATE

Kaiser & Rubin (2013) investigated a potential model to determine the maximum seed-safe application rate across fertilizer sources and soil types. Their results showed that the salt index multiplied by the application rate was able to predict damage including decreased seedling growth and reduced emergence for most fertilizer sources. The rates safe in fine sand textures were generally about half of that safe in clay and silt loams (10.6 kg/ha vs 5.7 kg/ha), presumably due to a reduced cation exchange capacity and water holding capacity.

PLACEMENT

Pan et al. (2016) found the zone of toxicity to be 1-5 cm from where the fertilizer is placed. Niehues et al. (2004) found that in wet conditions, no reductions in emergence occurred even under high nitrogen rates in direct seed contact; however, under average moisture, high nitrogen fertilizer rates decreased stands when placed in direct seed contact but not when fertilizer was dribbled over the row or banded 2 inches (5 cm) from the seed row.

SYMPTOMS

Symptoms of ammonium toxicity generally include a lowered root:shoot ratio, decreased fine roots, leaf chlorosis, and general growth suppression (Britto & Kronzucker, 2002). Roots tend to be hollow, discolored, and prone to rotting (Pan et al., 2016).

SPECIES

Pan et al. (2016) found that tap-rooted species like canola and faba bean were more susceptible to ammonium root toxicity due to seed-placed fertilizer compared to species such as wheat that developed lateral root growth early in development. Britto & Kronzucker (2002) note that sensitivity to ammonium is species dependent and to some degree, families can be separated into tolerance levels. Dowling (1993) found many cereals including maize, sorghum, and wheat to be intermediate in their tolerance to ammonium concentrations, in comparison to chickpeas (most tolerant) and cotton and canola (least tolerant).

NPK Cold Test Development

SoDak Labs, Inc. has developed a tool for corn growers wishing to evaluate seed germination/emergence in the prescence of cold soils and salt solutions to emulate starter fertilizer placement. We coined the name "NPK cold" as an easy reference for growers and as a test that more directly measures the impact of pericarp damage (Figure 1.). Tray cold, 50° F and aerobic stress is a widely used corn cold test and basis for NPK cold test. SoDak Labs also offers the traditonal "Pericarp Damage" (Gutormson 2020) test where damage is ranked as severe, medium, light or no damage (Figure 2.). We feel the NPK cold seedling emergence percentage will be more understandable than a total percentage of seeds with pericarp damage. Ferrie (2020) recommends caution if pericarp damage is above 6% and to skip starter fertilizer if damage is above 10%. SoDak Labs compared 40 seed corn lots (Table 1.) which were grouped into four levels of pericarp damage. Seed lots with 0–5% pericarp damage (medium plus severe ratings) had tray colds (water solution) and NPK colds (salt solution) at 91% and 90% respectively. As pericarp damaged increased to 6–10%, 11–15% and > 15% NPK colds dropped 0%, 4% and 4% below tray colds to 89%, 89%, and 86%, respectively. The tray cold results were similar to 4% higher than the NPK cold on the 11-15 & >15% pericarp damage. Another observation was slower seedling growth with the fertilizer solution (NPK cold) compared to water in tray cold. Saturated cold results were all similar and indicating good to high quality across the four pericarp damage ranges.

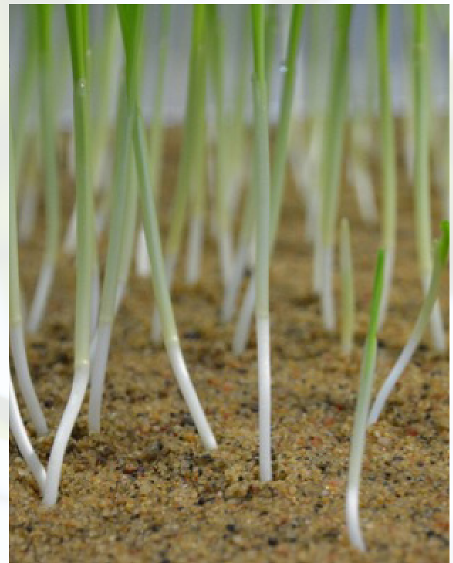

FIGURE 1. Seedling emergence at 120 GDDs in a NPK Cold test.

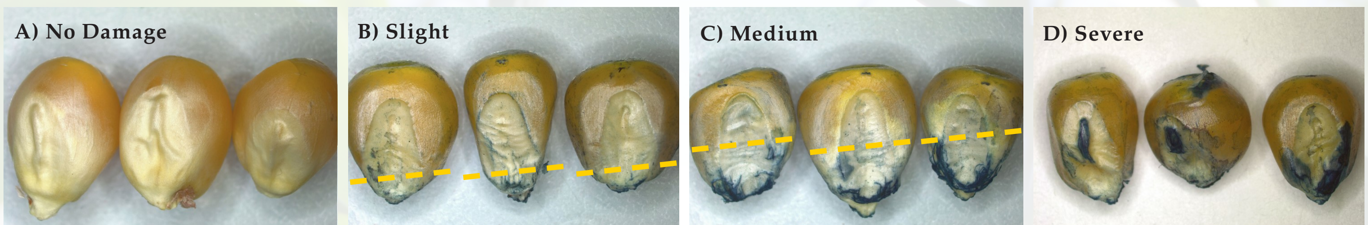

FIGURE 2. Pericarp Damage Test: A) None: no visible damage to pericarp covering, B) Slight: tearing of pericarp area extending up less than 25% length of embryo pericarp margin/edge, C) Medium: tearing of pericarp extending up to 50% of length of embryo pericarp margin/edge and D) Severe: cracks over the embryonic axis and major breaks in seed or missing parts of the seed.

TABLE 1. Comparison of Four Pericarp Damage Ranges (Medium + Severe ratings) with NPK Cold, Tray Cold, and Saturated Cold emergence percentages when averaged across 40 seed corn lots.

		NPK Cold, %		Tray Cold, %		Saturated Cold, %	
Pericarp Damage Quality Range (%)	# of Tests per Quality Range	Strong Normal Seedlings	Slow Normal Seedlings	Strong Normal Seedlings	Slow Normal Seedlings	Strong Normal Seedlings	Slow Normal Seedlings
0–5	11	90	2	91	0	80	8
6–10	6	89	3	89	1	82	8
11–15	11	89	2	93	1	83	8
>15	12	86	2	90	0	79	9

In 2021, SoDak Labs analyzed 681 corn lots, submitted by farmers, for pericarp damage (PD), electrolyte leakage or membrane permeability (EC) and seedling vigor using a NPK cold test and saturated cold (imbibitional chilling and anaerobic conditions). We grouped and averaged the data across five quality ranges to determine if there is a relationship between these seed quality indicators (Table 2). As NPK Cold seedling vigor decreased, the percent saturated cold strong normal seedlings also decreased. Furthermore, the saturated cold percent dead seeds and electrical conductivity (EC) results increased as the seed quality decreased, indicating a relationship between membrane permeability and seed quality. While an increase in membrane permeability results in more solutes leaking from the seed, it could also lead to the seed "taking in" the cold water at a faster rate than seeds with greater pericarp integrity. Pericarp damage results may indicate seed quality issues but may not indicate the severity of seed quality.

TABLE 2. Quality responses of 681 farmer submitted retail corn seed lots tested across three vigor tests and one mechanical damage test.

NPK Range	# of Tests per Quality Range	Percent of total samples	NPK Cold Tray Test		Saturated Cold				Pericarp Damage			EC
			%									
			Strong Normal	Slow Normal	Strong Normal	Slow Normal	Abnormal Seeds	Dead seeds	Severe & Medium	Light	None	µS cm^{-1} g^{-1} seed
>96	239	35	97	0	87	9	1	2	4	12	84	15
91–95	295	43	93	0	84	9	2	5	8	15	77	16
86–90	98	14	88	1	79	9	3	9	15	17	68	19
81–85	27	4	83	1	74	10	3	13	15	13	72	22
<80	22	3	72	1	64	9	4	24	17	9	74	21

During the summer of 2021, SoDak staff compared three fertilizer solutions with the tray cold test format (aerobic chilled imbibition) and data on Salt Index is presented in Table 3. Due to the density of seeds (commonly within 1" of other seeds within lab tests, i.e 200 seeds on a 12 inch x 18 inch tray) solution rates were adjusted to relate to starter fertilizer in row fertilizer field application rates. Six seed corn lots meeting seed industry quality standards were tested using four imbibition solutions and several rates (Table 4.). Traditional tray cold test responses (water 50F imbibition chilling and aerobic conditions) has a seed corn industry minimum of 85% germination. All six seed lots selected would be considered high quality and showed very little pericarp damage, ranging 0-4% for a combined severe and medium damage level. In general the fertilizer solutions and rates had minimal impact on % normal seedlings with the greatest impact expressed for lot B with decreases from water treatment of 7, 9 and 11%. Decreases in normal seedling percentage on the other five seed lots ranged from 0 to 5 percentage, this range falls within the normal expected variation for a vigor test using 200 seeds. A primary observation not reflected in the normal seedling percentages, was the reduction in growth rate, especially noted when comparing the water solutions with the higher rates of the three different fertilizer formulations (Table 5).

TABLE 3. Salt Index of the different concentrations of fertilizer formulations utilized in a tray cold test format.

Treatment	Rate*	Salt Index
Water	0	0.000000
KNO_3	1.25%	0.007661
	1.5%	0.009193
10-34-0	0.2 gal/acre	0.000031
	0.3 gal/acre	0.000025
6-24-6	0.3 gal/acre	0.000014
	0.4 gal/acre	0.000018

* Fertilizer application rate adjusted to account for seedling density per square foot within the laboratory test method

TABLE 4. Comparison of pericarp damage, electrical conductivity, and percent strong normal for different application rate* of KNO_3, 10-24-0 and 6-24-6 compared to Tray Cold for six corn seed lots that met industry standards

Sample	Cold	KNO_3		10-34-0*		6-24-6*		Pericarp Damage			Electrical Conductivity
		1.25%	1.5%	0.2 gal/acre	0.3 gal/acre	0.3 gal/acre	0.4 gal/acre	Severe & Medium	Light	None	
	----------------------------------% Normal Seedlings-------------------------------------							--------------%--------------			µS cm^{-1} g^{-1} seed
A	97	96	94	92	96	97	95	4	23	74	31.0
B	94	93	85	95	83	94	87	1	11	89	31.0
C	92	94	89	91	89	92	91	0	10	90	30.9
D	96	96	94	97	95	95	97	1	16	84	31.8
E	92	89	91	95	92	90	88	0	3	97	24.3
F	94	94	94	92	90	93	90	3	9	89	19.3

* Fertilizer application rate adjusted to account for seedling density per square foot within the laboratory test method

Seedling height above the sand was measured for each treatment (Table 5). A wide range of seedling height was observed for fertilizer solutions and concentrations compared to the water based cold test. The average heights of the treatments are displayed in Figure 3.

TABLE 5. Seedling height at different application rates of KNO_3 10-34-0, and 6-26-6 compared to standard cold.

Sample	Cold	KNO_3		10-34-0		6-24-6	
		1.25%	1.50%	0.2 gal/acre	0.3 gal/acre	0.3 gal/acre	0.4 gal/acre
	--------------------------------------Seedling Height*, cm--------------------------------------						
A	11	6*	4	10	6*	9*	7*
B	12	5	6	8	7	10	8*
C	12	8	5	8	9*	10*	10*
D	9	6	4	7	4*	8	5*
E	10	7	8	3	7	10	5*
F	9	7	6	9	5*	9	8

* Indicates a wide variety of seedling heights in the average.

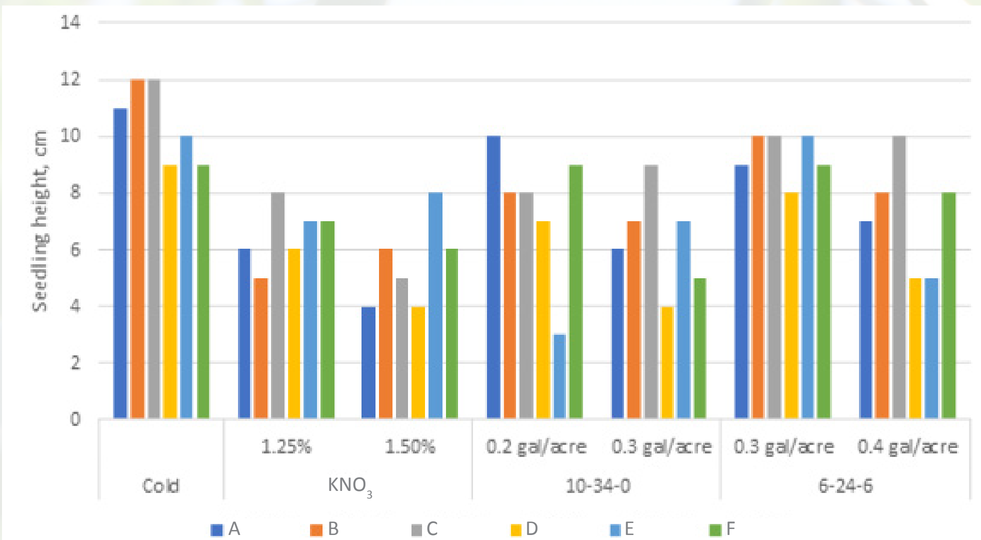

FIGURE 3. Average seedling heights with different application rates of KNO_3 10-34-0, and 6-26-6 compared to standard cold tray.

Conclusion To Date

In laboratory cold test with a fertilizer solution, in nearly all cases seedling growth rate is suppressed compared to water checks. Salt Index levels studied had less impact than expected. Osmotic stress may be a factor, but it seems ammonia toxicity may be a primary factor in seedling development or slow emergence.

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