UNDERSTANDING SALT INDEX OF FERTILIZERS

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Introduction

Most fertilizer materials are highly soluble salts, which dissociate in the soil solution following application. Almost every spring there are reports of fertilizer burn somewhere in Wisconsin. Seedling injury caused by fertilizer burn can result in minimal to extensive stand loss and can be extremely costly in high value vegetable crops. I have been asked recently to review several problem fields where liquid fertilizer was placed in-furrow with the seed both with and without Y-splitters or was dribbled above the row on the soil surface. Stands were significantly reduced in each field. It is important to understand salt index and factors which contribute to fertilizer burn in order to avoid fertilizer injury to seedlings.

Why Are Fertilizer Salts a Problem?

Excessive concentrations of fertilizer salts near a germinating seed or seedling root causes injury. The injury is caused when the concentration of ions in the soil is greater than the concentration of ions within the plant cells. The high osmotic pressure created by the fertilizer salts causes water to move out of the plant cells and into the soil. As water moves out of the plant cells, the tissue dessicates and becomes blackened; hence the term fertilizer burn. The result is the eventual death of the plant tissue.

Some nitrogen fertilizers may cause more seedling and germination injury than expected based on their salt content alone if they liberate ammonia when applied to the soil. Free ammonia is toxic and can move freely through the plant cell wall (Havlin et al., 1999). Urea, UAN, ammonium thiosulfate and DAP can cause more damage from ammonia toxicity than MAP, ammonium sulfate, and ammonium nitrate (Havlin et al., 1999; Mortvedt, 2001; Reid, 2006). Moderate alkaline soil conditions, either in the bulk soil or caused by reaction of the fertilizer, will promote ammonia production.

Factors Affecting Fertilizer Burn

Crops vary in their tolerance to salts. A list of common crops and their relative sensitivity to salts is given in Table 1. Reid (2006) suggests that no fertilizer be placed with the seed of super sweet hybrids of sweet corn, soybean, edible beans, and peas because of their sensitivity to salts.

Soil conditions are important for determining why injury may occur in one year and not another. Fertilizer salts diffuse away from the band in moist soils and become diluted, reducing the osmotic pressure. Little diffusion takes place in dry soils and the fertilizer remains concentrated with a high osmotic pressure presenting a greater risk to plant injury. Soils with low cation exchange capacity (CEC) (coarse-textured with low organic matter content) have a lesser ability to react with the fertilizer compared to high CEC soils (fine-textured) meaning that the

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concentration of fertilizer salts in the soil solution remains high (Reid, 2006). Thus, fertilizer burn is a bigger issue on sandy, low organic matter soils particularly in dry springs. In addition, soil temperature plays a role. In cold soils, roots grow slowly; thus, the root is exposed to the higher concentration of fertilizer for a longer period of time.

Table 1. Relative sensitivity of common crops to fertilizer salts.†

Crop	Relative sensitivity
Wheat	Least sensitive ‡
Corn	
Forage legumes	↓
Soybean and edible bean (dry or snap)	
Vegetables including sweet corn	Most sensitive

† Reproduced from Reid (2006).

† Least sensitive does not mean that the crop is not sensitive to salt.

Concentration of fertilizer salts is another factor which determines whether or not fertilizer burn occurs. Broadcast fertilizer applications do not often injury seedlings because the fertilizer is dispersed through a large volume of soil. Banded starter fertilizers placed two inches to the side and two inches below the seed are more likely to cause injury than broadcast applications because banded applications are much more concentrated in a small area near the seed. However, at typical starter fertilizer application rates, fertilizer burn from banded starter fertilizer is unlikely. In-furrow (pop up or seed row) placed fertilizers are typically applied at low rates but their very close proximity to the seed means that they are more likely to cause injury than 2” x 2” banded applications because there is little opportunity for the root to grow out of the zone of concentrated fertilizer salts before it dies. In general to avoid stand loss from fertilizer injury, no more than 10 lb/a of N + K_2O should be applied in-furrow regardless of soil texture. The most suitable fertilizers for in-furrow applications will have a low salt index, high water solubility, minimize compounds that liberate NH_3, and use potassium phosphate instead of potassium chloride as the potassium source (Mortvedt, 2001).

Salt Index

Salt index (SI) of a fertilizer is a measure of the salt concentration that fertilizer induces in the soil solution (Mortvedt, 2001). Salt index is the ratio of the increase in osmotic pressure produced by a fertilizer material or formulation to that produced by the same weight of $NaNO_3$ based on a relative value of 100 (Havlin et al., 1999). All fertilizers are compared to $NaNO_3$ because $NaNO_3$ is 100% water soluble and it was commonly used when the SI concept was developed (Rader et al., 1943). Salt index can be used to compare fertilizer materials but it can not be used to determine the amount of fertilizer that will cause injury. The SI of common fertilizer materials is provided in Table 2.

Higher analysis fertilizers have lower SI because fewer salt ions go into the soil solution per unit of plant nutrient when the fertilizer dissolves. However, it is possible for the SI of a high analysis formulation to be higher than the SI of a low analysis formulation. When this occurs, use of the high analysis formulation may not be more risky than the low analysis formulation because higher rates of the low analysis formulation are needed and may result in similar amounts of salt being added to the soil. Nitrogen and potassium fertilizers generally have higher SI values than phosphorus fertilizers.

Table 2. Salt index of fertilizer materials. †

	Material and analysis (N-P_2O_5-K_2O-S)	Salt index	
		Per equal weights of materials	Per unit of nutrients ‡
Nitrogen/ Sulfur	Ammonia, 82-0-0-0	47.1	0.572
	Ammonium nitrate, 34-0-0-0	104.0	3.059
	Ammonium sulfate, 21-0-0-24	68.3	3.252
	Ammonium thiosulfate, 12-0-0-26	90.4	7.533
	Urea, 46-0-0-0	74.4	1.618
	UAN, 28-0-0-0 (39% amm. nitrate, 31% urea)	63.0	2.250
	32-0-0-0 (44% amm. nitrate, 35% urea)	71.1	2.221
Phosphorus	APP, 10-34-0-0	20.0	0.455
	DAP, 18-46-0-0	29.2	0.456
	MAP, 11-52-0-0	26.7	0.405
	Phosphoric acid, 0-54-0-0		1.613 §
	0-72-0-0		1.754 §
Potassium	Monopotassium phosphate, 0-52-35-0	8.4	0.097
	Potassium chloride, 0-0-62-0	120.1	1.936
	Potassium sulfate, 0-0-50-18	42.6	0.852
	Potassium thiosulfate, 0-0-25-17	68.0	2.720

‡ Reproduced from Mortvedt (2001).

‡ One unit equals 20 lb.

§ Salt index per 100 lbs of H_3PO_4.

Calculating Salt Index

The SI of a fertilizer formulation/mixture can be calculated based on the fertilizer materials used to make the formulation. It is the sum of the SI of each component per unit of plant nutrient times the number of units in that component (Mortvedt, 2001). The steps to calculate SI of a formulation are as follows (Mortvedt, 2001). Table 3 outlines the SI calculation for 7-21-7 and 6-24-6.

1. List the material, grade, and weight for each component in columns 1-3.
2. Calculate nutrient units in columns 4-6 by multiplying the weight of each component (Column 3) by its nutrient content (Column 2) and dividing each result by 20 (one unit equals 20 lbs).
3. List SI per plant nutrient unit in each component in column 7 (SI is in Table 2).
4. Calculate the SI from each component by multiplying the sum of the nutrient units in columns 4-6 by the corresponding SI value in column 7.
5. Sum individual SI values of all components in column 8 to obtain the SI for the formulation.

The SI values for 7-21-7 and 6-24-6 demonstrate how potassium chloride increases SI (Table 3). The SI of 7-21-7, which contains potassium chloride, is 27.8. The SI of 6-24-6, which does not contain potassium chloride, is 11.9.

The salt index per unit of plant nutrient may also be calculated and used as a way to compare formulations. This is done by first summing the percentage of nutrients in a formulation and then dividing the SI by the total nutrient percentage. 7-21-7 has 0.79 SI per unit of plant nutrient which can be calculated by dividing the SI (27.8) by the total percent of nutrients (35 = 7 + 21 + 7).

Table 3. Calculating salt index of 7-12-7 and 6-24-6.

Component	% Nutrient	lbs of component per ton of formulation	Nutrient units			Salt index	
			N	P_2O_5	K_2O	Per unit (20 lb) †	in formulation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
7-21-7							
10-34-0	10% N 34% P_2O_5	1,235	6.2	21.0	-	0.455	12.4
UAN	28% N	57	0.8	-	-	2.250	1.8
KCl	62% K_2O	226	-	-	7.0	1.936	13.6
water		482	-	-	-	-	-
Formulation		2,000	7.0	21.0	7.0		**27.8**
6-24-6							
NH_3	82% N	146	6.0	-	-	-	-
H_3PO_4	54% P_2O_5	666	-	18.0	-	1.613 ‡	10.7
Potassium phosphate	22% P_2O_5 22% K_2O	546	-	6.0	6.0	0.097	1.2
water		642	-	-	-	-	-
Formulation		2,000	6.0	24.0	6.0		**11.9**

† Salt index per unit (20 lb) of plant nutrients listed in Table 2, also called partial salt index.
‡ Ammoniation of phosphoric acid to a 1-3-0 ratio forms a mixture of MAP and DAP.

Tips for Safely Using Liquid Fertilizers with/near the Seed

1. Do not use fertilizer with a SI greater than 20.0 (Table 4).
2. Avoid using fertilizer formulations containing ammonium thiosulfate as the SI may be high.
3. Apply no more than 10 lb/a of N + K_2O in-furrow.
4. If the soil is dry at planting, consider placing the fertilizer away from the seed.
5. If dribbling the fertilizer on the soil surface, be sure that the seed is planted deep enough and there is adequate soil moisture for the fertilizer to diffuse.

Table 4. Salt index of some common liquid fertilizer formulations. †

Formulation	Salt index	Salt index per unit of plant nutrient (20 lb)
2-20-20 ‡	7.2	0.17
3-18-18 ‡	8.5	0.22
6-24-6 ‡	11.5	0.32
6-30-10 ‡	13.8	0.30
9-18-9 ‡	16.7	0.48
10-34-0 §	20.0	0.45
7-21-7 ¶	27.8	0.79
4-10-10 ¶	27.5	1.18
28% UAN ¶	63.0	2.25

† Reproduced from Mortvedt (2001).
‡ These grades are formulated using potassium phosphate as the K source.
§ Use in-furrow placement with caution.
¶ Not suggested for use in-furrow placement.

References

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