FERTILIZER PLACEMENT WITH SEED – A DECISION AID

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ABSTRACT

Banding fertilizers with the seed at planting continues to be a popular option with producers in the Great Plains and North Central regions of the U.S. However, seed-placed fertilizer may limit germination/emergence of the seed/seedling. Nutrient source and rate are two factors affecting injury that are relatively simple to manage. Unfortunately, many crop producers and advisors have few rate guidelines for the many crop by fertilizer combinations that are common to the region. The objectives of this work are to (i) review the literature from the North Central and Great Plains states and adjoining Canadian provinces and determine the relationship of seed-placed fertilizer rate with resulting crop emergence and (ii) estimate safe rate of seed-placed fertilizer based on the above relationships. Studies cited had fertilizer rate treatments placed directly with the seed and final plant emergence data. All emergence measurements were converted to relative values based on 30 inch row spacings and one inch opener widths. Linear regression coefficients (relative plant stand upon fertilizer rate) were used to evaluate crop sensitivity to fertilizer injury or to evaluate fertilizers for their injury potential. A total of 219 separate crop by fertilizer studies covering 13 crops and 13 fertilizers were cited. In general, corn and sorghum were least sensitive to fertilizer salts while flax, mustard, canola, pea, and soybean were most sensitive. Generally, the liquid P fertilizers were safest followed by the dry P materials, KCl and nitrogen fertilizers were the least safe. A spreadsheet decision aid was developed using the regression coefficients to estimate "safe" seed-placed fertilizer rates.

INTRODUCTION

Banding fertilizer at planting is popular with many crop producers. Producers utilizing no-till production practices favor banding to avoid surface applications and position the fertilizer nearer to the seed. Applying P in a band 2 inches below and 2 inches to the side of the seed (2 x 2) has been shown to be an effective P placement for corn and soybean (Welsh et al. 1966; Hanson, 1979; Bullen et al., 1983; Randall and Hoeft, 1988). A 2 x 2 placement requires separate fertilizer openers that have a number of disadvantages. These inconveniences include cost, weight, residue clearance, planter space and soil disturbance which can adversely affect seed placement. Because of these faults, many producers are placing fertilizers directly with the seed at planting. However, seed-placed fertilizers can cause germination or seedling injury (Cummins and Parks, 1961; Clapp and Small, 1970; Gerwing et al., 1996; Gordon and Whitney, 2000; Harapiak and Flore, 1995; Hoeft, et al., 1975). Important considerations in selecting seed placement of fertilizer over other banding methods are the stand loss a producer is willing to accept and possible crop maturity delays (Harapiak and Flore, 1995).

Factors affecting germination or seedling injury from seed-placed fertilizers include; crop sensitivity (Ayers and Haywood, 1948; Cummins and Parks, 1961; Hoeft et al., 1975), row width and seed-fertilizer-spread width (Deibert, 1994b; Halverson, 1989; Harapiak and Flore, 1995), precipitation after seeding (Henry et al., 1995a; Raun et al., 1986), and distance of fertilizer from seed (Gordon and Whitney, 2000: Rehm, 1983). Soil factors that influence injury to the germinating seed include; pH, organic matter (OM), cation exchange capacity (CEC), soil texture and soil moisture (Ayers, 1952; Raun et al., 1986). Fertilizer factors influencing germination or seedling injury include fertilizer source (Gerwing et al., 1996; Gordon and Whitney, 2000), fertilizer analysis and rate (Hoeft et al., 1975).

Fertilizer nutrient source and rate are the factors that are easiest to manage by producers to limit injury from seed-placed materials. Chapin et al., (1964) found higher soil extract conductivity when using N and potassium (K) containing fertilizers than when using phosphatic materials. Most extension recommendations for seed-placed fertilizers include limits on total N and/or K_2O applied (Gerwing and Gelderman, 1998; Hoeft and Peck, 1999; Rehm et al., 1994). Raun et al. (1986), working with liquid P fertilizers on corn, concluded that rates greater than 8-11 kg ha^{-1} N + K_2O can produce significant stand loss. Such recommendations do not address materials such as triple super phosphate, which contain no N or K. In addition these "rule of thumb" guidelines are usually based on specific row widths and seed-fertilizer spread widths and are usually specific for only a very few crops. The guidelines must be adjusted for alternate cropping systems.

Some workers (Hoeft et al., 1975; Rader et al., 1943; Ross et al., 1942) have suggested using fertilizer salt index as a guide for seed-placed fertilizer. These studies, however, provide no method for developing safe seed-placed fertilizer rates other than suggesting a low-salt fertilizer should be selected.

The objectives of this work are to (i) review the literature from the North Central and Great Plains states and adjoining Canadian provinces and determine the relationship of seed-placed fertilizer rate with resulting crop emergence and (ii) estimate safe rate of seed-placed fertilizer based on the above relationships.

MATERIALS AND METHODS

This review evaluates the effect of fertilizer materials on seed germination by determining final plant stands while recognizing the two measurements are not necessarily equivalent. Both reviewed and non-reviewed (station bulletins, progress reports, personal communications, etc.) studies were cited that included data from fertilizer placed directly with the seed and recorded emergence or final plant stand data. Data citing relative plant stands (100 % stand where no seed-placed fertilizer) versus the fertilizer material rate (lb/a) were used. Reference data presented in a different format was adapted as above. All data was converted to a 30-inch row width assuming a straight dilution or concentration factor. For example, if 100 lb/a of seed-placed monoammonium phosphate (MAP) produced an 80% relative plant stand for wheat planted in 6 inch rows, the equivalent MAP rate for 30 inch rows producing an 80 % relative stand would be 100/5 = 20 lb/a. Similarly, the seed-spread (width of the seed furrow) was converted to a one inch equivalent. If the seed-spread width was not given in the reference, it was assumed to be one inch.

The final relative plant stands were regressed upon the material rates using simple linear regression. The regression equation intercept was forced through 100% relative stand with no fertilizer applied. In a few cases, with relatively high agronomic fertilizer rates, the higher rates appeared to produce a curvilinear function. These rates were removed from the data and only the linear portion of the curve was used. In some cases, fertilizer rates were not high enough to influence crop stands and these data were not used.

Mean regression coefficients were calculated for each crop by fertilizer combination only if there were two or more individual coefficients for each fertilizer material for each crop. This mean coefficient was used to calculate “safe” rates of that fertilizer for a specific crop by the following equation:

$$F = 30\ S\ (T-100)/CRMX$$

Where:

F = Fertilizer material in lb/a
S = seed spread in inches
T = Treated plant stand as a percent of the stand where no fertilizer is applied [the (T-100) term indicates the relative stand loss one is willing to accept due to fertilizer placed with the seed]
C = negative regression coefficient for the crop by fertilizer combination
R = Row width in inches
M = Soil moisture factor (moist = 1, borderline = 1.5, and dry = 2)
X = Soil Texture (fine/medium or coarse)

Soil moisture at planting for these referenced studies was assumed to be good or moist (M=1). Assuming soil moisture has a large affect on the influence of fertilizer salts on the germinating seed, a modification to the equation might be considered when soil moisture conditions are less than optimum for germination. Hapapiak and Flore (1995) present emergence data from seed-placed urea N with wheat and barley in optimum and less than optimum seedbed moisture conditions. The coefficient from the less than favorable moisture sites was about 1.5 times greater (more steep) than the favorable moisture sites. Harapiak and Fore (1993) recommend the rate of seed-placed N be divided by two when seedbed moisture conditions are less favorable. This seems to be a reasonable approach for other fertilizers as well. Definitions of the above moisture terms are: moist is defined as the level of soil moisture that is considered more than adequate for seed germination/emergence. Borderline is defined as the range of soil moisture that is just adequate to just inadequate for germination/emergence and dry is too dry for seed germination/emergence to occur. Similarly, texture can influence fertilizer salt effects on germination, primarily thru moisture content (i.e. finer-textured soils usually have more plant available moisture than coarse soils). In addition, with lack of rainfall, coarse soils will dry more quickly than finer-textured soils after planting thereby increasing seed-placed salt effects. The above moisture coefficients were increased by 0.5 units if the soil is coarse textured.

The above equation was incorporated into a user-friendly spreadsheet format.

RESULTS AND DISCUSSION

There were 36 separate references (primarily from the North Central and Great Plains states and adjacent Canadian provinces) cited that fit the above described format of which six were from refereed journals. Thirteen common crops and thirteen common fertilizers were cited. The references covered 219 separate crop by fertilizer studies. The number of studies by crop were: corn=48, soybean=39, flax=24, wheat=26, sunflower=21, pea=11, sorghum=11, barley=10, canola=10, oat=8, alfalfa=4, mustard=4 and lentil=3. The number of studies by fertilizer were: MAP=60, TSP=33, 10-34-0=24, urea=20, DAP=19, 0-0-60=18, Am. Nitrate=13, 7-21-7=11, UAN=7, 4-10-10=5, 9-18-9=5, Am. Sulfate=2 and ATS=2. After averaging coefficients within each crop by fertilizer category, there were 45 coefficients (32%) of a possible 139 (13 by 13) combinations (Table 1).

Of the 34 averaged coefficients, 22 were averaged from 2 or 3 individual coefficients. The corn x 10-34-0 average had 10 coefficients ranging from -0.02 to -0.40, while the flax x TSP average contained 10 coefficients ranging from -0.31 to 2.32. The pea by MAP combination had 9 coefficients ranging from 0.39 to 3.38. Obviously there is a wide range in coefficients within a crop and fertilizer combination. Some of the variability may be due to differences in the site factors that influence seedling injury such as soil moisture, soil texture, and rainfall soon after planting. Most of the references did not note these factors.

Crops vary in their germination/emergence sensitivity to fertilizer salts. An average of the regression coefficients over all fertilizers in Table 1 can give a relative crop ranking. However, not all coefficients are known and therefore such a ranking would produce biased results. Many of the phosphorus coefficients are known and therefore should produce a less biased ranking. A mean of all phosphorus fertilizer coefficients (if two or more) produces a relative ranking from least to most sensitive of corn=1, sorghum=1.8, oats=3.4, sunflower=3.5, wheat=4.7, barley=4.8, soybean=5.6, and flax=13.6. This ranking notes that flax is approximately 14 times more sensitive to fertilizer salts than is corn. It appears that mustard, canola, and pea are relatively sensitive to fertilizer salts as well (Table 1). The crop seedling sensitivity to fertilizer ranking agrees in general with those of Schoenau et al., 2007, and Muson, 1971.

Similarly, fertilizers can be rated as to their effect upon crop stands. Averaging coefficients over all crops (if more than two coefficients) yields a relative ranking from least damaging to most detrimental to crop stands. They are 4-10-10 = 1.00, 7-21-7 = 1.18, 10-34-0 = 1.44, 9-18-9 = 1.61, TSP = 2.40, DAP = 3.35, MAP = 6.40, 0-0-60 = 6.85, 34-0-0 = 8.30, and Urea = 9.73. In general the liquid P sources are safest followed by the dry P sources, KCl, and the nitrogen fertilizers are most detrimental to seed safety and eventual crop stands. However, because not all coefficients are present for all crops, this ranking may be biased and should not be used too literally. For example, it appears that MAP is approximately twice as detrimental as DAP. However, if the coefficients for MAP and DAP are averaged only for the crops where both coefficients are present in Table 1, the coefficients are similar (MAP=0.47, DAP=0.55.

Higher salt index fertilizers have been suggested as being more detrimental to crop germination when applied with the seed. Therefore the average regression coefficient of the above ten fertilizers should have some relationship to salt index. The average fertilizer coefficient is displayed in Table 3 and plotted in Figure 1. There is a fair relationship between the coefficients and salt index. An outlier appears to be KCl. The salt index indicates a more detrimental effect than what has been found from the literature.

Selected comparisons of “safe” fertilizer rates to apply with the seed for current South Dakota State University (SDSU) guidelines vs. the rates recommended with the decision aid described above are found in Table 2. Of 34 possible comparisons [using the values under the higher % stand (lower risk) column from Table 2] the decision aid results are higher than current guidelines about 74% of the time and lower 26% of the time. The higher recommendations are, in part, because the current guidelines suggest a zero rate in many cases instead of a very small rate of fertilizer. The decision aid allows the user to select their comfortable level of risk (% stand).

A laboratory emergence study is currently being conducted at SDSU using soil under standard conditions to evaluate a number of crop x fertilizer combinations. Hopefully, some preliminary results will be summarized for the meeting.

CONCLUSIONS

The developed decision aid for estimating safe rates of seed-placed fertilizer was developed using data from field and laboratory studies. The aid is user friendly and accounts for a number of cropping system and soil factors. The aid can be used for a number of crops, fertilizer sources, and row spacings. A disadvantage is not all coefficients are known. In addition, variability between coefficients within the same crop by fertilizer combination probably reflects differences in the experimental conditions of the studies. Unfortunately many of these conditions were not noted in the references. The aid appears to give reasonable estimates of safe fertilizer-with-seed rates.

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Table 1. Average regression coefficient of relative crop stand (y) upon fertilizer rate (x) for each crop by fertilizer combination.

Fertilizer	Corn	Soybean	Wheat	Alfalfa	Barley	Canola	Flax	Lentil	Mustard	Oat	Pea	Sorghum	Sunflower
	regression coefficient												
Urea (46-0-0)	-1.03		-2.18										
UAN (28-0-0)	-0.19												
Am. Nitrate			-0.41				-2.33						
MAP (11-55-0)	-0.08	-0.98	-0.46	-2.20	-0.48	-1.99	-1.52	-0.31	-3.02	-0.45	-1.65	-0.23	-0.35
DAP (18-46-0)	-0.21	-0.92			-0.58					-0.43			-0.53
TSP (0-46-0)	-0.06	-0.56	-0.31		-0.39		-1.10			-0.13			-0.22
APP (10-34-0)	-0.13	-0.40										-0.12	-0.30
7-21-7	-0.11	-0.28											
9-18-9	-0.08	-0.45											
4-10-10	-0.05	-0.28											
0-0-60		-1.70	-0.65			-1.04							
Am. Sulfate							-3.58						
ATS (12-0-0-26)	-0.36												

Table 2. Comparison of current SDSU fertilizer/seed guidelines with decision aid calculation values.

Crop/row width”	Corn – 30”			Wheat-7.5”			Soybean-30”			Soybean-7.5”			Sunflower-30”		
Recommendation	Curr.[1]	- - Aid - -		Curr.	- - Aid - -		Curr.	- - Aid - -		Curr.	- - Aid - -		Curr.	- - Aid - -	
Risk (Stand %)	- - -	90	95	- - -	80	85	- - -	80	85	- - -	80	85	- - -	90	95
Fertilizer	lbs material per acre														
Urea	0	10	5	54	37	28	0	- - -	- - -	22	- - -	- - -	0	- - -	- - -
Am. Nitrate	29	- - -	- - -	74	195	146	0	- - -	- - -	0	- - -	- - -	0	- - -	- - -
UAN	0	53	26	89	- - -	- - -	0	- - -	- - -	36	- - -	- - -	0	- - -	- - -
MAP	91	125	63	227	174	130	0	20	15	91	82	61	0	29	14
DAP	56	48	24	139	123	92	0	22	16	56	87	65	0	19	9
TSP	100	167	83	- - -	258	194	0	36	27	100	143	107	0	45	23
10-34-0	100	77	38	- - -	- - -	- - -	0	50	38	100	200	150	0	33	17
7-21-7	71	91	45	- - -	- - -	- - -	0	71	54	71	286	214	0	- - -	- - -
9-18-9	56	125	63	- - -	- - -	- - -	0	44	33	56	178	133	- - -	- - -	- - -
4-10-10	71	200	100	- - -	- - -	- - -	0	71	54	71	286	214	0	- - -	- - -
0-0-60	17	- - -	- - -	42	123	92	0	12	9	17	47	35	0	- - -	- - -

[1] Gerwing and Gelderman, 2005

Table 3. Selected fertilizer salt index and average regression coefficient (over crops) from Table 1.

Fertilizer	Regression coefficient	salt index*
0-0-60	-1.13	120.0
Am.Nit (34-0-0)	-1.37	104.0
Urea (46-0-0)	-1.61	74.4
DAP (18-46-0)	-0.55	29.2
7-21-7	-0.20	27.8
4-10-10	-0.17	27.5
MAP (11-55-0)	-1.06	26.7
APP (10-34-0)	-0.24	20.0
9-18-9	-0.27	16.7
TSP (0-46-0)	-0.40	10.1

* Mortvedt (1991)

Figure 1. Relationship of Fertilizer Salt Index (Mortvedt, 1991) and average regression coefficient from Table 1.