Decision Aid for Estimating Seed-Placed Fertilizer Rates – Final Report

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Introduction

Recently Gelderman (2007) developed a decision aid to assist crop planners in selecting the maximum safe fertilizer rate that can be applied with the seed for various crops. The aid uses regression coefficients (crop stand upon fertilizer rate) that were developed using published studies from the North Central region of the U.S. and adjacent Canadian provinces.

However, many common fertilizer by crop coefficients are still missing with the above review. Limited or no published studies exist for the missing crops and fertilizers. In addition, although each coefficient represents at least two independent studies, variables of the study may have influenced the coefficients. These variables include but are not limited to; soil texture, soil moisture, soil pH, soil CEC, soil OM, separation of fertilizer and seed, crop variety, and precipitation after seeding (both amount and timing of rainfall). In theory, enough studies would exist to obtain an average coefficient for the practical range of all the above variables. In practice, this is very unlikely. Therefore, coefficients produced under a uniform set of variables should produce a more uniform or standard set of coefficients.

The average ranking (over all fertilizers) of the crop coefficients (i.e. most sensitive to least sensitive crop) from the decision aid (Gelderman, 2007) are generally similar to rankings of Schoenau et al., 2007; Dowling, 1998; and Mason, 1971. A standard set of coefficients would allow determination of crop ranking for each fertilizer used (interaction of the two factors). Fertilizer influences on germination (most damaging to least) also seem to fit a general ranking over all crops which could be better defined under more controlled conditions such as in a laboratory.

Coefficient relationships for fertilizers and crops determined under laboratory conditions may also be useful for calculating local or regional subsets of those coefficients. For example, if a coefficient for a crop by fertilizer combination is well established in a region, a standard set of coefficients could be used to calculate a complete set of coefficients based on the single regional coefficient. Multiple coefficients can be used to calculate multiple coefficient tables for which a mean regional coefficient table could be developed.

Objective:

The objective of this work is to establish a standard set of regression coefficients for crop stand regressed upon fertilizer rate for some common crops and fertilizers used in the US. The laboratory developed coefficients will be used to modify a previously developed decision aid that assists crop advisors and producers in estimating safe seed-placement fertilizer rates.

Materials and Methods

A clay loam soil (38% sand, 30% silt, 32% clay) (4.3% OM, 7.3 pH) was collected, well mixed and screened (¼ inch mesh) for the study. Air dry soil (6.0 lbs) is

placed into a 9x13x2 inch aluminum pan and 500 mL of tap water is sprinkled on the soil [~18% water (mass basis)]. After equilibrating at least 2 hours, the moist soil is removed from the pan and well mixed. Either ½ or ¾ of the moist soil is replaced into the pan depending if a deep-seeded (1 inch) or shallow-seeded (½ inch) crop (Table 1), respectively, is being planted. The soil is leveled, slightly firmed and five 8 inch rows (1 inch wide) were slightly impressed into the soil with a planting tool. Ten seeds are evenly planted in each row and the appropriate fertilizer rate is spread within the row. The remaining soil is gently placed over the rows, leveled, and slightly firmed. To limit water loss, the pans are placed within a 2-gal plastic bag which is sealed except for about a 2 inch section. The bagged pans are placed on a plastic food tray, the tray and pan placed onto a food tray cart to await seedling emergence. A minimum of three separate runs of each crop x fertilizer combination (1 pan) were completed except for sorghum (2 runs).

A fertilizer rate (one being a zero fertilizer control) was placed in each of the five 8 inch rows per pan. The rates were equivalent to a field fertilizer concentration for a 30 inch row and 1 inch furrow opening for all crops.

Dailey plant emergence counts began when emergence was first noted and ended about 14 days after planting (DAPL). The emergence counts from 9 to 11 DAPL were used for all study crops except for cotton (13 days). The DAPL count was selected when it was judged that most plants had emerged for that crop. The selected DAPL emergence count will be referred to as final stand or final emergence.

Emergence counts were converted to relative values by dividing the control count mean by the treated value x 100. The control count mean for a crop was calculated from the control counts from all 16 fertilizer pans in a run. Sixteen crops and sixteen fertilizer materials were used (Table 1).

Fertilizer rate was not necessarily constant for each of the three runs. Final stand was noted after each run and rates adjusted so a rate response curve could be obtained. Fertilizer rate was not randomized within each pan but placed from low to high rate (from left to right) within the pan. Preliminary observations of emergence and final stand from control rows near relatively high fertilizer rate rows for several fertilizers indicated no influence of nearby row treatments.

Nlin (SAS) procedures [both linear (L) and plateau-linear (PL)] were used to define the resulting response curves (final stand regressed on fertilizer rate (lb/a material).

Figure 1. Pan, soil, seed, and fertilizer before covering with soil in laboratory

Figure 2. Emerged seedlings in laboratory emergence study.

Table 1. Crop and fertilizers used in laboratory study, 2007 – 2008.

Crop				Fertilizer		
Common Name	**Scientific Name**	**Variety**	**Seeding Depth Inches**	**Name**	**Analysis (N-P_2O_5- K_2O)**	**Type**
Corn	*Zea mays*	DKC C46-60 AF2	1	Amm. Nitrate	34-0-0	solid
Soybean	*Glycine max*	Asgrow Ag 1401	1	Urea	46-0-0	solid
Spring Wheat (Hard Red)	*Triticum aestivum*	Briggs	1	Urea + NBPT[1]	46-0-0	solid
Durum	*Triticum turgidum*	Pierce	1	DAP	18-46-0	solid
Oat	*Avena sativa*	Stallion	1	MAP	11-55-0	solid
Barley	*Hordeum vulgare*	Robust	1	TSP	0-46-0	solid
Sunflower	*Helianthus annuus*	Pioneer 64H41	1	KCl	0-0-60	solid
Safflower	*Carthamus tinctorius*	Foundation Finch	1	K sulfate	0-0-50-18% S	solid
Lentil	*Lens culinaris*	ODC Richlea	1	KSMg	0-0-22-22% S - 11% Mg	solid
Green Field Pea	*Pisum sativum arvense*	Unknown	1	10-34-0	10-34-0	liquid
Sorghum	*Sorghum bicolor*	Unknown	½	7-21-7	7-21-7	liquid
Flax	*Linum usitatissimum*	Selby	½	9-18-9	9-18-9	liquid
Mustard	*Brassica nigra*	Dahinda Yellow	½	3-18-18	3-18-18	liquid
Canola	*Brassica napus*	Unknown	½	4-10-10	4-10-10	liquid
Alfalfa	*Medicago sativa*	WL357HQ	½	ATS[2]	19-0-0-43% S	liquid
Cotton	*Gossypium hirsutum*	All-Tex Apex B2EF	½	28-0-0	28-0-0	liquid

[1] The urease inhibitor - N-(n-butyl)-thiophosphoric triamide (5 qt/ton)
[2] Ammonium thiosulfate

Results

Final relative stand regressed upon fertilizer rate for many crop by fertilizer combinations resulted in plateau-linear functions similar to the example in Figure 3. However, for more sensitive combinations, a simple linear function (forced thru 100) appeared to fit the data points (Figure 3). In general, the linear portion of the PL function produced similar estimates of safe fertilizer-with-seed rates (FR) compared to the linear (L) model on the more sensitive crop by fertilizer combinations (data not shown). However, with less sensitive combinations the PL model gave larger FR values than the L model. A subset of 44 crop by fertilizer combinations that had literature FR values (Gelderman, 2007) was used to evaluate FR values from the L and LR functions. The L model produced 8 (18%) FR values that were 20 lb/a or greater than the literature values. The LP model produced 20 (45%) FR values 20 lb/a or greater than the literature values. However, these results may have been biased since the literature derived values also use a linear model. The more conservative L model was chosen to calculate FR for the decision aid.

The 256 slope coefficients from the L regression model resulting from the 16 crop by 16 fertilizer combinations from the laboratory study are given in Table 2. The L model slope coefficients range from 0.04 for the 4-10-10 by corn combination to 7.21 for the urea by flax combination.

Regression coefficients (r^2) for the laboratory L model for the 256 crop by fertilizer combinations range from 0.17 to 0.92 (Table 3). Twelve r^2 values are below 0.30 and 21 values range from 0.30 - 0.40. About 88% of the r^2 coefficients were greater than 0.40.

The calculation for a seed-placed "safe" fertilizer rate using the L model is: F=30S (-T)/CR; Where F=fertilizer material (lb/a), S=seed spread in inches (furrow opening), T=Tolerated Stand Loss (%) over stands where no fertilizer was applied, C=crop coefficient (L model slope), R=row width in inches. Seed-placed fertilizer rates were calculated for the 256 crop by fertilizer combinations using assumed tolerated stand loss and row widths as given in Table 4. The resulting rates are provided in Table 5. For comparison, the estimated safe rates as calculated from literature data (Gelderman, 2007) are listed beside the laboratory coefficient in Table 5. The laboratory:literature values (where both are listed) averaged 53:51, 28:41, and 146:152 for the corn, soybean and wheat, respectively.

Relative injury potential for the 256 crop by fertilizer combinations and a mean injury potential for the fertilizers (over all crops) and the crops (over all fertilizers) were calculated (Table 6). The potentials are based on the laboratory regression slope coefficients (Table 2) from each combination and not on average FR (Table 5) which considers tolerated stand loss, row width and seed-furrow opening width. The mean injury potential for fertilizer materials (over all crops) compares that fertilizer's potential to produce injury relative to 4-10-10 which produced the lowest average injury potential (Table 6). Liquid phosphate sources tend to be less injurious to germinating seeds followed by dry phosphate sources and nitrogen sources tend

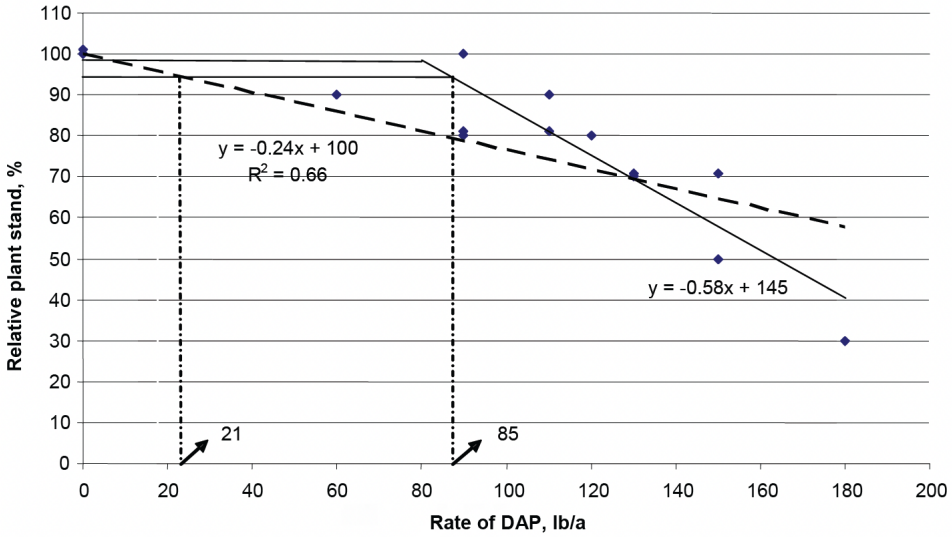

Figure 3. Example of linear and plateau-linear models for relative final emergence of corn upon rate of DAP.

to be most injurious. The same trends were noted in the literature review (Gelderman, 2007). Of the fertilizer materials evaluated, the liquid P sources tend to be least damaging to plant stands. Injury potential from seed application is much higher for both ATS and urea than other fertilizer sources. The mean ranking of injury potential (from least to greatest) for the evaluated fertilizers is: 4-10-10 (5.2); 7-21-7 (7.3); 3-18-18 (8.8); 10-34-0 (9.6); 9-18-9 (12.8); TSP (12.8); KSMg (17.1); K sulfate (18.4); MAP (19.4); DAP (22.3); 28-0-0 (30.9); KCl (34.5); Am.Nit. (41.7); urea+NBPT (41.9); ATS (66.7); urea (78.3).

Of the evaluated crops, corn is least sensitive to fertilizer salts and alfalfa most sensitive (Table). The small grains of barley, hard red spring wheat, durum wheat, and oat are similar in relative susceptibility to fertilizer salts and follow corn in the ranking. Canola, flax, and soybean are somewhat less sensitive than alfalfa in the relative ranking and have been noted by other workers (Mason, 1971) (Nyborg, 1961) (Gelderman et al. 1995) as relatively susceptible to fertilizer salts. The mean ranking of crop sensitivity to fertilizer salts (from least to greatest) is: corn (6.5); barley (11.3); HRS wheat (14.1); durum (15.1); sunflower (16.5); oat (17.8); sorghum (21.8); pea (23.3); cotton (23.8); lentil (31.4); safflower (33.2); soybean (40.6); mustard (41.2); flax (41.6); canola (41.7); alfalfa (47.6).

Conclusions

A laboratory procedure was developed to estimate injury potential from seed-placement of 16 common fertilizers upon 16 common crops of the U.S. The linear-plateau model produced coefficients that were higher, on average, than the linear model. The study produced a standard set of linear slope coefficients that were, on average, similar to literature obtained coefficients. Based on the author's field results, the linear model produces FR values that may be too conservative for some combinations such as TSP and MAP with corn.

Corn is the least sensitive crop to fertilizers while alfalfa is most sensitive of the 16 evaluated crops. Urea and ammonium thiosultate are most injurious to plant stands while the liquid phosphorus sources had lower injury levels.

The developed linear coefficients were used to modify the previously developed decision aid which estimates safe seed-placed fertilizer rates. The updated decision aid includes more crops and fertilizer materials. The aid appears to give reasonable estimates of safe seed-placed fertilizer rates.

Deliverables

A. Decision aid to apply fertilizer with seed.
B. Presentations
    1. NC-Ext. Industry, Nov. 14-15, 2007. Des Moines, IA
    2. WinField agronomists, Feb. 12, 2008. Brookings, SD
    3. Great Plains Soil Fertility Conference. Mar. 4-5. Denver, CO.
    4. SD Independent Ag. Consultants. Mar. 24, 2008. Brookings, SD
    5. SD Agronomy Educators, Mar. 26, 2008. Brookings, SD.
    6. Conservation Tillage Conference, Jan. 28-29, 2009. Morton, MN.
    7. 19th North Central Soil-Plant Analysts Workshop, Feb. 24-25, 2009. Bettendorf, IA.

References

Dowling, C.W. 1998. Seed and Seedling Tolerance of Cereal, Oilseed, Fibre and Legume Crops to Injury from Banded Ammonium Fertilizers. Ph.D diss. Univ. of New England, Armidale, New South Wales, Australia

Gelderman, R.H. March 2007. Fertilizer Placement with Seed – A Decision Aid. Final Report for the International Plant Nutrient Institute. 22 p.

Gelderman, R., J. Gerwing, and R. Berg. 1995. The Influence of Seed-Placed Fertilizer on Corn and Soybean Emergence and Yield. Soil Progress Rep. 94-23. Pl. Sci. Dept., South Dakota Agric. Exp. Stn., South Dakota State Univ., Brookings, SD.

Mason, M.G. 1971. Effects of Urea, Ammonium nitrate and super phosphate on establishment of cereals, linseed, and rape. Aust. J. Expt. Ag. Ani. Husb., 11(53) 662- 669.

Nyborg, M. 1961. The effect of fertilizers on emergence of cereal grains, flax, and rape. Can. J. Soil Sci 49:19.

Schoenau, J.J., P. Qian, and T. King. January 2007. Strategies for Improving the Efficiency and Crop Safety of Starter Fertilizer Phosphorus and Potassium. Final Report, PPI Project no. SK-37F. 22 p.

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Table 2. Slope coefficients from laboratory crop emergence regressed on fertilizer rate

Fertilizer	Corn	Soybean	HRSW[1]	Durum	Oats	Barley	Sunflower	Safflower	Lentil	Pea	Sorghum	Flax	Mustard	Canola	Alfalfa	Cotton
	Regression Slope															
Am.Nit	-0.215	-2.378	-0.893	-1.107	-0.807	-0.432	-0.993	-2.271	-1.825	-1.062	-1.038	-2.479	-2.604	-3.034	-2.924	-0.621
Urea	-0.965	-3.330	-1.436	-1.468	-1.634	-1.207	-2.258	-3.175	-2.706	-1.489	-2.521	-7.208	-2.903	-4.457	-6.373	-3.201
Urea+NBPT	-0.434	-3.403	-0.951	-0.900	-0.978	-0.772	-0.857	-2.186	-1.504	-1.236	-0.925	-2.194	-2.150	-2.509	-2.225	-2.291
DAP	-0.236	-1.080	-0.541	-0.617	-0.545	-0.477	-0.306	-1.082	-1.141	-0.703	-0.862	-1.153	-1.182	-1.567	-1.074	-0.645
MAP	-0.161	-1.097	-0.406	-0.700	-0.578	-0.302	-0.367	-0.777	-1.115	-0.678	-0.465	-0.902	-1.235	-0.971	-1.107	-0.607
TSP	-0.099	-0.592	-0.266	-0.328	-0.210	-0.179	-0.335	-0.610	-0.587	-0.247	-0.274	-0.655	-1.061	-0.977	-0.955	-0.207
KCL	-0.473	-2.166	-0.891	-1.156	-1.067	-0.618	-0.764	-1.426	-1.632	-1.282	-1.189	-1.419	-2.357	-1.479	-1.505	-0.982
K Sulfate	-0.095	-0.693	-0.474	-0.569	-0.507	-0.212	-0.337	-0.693	-0.824	-0.449	-0.984	-0.954	-1.398	-1.177	-0.970	-0.564
KSMg	-0.215	-0.822	-0.558	-0.578	-0.782	-0.364	-0.261	-0.663	-0.799	-0.344	-0.803	-0.749	-0.883	-0.981	-0.725	-0.623
10-34-0	-0.037	-0.478	-0.105	-0.234	-0.213	-0.199	-0.244	-0.583	-0.582	-0.143	-0.172	-0.537	-0.340	-0.685	-0.650	-0.455
7-21-7	-0.053	-0.597	-0.143	-0.153	-0.193	-0.058	-0.163	-0.387	-0.474	-0.218	-0.166	-0.291	-0.303	-0.483	-0.381	-0.255
9-18-9	-0.154	-0.688	-0.140	-0.193	-0.378	-0.125	-0.328	-0.557	-0.502	-0.222	-0.501	-0.827	-0.694	-0.673	-1.157	-0.468
3-18-18	-0.103	-0.521	-0.070	-0.165	-0.099	-0.098	-0.155	-0.452	-0.424	-0.240	-0.263	-0.617	-0.493	-0.613	-0.573	-0.313
4-10-10	-0.045	-0.506	-0.050	-0.200	-0.121	-0.081	-0.098	-0.286	-0.314	-0.121	-0.122	-0.162	-0.252	-0.269	-0.303	-0.123
ATS	-0.300	-4.001	-1.169	-0.934	-1.889	-1.306	-1.758	-2.976	-2.856	-4.557	-1.774	-1.981	-4.540	-2.920	-4.418	-2.090
28-0-0	-0.236	-1.703	-0.258	-0.396	-0.551	-0.281	-0.556	-1.539	-1.290	-0.799	-0.825	-2.495	-2.017	-1.873	-2.821	-0.640

[1]Hard Red Spring Wheat

Table 3. Linear regression coefficients (r^2) from the laboratory crop emergence regressed on fertilizer rate.

Fertilizer	Corn	Soybean	HRSW[1]	Durum	Oats	Barley	Sunflower	Safflower	Lentil	Pea	Sorghum	Flax	Mustard	Canola	Alfalfa	Cotton
	Regression Coefficient, r^2															
Am.Nit	0.33	0.79	0.71	0.37	0.39	0.28	0.68	0.81	0.82	0.57	0.56	0.62	0.81	0.56	0.52	0.57
Urea	0.66	0.75	0.76	0.58	0.58	0.61	0.82	0.82	0.78	0.46	0.72	0.57	0.47	0.80	0.89	0.87
Urea+NBP	0.57	0.80	0.73	0.83	0.76	0.77	0.59	0.83	0.79	0.65	0.55	0.17	0.72	0.74	0.58	0.79
DAP	0.66	0.71	0.84	0.49	0.74	0.57	0.51	0.89	0.76	0.56	0.74	0.65	0.59	0.76	0.65	0.74
MAP	0.57	0.87	0.59	0.74	0.85	0.50	0.67	0.80	0.85	0.65	0.71	0.42	0.71	0.81	0.62	0.72
TSP	0.52	0.81	0.81	0.68	0.55	0.64	0.63	0.78	0.81	0.37	0.54	0.44	0.58	0.74	0.78	0.45
KCL	0.64	0.80	0.74	0.57	0.59	0.74	0.66	0.88	0.62	0.52	0.65	0.52	0.76	0.85	0.72	0.73
K Sulfate	0.58	0.74	0.73	0.62	0.77	0.38	0.64	0.81	0.86	0.44	0.63	0.30	0.67	0.69	0.57	0.78
KSMg	0.50	0.81	0.86	0.56	0.73	0.75	0.42	0.84	0.86	0.40	0.75	0.25	0.34	0.71	0.42	0.66
10-34-0	0.39	0.55	0.59	0.54	0.49	0.47	0.53	0.77	0.77	0.31	0.47	0.26	0.43	0.72	0.47	0.72
7-21-7	0.34	0.80	0.28	0.33	0.53	0.37	0.48	0.85	0.84	0.35	0.39	0.29	0.43	0.62	0.46	0.74
9-18-9	0.48	0.81	0.44	0.48	0.81	0.42	0.67	0.78	0.70	0.43	0.71	0.57	0.67	0.57	0.71	0.63
3-18-18	0.53	0.73	0.19	0.38	0.36	0.46	0.48	0.76	0.86	0.52	0.69	0.44	0.39	0.64	0.60	0.78
4-10-10	0.32	0.57	0.22	0.47	0.38	0.45	0.54	0.80	0.70	0.52	0.27	0.28	0.32	0.70	0.53	0.48
ATS	0.58	0.72	0.63	0.61	0.85	0.71	0.84	0.69	0.78	0.68	0.73	0.58	0.86	0.52	0.77	0.82

[1]Hard Red Spring Wheat

Table 4. Assumed parameters[1] to calculate fertilizer rate to be placed with the seed.

Assumed Parameters	Units	Corn	Soybean	HRS Wheat	Durum Wheat	Oat	Barley	Sunflower	Safflower	Lentil	Pea	Sorghum	Flax	Mustard	Canola	Alfalfa	Cotton
stand loss[2] (T)	%	5	20	20	20	20	20	10	10	20	20	10	15	20	15	15	5
row width (R)	inches	30.0	30.0	7.5	7.5	7.5	7.5	30.0	7.5	7.5	7.5	30.0	7.5	7.5	7.5	7.5	30.0

[1]planter seed opening width was one inch in all cases.
[2]Tolerated stand loss – as percent stand loss over stands where fertilizer is not applied.

Table 5. Rate of seed-placed fertilizer as calculated[1] from laboratory and literature data (in parenthesis).

Fertilizer	Corn	Soybean	HRS Wheat	Durum Wheat	Oat	Barley	Sunflower	Safflower	Lentil	Pea	Sorghum	Flax	Mustard	Canola	Alfalfa	Cotton
	Fertilizer Rates, lb/a															
Am.Nit	23	8	90 (195)	72	99	186	10	18	44	75	10	24	31	20	21	8
Urea	5 (5)	6	56 (37)	54	49	66	4	13	30	54	4	8	28	13	9	2
Urea + NBPT	12	6	84	89	82	104	12	18	53	65	11	27	37	24	27	2
DAP	21 (24)	19 (22)	148 (123)	129	148 (186)	167 (138)	32 (19)	37	70	114	12	52	68	38	56	8
MAP	31 (63)	18 (20)	195 (174)	114	138 (178)	267 (167)	27 (29)	51	72 (258)	116 (48)	21 (43)	67 (39)	65 (26)	62 (38)	54 (27)	8
TSP	50 (83)	34 (36)	296 (258)	242	381 (615)	444 (205)	30 (45)	66	136	320	37	91 (55)	75	61	63	24
KCL	11	9 (12)	90 (125)	69	75	129	13	28	49	63	8	42	34	41 (58)	40	5
K Sulfate	50	29	170	140	157	381	29	58	98	178	10	63	57	51	62	9
KSMg	24	24	143	138	103	222	38	61	100	235	13	80	91	61	83	8
10-34-0	125 (83)	42 (50)	727	348	381	400	42 (33)	69	138	571	59 (83)	111	235	86	92	11
7-21-7	100 (45)	33 (71)	571	533	421	1379	63	103	170	364	59	207	267	125	158	20
9-18-9	33 (63)	29 (44)	571	421	211	615	30	71	160	364	20	72	116	90	52	11
3-18-18	50	38	1143	471	800	800	63	89	190	348	38	97	163	98	105	16
4-10-10	125 (100)	39 (71)	1600	400	667	988	100	138	160	667	83	375	320	222	200	42
ATS	17 (14)	5	68	86	42	61	6	13	28	18	6	30	18	21	13	2
28-0-0	21 (26)	12	308	200	145	286	18	26	62	100	12	24	40	32	21	8

[1] F=30S (-T)/CR, Where F=fertilizer material (lb/a), S=seed spread in inches (furrow opening) (1"), T=Tolerated stand loss as % over a stand where no fertilizer is applied (Table 4), C=crop coefficient (slope of linear portion of curve) (Table 4), R=row width in inches (Table 4).

Table 6. Relative sensitivity or injury index for 16 crop by 16 fertilizer combinations based on coefficients in Table 2, where lowest coefficient (corn by 10-34-0) =1.

Fertilizer	Corn	Soybean	HRSW[1]	Durum	Oats	Barley	Sunflower	Safflower	Lentil	Pea	Sorghum	Flax	Mustard	Canola	Alfalfa	Cotton	Fertilizer injury mean
	Relative Sensitivity or Injury Index																
Am.Nit.	5.8	64.3	24.1	29.9	21.8	11.7	26.8	61.4	49.3	28.7	28.1	67.0	70.4	82.0	79.0	16.8	41.7
Urea	26.1	90.0	38.8	39.7	44.2	32.6	61.0	85.8	73.1	40.2	68.1	194.8	78.5	120.5	172.2	86.5	78.3
Urea +NBPT	11.7	92.0	25.7	22.5	26.4	20.9	23.2	59.1	40.6	33.4	25.0	59.3	58.1	67.8	60.1	61.9	43.0
DAP	6.4	29.2	14.6	16.7	14.7	12.9	8.3	29.2	30.8	19.0	23.3	31.2	31.9	42.4	29.0	17.4	22.3
MAP	4.4	29.6	11.0	18.9	15.6	8.2	9.9	21.0	30.1	18.3	12.6	24.4	33.4	26.2	29.9	16.4	19.4
TSP	2.7	16.0	7.2	8.9	5.7	4.8	9.1	16.5	15.9	6.7	7.4	17.7	28.7	26.4	25.8	5.6	12.8
KCL	12.8	58.5	24.1	31.2	28.8	16.7	20.6	38.5	44.1	34.6	32.1	38.4	63.7	40.0	40.7	26.5	34.5
K Sulfate	2.6	18.7	12.8	15.4	13.7	5.7	9.1	18.7	22.3	12.1	26.6	25.8	37.8	31.8	26.2	15.2	18.4
KSMg	5.8	22.2	15.1	15.6	21.1	9.8	7.1	17.9	21.6	9.3	21.7	20.2	23.9	26.5	19.6	16.8	17.1
10-34-0	1.0	12.9	2.8	6.3	5.8	5.4	6.6	15.8	15.7	3.9	4.6	14.5	9.2	18.5	17.6	12.3	9.6
7-21-7	1.4	16.1	3.9	4.1	5.2	1.6	4.4	10.5	12.8	5.9	4.5	7.9	8.2	13.1	10.3	6.9	7.3
9-18-9	4.2	18.6	3.8	5.2	10.2	3.4	8.9	15.1	13.6	6.0	13.5	22.4	18.8	18.2	31.3	12.6	12.8
3-18-18	2.8	14.1	1.9	4.5	2.7	2.6	4.2	12.2	11.5	6.5	7.1	16.7	13.3	16.6	15.5	8.5	8.8
4-10-10	1.2	13.7	1.4	5.4	3.3	2.2	2.6	7.7	8.5	3.3	3.3	4.4	6.8	7.3	8.2	3.3	5.2
ATS	8.1	108.1	31.6	25.2	51.1	35.3	47.5	80.4	77.2	123.2	47.9	53.5	122.7	78.9	119.4	56.5	66.7
28-0-0	6.4	46.0	7.0	10.7	14.9	7.6	15.0	41.6	34.9	21.6	22.3	67.4	54.5	50.6	76.2	17.3	30.9
Crop Sensitivity Mean	6.5	40.6	14.1	16.3	17.8	11.3	16.5	33.2	31.4	23.3	21.8	41.6	41.2	41.7	47.6	23.8	--

[1]Hard Red Spring Wheat