Using routinely collected soil test data to estimate the spatial distribution of soybean cyst nematode in Minnesota.

by

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Soybean cyst nematode, *Heterodera glycines*, (SCN) was first discovered in the United States in North Carolina in 1954 (Riggs, 1997). Since then, SCN has migrated to 28 other soybean- producing states and has become one the most destructive soybean pests (Chen, et al., 2001). In 2002 alone, Minnesota farmers experienced a 1,269,842 metric ton loss of soybean yield due to disease (Wrather, Koenning and Anderson, 2003). Of that total, almost 30% was due to SCN. With yield losses as great as this, the on farm-management of SCN is of utmost importance.

Minnesota farmers have faced many challenges in trying to manage SCN. There is evidence that tillage regimes (Young, 1987) and certain soil properties affect the survivability and reproductive success of SCN (Todd and Pearson, 1988) and the spatial variation of SCN within fields makes directing management tactics more difficult, more labor intensive and economically inefficient – especially when chemical tactics are included into SCN management programs. These issues make a program capable of identifying field locations that have a higher probability of sustaining economically significant populations of SCN worthy of pursuing.

Many Minnesota growers have a history of soil test data from their fields and every year more fields are being subjected to more intensive sampling regimes, such as grid sampling and management zone creation (Agvise Laboratories, 2005). What is not known is if these data, that are routinely collected, can be used to estimate the spatial distribution of SCN populations.

Objective:

The objective of this research was to investigate the feasibility of using information available to soybean growers to identify field locations that have the ability to sustain SCN in order to more accurately direct SCN management tactics.

Introduction to the Soybean Cyst Nematode

I. Life cycle

The SCN is a microscopic roundworm that attacks and penetrates soybean roots. The life stages consist of the egg, juvenile and adult. The juvenile stage consists of four developmental stages (J1 – J4) and it is the second juvenile life stage (J2) that makes contact with and penetrates the soybean root. Once in the plant root, the juvenile nematode attaches to the vascular tissue and becomes immobile. It will molt three times before becoming an adult, and in the last molt, it will become either male or female. The egg-laden female body then becomes the familiar cyst that is visible on soybean roots. The cyst protects the eggs from environmental damage and serves as an over-wintering vessel to ensure continued field infestation. The life cycle, under ideal conditions, can take as little as 30 days to complete (Chen, *et al*, 2001).

Before death (the point at which the female body is considered a cyst), some eggs are deposited outside of the body and begin to hatch. These newly hatched juveniles begin the life process over again allowing for multiple generations per growing season.

II. SCN symptoms

Yellow, stunted plants are a typical symptom of SCN infections, yet SCN by themselves generally do not cause the symptoms. It usually is the interaction between SCN and other plant pathogens or stresses that cause the outward manifestation of stunted and yellowed plants (Scherer, 2005). Many works have documented an increase of severity of disease when SCN is present and the symptoms they produce are often the first sign that SCN may be present in the field (Schmitt, Wrather and Riggs, 2004).

"Soybean cyst nematode injury can be easily confused with other crop production problems such as nutrient deficiencies, injury from herbicides, soil compaction, or other disease" (Riedel, et al. 2005). These symptoms can range from virtually non-existent to very severe, causing plants to die prematurely. In Minnesota, the affected areas will generally start showing up in mid summer. Since mechanical movement of soil is a good method of transport for SCN (Riggs, 1977), field entry points will sometimes be the first place that SCN is introduced to the field and symptoms will first appear there. Often times, the field symptoms will follow the direction of tillage, offering another indication that SCN is a probable cause of the symptoms.

III. SCN variability

There are many natural environmental conditions and human-induced conditions that determine a field's ability to sustain a population of SCN. A common question among soybean growers is whether or not they should apply control measures to an entire field. One probable explanation for this query is an economic one; they wish to limit their production costs and treat only the portion of their farm that needs it. To address this, an understanding of what factors contribute to the spatial distribution of SCN is needed.

Several researchers have documented that soil texture plays a significant role in SCN establishment and reproduction. Young and Heatherly (1990) as well as Todd and Pearson (1988) have been able to show that a soil with a higher sand content seemed to be more favorable to early SCN establishment, but neither were able to determine the exact mechanism that the SCN found more favorable. It is unclear from their work whether the SCN found the soil texture to their advantage or if the soybean root growth is influenced by the soil texture to the benefit of the SCN. The question of whether the soil type or the phenology of the soybean root in a particular soil type is compounded when looked at in the context of disturbed or undisturbed soil. Greenhouse studies show that cysts develop in conventionally tilled soil more abundantly than in no-tilled soil, even when there can be more soybean root mass in soil that is undisturbed (Young, 1987). This seems to be a bit inconsistent with the work of Noel and Wax (2003), who found little interaction between tillage and SCN population dynamics, at least in the short term. It is clear that continued work is needed to fully understand the effects of tillage on SCN populations.

Crop rotation has also been recognized as influencing the reproduction and survivability of SCN. In many of the soybean growing areas of the upper Midwest, corn is typically rotated as a non-host to SCN with soybean every other year. This rotation has been found to do little to alleviate SCN associated production problems on a long-term basis (Porter, et al). Porter, et al. found that it would take up to five years of planting a non host crop to significantly reduce SCN egg densities but it would only take a year or two after that of planting a host crop to allow SCN numbers to rebound to their original level.

IV. SCN management strategies
According to the Plant Health Initiative (http://www.planthealth.info/), the management goal of SCN is multi-tiered. They state that soybean management in SCN infested soils must include improved soybean health, reducing SCN numbers and preserving the yield potential of resistant varieties (Niblack and Tylka, 2005). They go on to say that since "no single management practice will meet all three goals, you must use an integrated system" which uses several management components. Chief is the use of resistant soybean cultivars and crop rotation.

In the upper Midwest, where corn is the principle crop in rotation with soybean, an accepted practice is to use susceptible, SCN resistant and non-hosts (table 1) in a six-year rotation in order to maintain effectiveness of resistance and a high soybean yield (Tylka, 1995, Ministry of Agriculture, Food and Rural Affairs, 2002).

Table 1
Accepted Crop Rotation for Fields Infested with SCN

Year 1	Non Host
Year 2	SCN resistant soybean 'A'
Year 3	Non Host
Year 4	SCN resistant soybean 'B'
Year 5	Non Host
Year 6	SCN susceptable soybean

The continued use of this type of cropping sequence will be of paramount importance to soybean growers. The continued use of a single resistant cultivar has shown to induce SCN population shifts and reduced effectiveness of the host resistance (Schmitt, 1991).

Currently there are only a handful of SCN management tactics available to Minnesota growers. Of these, most are cultural practices – planting non host crops, using SCN resistant cultivars, and rotating resistant and non resistant crops – and one is a chemical tactic; the use of nematicides. Each of these tactics has strengths and weaknesses and the need to direct their use is of paramount importance.

Materials and Methods

This study was conducted on two production fields (fields A and B) in southwest Minnesota that have been under a corn-soybean rotation for at least 15 years. The soils consist of Ves-Canisteo-Spicer soil associations and are well drained. The soil series composition of each field can be seen in figures 1 and 2. Each field was partitioned into 4.4 acre grids and sampled for both SCN (eggs/100cc of soil) and chemical analysis using a hand held computer with HGIS sampling software (Starpal, Inc., Fort Collins, CO). Each sample was collected from the center point of each grid and comprised of 10-12 sub-cores collected from within 10 feet of the sample point. Samples were collected on July 8 and 16, 2004 for fields A and B, respectively, and sent to Agvise Laboratories (Benson, MN) for analysis (tables 2 and 3). While sampling, there were several areas of the field that showed symptoms of chlorosis. However, none of the samples, with the exception of grid number 21 (field A, figures 4 & 5), were taken where chlorosis symptoms were apparent. A random visual inspection of several soybean roots indicated that SCN cysts were present and numerous. All sample cores were taken within the soybean row.

Field B, as part of the grower's routine management, was submitted for zone management creation using the proprietary methods of Management Zone Based Technologies, LLC. (MZB) of Watertown, SD. It was decided to also include this method of sampling into this study. Soil samples were collected using geo-referenced sampling points on October 14, 2004 (after the crop was harvested) and also sent to Agvise Laboratories for analysis (table 4). Each zone was sampled independently and each was comprised of 6-7 cores. Figure 3 shows the zone delineation of the field. Field B is bisected by a drainage ditch and only the portion of the field north of the ditch was grid sampled for this study. However, management zones were created on the entire field and soil samples taken from each zone were comprised of soil cores taken from the portion of the field south of the drainage ditch as well as the portion of the field north of the drainage ditch.

Data were analyzed for correlations between SCN population density and soil analytical properties using JMP statistical software (SAS Institute, Inc., Cary, NC). Coefficient of determination (R^2) values are listed in table 5. A comparative analysis was also conducted between sampling regimes to determine if one sampling procedure produced more conclusive results than the other.

The weather conditions for the 2004 growing season could be described as polar; early season moisture was severely lacking and by mid summer was too plentiful. The temperature gradient during the summer was similar; warm during the spring and turning cool during the summer.

Fertility for these fields was typical for the region. Nutrients are applied before the corn crop and no supplemental nutrients are applied subsequent to soybean planting. Tillage is also typical for the region. After corn harvest, a chisel plow is used to bury corn residue and a spring field cultivator is used to prepare the seed bed for soybean planting. A fall chisel plow is used after soybean harvest.

The soybean planted into the two fields were a Pioneer brand cultivar, but due to unforeseen circumstances, the variety name has been lost.

Results and Discussion

The laboratory results (tables 2 &3) of both fields are typical for southwest Minnesota. There are typically wide variations in many, if not most, of the soil properties as well as SCN egg counts.

Final analysis shows essentially no correlations between soil properties and SCN, either positively or negatively (table 5). There are two exceptions to this determination: the r^2 values for zinc and SCN in field A and for potassium and SCN in field B with management zones. However, with no other supporting data and no corroborating evidence for potassium relationships and with little corroborating evidence of zinc relationships in field environments (Behm et al., 1995) within the literature, these two results have to be considered coincidental.

Finding no correlations seemed, at first, counter to some known relationships between SCN and factors in the soil environment such, as pH (Francl, 1993, Niblack and Tylka, 2005), soil texture (Avendano, et al., 2004, Todd and Pearson, 1988), and tillage (Young, 1987, Noel and Wax, 2003). It seems that the interactions between soil physical and chemical properties have a larger influence on SCN survivability than any single property. Francl (1993) has found that soil "factors are interrelated, and they interact with soil biota in many ways". Because of the many cause-and-effect relationships that tend to develop in the soil environment, he felt that multivariate analysis would be the best tool for deciphering the mass of information available between SCN and the many possible soil properties; a method not conducted in this study.

Other factors have also played a role in the findings of this study. Flowers, Weisz and White (2005) have found that the sampling method, grid size and zone delineation techniques all influence the description of the in-field variability of soil factors. They found that the grid cell sampling technique was a more accurate procedure than the grid center technique (the one used in this study) and a smaller grid size, likewise, was more accurate than a larger one. They also caution that the accuracy of one procedure may not necessarily fit all fields and to definitively determine the best method, multiple techniques should be used. It is possible, if the two fields in my study were broken down into smaller grids, that the relationship between SCN and soil properties might have been more definitive. Likewise, as Flowers, Weisz and White (2005) pointed out, a larger number of fields to which data could have been extracted may have provided different results. It is possible that the limited number of samples collected in just two fields did not provide enough information to allow any decisions to be made.

Though there was not a strong correlation between the soil samples taken in the field with the management zone regime, some reasonable conclusions can be made in the comparison between grid sampled and zone sampled fields. First, the soil that comprises a zone (at least with the management zone system used in this study) will have a more similar soil type than the soil that comprises a standard 4.4 ac. grid. Secondly, using soil texture to estimate SCN populations would be easier for a grower who is using management zones than one who is using grids. Avendano, Pierce and Melakeberhan (2004) have determined that correlations between SCN population densities and soil texture are stronger in fields that have greater variability than in fields that have a relatively uniform soil texture. Because of this relationship and the management zone system being able to create zones based, in part, on soil texture, it is easy to see that the management zone system would be more apt to segregate SCN populations because of its ability to delineate the soil texture variation across a field. This would seem to concur with Schmitt, *et al*. (1990) who found that efficiency in sampling can be realized when soil type is taken into consideration – something that grid sampling does not do.

Conclusion

This study did not find any conclusive evidence that routinely collected soil grid test data could be used to estimate soil SCN populations. In order to visualize the distribution of SCN, intensive sampling with either management zones or grid samples for SCN is still the most accurate method. However, if a grower wished to use soil type as a delineation tool, then management zones would be the superior method to use.

Tables and Figures:

Table 2. Field A laboratory analysis data – sampled July 8, 2004.

Grid Number	count			%	ppm-olson	ppm	ppm	ppm	meq	ppm	#/ac	Percent Base Saturation %					%	ppm	ppm	ppm	ppm	ppm
Field A	**eggs/100cc**	**pH**	**Salts**	**O.M.**	**P**	**K**	**Ca**	**Mg**	**CEC**	**Zn**	**S**	**K**	**Ca**	**Mg**	**H**	**Na**	**CCE**	**Na**	**Cu**	**Mn**	**Fe**	**B**
1	4500	7.9	0.47	5.1	14	167	6131	673	36.8	0.51	10	1.2	83.3	15.2	0	0.3	1.70	26	0.75	3.35	6.97	1.55
2	8600	8	0.34	4	9	172	5391	382	30.7	0.34	10	1.4	87.8	10.4	0	0.3	2.00	24	0.54	4.34	7.05	1.19
3	0	6.8	0.35	5.2	29	269	3745	826	26.4	1.27	10	2.6	70.9	26.1	0	0.4		26	1.05	3.39	39.39	0.72
4	200	7.8	0.45	4.9	11	152	4950	907	32.8	0.61	10	1.2	75.4	23	0	0.4	0.80	31	0.76	2.72	6.16	1.38
5	0	7.9	0.43	4.9	8	128	4866	1071	33.8	0.52	10	1	72	26.4	0	0.6	0.30	44	0.78	2.89	7.06	1.53
6	300	8.1	0.51	6.4	13	145	6324	1414	44	0.84	14	0.8	71.9	26.8	0	0.4	5.20	45	0.97	2.3	5.84	2.47
7	200	6.8	0.33	5.3	28	300	3546	686	24.4	1.09	108	3.2	72.8	23.5	0	0.6		33	0.78	6.67	28.64	0.93
8	0	6.7	0.31	4.8	26	369	3018	634	21.4	0.99	20	4.4	70.4	24.6	0	0.6	0.20	29	0.78	6.88	31.71	0.79
9	500	6.8	0.28	4.6	22	363	3088	675	22.1	0.99	14	4.2	69.8	25.4	0	0.5	0.10	26	0.73	6.03	21.45	0.82
10	0	7.9	0.48	5.6	11	221	6560	605	38.5	0.96	16	1.5	85.1	13.1	0	0.3	2.60	27	0.73	2.74	6.79	1.64
11	300	7.8	0.33	4	7	143	4498	459	26.8	0.53	6	1.4	83.9	14.3	0	0.4	0.90	25	0.65	2.96	7.85	0.83
12	0	6.3	0.27	4.9	12	174	3227	630	21.9	0.95	8	2	73.5	23.9	0	0.5	0.20	26	0.87	9.44	37.13	0.71
13	200	6.3	0.23	3.6	13	155	2702	613	19.1	0.65	10	2.1	70.6	26.7	0	0.6		26	0.96	9.51	30.98	0.52
14	0	6.6	0.27	5.1	10	153	3704	736	25.2	0.78	20	1.6	73.5	24.3	0	0.6	0.10	33	0.93	7.55	29.41	0.79
15	1500	6.7	0.25	4.3	13	130	3356	755	23.6	0.73	8	1.4	71.2	26.7	0	0.6	0.10	34	0.84	6.36	31.77	0.82
16	7800	7.3	0.39	4.5	12	286	3686	659	24.8	0.59	8	3	74.4	22.2	0	0.4		25	0.95	4.68	14.04	0.9
17	14100	7.3	0.34	4.9	6	127	3834	724	25.7	0.47	10	1.3	74.7	23.5	0	0.5		32	0.61	4.42	12.95	1.02
18	4700	8	0.51	5.1	6	128	6271	968	39.9	0.39	10	0.8	78.6	20.2	0	0.4	1.70	38	0.76	2.49	6.92	1.8
19	10700	7.8	0.48	4.7	8	129	4633	1086	32.7	0.36	12	1	70.8	27.7	0	0.5	0.30	39	0.82	3.78	8.7	1.79
20	5000	6.3	0.24	4.5	7	110	3021	708	21.5	0.43	8	1.3	70.4	27.5	0	0.8		41	0.87	7.3	32.57	0.64
21	300	8	0.47	4.1	8	165	6170	734	37.5	0.48	8	1.1	82.3	16.3	0	0.3	6.80	24	0.71	3.2	6.25	1.58
22	0	6.7	0.25	4.5	7	134	3316	626	22.3	0.65	14	1.5	74.3	23.4	0	0.8	0.20	39	0.83	6.77	32.33	0.71
23	200	6.3	0.24	4.4	6	121	3032	643	21	0.7	8	1.5	72.3	25.6	0	0.6		31	0.92	8.18	44.72	0.62
24	0	6.7	0.34	4.3	12	229	3373	753	23.8	0.84	8	2.5	70.8	26.3	0	0.4		21	0.97	4.32	26.3	0.59
25	0	6.8	0.34	5	13	189	3860	752	26.2	1.17	8	1.9	73.8	24	0	0.4	0.10	23	0.89	6.23	16.93	0.83
26	0	6.8	0.27	5	13	152	3765	652	24.8	0.63	8	1.6	75.9	21.9	0	0.6		36	0.9	6.51	18.64	0.8

Table 3. Field B laboratory analysis data – sampled July 16, 2004.

Grid Number Field B	count eggs/100cc	pH	Salts	% O.M.	ppm-olson P	ppm K	ppm Ca	ppm Mg	meq CEC	ppm Zn	#/ac S	Percent Base Saturation % K	Ca	Mg	H	Na	% CCE	ppm Na	ppm Cu	ppm Mn	ppm Fe	ppm B
1	0	7.3	0.35	6.6	22	214	3974	796	27.2	3.9	18	2	73.1	24.4		0.5	0.20	34	0.77	2.24	18.94	1.24
2	0	8	0.32	4	7	181	5092	482	30.06	1.6	10	1.5	84.7	13.4		0.4	1.00	27	0.63	2.1	1.36	1.05
3	100	7.6	0.36	4.5	6	150	4072	748	27.1	0.61	10	1.4	75.1	23		0.4	0.10	27	0.81	1.72	8.95	1.21
4	0	6.4	0.28	4.2	15	194	3164	852	23.5	1.21	8	2.1	67.3	30.2	0	0.4		20	1.09	3.99	40.52	0.63
5	0	8	0.31	3.7	8	122	4839	488	28.7	3.49	6	1.1	84.3	14.2		0.5	0.80	30	0.59	2.21	6.96	1.31
6	700	7.8	0.49	4.6	7	219	5038	617	30.98	0.91	10	1.8	81.3	16.6		0.3	0.40	19	0.78	1.55	8.8	0.98
7	1800	8	0.69	4.7	7	144	5961	1037	38.96	0.72	104	0.9	76.5	22.2		0.4	3.90	33	0.72	1.32	6.56	1.59
8	0	7.8	0.27	3.5	11	144	3605	601	23.5	0.85	14	1.6	76.7	21.3		0.4	0.60	22	0.61	3.54	8.23	0.69
9	0	7	0.33	4.3	10	126	3663	660	24.23	1.28	8	1.3	75.6	22.7		0.4		21	0.71	4.26	12.93	0.86
10	0	8.1	0.31	1.7	6	163	4994	387	28.73	0.89	8	1.5	86.9	11.2		0.4	8.10	28	0.85	1.83	7.43	0.76
11	0	7.5	0.34	4.8	6	150	5218	760	27.94	0.76	8	1.4	75.5	22.7		0.5	0.60	30	0.77	2.57	12.84	0.94
12	0	7.5	0.28	6	13	185	3858	699	25.73	3.15	12	1.8	75	22.6		0.5	0.10	32	0.69	2.07	13.66	1.55
13	0	7.1	0.34	7.2	31	166	4075	693	26.71	3.3	18	1.6	76.3	21.6		0.5		32	0.8	1.83	31.49	1.22
14	4600	8	0.23	3.1	8	141	4052	492	24.86	0.9	14	1.5	81.5	16.5		0.6	1.20	32	0.61	1.6	9.57	1.5
15	2600	8	0.39	4.5	12	144	5329	742	33.39	0.41	8	1.1	79.8	18.5		0.6	1.30	45	0.68	1.95	8.33	1.44
16	300	7.1	0.27	4.1	7	121	3710	782	25.5	0.48	8	1.2	72.7	25.6		0.5	0.50	28	0.72	3.38	14.32	1.03
17	0	7.9	0.36	3.8	3	130	4208	1032	30.04	2.31	8	1.1	70	28.6		0.2	0.30	16	0.83	2.05	6.46	1.58
18	0	6.2	0.16	2.8	7	94	2404	596	17.1	0.66	8	1.4	70.3	27.7	0.2	0.6		23	0.64	6.39	29.85	0.55
19	0	7.6	0.27	2.9	12	120	3495	639	23.23	0.59	8	1.3	75.2	22.9		0.5		27	0.64	2.89	11.93	0.63

Table 4. Field B (zone) laboratory analysis – sampled October 14, 2004.

Zone Number Field B	count eggs/100cc	pH	Salts	% O.M.	lbs N	ppm-olson P	ppm K	ppm Ca	ppm Mg	meq CEC	ppm Zn	#/ac S
1	100	7.3	0.53	3	12	6	174				0.68	16
2	100	6.7	0.39	7.7	92	21	208				6.71	264
3	5800	7.3	0.45	5	56	19	3				3.07	48
4	1500	7.6	1.9	4.2	24	6	194				0.84	480
5	6000	7.8	0.41	2.5	20	7	174				0.81	480
7	0	7.9	0.41	3.7	24	10	196				1.21	40
8	0	7.4	0.44	3.7	20	10	166				0.84	32
9	200	7.7	0.37	3.5	24	9	160				0.92	16
11	0	6.8	0.34	4.9	40	21	200				2.06	48

Table 5. Coefficient of Determination Values (R^2)

	pH	Salts	OM	N-#	P - ppm	K -ppm	Ca - ppm	Mg -ppm	CEC	Zn - ppm	S - #	K -PBS	Ca - PBS	Mg - PBS
Field A	0.089	0.044	0.012		0.114	0.042	0.016	0.00006	0.012	0.345	0.017	0.05	0.024	0.015
Field B	0.133	0.027	0.017		0.014	0.006	0.078	0.0019	0.08	0.091	0.074	0.049	0.075	0.0718
Zone Field	0.07	0.00019	0.038	0.0017	0	0.423				0.009	0.189			

	H -PBS	Na - PBS	CCE %	Na - ppm	Cu -ppm	Mn - ppm	Fe - ppm	B - ppm
Field A	0	0.0177	0.0008	0.007	0.16	0.046	0.114	0.04
Field B	0	0.152	0.0044	0.219	0.073	0.115	0.05	0.224
Zone Field								

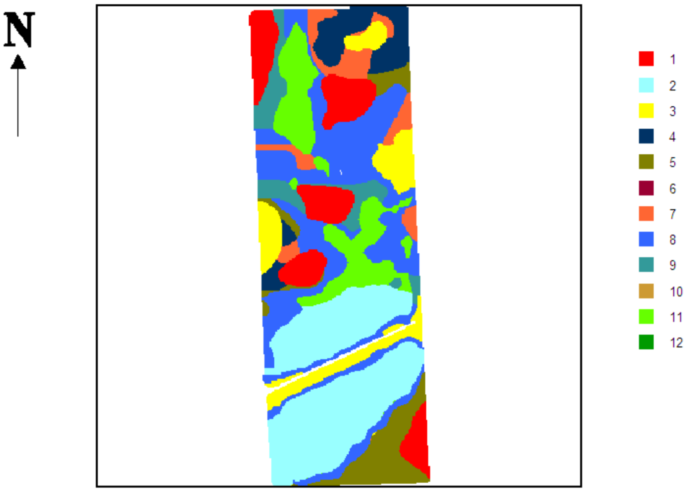
Code	Soil Description	Acres	Percent of field	Corn	Soybeans
954B2	Ves-Storden loams, 3 to 6 percent slopes, eroded	28.6	25.1%	141.4	45
421B	Ves loam, 1 to 4 percent slopes	25.3	22.2%	146.0	47
113	Webster clay loam	20.2	17.8%	140.0	44
140	Spicer silty clay loam	16.1	14.1%	131.0	39
444	Canisteo silty clay loam	15.5	13.6%	135.0	40
134	Okoboji silty clay loam	4.1	3.6%	128.0	40
423	Seaforth loam, 1 to 3 percent slopes	3.0	2.6%	146.0	47
446	Normania clay loam, 1 to 3 percent slopes	1.0	0.9%	146.0	47
			Weighted Average	**139.4**	**44**

Figure 1. The soil series make-up of Field A.

Code	Soil Description	Acres	Percent of field	Corn	Soybeans
134	Okoboji silty clay loam	39.4	34.8%	128.0	40
954B2	Ves-Storden loams, 3 to 6 percent slopes, eroded	24.4	21.6%	141.4	45
444	Canisteo silty clay loam	21.3	18.8%	135.0	40
113	Webster clay loam	19.8	17.5%	140.0	44
423	Seaforth loam, 1 to 3 percent slopes	4.5	4.0%	146.0	47
421B	Ves loam, 1 to 4 percent slopes	3.8	3.4%	146.0	47
			Weighted Average	**135.8**	**42**

Figure 2. The soil series makeup of Field B.

Figure 3. Field B with associated zone composition



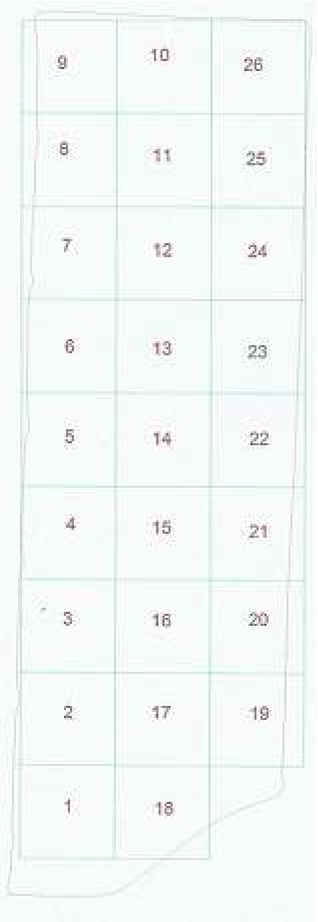
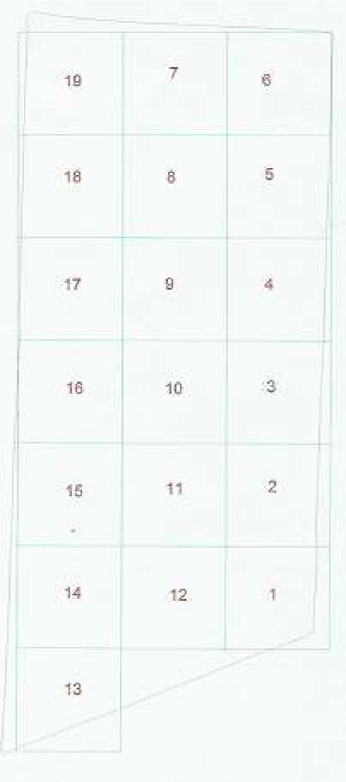


Figure 4. Field A sample grid orientation.

Figure 5. Field B sample grid orientation.



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