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TILLAGE MANAGEMENT FOR MANURED CROPLAND

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Introduction

Nutrient management plans will be required for most Wisconsin farms within the next five years. Planning will result in a more comprehensive accounting of on-farm nutrient credits and will likely prescribe manure application at more modest rates to more fields, especially if applied on a P basis. Therefore manure will be allocated to more acres on the farm, much of it sloping and managed with high residue tillage systems implemented to meet “T” as required by the conservation plan. Manure will be directed to fields where corn was the previous crop because legume N credits will supply N needs for corn when rotating from alfalfa. Thus producers will be confronted with the potential for reduced yields because surface-applied manure, with existing high crop residue levels, could impact planter performance and promote slow early growth.

Conservation tillage systems that leave crop residue are important practices for sloping fields and are the best practice farmers can use to meet the allowable soil loss. These systems have been adopted over the past several decades as equipment and cropping systems that can handle the residue have become available. Many producers have taken advantage of other conservation tillage benefits such as time and fuel savings and reduced equipment needs. It is conceivable that producers will be forced to decide whether they should follow their nutrient management plan or their conservation plan, or develop a hybrid strategy that does not meet the specifications of either plan.

It is imperative that reasonable crop production systems for sloping, manured land be developed. These should leave adequate levels of residue for soil erosion protection while not creating a growing environment that significantly reduces yield because of cool soil and unfavorable seedbed conditions.

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Table 1. Summary of soil factors and management practices at the Wisconsin tillage/manure management studies, 2002 - 2003.

			Soil test				Manure				Planting	N
Location	Soil	Year	pH	P	K	OM	DM	N*	P_2O_5	K_2O	date	rate
				--- ppm ---		%	%	--- lb available/ton ---				lb/acre
Arlington	Plano sil	2002	5.7	68	96	4.1	16.9	3.1	2.2	5.9	7 May	Var.**
		2003	7.0	116	135	3.6	20.9	3.5	2.4	8.0	17 May	
Lancaster	Rozetta sil	2002	6.8	31	102	2.3	22.0	3.7	3.8	7.6	10 May	160
		2003	7.0	40	128	2.5	23.7	4.4	3.1	8.7	3 May	
Marshfield	Withee sil	2002	6.5	83	208	3.6	24.5	2.4	2.2	5.7	22 May	120
		2003	6.5	64	185	3.3	29.4	3.9	2.9	10.4	2 May	
Spooner	Pence ls	2002	6.7	89	65	1.7	24.5	3.2	3.8	8.1	13 May	120
		2003	6.4	140	93	1.3	44.9	2.2	2.2	2.5	8 May	200

* N credit for unincorporated manure shown. ** N rate was a sub-subplot treatment at 0, 50, 100, 150 lb N/acre.

Another issue that has been raised by some relates to the "Criteria for Surface Water Protection" found in USDA-NRCS Technical Standard 590 as it relates to manure incorporation in certain situations. Application of manure within a Surface Water Quality Management Area can require incorporation that meets "T" as one of several acceptable practices. The question that has been asked is: "What type or amount of tillage results in incorporation that would satisfy the standard"?

This paper summarizes the two years of research that was conducted to examine corn growth and yield response to the various tillage practices on manured corn residue at several Wisconsin locations. It also discusses management issues that may be expected where conservation and nutrient management planning efforts conflict.

Methods and Materials

Small plot research studies were conducted at four locations on Wisconsin Agricultural Research Stations at Arlington, Lancaster, Marshfield, and Spooner in 2002 and 2003. Straw- or stalk-bedded dairy manure was applied in the spring to fields having full, un-chopped corn residue remaining from the previous season. The manure was applied with calibrated box-type spreaders at all locations except Arlington, where a side-delivery model was used. The surface-applied manure was allowed to dry several days and was subsequently tilled by the various methods. Corn was planted shortly after tillage. The tillage and planting equipment used was that which was available at each research station. It was not possible to standardize settings and operating characteristics and therefore performance variability between locations was expected. The Spooner site was irrigated. A summary of the soil types, routine soil test, manure characteristics, and general management practices is shown in Table 1.

Treatments were set out in a split-plot treatment arrangement with four replications at Lancaster, Marshfield, and Spooner. The Arlington study had similar manure and tillage treatments, but was further split into four N rate sub-subplots (0, 50, 100, and 150 lb N/acre). Main plot was manure that was applied with standard manure spreading equipment at rates of 0, 15, and 30 tons/acre. The split plot treatment was tillage conducted after manure application. Treatments were no-till using a planter equipped only with standard disk openers for dry fertilizer and the seeding unit; strip-till in the row using a four row Remlinger strip-till unit; light (~3 inches) tandem disking; chisel plowing; and, moldboard plowing. The chisel and moldboard systems received secondary tillage to prepare a seedbed using the tandem disk. Phosphorus and potassium were applied according to soil test requirement and some starter fertilizer was used at each site to ensure that these nutrients were not limiting. Each site, other than Arlington, received a uniform application of N fertilizer at the UWEX recommended rate. Measurements taken included emergence, surface crop residue using the line-transect method, and grain yield and moisture.

Data were subjected to statistical analysis using methods for a split plot design. Where significant differences were found at the $p=0.05$ level a least significant difference (LSD) was calculated.

Results and Discussion

A summary of the main effects of manure rate and tillage system on the surface crop residue after planting is shown in Table 2. The tillage treatments established a range of conditions as no-till left 90% of the initial residue on the soil surface while moldboard tillage buried 90% of the residue. The amount of residue left by the other practices (chisel, disking, and strip-till) was more variable and was affected by the available tillage tool, soil conditions, and operation. Where incorporation of manure is preferred, but relatively high amounts of residue are needed for conservation purposes, the "intermediate" intensity practices appear to be desirable. Manure, especially straw- or stalk-bedded manure, will provide a substantial amount of residue that can be counted for conservation planning purposes.

Table 2. Main effect of straw-bedded manure and tillage on the surface crop residue following planting at four study locations in Wisconsin, 2002-2003.

	Arlington		Lancaster		Marshfield		Spooner	
Treatment	2002	2003	2002	2003	2002	2003	2002	2003
	------------------------------- % -------------------------------							
Manure (tons/acre)								
0	53	47	42	49	51	43	44	58
15	60	53	47	61	53	52	56	60
30	60	60	62	66	63	62	56	64
LSD $_{(0.05)}$	7	5	13	10	8	11	6	NS
Tillage								
No-till	98	86	72	86	86	89	82	93
Strip-till	68	71	66	71	72	58	72	84
Disk	73	55	66	55	77	62	60	71
Chisel	33	50	34	50	38	46	43	48
Moldboard	15	6	13	6	6	7	3	7
LSD $_{(0.05)}$	10	6	9	6	9	7	8	8
Significance (Pr>F)								
Manure	0.03	<0.01	0.02	0.01	0.03	0.02	<0.01	0.07
Tillage	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
M x T	0.66	0.36	0.71	0.06	0.84	0.05	0.58	0.92

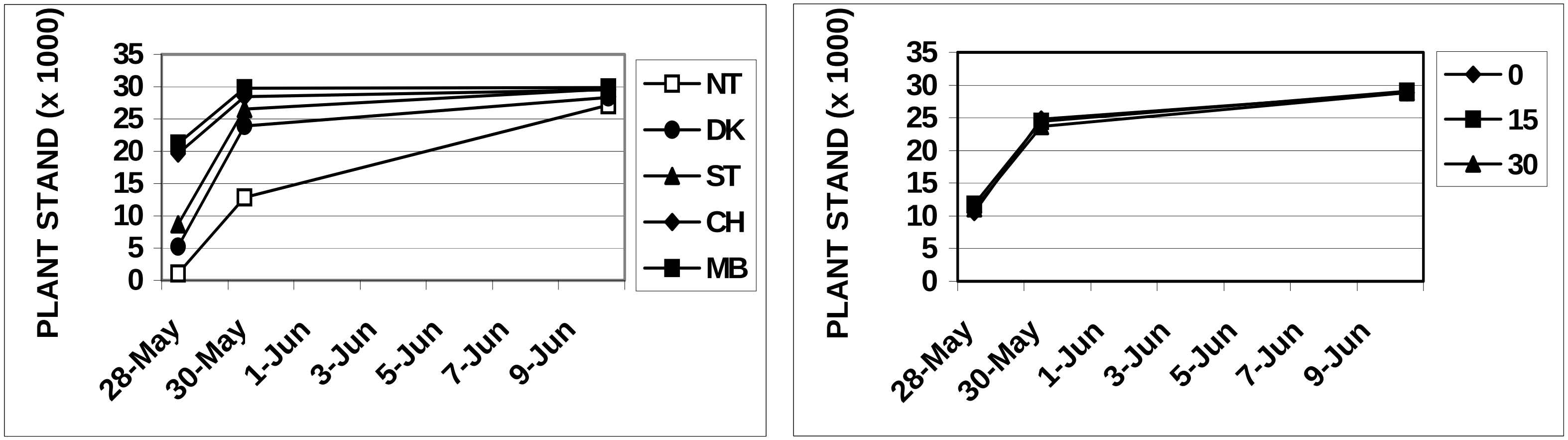
Increasing manure rate from none to 30 tons/acre increased surface residue a minimum of 7% at Arlington in 2002 and a maximum of 20% at Lancaster in 2002 when compared to the non-manured treatment. The 30 tons/acre manure rate added about 13% residue to the surface when averaged over the tillage treatments at all locations. Residue coverage ranged from 3% for moldboard system at Spooner to 98% for no-till at Arlington, both in 2002. The disk and strip-till systems were generally similar, and left fields covered with an average of about 60 to 70% residue. Of course there were substantial differences in the distribution of the residue within the field between these systems. The chisel systems typically left about 35 to 40% residue. The residue level at Spooner where chiseled was slightly higher, because the tool used at that location did not have any proceeding disks or coulters. There was a strong trend for an interaction between manure rate and tillage type and Lancaster and Marshfield in 2003. These data showed that as expected manure rate tended to affect residue more in the intermediate tillage intensity systems when compared to no-till or moldboard.

It would be assumed that high levels of surface crop residue, especially where surface applied manure remains on the surface would slow emergence and possibly reduce stands. These effects would be in response to cooler soils and perhaps less effective planter performance (shallower depth, inadequate slot closure, residue interference) in the wetter soil. Plant counts were taken as soon as the plants began to emerge at the Arlington and Marshfield locations in 2002 and at all location about six weeks after planting.

Emergence data for the manure rate and tillage main effects for the Arlington and Marshfield locations are shown in Figures 1 and 2, respectively. Plant counts were taken along a measured length of row on several dates in late spring, beginning when approximately 1/3 of the total seeds had emerged from the intensively tilled treatments. Manure rate did not affect emergence at Arlington, possibly because the lower dry matter content of the manure did not impose a significant restriction to planting. Emergence was delayed with the 30 tons/acre rate at Marshfield. This site was very wet in the spring and was worked when conditions were relatively wet. Emergence was faster in the moldboard system for both locations. Chisel was intermediate to either the disk or strip-till treatment and no-till was the slowest, especially at Arlington.

The final stand values recorded for all locations in each year are shown in Table 3. These data show that increasing manure rate decreased stand several thousand plants per acre at Marshfield and Spooner, slightly decreased stand at Arlington in 2003, and increased stand several hundred plants per acre at Lancaster in 2002. This response reflects both the manure application equipment and the performance of the planter. Manure at Arlington was spread very uniformly with a side-slinger, whereas the other sites were treated with a box-type spreader. Also, the planters used at both Arlington and Lancaster were designed as conservation tillage units and as such were heavier resulting in better penetration through the residue.

The effect of tillage treatment on the final stand is also shown in Table 3. No-till at Arlington was lower in 2002 compared to the other treatments, but did not affect stand in 2003. Tillage did not affect stand at Lancaster in either year or at Marshfield in 2002, although the difference at Marshfield in 2002 was significant at the p=0.10 level. There were clearly planting issues in all but the moldboard system at Marshfield in 2003 because of the heavy, wet condition of the soil. The moldboard system overall tended to produce the highest stands because of the removal of interference from the residue, although differences were not consistently statistically different. The strip-till and disk systems performed similarly to the chisel system with respect to final stand. The no-till



[*] N credit for unincorporated manure shown. [**] N rate was a sub-subplot treatment at 0, 50, 100, 150 lb N/acre.

Figure 1. Main effect of tillage and manure rate (tons/acre) on the emergence of corn at Arlington, Wis., 2002.

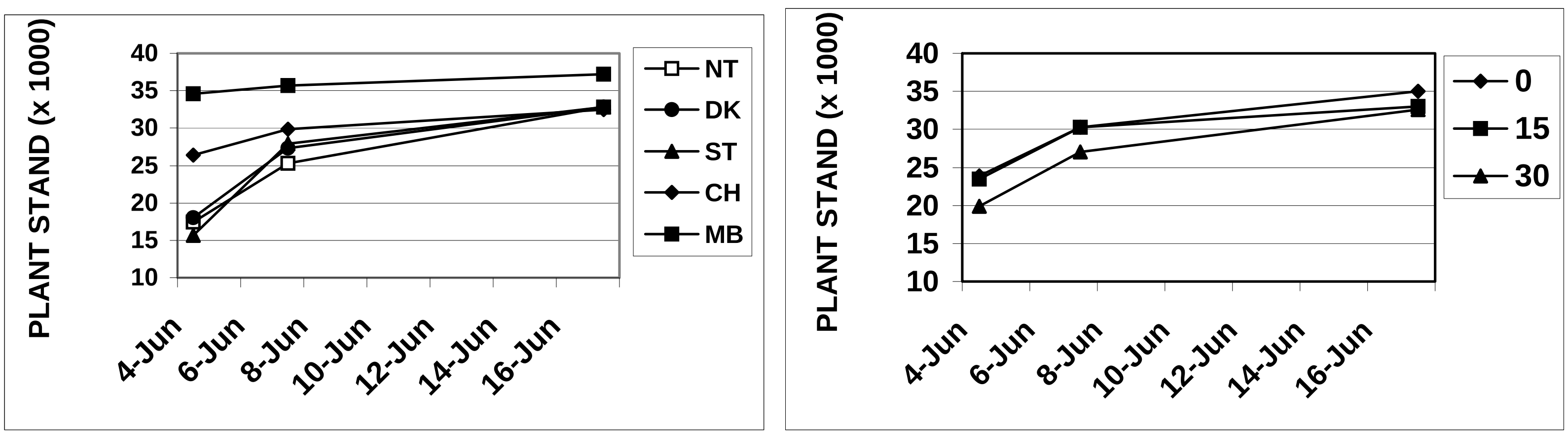


Figure 2. Main effect of tillage and manure rate (tons/acre) on the emergence of corn at Marshfield, Wis., 2002.

system performed relatively poorly at Spooner because the planter at this station was light and not designed for un-tilled situations.

Table 3. Main effect of straw-bedded manure and tillage on the final stand at four study locations in Wisconsin, 2002-2003.

	Arlington		Lancaster		Marshfield		Spooner	
Treatment	2002	2003	2002	2003	2002	2003	2002	2003
	x 1000							
Manure (tons/acre)								
0	28.8	29.8	30.4	32.8	35.0	25.5	29.4	28.4
15	29.1	29.8	31.1	32.2	33.0	23.9	24.3	28.4
30	28.8	29.2	31.0	32.1	32.6	22.7	24.3	26.8
$LSD_{(0.05)}$	NS	0.5	0.5	NS	1.6	NS	1.9	NS
Tillage								
No-till	27.1	29.5	30.8	33.0	32.8	15.9	17.0	24.8
Strip-till	29.7	30.0	30.4	32.1	32.8	25.1	27.9	27.6
Disk	28.3	29.3	31.5	34.3	32.8	24.6	25.0	29.7
Chisel	29.5	29.3	30.8	31.7	32.5	24.7	28.5	28.1
Moldboard	29.9	29.7	30.6	30.9	37.2	30.0	31.6	29.0
$LSD_{(0.05)}$	0.8	NS	NS	NS	NS	2.6	4.3	3.0
Significance (Pr>F)								
Manure	0.03	<0.01	0.02	0.46	0.03	0.12	<0.01	0.34
Tillage	<0.01	0.23	<0.01	0.13	<0.01	<0.01	<0.01	0.02
M x T	0.66	0.69	0.71	0.23	0.84	0.08	0.58	0.24

The main effect of manure rate and tillage on the corn grain yield response is shown in Table 4. Increasing manure rate significantly increased, or tended to increase, yield at all locations each year except Marshfield in 2002. Manure application that year was delayed well into May that year because of wet conditions and when treatments were made soil compaction was inevitable. The positive yield response may be attributed to improved soil physical characteristics, increased water holding capacity, or the addition of nutrients even though the response occurred where the recommended N rate was applied. The corn also received substantial P and K to meet soil test either in the form of starter fertilizer or preplant broadcast. It is possible the S or other nutrients from the manure may have increased yield, but this would be expected to be a poorer explanation compared to the enhancement of the soil tilth.

Table 4. Main effects of straw-bedded manure and tillage on the corn grain yield at four study locations in Wisconsin, 2002.

Treatment	Arlington* 2002	Arlington* 2003	Lancaster 2002	Lancaster 2003	Marshfield 2002	Marshfield 2003	Spooner 2002	Spooner 2003
	-----------------------------			bu/acre	---------------------------			
Manure (tons/acre)								
0	147	157	224	125	181	97	167	180
15	175	174	232	138	172	113	173	194
30	182	178	236	145	146	104	178	185
LSD $_{(0.05)}$	25	16	7	NS	19	15	NS	NS
Tillage								
No-till	164	161	234	143	156	96	126	172
Strip-till	166	168	229	143	172	108	173	190
Disk	162	169	236	137	153	100	179	191
Chisel	170	172	229	135	165	110	189	195
Moldboard	178	178	225	122	183	109	198	183
LSD $_{(0.05)}$	11	8	NS	12	14	NS	25	NS
N rate (lb/acre)								
0	139	161	--	--	--	--	--	--
50	167	170	--	--	--	--	--	--
100	179	172	--	--	--	--	--	--
150	186	174	--	--	--	--	--	--
LSD $_{(0.05)}$	6	5	--	--	--	--	--	--
Significance (Pr>F)								
Manure (M)	0.03	0.03	0.03	0.21	0.01	0.01	0.36	0.40
Tillage (T)	0.04	<0.01	0.11	<0.01	<0.01	0.20	<0.01	0.22
M*T	0.99	0.23	0.17	0.03	0.47	0.11	0.91	0.60
N Rate (N)	<0.01	<0.01	--	--	--	--	--	--
M*N	<0.01	<0.01	--	--	--	--	--	--
T*N	0.21	0.39	--	--	--	--	--	--
M*T*N	0.98	0.99	--	--	--	--	--	--

*N rate treatments at Arlington only.

Table 4 also shows the effect of the various tillage systems on yield. Moldboard plowing tended to consistently produce optimum yields across the sites and years; however differences were often not different from the other tillage methods. It is interesting to note that moldboard plowing had the lowest yields at the Lancaster site, being significant in 2003. Moldboard plowing produced the highest yield at Marshfield in 2002 and presumably reduced the yield limiting effects of the wet spring soil conditions. Manure was applied to frozen ground at Marshfield in 2003 to limit compaction and there were no tillage differences with the exception of no-till, which performed very poorly. There was much more variability at Spooner they may have been related to the performance of the planter. This was especially obvious for no-till. There were no significant interactions at any location for the relationship between manure rate and tillage except at Lancaster in 2003, where the moldboard system performed similarly at all manure rates and the corn yield increased with added manure with the other tillage treatments.

An N rate variable was installed at the Arlington location. This resulted in a total of 240 plots making a similar design impractical at the other locations. Table 4 shows that the main effect of N fertilization was significant in both years. There was a significant interaction between N rate and manure application in both years. These effects are shown in Figure 3 and demonstrate the expected response where the yield increase to N fertilization is lower where manure is applied. The manure treatments would be expected to supply an estimated 45 and 90 lb N/acre, respectively. These data show that a combination of manure and N fertilizer optimized yield in these fields.

Manure has been shown to provide ground cover and can therefore be counted when measuring residue. Furthermore, its ability to improve aggregation and other soil physical properties are recognized in RUSLE2 as factors that will lower soil loss compared to a similar management scheme without manure.

The application of manure over crop residue was been shown to increase residue by this research project. These increases were variable between sites depending on the initial crop residue cover and manure application method. The evaluation of the relative effectiveness of the tillage treatments to incorporate the residue show that as the manure rate increased the incorporated fraction decreased (Table 5). These values were calculated by dividing the measured crop residue for a tillage system by the residue measured in no-till within each manure rate and subtracting the value from 1. This method standardizes the incorporation by comparing it to the initial residue level prior to tillage. For example, the chisel system incorporated half of the residue when not manured and only one-third where 30 tons/acre was spread. Trends were similar, but lower with the less intense strip-till and disk systems. No differences were observed with moldboard plowing.

Table 5. Tillage residue incorporation ratio averaged over the four manure x tillage studies, 2003. *

	Manure rate (tons/acre)		
Tillage	0	15	30
Strip-till	0.19	0.20	0.14
Disk	0.38	0.30	0.27
Chisel	0.51	0.36	0.34
Moldboard	0.90	0.92	0.88

* Residue incorporation ratio = 1 – {% residue for a tillage / % residue for no-till}. Comparison made within each manure rate.

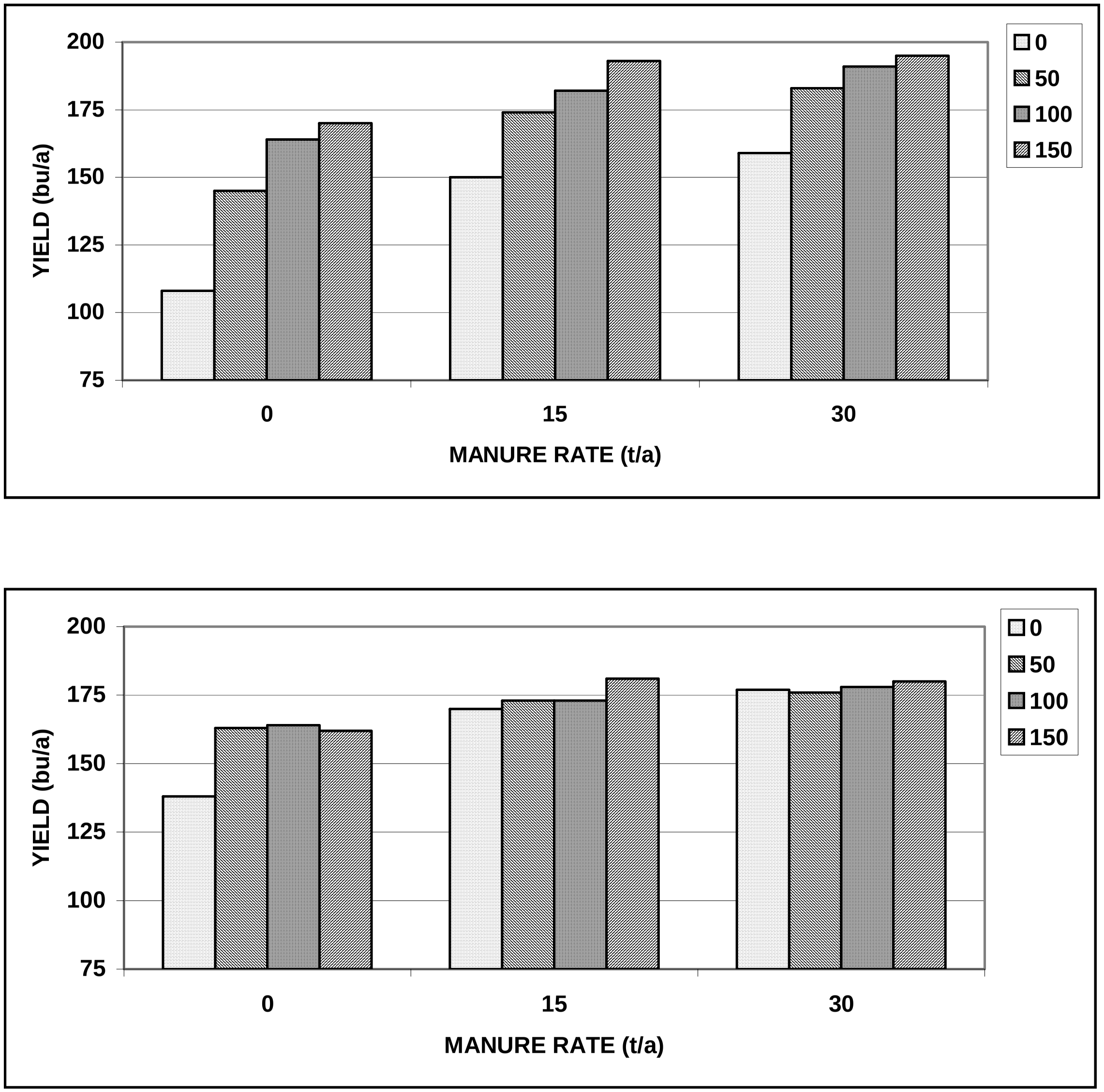


Figure 3. Interaction between manure and N fertilizer rate at Arlington, Wis. in 2002 (upper) and 2003 (lower).

Summary

Future nutrient management efforts will likely direct more manure to sloping fields having corn stubble. This will create a management issue where tillage may be needed to create a reasonable seedbed, but may result in the incorporation of too much residue, potentially increasing the risk of soil erosion from the field. Small plot field studies were established at four locations to examine the effectiveness of different tillage systems for providing adequate cover for conservation purposes with minimal yield reduction. Tillage treatments were applied to full corn stubble that had received no manure, 15, or 30 tons/acre of straw-bedded dairy manure. Responses were site-specific and are likely a result of differences in climate, equipment, and operation parameters. These data show that uniform application of manure, even at relatively high rates can be managed in high residue systems on well-drained soils. The fraction of residue incorporated decreased with increasing manure rate, demonstrating that manure increased surface residue coverage. Yields were typically higher where manure was applied, even where full rates of fertilizer were applied suggesting benefits from improved soil tilth.

The selection of the high residue system that works best under manured conditions will depend on the grower's preference and the availability of equipment. Regardless of the conservation tillage system selected, planters designed to operate in heavy residue are important for successful crop production. As always, operations under wet conditions should be avoided.