SOIL pH AND MANGANESE EFFECTS ON ROUNDUP READY® SOYBEANS

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Abstract

Soybean "flash" is a general yellowing of the upper soybean canopy thought to be associated with high rates of glyphosate and reduced levels of manganese (Mn) with glyphosate-resistant soybeans. Several field sites varying in soil Mn levels and some with within field variable pH levels were evaluated between 2004 and 2006 for responsiveness of soybeans to glyphosate rate and Mn treatments. The objectives of this study were to 1) evaluate the effects of foliar applied Mn and soil applied Mn on yields of Roundup Ready® soybeans, 2) determine the interaction of glyphosate rates on Mn levels in soybean leaves and effects on soybean yields, 3) evaluate whether differences in soil pH levels affect glyphosate x Mn interactions**.** Glyphosate rates consisted of none, 1x (22 oz/acre), 2x (44 oz/acre) and 4x (88 oz/acre) rates of Roundup WeatherMax®**.** Mn treatments consisted of foliar Mn applied 3-5 days prior to application of Roundup (Pre RU), foliar Mn applied 10 days after Roundup (Post RU), and soil applied Mn applied surface broadcast immediately after soybean planting**.**

Mn level was significantly reduced with the application of lime at both Dixon Springs (DS) and Brownstown (BR). In general liming of the acid soils at DS and BR reduced plant uptake of Mn which occasionally led to a yield increase. Very high rates of glyphosate showed significant symptoms of soybean flash and significantly reduced soybean yields at most of the locations studied. However, the effects of glyphosate rate on soybean flash and grain yields do not appear to be related to Mn level in the plant. Mn treatment had little effect on preventing soybean flash or in preventing a loss of soybean yield associated with high rates of glyphosate.

Introduction

Several reports of reduced weed control from tank mixes of manganese (Mn) and glyphosate herbicide (Roundup®) indicate a problem of glyphosate interacting with Mn to reduce the effectiveness of the glyphosate (Bailey et al., 2002; Bernards et al., 2005a). There is also increasing evidence that the glyphosate is rendering the Mn less metabolically useful within the plant (Benards et al., 2005b; Huber, 2007). This has led to more frequent observations of Mn deficiency symptoms appearing in soybean fields, often referred to as soybean "flash", even though tissue test levels for Mn are found to be adequate. A recent review by Huber et al. (2004) indicated a trend of reduced Mn uptake and physiological efficiency by glyphosate-resistant soybeans. In their studies, glyphosate immobilized Mn applied before, concurrent with, or within 6-8 days after the application of glyphosate. Applying Mn more than eight days after glyphosate application reduced the antagonism. A study in Kansas showed improved yields of glyphosate-resistant soybeans with Mn application, but a decrease in yields of non-glyphosate resistant soybeans (Gordon, 2007).

The objectives of this study were to 1) evaluate the effects of foliar applied Mn and soil applied

Mn on yields of Roundup Ready® soybeans, 2) determine the interaction of glyphosate rates on Mn levels in soybean leaves and effects on soybean yields, 3) evaluate whether differences in soil pH levels affect glyphosate x Mn interactions.

Materials and Methods

Field sites were identified at two locations, the University of Illinois (UI) Dixon Springs Ag. Center (DS) and the UI Brownstown Agronomy Res. Center (BR). Lime treatment blocks (0 versus 4 ton/acre) were established in the spring of 2004 to create pH environments of 6.0-6.2 which would encourage higher Mn availability and pH 6.8-7.0 which would encourage lower Mn availability. Treatments identified in Table 2 were applied to soybeans grown under these two pH environments. The first group (A) of treatments (1-9) was used to determine if Mn interacts with glyphosate and whether variety (Asgrow 4702 [in 2004, Asgrow 4502 in 2005], FS 4516, or Pioneer 94B74 [in 2004, Pioneer 94B54 in 2005, Pioneer 94M79 in 2006]) had any impact on this interaction. The second group (B) of treatments (10-18) was used to test to see if soybeans respond to Mn without the presence of glyphosate. Hand weeding occurred on a weekly basis or as needed to insure no weed pressure. The third group (C) of treatments (19-24) when combined with treatments 7-9 was used to determine if rate of glyphosate affects the interaction with Mn. Glyphosate rates consisted of none, 1x (22 oz/acre), 2x (44 oz/acre) and 4x (88 oz/acre) of Roundup WeatherMax®.

A split plot design was implemented with pH level as main block and treatments as subplots with three replications per location. Plot size was 10' by 30' with the center 5' x 30' harvested for grain yield. The foliar Mn was supplied as a 5% mannitol chelate (Brandt Consolidated) and was applied 3-5 days prior to application of Roundup (Pre RU). In 2005 and 2006, an additional treatment of foliar Mn applied 10 days after Roundup (Post RU) was included (on farmer fields) or replaced the Pre RU at DS and BR. The soil applied Mn was supplied as Manganese Sulfate (32% Mn, United Suppliers, Inc.) and was applied surface broadcast immediately after soybean planting.

In addition to the two locations above, three other sites were identified on farmer fields where Mn problems were thought to exist. The sites were located near the towns of Ridgway (RW) and Wayne City (WC) [in 2004, New Haven (NH) in 2005] in southern IL and Monmouth (MN) in northern IL. On these sites the four Roundup rates and three Mn treatments were used with a single soybean variety (farmer's own) and there were four replications in a randomized complete block design. Further study details are presented in Table 1, below. An additional treatment of foliar Mn applied 10 days after Roundup (Post RU) was included on these farmer fields.

Table 1. Study site information, 2004-06.

2004	**Location:**	**BR**	**DS**	**MN**	**RW**	**WC**
Soil Type		Cisne sil.	Grantsburg sil.	Muscatine sil.	Patton sil.	Bluford sil.
DPTA Extractable Mn (ppm)		15 (L) 21 (UL)	32 (L) 43 (UL)	18	17	30
pH		6.6 (L) 5.9 (UL)	6.5 (L) 5.9 (UL)	6.7	6.4	7.1
Soybean Variety		see table 2	see table 2	Kruger 355	P. 94B73	DK 3852
Planting Date		May 12	June 7	May 11	May 12	May 11
Foliar Mn applied		June 28	June 30	June 15	June 21	June 21
Roundup applied		July 1	July 6	June 21	June 24	June 24
2005	**Location:**	**BR**	**DS**	**MN**	**RW**	**NH**
Soil Type		Cisne	Grantsburg	Muscatine	Patton	Allison
DPTA Extractable Mn (ppm)		15 (L) 21 (UL)	32 (L) 43 (UL)	27	30	34
pH		6.6 (L) 5.9 (UL)	6.5 (L) 5.9 (UL)	6.4	6.7	7.6
Soybean Variety		see table 2	see table 2	Kruger 282	P. 94B73	P. 94M70
Planting Date		May 11	May 23	May 4	May 7	May 10
Foliar Mn (Pre RU)		n/a	n/a	July 5	June 1	June 1
Roundup applied		July 5	July 1	July 13	June 15	June 15
Foliar Mn (Post RU)		July 15	July 14	July 22	June 30	June 30
2006	**Location:**	**BR**	**DS**	**MN**	**RW**	
Soil Type		Cisne	Grantsburg	Muscatine	Patton	
DPTA Extractable Mn (ppm)		18 (L) 22 (UL)	23 (L) 42 (UL)	18	3.4	
pH		6.6 (L) 5.9 (UL)	6.5 (L) 5.9 (UL)	6.7	6.4	
Soybean Variety		see table 2	see table 2	Kruger 355	P. 94B73	
Planting Date		May 31	June 6	May 10	May 5	
Foliar Mn (Pre RU)		n/a	n/a	June 20	June 28	
Roundup applied		July 11	July 17	July 3	July 10	
Foliar Mn (Post RU)		July 26	.July 31	July 13	July 21	

L = limed. UL = unlimed.

Table 2. The following treatments were applied for each rep and pH level (6.0-6.2 vs 6.8-7.0).

Group	Treat	Variety†	Roundup Rate	Mn Source
A)	1	A. 4702	2x	None
	2	A. 4702	2x	Foliar‡ @ 0.5 # Mn/acre
	3	A. 4702	2x	Soil Applied @ 5 # Mn/acre
	4	FS 4516	2x	None
	5	FS 4516	2x	Foliar @ 0.5 # Mn/acre
	6	FS 4516	2x	Soil Applied @ 5 # Mn/acre
	7	P. 94B74	2x	None
	8	P. 94B74	2x	Foliar @ 0.5 # Mn/acre
	9	P. 94B74	2x	Soil Applied @ 5 # Mn/acre
B)	10	A. 4702	Handweed	None
	11	A. 4702	Handweed	Foliar @ 0.5 # Mn/acre
	12	A. 4702	Handweed	Soil Applied @ 5 # Mn/acre
	13	FS 4516	Handweed	None
	14	FS 4516	Handweed	Foliar @ 0.5 # Mn/acre
	15	FS 4516	Handweed	Soil Applied @ 5 # Mn/acre
	16	P. 94B74	Handweed	None
	17	P. 94B74	Handweed	Foliar @ 0.5 # Mn/acre
	18	P. 94B74	Handweed	Soil Applied @ 5 # Mn/acre
C)	19	P. 94B74	1x	None
	20	P. 94B74	1x	Foliar @ 0.5 # Mn/acre
	21	P. 94B74	1x	Soil Applied @ 5 # Mn/acre
	22	P. 94B74	4x	None
	23	P. 94B74	4x	Foliar @ 0.5 # Mn/acre
	24	P. 94B74	4x	Soil Applied @ 5 # Mn/acre

† In 2005, P. 94B54 replaced P. 94B74 and A. 4502 replaced A. 4702.
In 2006, P. 94M70 replaced P. 94B54.

‡ In 2004, foliar Mn applied 7-10 days prior to Roundup, in 2005 and 2006 foliar Mn applied 10-14 days after Roundup.

Results and Discussion

Soil test Mn ranged from 15 to 43 ppm across the locations (Table 1). However, it is interesting to note that the soil Mn level was significantly reduced with the application of lime at both DS and BR even though there was not a lot of reaction time for the lime since it was applied in the spring of 2004. Lime and pH changes may be associated with this effect. In general liming of the acid soils at DS and BR reduced plant uptake of Mn (Figure 1) which occasionally led to a yield increase (Figure 2).

Roundup rate significantly affected soybean yield at three of the locations in 2004 (Table 3). At RW, the 88 oz/acre rates had the lowest yield, and at WC and DS (limed) the 44 and 88 oz rates both significantly reduced yields. The 88 oz/acre rate is twice the recommended highest labeled rate and represents a possible overlap effect, so is not likely to occupy much of the area within a field. In cases where the zero roundup rate yielded less than the 22 oz rate, it is likely that weed control was not as timely and that significant weed competition existed before handweeding. At DS, there was a significant lime x roundup rate interaction. The limed plots had significantly higher soybean yields, even with the negative effects of the high roundup rates, than the unlimed plots. This was due to the lower Mn availability in the limed plots as indicated by the lower levels of Mn in the trifoliate leaf samples. This same pH effect on leaf Mn was seen at BR, but to a lesser extent. Roundup rate had no effect on leaf Mn level.

In 2005, similar observations were made at several of the locations (Table 4). In general, the highest rate of Roundup significantly reduced yields by an average of about 3 bu/acre. Again, Roundup rate had no effect on leaf Mn levels. In 2006, only the on-farm locations had a significant yield decrease associated with only the highest Roundup rate (Table 5).

Roundup induced “flash” ratings were significantly affected by roundup rate (Tables 3-5). Ratings were scored on a 1-5 scale with 5 having no symptoms of yellowing and 1 having severe stunting and chlorosis (Figure 3). Surprisingly, the RW site showed the least visual symptoms of flash in 2004 but had the larger yield decrease associated with the 88 oz/acre roundup rate. This site also had the lowest soil test Mn level and lowest tissue Mn levels (approaching deficiency). In 2005 and 2006 only MN was rated for “flash”, however the same injury symptoms appeared at the other locations in 2005 and 2006 that were observed in 2004. At MN there was a very good relationship between the effects of Roundup rate on yield and the effects of Roundup rate on flash ratings (Figure 4).

In an effort to get a better evaluation of leaf injury (“Flash”) associated with Roundup rates, a crop canopy active sensor was used to determine NDVI (normalized difference vegetative index) on each plot. In general terms, NDVI is rated on a 0-1 scale with numbers approaching one having a higher yield potential (less damage) than lower numbers. NDVI was significantly decreased with increasing rates of Roundup at two of the locations in 2006, RW and BR. NDVI seemed to share a relationship to yield and Roundup rate similar to that of flash ratings (Figure 5).

In general, Mn treatments had no effect on soybean yield, trifoliate leaf Mn composition, or flash ratings (Tables 6-8) except for very high leaf Mn levels at several locations associated with the

post Roundup foliar application of Mn. Apparently the application of Mn just prior to tissue sampling elevated the leaf levels, perhaps due to low rainfall after application not washing materials off the leaf surface. In the other situations it appears that the soil test levels of Mn were high enough that the addition of fertilizer Mn did not significantly increase plant uptake above the check treatments.

Three variety comparisons were made at DS and BR with mixed results (Table 9). At DS in 2004, the FS 4516 yielded slightly higher that the other varieties, whereas at BR, the Pioneer variety 94B74 yielded slightly higher. In 2005, at DS the A. 4502 and FS 4516 yielded about equally, whereas at BR, the FS 4516 had the higher yield. In 2006, the FS 4516 had slightly lower yields at BR. There were no interactions between varieties and either Roundup treatments or Mn treatments. There also were no differences among varieties for leaf Mn levels in 2005 and only slight differences in 2004 and 2006 (Table 10).

Conclusions

The effects of Roundup rate on soybean flash and grain yields do not appear to be related to Mn level in the plant (Figure 6) or to Mn application (Tables 6-8). Mn treatments had little effect on preventing flash or in preventing a loss of soybean yield associated with high rates of roundup. The additional treatment of a "rescue" application of Mn 8-10 days after the roundup application did not lead to better soybean responses, contrary to results shown by researchers at Purdue (Huber et al., 2004).

Literature Cited

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Table 3. Effects of roundup rate on soybean yield, leaf Mn level, and flash rating, 2004.

Roundup Rate	RW	MN	WC	BR - L†	BR - UL	DS - L	DS - UL	Ave.
				Soybean Yield (bu/acre)				
0	68.3	79.3	50.7	67.5‡	67.0	50.2	43.2	60.9
22	62.2	80.4	52.6	69.9	65.9	55.0	41.1	61.0
44	71.4	78.4	48.7	67.6	68.0	48.1	43.4	60.8
88	54.7	78.8	48.0	65.1	65.1	47.5	42.5	57.4
linear	***	*NS*	**	*NS*	*NS*	**	*NS*	
quadratic	**	*NS*	*NS*	*NS*	*NS*	**	*NS*	
				Trifoliate Leaf Mn (ppm)				
0	26	56	65	56	70	85	108	67
22	28	56	62	55	70	75	113	66
44	29	58	60	57	68	81	94	64
88	28	57	65	59	63	79	115	67
linear	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	
quadratic	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	
				"Flash" (5 = no injury, 1 = severe yellowing)				
0	5.0	5.0	5.0	5.0	5.0	Data		5.0
22	5.0	4.4	5.0	4.0	4.7	not		4.6
44	5.0	4.0	4.8	3.5	3.9	collected		4.2
88	4.0	3.0	4.0	2.7	2.3			3.2
linear	*NS*	***	***	***	***			
quadratic	*NS*	*NS*	***	*NS*	*NS*			

† L = limed, UL = unlimed.

‡ Only P. 94B74 used for BR and DS.

Table 4. Effects of roundup rate on soybean yield, leaf Mn level, and flash rating, 2005.

Roundup Rate	RW	MN	NH	BR - L†	BR - UL	DS - L	DS - UL	Ave.
				Soybean Yield (bu/acre)				
0	66.3	67.6	45.7	52.5	47.6	44.0	48.5	53.2
22	68.2	67.0	44.1	53.4	46.0	49.2	45.5	53.3
44	68.8	65.7	43.8	51.7	47.3	43.5	44.9	52.2
88	64.6	62.1	41.2	45.9	44.9	43.8	45.6	49.7
linear	*NS*	***	***	*	*	*NS*	*NS*	
quadratic	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	
				Trifoliate Leaf Mn (ppm)				
0		Data		89	99	80	96	91
22		not						
44		collected		94	100	78	95	92
88								
linear				*NS*	*NS*	*NS*	*NS*	
quadratic				*n.a*	*n/a*	*n/a*	*n/a*	
				"Flash" (5 = no injury, 1 = severe yellowing)				
0		5.0		Data		Data		
22		4.5		not		not		
44		3.7		collected		collected		
88		2.1						
linear		***						
quadratic		*						

† L = limed, UL = unlimed.

‡ Only P. 94B54 used for BR and DS.

Table 5. Effects of roundup rate on soybean yield, leaf Mn level, and flash rating, 2006.

Roundup Rate	RW	MN	BR - L†	BR - UL	DS - L	DS - UL	Ave.
			Soybean Yield (bu/acre)				
0	70.1	72.2	57.7	58.3	63.1	66.3	64.6
22	69.2	71.0	59.7	57.9	60.9	61.7	63.4
44	70.0	72.2	57.9	58.3	62.1	64.2	64.1
88	66.0	69.9	56.1	57.6	62.9	63.1	62.6
linear	**	*	*NS*	*NS*	*NS*	*NS*	
quadratic	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	
			Trifoliate Leaf Mn (ppm)				
0	37.9	54.9	108	119	140	215	112
22	39.2	54.2	91	113	105	193	99
44	38.4	54.5	107	100	151	192	109
88	38.8	54.6	132	135	129	179	111
linear	*NS*	*NS*	*	*	*NS*	*NS*	
quadratic	*NS*	*NS*	*	*	*NS*	*NS*	
			"Flash" (5 = no injury, 1 = severe yellowing) or NDVI				
0	0.805	5.0	0.816	0.812	0.801	0.800	0.807
22	0.805	4.9	0.794	0.791	0.785	0.785	0.792
44	0.801	5.0	0.775	0.769	0.787	0.801	0.787
88	0.793	4.1	0.709	0.713	0.798	0.795	0.762
linear	***	***	***	***	*NS*	*NS*	
quadratic	*	***	**	**	*NS*	*NS*	

† L = limed, UL = unlimed.

‡ Only P. 94M70 used for BR and DS.

Table 6. Effects of Mn treatment on soybean yield, leaf Mn level, and flash rating, 2004.

Mn Trt.	RW	MN	WC	BR - L†	BR - UL	DS - L	DS - UL	Ave.
				Soybean Yield (bu/acre)				
Check	64.4	79.0	50.5	66.8‡	67.6	49.1	43.5	60.1
Foliar	65.0	79.5	49.0	69.6	64.4	50.8	43.6	60.3
Soil	63.0	79.1	50.6	66.2	67.5	50.7	40.5	59.7
LSD	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	
				Trifoliate Leaf Mn (ppm)				
Check	28	57	63	59	68	80	107	66
Foliar	29	56	67	54	68	78	104	65
Soil	28	57	60	57	68	81	112	66
LSD	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	
				"Flash" (5 = no injury, 1 = severe yellowing)				
Check	4.8	4.1	4.6	3.9		Data		4.4
Foliar	4.8	4.0	4.7	3.9		not		4.4
Soil	4.8	4.2	4.8	3.9		collected		4.4
LSD	*NS*	*NS*	*NS*	*NS*				

† L = limed, UL = unlimed.

‡ Only P. 94B74 used for BR and DS.

Table 7. Effects of Mn treatment on soybean yield, leaf Mn level, and flash rating, 2005.

Mn Trt.	RW	MN	NH	Ave.	BR - L†	BR - UL	DS - L	DS - UL	Ave.
					Soybean Yield (bu/acre)				
Check	67.0	64.5	43.5	58.3	50.4	46.0	42.2	45.2	46.0
Pre RU	68.6	66.2	43.4	59.4					
Soil	68.2	65.0	44.4	59.2	50.8	47.5	48.1	48.4	48.7
Post RU	64.2	66.8	43.5	58.2	51.5	45.9	45.1	44.8	46.8
LSD	*NS*	*NS*	*NS*		*NS*	*NS*	*NS*	*NS*	
					Trifoliate Leaf Mn (ppm)				
Check	34	47	62	48	106	94	75	85	90
Pre RU	33	53	58	48					
Soil	36	46	63	48	81	81	80	92	84
Post RU	224	58	178	153	81	124	85	109	100
LSD	***	*NS*	***		*NS*	*NS*	*NS*	*NS*	
					"Flash" (5 = no injury, 1 = severe yellowing)				
Check		3.8			Data		Data		
Pre RU		3.8			not		not		
Soil		3.8			collected		collected		
Post RU		3.8							
LSD		*NS*							

† L = limed, UL = unlimed.

‡ Only P. 94B54 used for BR and DS.

Table 8. Effects of Mn treatment on soybean yield, leaf Mn level, and flash rating, 2006.

Mn Trt.	RW	MN	Ave.	BR - L†	BR - UL	DS - L	DS - UL	Ave.
				Soybean Yield (bu/acre)				
Check	69.7	71.5	70.6	58.0	59.9 a	62.5	64.4	61.2
Pre RU	67.7	70.3	69.0	--	--	--	--	--
Soil	68.7	71.3	70.0	57.7	55.6 b	60.6	63.4	59.3
Post RU	69.2	72.3	70.8	57.9	58.6 a	63.7	63.7	61.0
LSD	*NS*	*NS*		*NS*	*1.99*	*NS*	*NS*	
				Trifoliate Leaf Mn (ppm)				
Check	30 b	54	42	79 b	79 b	109 b	154 b	105
Pre RU	29 b	53	41	--	--	--	--	--
Soil	30 b	56	43	79 b	82 b	108 b	173 b	111
Post RU	66 a	56	61	169 a	190 a	178 a	257 a	199
LSD	*9.2*	*NS*		*19.1*	*19.1*	*25.5*	*25.5*	
				"Flash" (5 = no injury, 1 = severe yellowing) or NDVI				
Check	0.801	4.8		0.775	0.772	0.796	0.788	0.783
Pre RU	0.802	4.8		--	--	--	--	--
Soil	0.799	4.8		0.772	0.770	0.797	0.800	0.785
Post RU	0.802	4.8		0.774	0.773	0.785	0.798	0.783
LSD	*NS*	*NS*		*NS*	*NS*	*NS*	*NS*	

† L = limed, UL = unlimed.

‡ Only P. 94M70 used for BR and DS.

Table 9. Variety effects on soybean yield, 2004-06.

Variety	BR - L†	BR - UL	Average	DS - L	DS - UL	Average
2004 Soybean Yield (bu/acre)						
A. 4702	61.6	66.3	63.9 b	51.1	44.0	47.5 ab
FS 4516	66.4	67.2	66.8 ab	53.2	47.3	50.3 a
P. 94B74	67.6	67.5	67.5 a	49.1	43.3	46.2 b
LSD			*2.89*			*3.12*
2005 Soybean Yield (bu/acre)						
A. 4502	50.6	48.0	49.3 b	57.2	52.8	55.0 a
FS 4516	61.6	54.0	57.8 a	57.0	55.8	56.4 a
P. 94B54	52.1	47.4	49.8 b	43.8	46.5	45.1 b
LSD			*3.89*			*2.90*
2006 Soybean Yield (bu/acre)						
A. 4502	57.3	59.2	58.2 a	64.7	65.2	65.0
FS 4516	54.0	56.4	55.2 b	63.3	64.2	63.7
P. 94M70	57.8	58.3	58.1 a	52.6	65.2	63.9
LSD			*1.24*			*NS*

† L = limed, UL = unlimed.

Table 10. Variety effects on soybean leaf Mn level, 2004-06.

Variety	BR - L†	BR - UL	Average	DS - L	DS - UL	Average
2004 Trifoliate Leaf Mn (ppm)						
A. 4702	60	75	68 a	89	115	102 b
FS 4516	58	66	62 b	102	119	110 a
P. 94B74	56	69	63 ab	83	101	92 c
LSD			*4.9*			*7.3*
2005 Trifoliate Leaf Mn (ppm)						
A. 4502	79	88	84	90	95	92
FS 4516	78	86	82	83	112	97
P. 94B54	89	99	94	80	95	88
LSD			*NS*			*NS*
2006 Trifoliate Leaf Mn (ppm)						
A. 4502	112	121	116	98	186	142 b
FS 4516	120	130	125	126	141	134 b
P. 94M70	107	110	108	146	204	175 a
LSD			*NS*			*26*

† L = limed, UL = unlimed.

Figure 1.

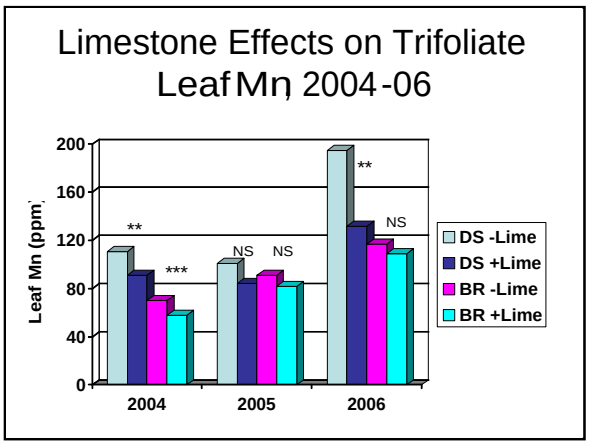


Figure 2.

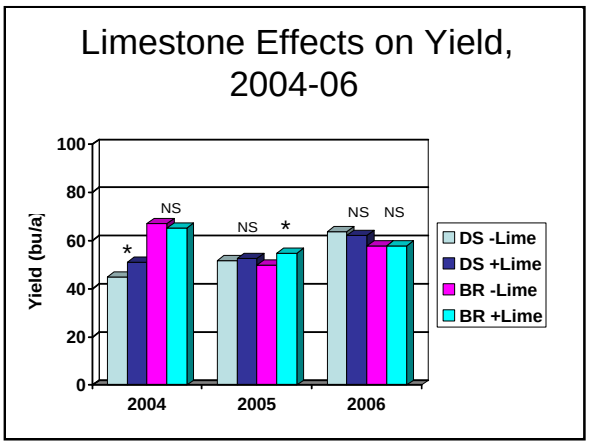


Figure 3.

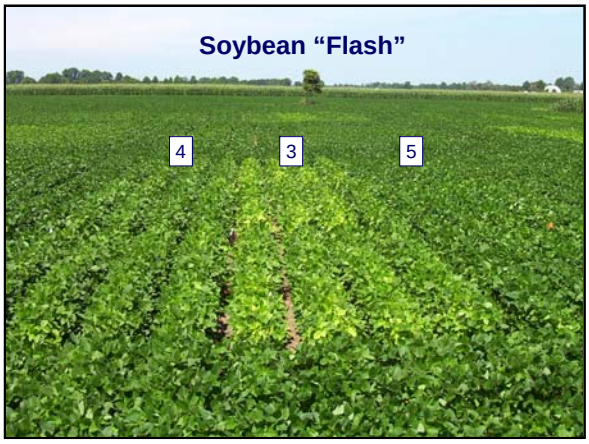


Figure 4.

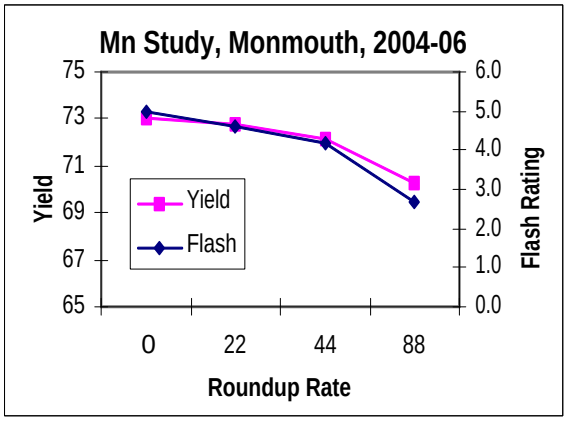


Figure 5.

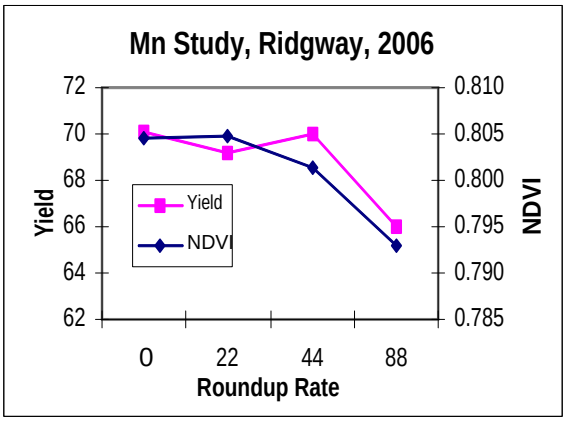
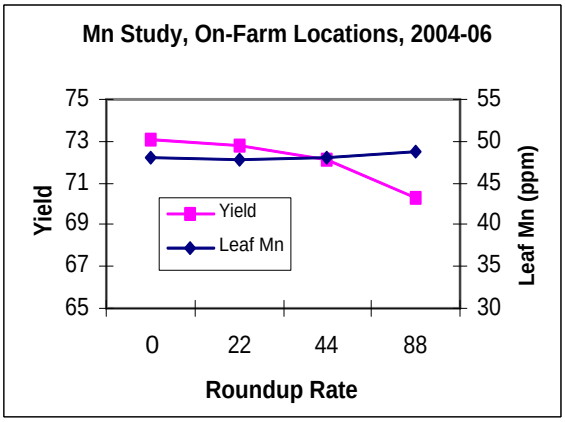


Figure 6.



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