NUTRIENT DEFICIENCIES IN GLYPHOSATE-RESISTANT SUGAR BEETS?

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Introduction and Objective:

In the US Roundup-tolerant sugar beets were planted in 2010 on 95 percent of the farmland (over one million acres), enabling the farmers to weed their crops chemically at low production costs with a high weed control efficacy and without harming the beets (Wilson et al., 2002; Kniss et al., 2004). Additionally, Märländer (2005) predicted costs savings in sugar beet production of more than 50% in Europe using glyphosate-tolerant varieties. Significant increases in net economic return to sugar beet growers in UK were calculated by May (2003) and recently demonstrated by Kniss (2010) for Wyoming. Altogether good prerequisites are exsisting to assume that the commercial adoption of glyphosate-resistant sugar beet cultivars could even exceed the 95 percent acreage in the future.

Observations during recent years in Roundup Ready® soybeans suggest that the use of glyphosate complicates the uptake of micronutrients, in particular manganese (causing "yellow flash" symptoms in beans). The application of micronutrients has been recommended to overcome manganese deficiencies in soybean production. Nothing is known regarding such possible complications in Roundup Ready sugar beets. Trials were conducted over a three year period to determine if spray application of manganese fertilizer affects the micronutrient content in the leaves, or yield and quality at harvest in Roundup Ready sugar beets.

Materials and Methods

Roundup Ready sugar beet cultivar Beta 5501RR was planted in strip trials (12 rows) at Rosemount, MN and Randolph, MN location in 2008, 2009 and 2010. Trials were fertilized and maintained following management practices customary in these places. All plots were 11´ x 40´ encompassing 12/22" rows. The six treatment rows were sprayed "down the row" with manganese fertilizer (manganese chelate 5%, 20 fl oz/acre for rate of 20 gal/acre spray solution) approx. 14 days after Roundup application, the check rows receiving no manganese. Treatments "across the row" were 3 replications of Roundup herbicide (32 fl oz/acre, one application in 2008, two applications in 2009 and 2010) using Roundup WeatherMax®. All three check plots were hand weeded. Leaf samples were collected prior to and 4 to 6 weeks after Roundup application. At least 90 beets were harvested from the center two rows of each plot for yield and quality data.

Soil samples were taken prior to sugar beet sowing in the surface foot of the profile. The soil analyses were performed at Agvise Laboratories, Northwood, MN (2008), Minnesota Valley Testing Laboratories, Inc., New Ulm, MN (2009) and University of Minnesota, Research Analytical Laboratory, St. Paul, MN (2010) using standard accepted procedures. Leaf samples have been analyzed at the University of Minnesota, Research Analytical Laboratory, St. Paul, MN.

Sugar beets were harvested (at least 90 beets from the middle two rows of each plot) and quality analyses were determined by using the VENEMA laboratory.

For statistical data analysis data were analyzed in GenStat® (edition 10.2 for Windows) in an unbalanced ANOVA using the regression directives in GenStat®.

Results and Discussion

The analyses data of the soil samples at all locations is presented in Table 1. As requested in 2008, the two locations Rosemount and Randolph showed different pH values.

The soil chemical parameters at all four locations did not show large differences. Besides sulphur and boron all analyzed macro- and micronutrients were in a range that additional broadcast application was not recommended by the analytical laboratories (Table 1).

Table 1. Analyses data of soil samples taken prior to sugar beet sowing at Rosemount location (2008) and Randolph locations (2008, 2009 and 2010).

location		Rosemount 2008	Randolph 2008	Randolph 2009	Randolph 2010	application recommended *
pH		5,5	6,5	6,3	6,2	
OM	[%]	4,4	3,4	3,6	3,3	
CEC	[meq]	18,0	11,9	17,0		
P	[ppm]	34,0	79,0	85,2	152,8	**no**
K	[ppm]	184,0	278,5	234,2	342,0	**no**
S	[lb/ac]	14,0	11,0	6,2		**yes**
B	[ppm]	0,2	0,3	0,4		**yes**
Zn	[ppm]	1,1	3,1	2,1	5,9	**no**
Fe	[ppm]	83,7	65,1	50,2	259,7	**no**
Mn	[ppm]	11,3	6,5	14,8	136,5	**no**
Cu	[ppm]	0,7	1,1	0,7	1,7	**no**
Mg	[ppm]	291,5	336,5	356,5	380,5	**no**
Ca	[ppm]	1416,0	1651,0	2160,8	1950,7	**no**
Na	[ppm]	18,5	20,5	8,5	7,5	**no**

* general comments in the soil test reports of different laboratories

The sugar beet crops showed no visual deficiency symptoms in the canopy at all study sites. Due to the fact that soil pH is a significant factor affecting the availability of manganese (higher pH levels may result in limited manganese availability for uptake), two trials were conducted in 2008 on locations with different soil pH (Rosemount, pH 5.5 and Randolph, pH 6.5). Data of leaf analyses from samples taken before and approximately four weeks after application of Roundup (i.e. before and two weeks after foliar application of manganese) indicate that different soil pH did not affect the uptake of the micronutrients boron, iron and zinc (Table 2 and 3), but had an influence on the uptake of manganese at the location Rosemount. Regardless of the weed management (Roundup vs. hand weeding) and the manganese spray application (with vs. without Mn) leaf samples at the location Rosemount showed a higher manganese content in August (Table 2) compared to the data from the location Randolph, on which the higher soil pH was expected to encourage lower Mn availability (Table 3). The results provide evidence of an increased availability of manganese at the location with the lower pH (Rosemount) compared to location Randolph (pH 6.5).

Table 2. Analyses of leaf samples taken before application of Roundup and manganese and approximately four weeks after Roundup was applied (two weeks after manganese spray application) at Rosemount 2008.

Location Rosemount, MN 2008; pH 5.5					
	June 19	August 19			
	no Roundup	Roundup		Hand weeding	
micro nutrient	no MN	+ Mn	no MN	+ Mn	no MN
B [ppm]	27	29	31	28	29
Fe [ppm]	564	293	229	251	681
Mn [ppm]	226	442	423	430	425
Zn [ppm]	70	70	71	69	82

Table 3. Analyses of leaf samples taken before application of Roundup and manganese and approximately four weeks after Roundup was applied (two weeks after manganese spray application) at Randolph 2008.

Location Randolph, MN 2008; pH 6.5					
	June 15	August 16			
	no Roundup	Roundup		Hand weeding	
micro nutrient	no MN	+ Mn	no MN	+ Mn	no MN
B [ppm]	27	41	41	44	44
Fe [ppm]	677	1153	522	129	123
Mn [ppm]	110	124	106	156	105
Zn [ppm]	71	91	68	72	65

Interestingly the iron content of the leaves decreased at both locations from the first sampling in June to the second one in August. The decrease of the iron content independent of the weed management and the manganese application was also confirmed by assembling all analyses data from four locations over three years (Table 4).

It has to be mentioned that apart from boron the concentration of all other micronutrients in the leaves over all studies have been in the sufficient level of plant nutrients (Table 5).

Table 4. Analyses of leaf samples taken before application of Roundup and manganese and approximately four to six weeks after Roundup was applied (two to four weeks after manganese spray application) at four locations over three years.

Average of all locations 2008-2010 (n=4)					
	before	leaf sampling after RU application			
	no Roundup	Roundup		Hand weeding	
micro nutrient	no MN	+ Mn	no MN	+ Mn	no MN
B [ppm]	31	39	40	41	41
Fe [ppm]	442	235	214	193	209
Mn [ppm]	145	198	176	200	174
Zn [ppm]	66	75	64	72	66

Table 5. Range showing symptoms for deficiency and no deficiency in sugar beet blades (after Bennett, 1993).

	B [ppm]	Fe [ppm]	Mn [ppm]	Zn [ppm]
Deficiency	12 - 40	20 - 55	4 - 20	2 - 13
No deficiency	35 - 200	60 - 140	25 - 360	10 - 80

Effects of different years and locations were significant with respect to all parameters evaluated (Table 6 and 7). Neither the weed management (application of Roundup vs. hand weeding) nor the spray application of manganese and the interaction effect of weed management by manganese application were significant with respect to leaf content with boron, iron, manganese and zinc and both root yield and sugar content. The fact that no weed management by manganese application effect could be found indicates that the uptake of micronutrients as well as root yield and sugar content were independent on the application of Roundup and additional spray applications of manganese.

Table 6. Analysis of variance for weed management (Roundup application vs. hand weeding), manganese spray application (with vs. without), and interaction effects on leaf analyses data (after spray application of Roundup and manganese).

	NUM	Boron (B)		Iron (Fe)		Manganese (Mn)		Zinc (Zn)	
Treatment effect	DF*	v.r.*	F pr.*	v.r.*	F pr.*	v.r.*	F pr.*	v.r.*	F pr.*
Analyses of leaf samples									
- location and year	3	52,01	<0,001	59,27	<0,001	93,34	<0,001	4,79	0,006
- weed management	1	0,71	0,405	1,99	0,165	0	0,99	0	0,971
- w/o Mn	1	0,09	0,767	0,03	0,866	2,04	0,161	2,72	0,107
- weed m. X w/o Mn	1	0,14	0,709	1,22	0,276	0,01	0,904	0,16	0,691

* **DF**: degrees of freedom; **v.r.** : variance ratio; **F pr.**: probability associated with the F value (p > F)

Table 7. Analysis of variance for weed management (Roundup application vs. hand weeding), manganese spray application (with vs. without), and interaction effects on root yield and sugar content of sugar beets.

	NUM DF*	v.r.*	F pr.*
Sugar beet root yield			
- location and year	3	502,49	<0,001
- weed management	1	1,3	0,261
- w/o manganese	1	1,21	0,278
- weed man. X w/o mang.	1	0,03	0,863
Sugar content (pol sucrose)			
- location and year	3	489,11	<0,001
- weed management	1	1,35	0,251
- w/o manganese	1	0,53	0,471
- weed man. X w/o mang.	1	0,09	0,763

* **DF**: degrees of freedom; **v.r.** : variance ratio; **F pr.**: probability associated with the F value (p > F)

Studies in soybeans have shown that problems in micronutrients uptake after application of Roundup can occur due to chelating properties of the molecule glyphosate (Huber et al., 2004). It was also stated that glyphosate may adversely affect populations of soil micro-organisms responsible for transforming micronutrients into a plant-available form

(Huber; cited in Reichenberger, 2007). Neumann et al. (2006) investigated soybeans in pot and nutrient solution experiments and found that glyphosate was translocated from shoots to roots. Their assumption is that translocation of glyphosate into the rhizosphere can inhibit the acquisition of micronutrients such as manganese, iron, boron and zinc.

Conclusions

Based on the described three years trials on four locations with a variable range in environmental conditions and production potential there is no evidence that the application of Roundup leads to nutrient deficiencies in sugar beets as described in soybeans. No negative yield or quality response could be found when comparing with and without spray application of manganese in sugar beets. The results and observations regarding the occurrence of manganese deficiency symptoms ("yellow flash") in soybean studies can not be transferred to sugar beets. One explanation could be that in soybeans rhizobacteria play an important role in the fixation of nitrogen. These microorganisms could be affected by a translocation of glyphosate into the root system under certain conditions. On the other it is assumed that in many cases the reasons for the so called "yellow flash" symptoms in soybeans (manganese deficiency) are mainly high soil pH values, high organic matter of the soil, low soil content of micronutrients and the possibility of leaching of nutrients in sandy soils.

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