Effect of Soil pH on Sulfentrazone Phytotoxicity

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Introduction

We have reported that sulfentraznoe phytotoxicity in prairie soils is strongly correlated to organic carbon concentration based on investigation of ten western Canadian soils (Szmigielski et al. 2009).. These soils had a broad range of organic carbon and a narrow range of soil pH that may have restricted revealing the effect of soil pH on sulfentrazone phytotoxicity.

Objectives

The objective of this study was to investigate the effect of soil pH on sulfentrazone phytotoxicity in Canadian prairie soils after altering the natural soil pH.

Materials and Methods

Five Saskatchewan soils were used in the study of the effect of soil pH on sufentrazone phytotoxicity (Table 1). Soil pH was altered through addition of HCl solution and $CaCO_3$ suspension to produce values either above or below natural pH values shown in Table 1. In Scott, Clavet, Central Butte (lower slope) and Saskatoon soils, pH was lowered using 0.5 mL and 1 mL of 1M HCl solution per 50 g soil added to soil with a volume of water equivalent to 100% FC. To increase soil pH in these four soils, a suspension of 0.2 g $CaCO_3$ per 50 g soil in a volume of water equivalent to 100% FC was added to soil. In Central Butte (upper slope) addition of $CaCO_3$ did not increase soil pH as the soil already had free lime ($CaCO_3$) naturally present. The pH in this soil was lowered using 0.5 mL, 1 mL and 2 mL of 1M HCl solution per 50 g soil. More acid was required in this soil due to the need to neutralize all the free solid phase carbonates present before the pH could effectively begin to decrease. After acid or base addition, soils in plastic containers were covered and allowed to equilibrate for one week. Soils were then air-dried and sieved (2 mm) and pH and electrical conductivity (EC) were determined in a water extract (2:1 water:soil ratio). The pH range in each soil was not equal as addition of the above amounts of acid and base had different effect on soil pH in the different soils (Table 2) due to differences in buffering capacity of the soils

Soils from Scott, Clavet, Central Butte (lower slope) and Saskatoon were spiked with sulfentrazone in a range from 0 to 300 ppb, while Central Butte (upper slope) was spiked in a range of 0 to 200 ppb because of higher sulfentrazone phytotoxicity in this soil. Sugar beet shoot length bioassay was applied as described in Szmigielski et al. (2009). Each combination of soil pH and sulfentrazone concentration was replicated three times. A log-logistic model was used to plot shoot length inhibition vs sulfentrazone concentration and concentration corresponding to 50% inhibition (I_{50} value) was determined for each soil pH.

Results

Absolute shoot length of the sugar beet was shorter in acidified soils. This may be attributed to the slight increase in soil salinity associated with acidification treatment, as indicated by rising electrical conductivity (EC) values when pH was lowered below the natural levels. Neutralization of $CaCO_3$ in the soil by HCl will produce carbonic acid and $CaCl_2$, a soluble salt. Further soil acidification (below the pH values listed in Table 2) rendered the assessment of the soil incorporated sulfentrazone difficult due to further reduction of sugar beet growth and consequently did not produce the typical "S" shape plant response curves (data not shown).

The phytotoxicity curves for sulfentrazone in soils with altered pH are presented in Fig. 1, 2, 3, 4, and 5. In each of the investigated soils sulfentrazone phytotoxicity was reduced when soil pH was lowered and was greater when soil pH increased. Soil pH influences adsorption and bioactivity of ionic herbicides by affecting the ionic character of the organic matter and clay colloids, and by affecting the ionization of the herbicide. Because organic matter and clay have pH-dependent charges, soil adsorption of anionic herbicides generally decreases as soil pH increases resulting in higher concentration of bioavailable herbicide in soil. At pH values greater than the herbicide pKa value, weak acidic herbicides exist predominantly in the anionic form. Therefore, concentration of a herbicide in soil solution is higher and more herbicide is available for plant uptake.

I_{50} values estimated from the phytotoxicity curves increased in acidified soils and decreased in alkalized soils (Table 2). For each soil, the I_{50} values were significantly correlated with soil pH (Table 2) demonstrating a strong relationship of soil pH and sulfentrazone phytotoxicity. Also, I_{50} values for each soil were significantly different ($p = 0.05$) based on the asymptotic z-test, except for the Scott soil at pH 4.5 and pH 4.9 due to the fact that the asymptotic standard error for the Scott soil at pH 4.5 was large as the plant response curve represented only the beginning of the log-logistic curve (Fig. 1). The significant differences between I_{50} values demonstrated that sulfentrazone phytotoxicity is highly sensitive to changes in soil pH.

We have previously reported that sulfentrazone phytotoxicity was primarily related to organic carbon concentration (Szmigielski et al. 2009), based on the investigation of ten western Canadian soils having a broad range of organic carbon and a narrow range of soil pH that may have restricted revealing the effect of soil pH on sulfentrazone phytotoxicity. The present study shows that soil pH also has a significant effect on sulfentrazone phytotoxicity and that sulfentrazone is less available to plants at lower pH. These results are in good agreement with the study of Grey et al. (1997) who reported that sulfentrazone adsorption increased and mobility decreased when pH decreased in soils from southern US. Sulfentrazone will have the greatest soil phytotoxicity in soils of low organic matter content and high pH, such as in eroded upslopes of prairie landscapes.

Table 1. Selected properties of soils used in the study of the effect of soil pH on sulfentrazone phytotoxicity.

Soil (location)	pH	EC µS per cm	Organic Carbon (%)	Texture			Moisture content at FC (%)
				Sand (%)	Silt (%)	Clay (%)	
Scott	5.5	351	3.2	33	28	39	16
Clavet	6.0	278	2.4	60	14	26	22
Central Butte (lower slope)	6.6	308	2.6	24	25	51	25
Saskatoon	7.8	403	3.0	14	19	67	27
Central Butte (upper slope)	8.0	170	1.3	51	18	31	14

Table 2. I_{50} values (concentrations corresponding to 50% inhibition, ppb) for sufentrazone in five soils at four pH levels.

Soil	pH	EC (µS)	I_{50}[a] (± SE)	R[b]
Scott	6.8	583	48.7 c (± 2.8)	-0.78**
	5.5 (natural)	351	85.7 b (± 7.0)	
	4.9	981	130.4 a (± 5.9)	
	4.5	1588	216.4 a (± 59.4)	
Clavet	7.3	452	25.4 d (±1.6)	-0.95**
	6.0 (natural)	278	54.7 c (± 2.6)	
	5.4	933	85.6 b (± 3.6)	
	5.0	1455	105.2 a (± 8.4)	
Central Butte (lower slope)	7.2	480	38.5 d (± 1.9)	-0.95**
	6.6 (natural)	308	71.3 c (± 2.5)	
	6.0	885	90.0 b (± 5.0)	
	5.6	1418	107.3 a (± 2.9)	
Saskatoon	8.0	414	42.6 d (± 2.5)	-0.95**
	7.8 (natural)	403	70.3 c (± 6.8)	
	7.3	984	86.5 b (± 4.6)	
	6.8	1432	128.0 a (± 5.3)	
Central Butte (upper slope)	8.0 (natural)	170	17.2 d (± 0.6)	-0.68*
	7.6	714	27.0 c (± 1.3)	
	7.5	1307	40.3 b (± 3.6)	
	7.4	2350	77.6 a (± 5.5)	

[a] values for each soil followed by the same letter are not significantly different at 0.05 level using the asymptotic z-test;
[b] correlation coefficient for the relationship of soil pH and I_{50} (** significant at 0.01 level, * significant at 0.05 level).

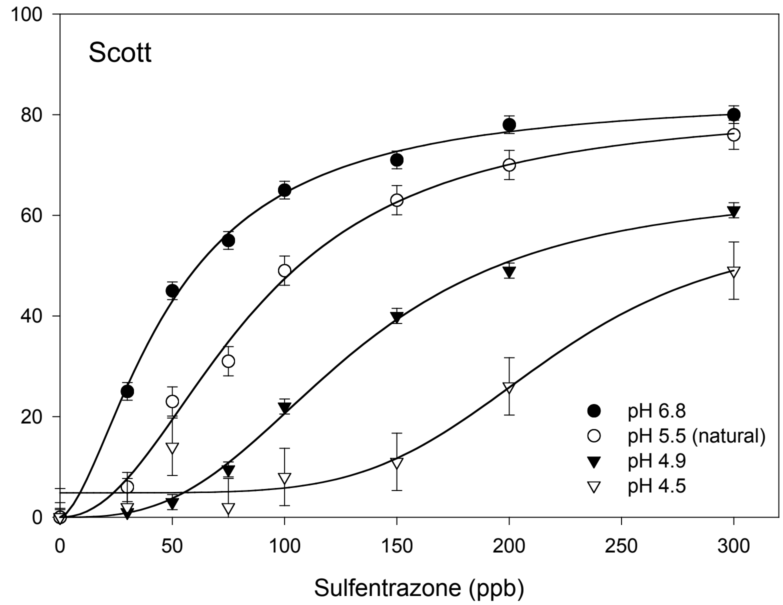

Fig. 1. Effect of soil pH on sulfentrazone phytotoxicity in Scott soil.

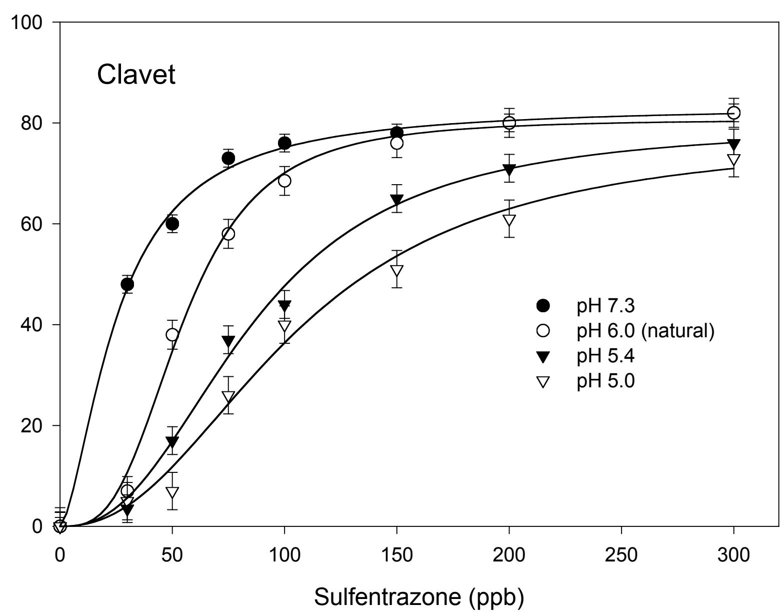

Fig. 2. Effect of soil pH on sulfentrazone phytotoxicity in Clavet soil.

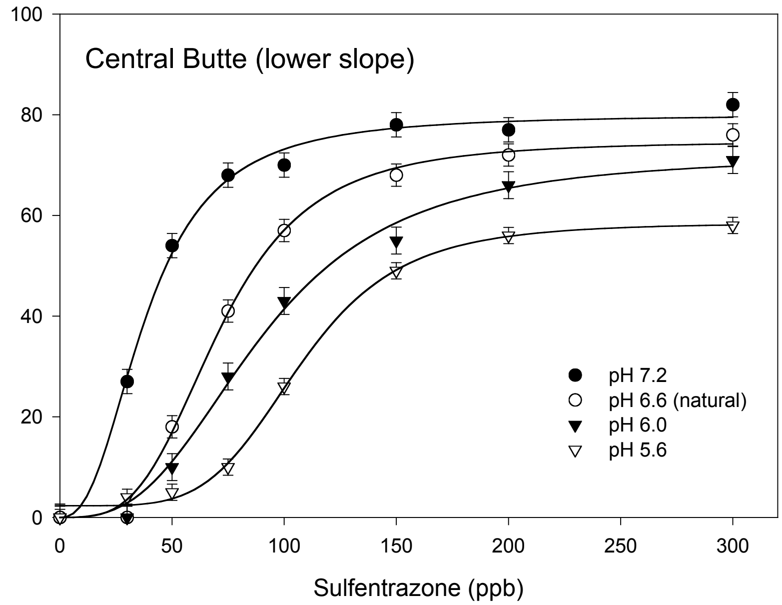

Fig. 3. Effect of soil pH on sulfentrazone phytotoxicity in Central Butte (lower slope) soil.

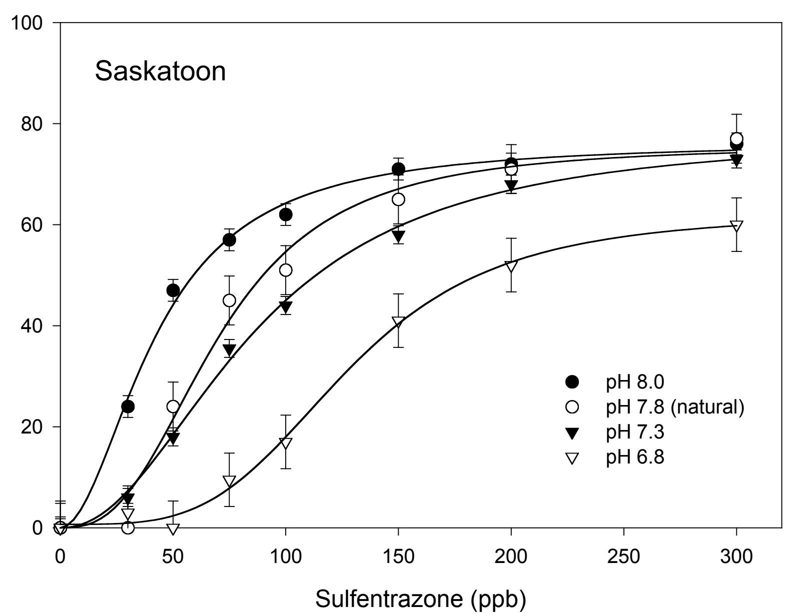

Fig. 4. Effect of soil pH on sulfentrazone phytotoxicity in Saskatoon soil.

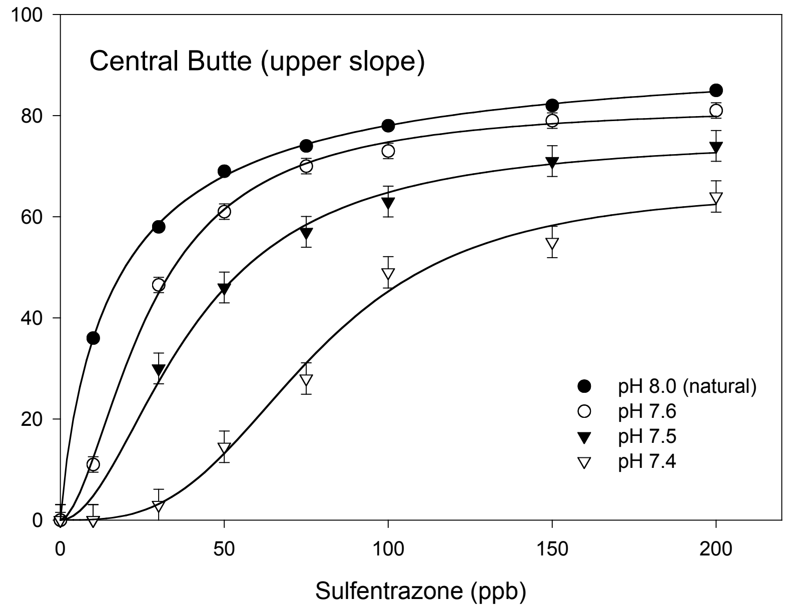

Fig. 5. Effect of soil pH on sulfentrazone phytotoxicity in Central Butte (upper slope) soil.

Conclusions

This study demonstrates that soil pH has a significant effect on sulfentrazonde phytotoxicity and that sulfentrazone is less available to plants at lower pH in soils of Canadian prairies.

References

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