Mosaic® AgriSight®
TRUSTED CROP NUTRITION EXPERTISE℠
ISSUE 18: 2020

# Effect of Climate and Soil Properties on Sulfate and Elemental Sulfur Recovery from MicroEssentials®

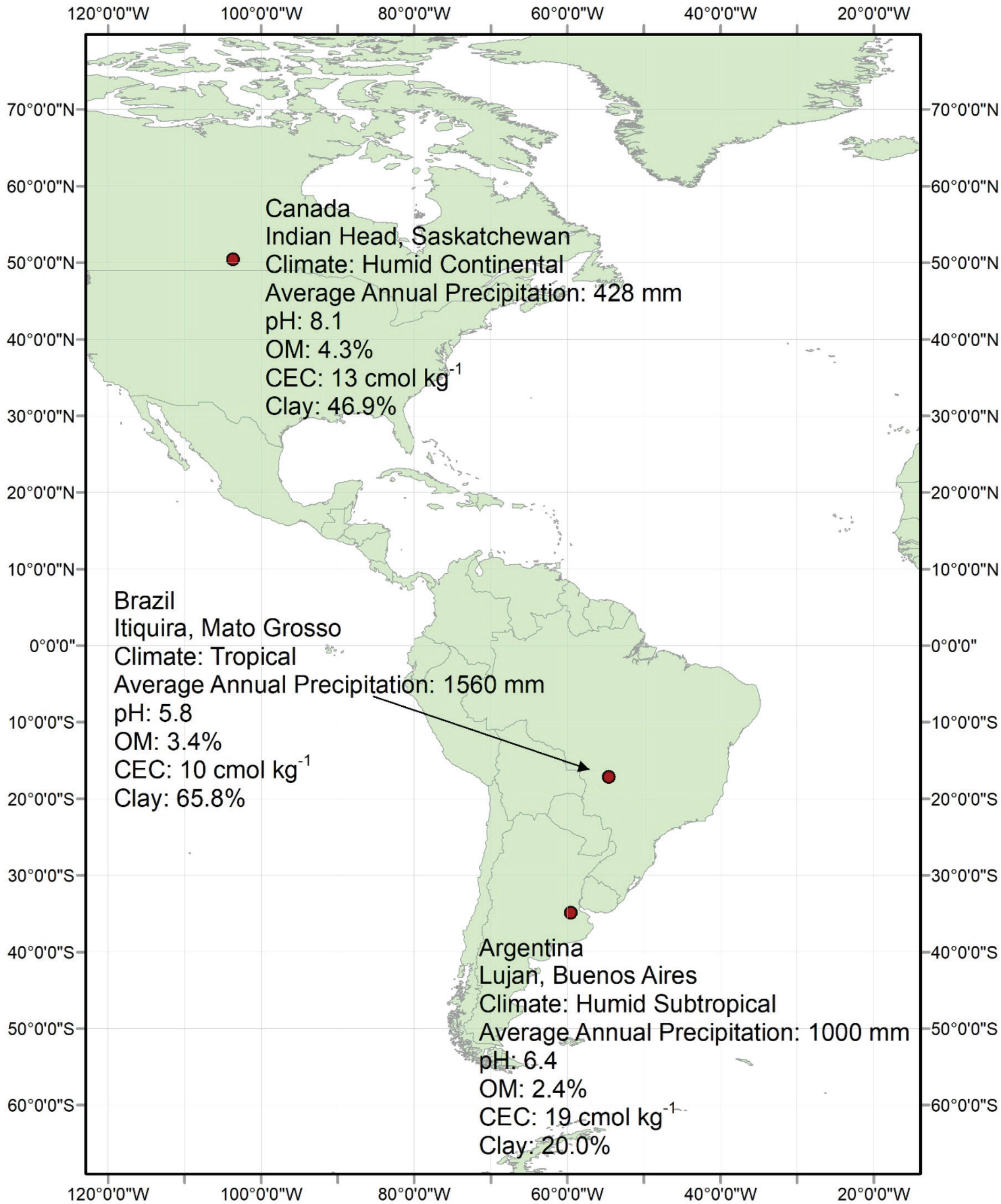
Sulfur (S) is an essential element for all crops. Sulfur deficiency has become more common due to decreased atmospheric inputs, higher yields, and a shift to high-analysis fertilizers with little or no S. Commonly used S fertilizer sources contain either sulfate-S ($SO_4$-S) or elemental sulfur (ES). Sulfate-S is readily available to plants but is vulnerable to leaching in most soils. On the contrary, ES is not prone to leaching and must be oxidized into plant-available $SO_4$-S. The rate of oxidation depends on several factors, including climate, soil properties, and fertilizer granule characteristics. Oxidation of ES is a biological process and it generally increases with an increase in temperature, soil pH, organic matter content, and microbial activity. Among fertilizer granule characteristics, ES particle size and %ES concentration within the granule greatly affect the oxidation rates. Oxidation is dependent on surface area and decreases dramatically as the particle size increases. The surface area available for oxidation also depends on the total concentration of ES in the granule. As the ES concentration within the granule increases, the oxidation rate decreases due to decreased contact with the soil (Degryse et al, 2016a, 2016b; Crop Nutrition, 2017).

Climate and soil properties also have a large effect on the fate of $SO_4$-S and ES fertilizers. Leaching of $SO_4$-S depends on average annual precipitation and soil type, whereas the oxidation of ES is highly temperature and soil pH dependent. This study aimed to evaluate the effect of climatic and soil conditions on the recovery and residual value of $SO_4$-S and ES applied from MicroEssentials using stable isotope tracing (Degryse et al, 2020). Three field trials were conducted for 2 years in Argentina, Brazil, and Canada (Fig. 1). Crops commonly grown in these geographies were planted with MicroEssentials applications made in the first year as a broadcast application to measure the S recovery for two years (Table 1). Plant samples for S uptake were collected at harvest.

The recovery of plant S from $SO_4$-S and ES is shown in Figure 2. For Argentina, total recovery in the harvested material at the end of the second year was 85.7% (77.6+8.1) for $SO_4$-S compared to 25.7% (12.3+13.4) for ES. More $SO_4$-S recovery can be explained by low rainfall in the first two months after fertilizer application (Fig. 3) and low ES recovery is due to slower oxidation in the slightly acidic soil with low organic matter content. For Canada, total recovery was 65.6% (59.1+6.5) for $SO_4$-S and 19.2% (5.8+13.4) for ES. In the colder climate, slower conversion of $SO_4$-S to organic S led to higher $SO_4$-S uptake and slower ES oxidation lead to reduced ES recovery. The trends over time were similar for both sites, where recoveries of $SO_4$-S were considerably greater than those of ES in the first-year due to the rapid availability of $SO_4$-S for plant uptake and slower oxidation of ES. For these situations, the remaining ES continues to oxidize over time and contributes to plant uptake. However, the total uptake of S in the second year was considerably lower at both sites, indicating there was insufficient S available for plants for the second crop. Therefore, additional S application to the next crop in rotation is necessary to meet the crop's S needs.

- Sulfur (S), commonly applied as sulfate-S (SO4-S) or elemental sulfur (ES) is an essential element for all crops.
- Sulfate-S is readily available to plants, but is vulnerable to leaching in most soils, ES is not prone to leaching and must be oxidized into plant available $SO_4$-S.
- The rate of ES oxidation depends on several factors including climate and soil properties, and ES oxidation generally increases with increase in temperature, soil pH, and organic matter content.

**Fig 1:** Map showing climatic conditions and key soil properties of three field trial locations.



For the Brazilian site, the recovery from applied fertilizer was more from ES than $SO_4$-S for all crops except soybean in the first year, where both forms of S had a similar recovery. The total recovery of S at the end of the second year was 9.3% for $SO_4$-S compared to 15.9% for ES. Lower $SO_4$-S recovery was due to faster immobilization and excess rainfall because nearly 600 mm rainfall occurred in the first 2 months after S application (Fig. 3). Higher recovery for ES was due to faster oxidation in a warmer climate. Lower total S recovery can also be due to leaching of $SO_4$-S that was oxidized from ES during the 2-year period in the warmer climate. More contribution from ES in Brazilian conditions thus suggests the need for ES as an S source for better utilization of applied S fertilizers.

Recoveries of fertilizer S varied quite dramatically across different climatic and soil conditions. The $SO_4$-S recovery in the year of the application was much smaller for the Brazilian site than for Argentinean and Canadian sites due to high leaching potential at the location in Brazil, indicating the importance of ES source in Brazil. Therefore, products like MicroEssentials® S9® with $SO_4$ (2%) and ES (7%) are a great fit for Brazil's climate and soil conditions. For colder climates like Canada, crop S needs for early growth stages can be met by including higher $SO_4$-S amounts along with ES, like in MicroEssentials S15 (7.5% $SO_4$ and 7.5% ES). Therefore, depending on climate and soil conditions, a fertilizer containing both forms of S in suitable amounts will help reduce leaching risks, provide readily available S, and supply season-long S. The study also showed a trend of decreased contribution from total fertilizer S in the second year, demonstrating that the fertilizer applied only once in the first year is not sufficient to meet crop demand. Therefore, the application of S every year, and to every crop, is very critical.

## Suggested Readings


Oxidation of Elemental Sulfur in soils. Crop Nutrition 2017, 13. https://www.cropnutrition.com/resource-library/oxidation-of-elemental-sulfur-in-soils

Fien Degryse, Roslyn Baird, Rodrigo C. da Silva, Christopher B. Holzapfel, Claudinei Kappes, Monica Tysko and Mike J. McLaughlin. Sulfur Uptake from Fertilizer Fortified with Sulfate and Elemental S in Three Contrasting Climatic Zones. Agronomy 2020, 10, 1035

Degryse, F.; Ajiboye, B.; Baird, R.; da Silva, R.C.; McLaughlin, M.J. Oxidation of elemental sulfur in granular fertilizers depends on the soil-exposed surface area. Soil Sci. Soc. Am. J. 2016a, 80, 294–305.

Degryse, F.; da Silva, R.C.; Baird, R.; McLaughlin, M.J. Effect of cogranulation on oxidation of elemental sulfur: Theoretical model and experimental validation. Soil Sci. Soc. Am. J. 2016b, 80, 1244–1253.



Acknowledgement: Fertilizer Technology Research Centre, University of Adelaide.


**Table 1.** Details of fertilizer type, S rate, and planting date of different crops in three climatic zones. Fertilizer was applied only once in the start of the first year to assess the residual effect of MicroEssentials for two years.

| Site | MicroEssentials (%$SO_4$-S/%ES) | S Rate (kg/ha$^{-1}$) | Crop | Planting Date |
|---|---|---|---|---|
| Argentina | MicroEssentials S10 (5/5) | 20 | Maize | 11 November 2011 |
| | | | Soybean | 20 November 2012 |
| Brazil | MicroEssentials S9 (2/7) | 28 | Soybean | 2 December 2011 |
| | | | Maize | 23 March 2012 |
| | | | Soybean | 27 November 2012 |
| | | | Maize | 5 March 2013 |
| Canada | MicroEssentials S15 (7.5/7.5) | 32 | Canola | 6 June 20112 |
| | | | Wheat | 1 June 2013 |

**Fig 2:** Recovery of S in the plant derived from $SO_4$-S and ES from MicroEssentials for three sites in (A) Argentina, (B) Brazil and (C) Canada. Plants for fertilizer recovery were collected at the harvest.

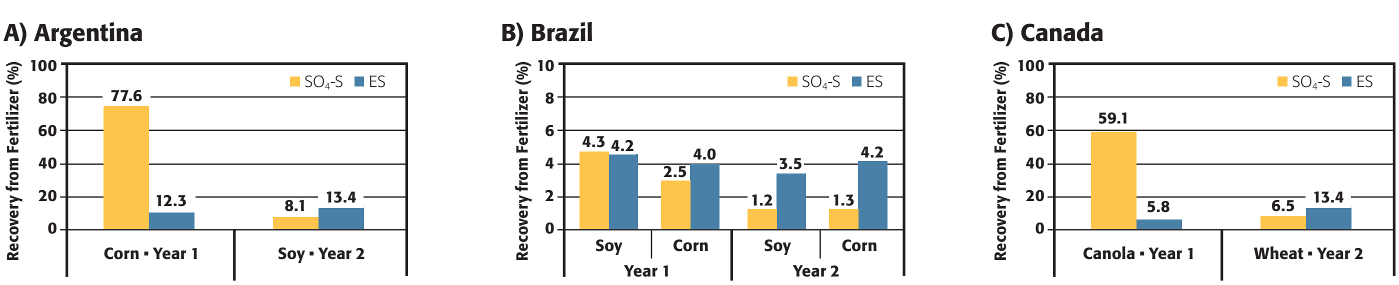
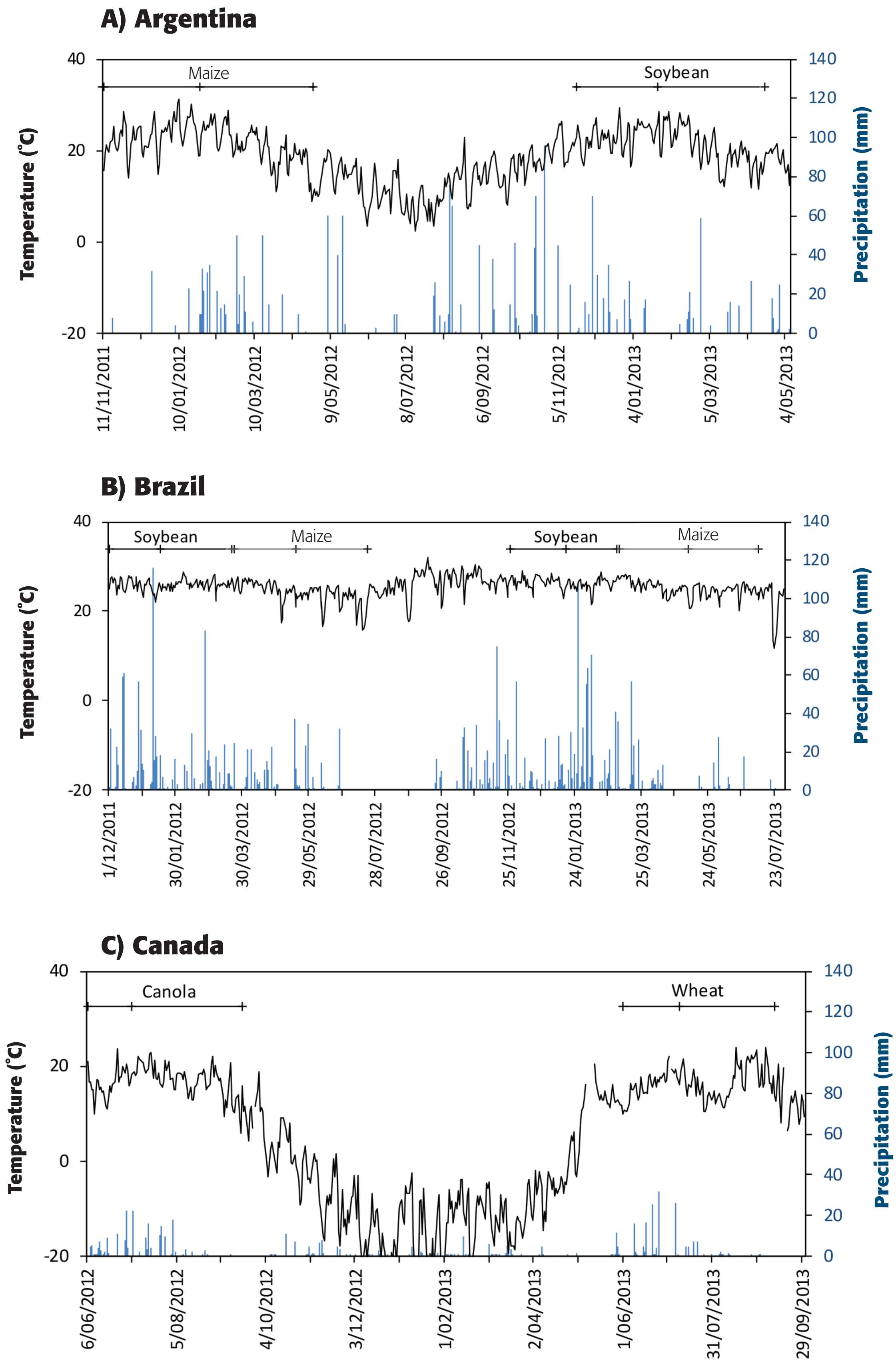


**Fig 3:** Daily average temperature (black) and precipitation (blue) from the start of the experimental period for the sites in (A) Argentina (B) Brazil and (C) Canada. The horizontal lines at the top of the graph indicate the periods of crop growth (planting, early-stage and maturity marked by a vertical line).



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