Sulfur uptake by corn from fall- or spring-applied ^{34}S-labelled fertilizer

Fien Degryse, Rodrigo Coqui da Silva, Roslyn Baird and Mike McLaughlin

Sulfur fertilizers

- Sulfur is an essential major plant nutrient, but has received relatively little attention

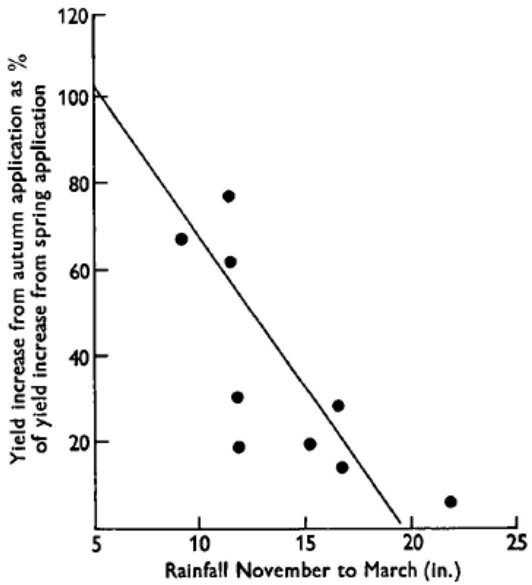
- S deficiency has become more common, because of reduced input (fertilizer, atmospheric) and increased output (yields)

- Inorganic S fertilizers:

Sulfate	Elemental S 
+ Readily available	+ Lower transportation/application cost
- Susceptible to leaching losses	Sustained release
High transport/application cost on a nutrient basis (SO_4^{2-})	- Only available when oxidised

Leaching of SO_4-S

- Solid-liquid partitioning coefficient (K_d) in most soils <0.2 L/kg
  ⇒ little retardation
- 250 mm (10 in) of excess rainfall can leach SO_4-S to a depth of 60 cm (24 in)
  ⇒ high leaching losses of sulfate in high-rainfall environments may occur, particularly with fall-applied fertilizer, e.g.

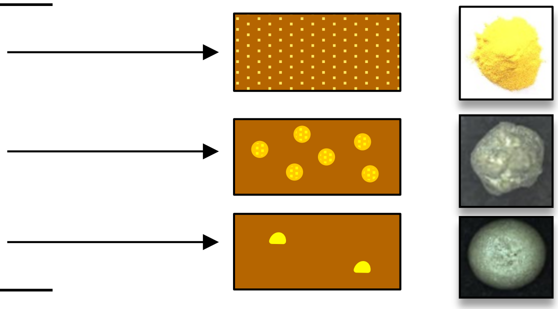


Devine and Holmes, *J. Agric. Sci.* 1964

Oxidation of elemental S

- Oxidation of elemental S depends on:
  - environmental factors, mainly temperature (Q10 around 3.5);
  - soil chemical and biological factors; and
  - fertilizer properties (surface area)
- Oxidation of co-granulated ES is slower than for particulate ES due to reduced surface area, e.g.

Fertiliser	k_{oxid} (d^{-1})	$t_{1/2}$ (days)
Powdered ES	0.02	35
MAP+5%ES	0.006	120
ES pastille	0.0005	1400

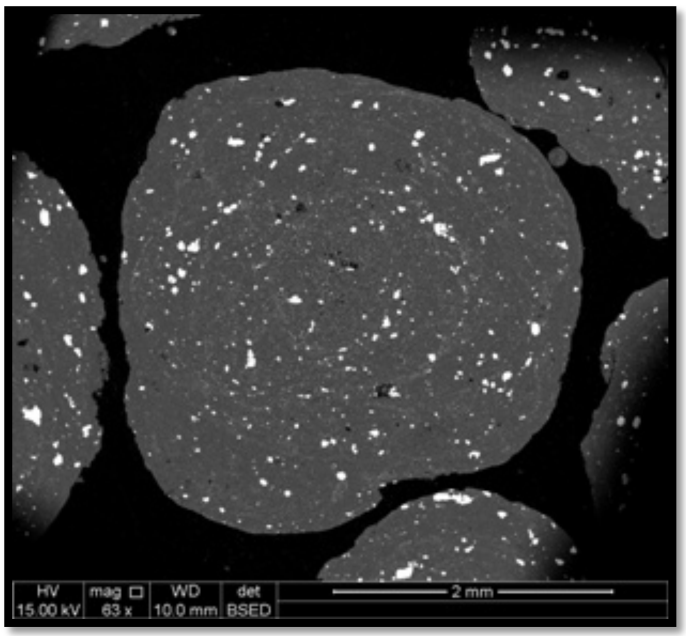


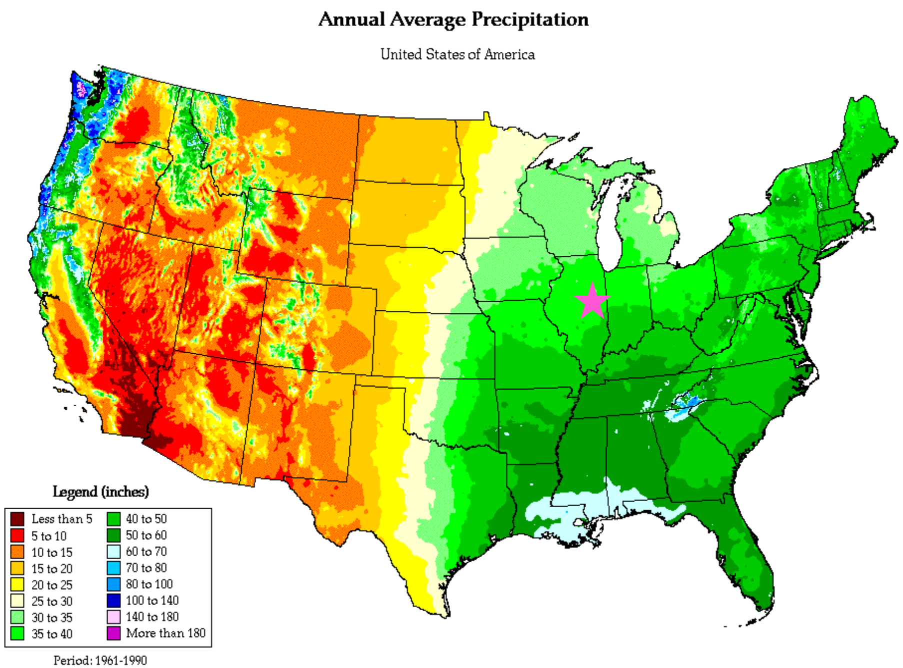
Degryse et al, *under review*;
Similar oxidation rates estimated from pot trial (Degryse et al, Plant Soil 2015)

Aim

Assess contribution of fertilizer SO_4-S and elemental S (ES) in MAP fertilizer (MESZ) to crop uptake in the Corn Belt region when fertilizer is fall or spring applied

MESZ ≡ MAP + **5% ES** + 5 %SO_4-S + 1%Zn



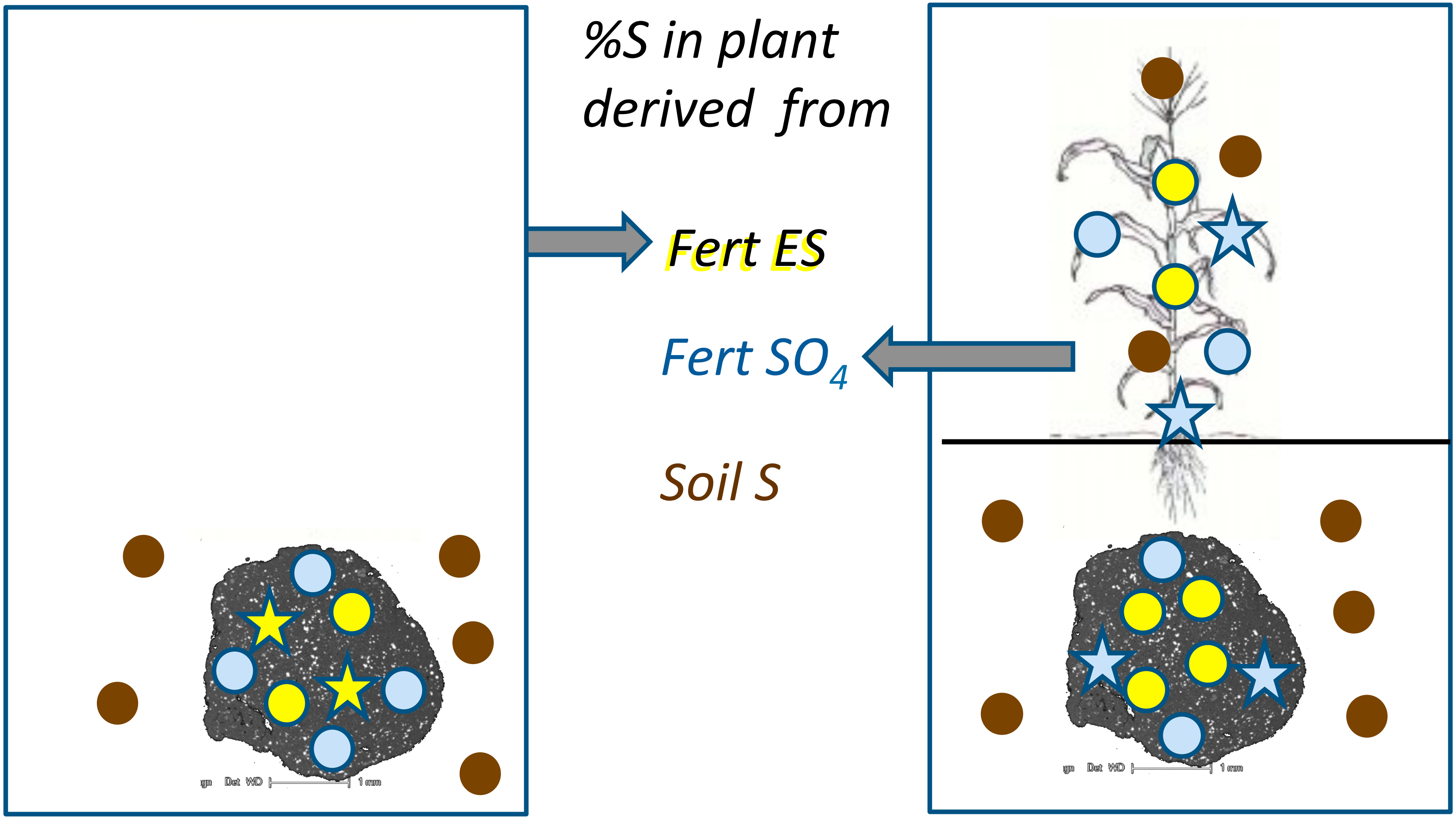


Source: http://www.wrcc.dri.edu/precip.html

^{34}S labelling – principle

ES labelled plots: ^{34}S ☆

SO_4 labelled plots: $^{34}SO_4$ ☆

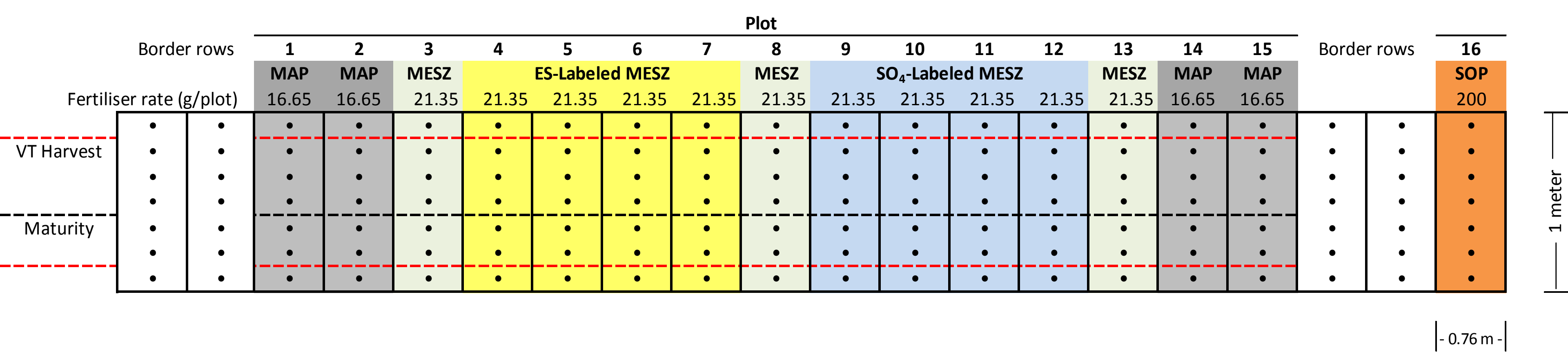


$$\%Sdf(\text{fert ES}) = \frac{\text{atom\%}^{34}\text{Sexcess}_{plant}}{\text{atom\%}^{34}\text{Sexcess}_{fertES}} \times 100$$

$$\%Sdf(\text{fert } SO_4) = \frac{\text{atom\%}^{34}\text{Sexcess}_{plant}}{\text{atom\%}^{34}\text{Sexcess}_{fertSO4}} \times 100$$

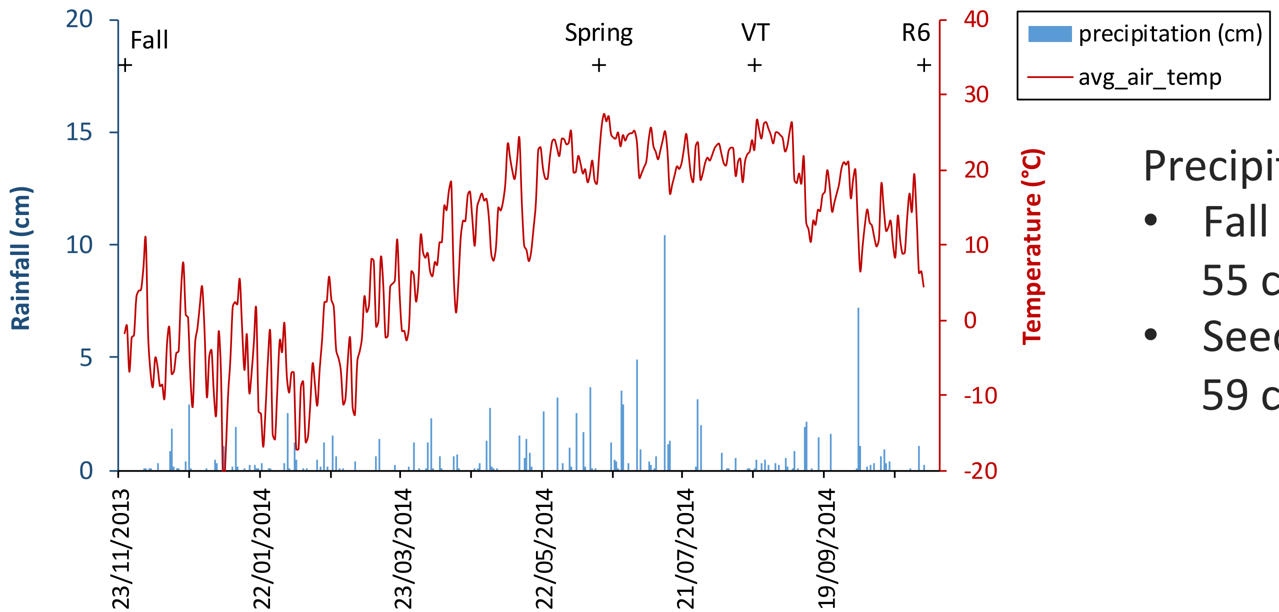
Experimental design and methods

- Champaign (Illinois, US) – humid continental climate
- MESZ applied at 280 kg/ha (=28 kg S/ha) in fall (25 Nov ‘13) or in spring at time of sowing (15 June ‘14);
  SO_4-S or ES labeled with ^{34}S
- Corn manually sown in spring
- Early stage (20 Aug ‘14) and maturity harvest (31 Oct)
- ^{34}S atom% in plant material analysed by IRMS (Isolytix)



Assessing sulfate leaching

- To estimate SO_4-S leaching:
  - plot with sulfate of potash (SOP) at 2630 kg/ha; applied at fall or spring
  - three cores sampled up to 90 cm (36 in) and analysed for SO_4-S (0.01 M $Ca(H_2PO_4)_2$ extraction)
- Weather during experimental period:



Precipitation

- Fall application to seeding 55 cm (21.6 in)
- Seeding to harvest 59 cm (23.3 in)

Yields and S uptake

Stage	Whole plant yield (ton/ha)	S in plant (mg/kg)	S uptake (kg/ha)
VT	11.3	821	9.3
R6	21.4 / 14.4 [a]	745 / 434 [a]	22.6

[a] grain/vegetative biomass

% plant S derived from fertiliser

Spring applied

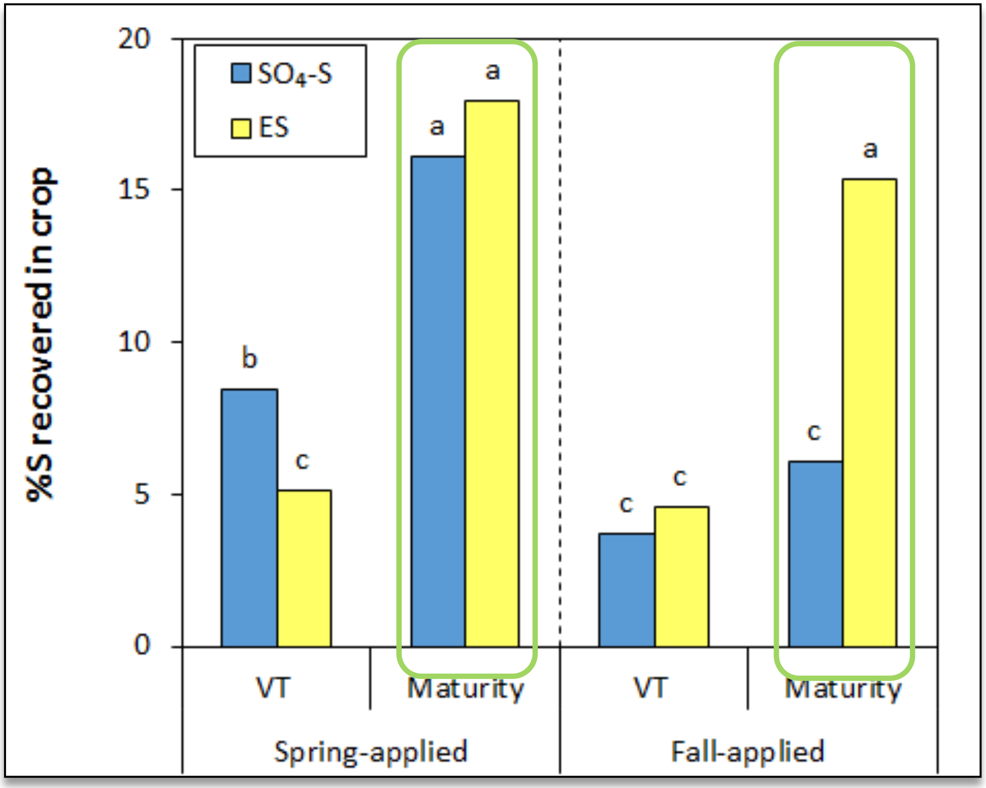
Stage	SO_4-S		ES
VT	13.7	>	8.3
R6	10.6	ns	11.8

Fall applied

Stage	SO_4-S		ES
VT	5.6	ns	6.4
R6	4.1	<	10.4

- Spring applied:
  - lower uptake from ES than SO_4-S at tasseling
  - similar uptake at maturity
- Fall applied:
  - similar uptake at tasseling
  - higher uptake from ES than SO_4-S at maturity

Recovery of fertilizer S in plant

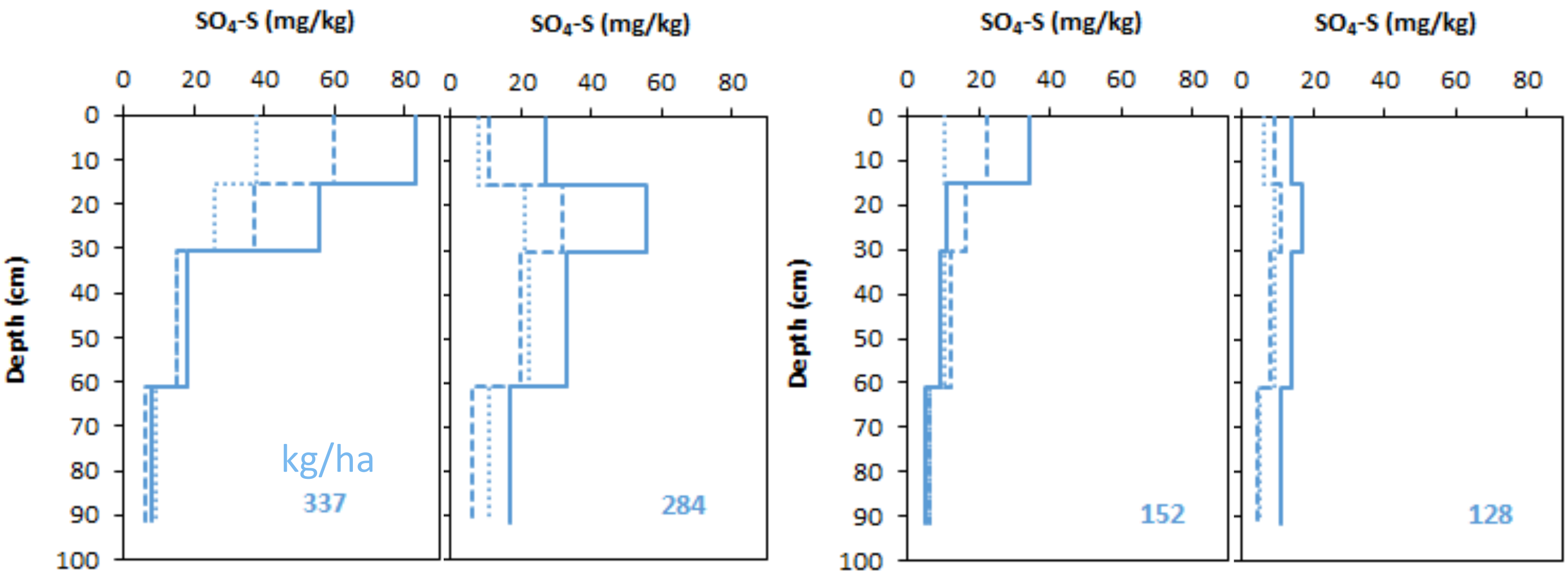


- Spring applied: ca 16% of fertilizer ES and SO_4-S recovered in crop at maturity
- Fall applied: recovery similar to spring-applied for ES but 2.5-fold lower for SO_4-S

Sulfate leaching

Spring applied	
VT	Mat

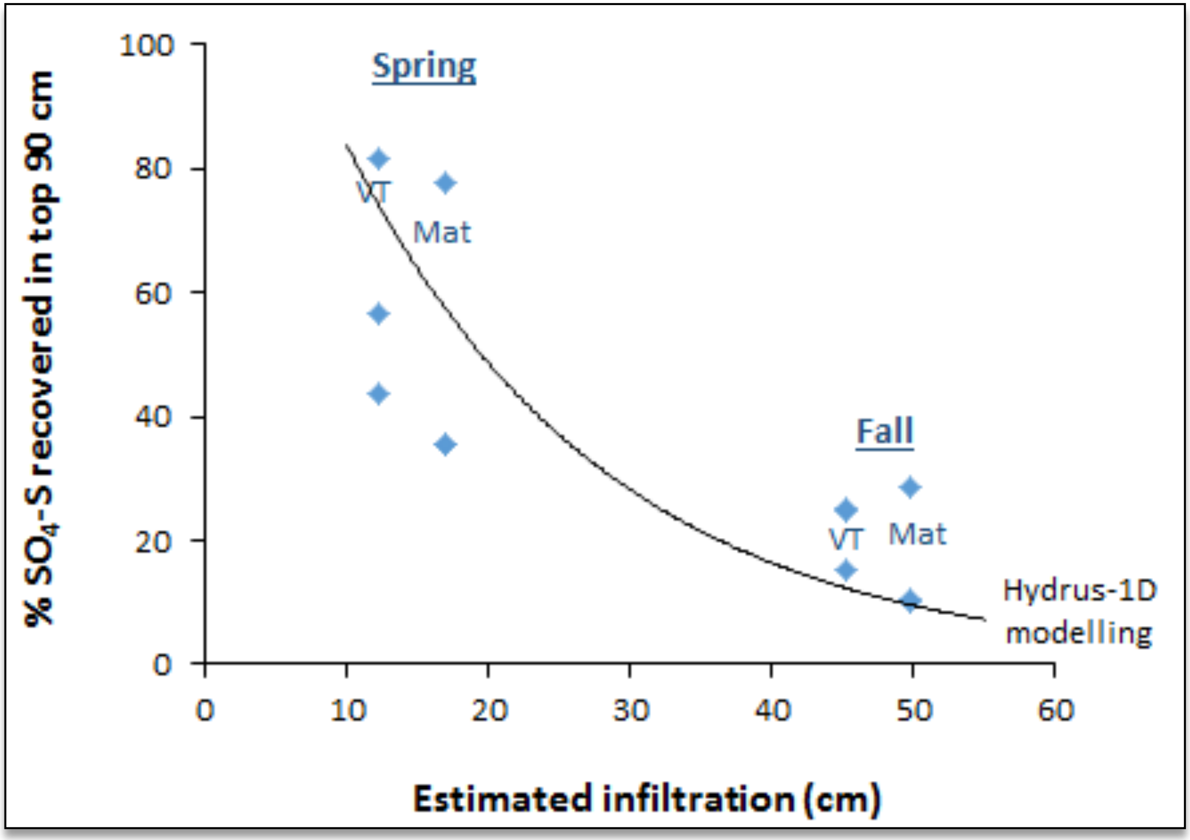
Fall applied	
VT	Mat



Recovery (%)	**61** (43-82)	**49** (35-78)
Precip (cm)	36	59

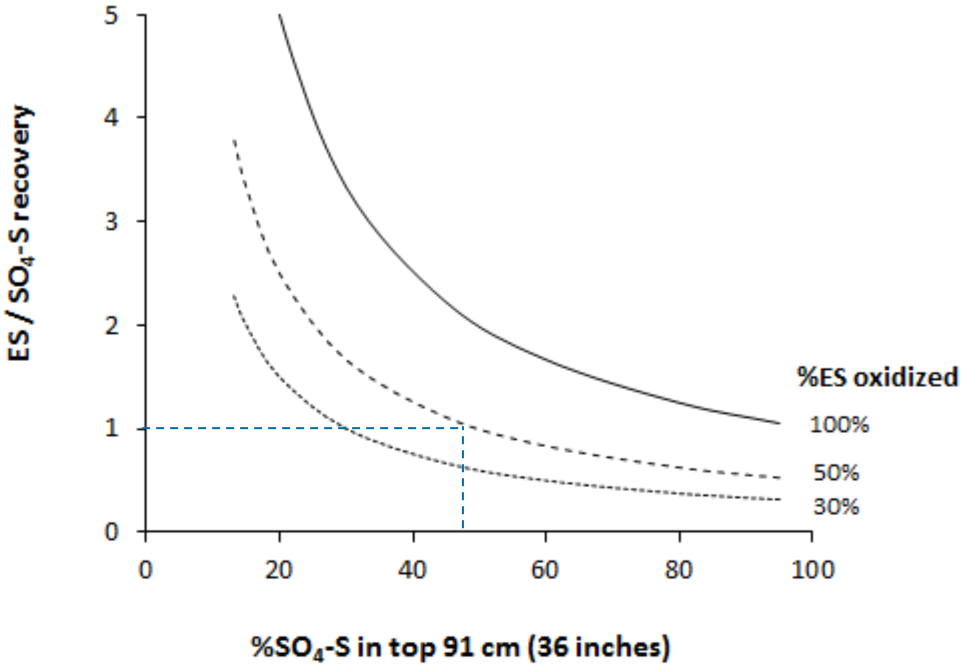
Recovery (%)	**22** (15-25	**16** (10-29)
Precip (cm)	91	114

Sulfate leaching



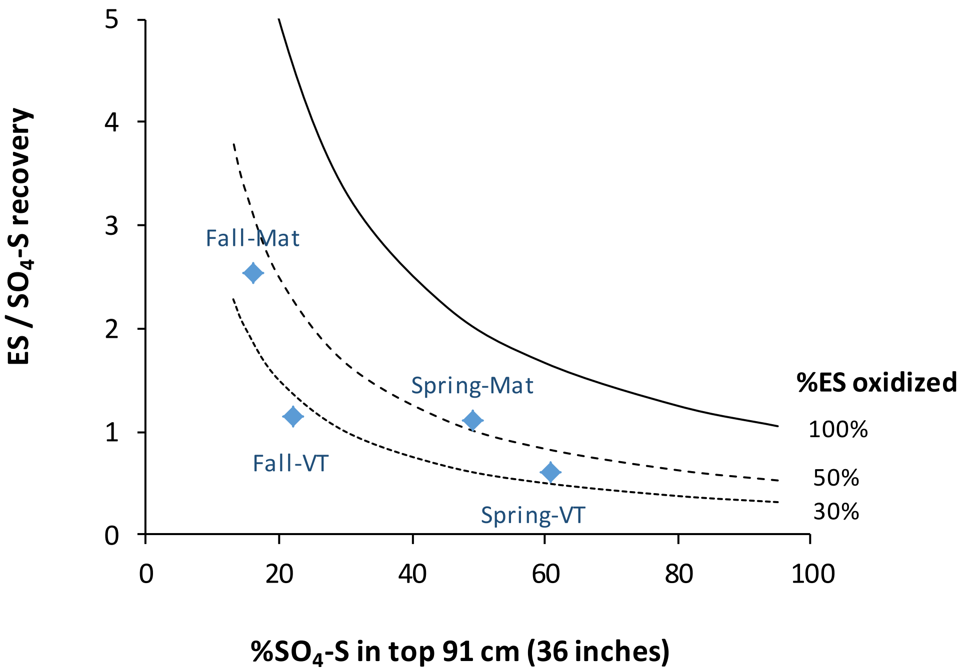
- Leaching can be related to estimated infiltration
  (water use estimated based on Algoazany et al. JEQ 2007; same watershed)
- Leaching in agreement with solute transport predictions (Hydrus-1D)

Sulfate leaching vs S fertilizer recoveries



- ES fully oxidized and no SO_4-S leaching
  ⇒ circa equal recoveries
- ES fully oxidized and 50% SO_4-S leached below root zone
  ⇒ ES/SO_4-S recovery = 2
- ES 50% oxidized and 50% SO_4-S leached below root zone
  ⇒ circa equal recoveries

Sulfate leaching vs S fertilizer recoveries



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- ES 50% oxidized and 50% SO_4-S leached below root zone
  ⇒ circa equal recoveries

⇒ From the recovery of ES relative to SO_4-S and the extent of sulfate leaching, it is estimated that:

- *ca* 30% of ES was oxidized at early stage; and
- *ca* 50% of ES was oxidized at maturity.

Conclusions

- Oxidation of elemental S in one season was estimated to be *ca* 50%
- Spring application of MESZ (5% SO_4-S and 5% ES):
  - About 50% of SO_4-S estimated to be leached below the root zone
  - Similar contribution of fertilizer SO_4-S and ES
- Fall application of MESZ:
  - About 85% of SO_4-S estimated to be leached below the root zone
  - 2.5 times more S in the plant derived from ES than from SO_4-S

➢ Benefit of a slow release S source in high-rainfall environments, especially with fall applications

Acknowledgements

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Thank you for your attention!