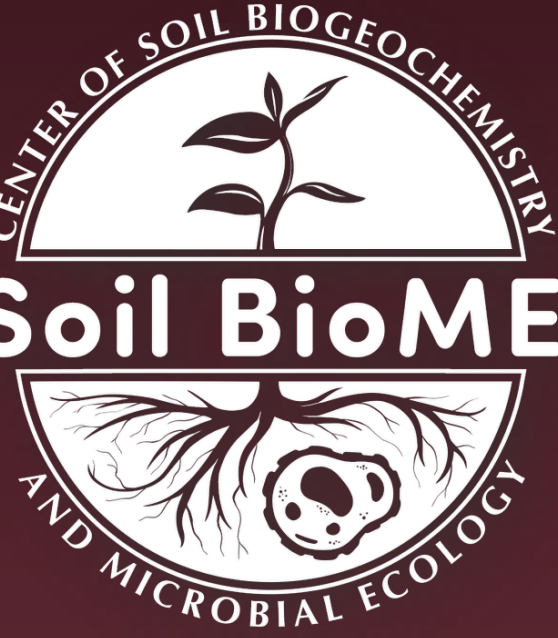


Tracing Nitrogen Fertilizer Journey through Soil: How Microbes and Soil Organic Matter Enhance Nitrogen Use Efficiency?



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Background

- Despite intensive fertilization, 50% of crop nitrogen (N) originates from soil organic matter (SOM) pool
- However, the fraction of SOM-N originating from fertilizers is unknown
- Cycling of fertilizer through MAOM via microbial processing can have implications for fertilizer nitrogen use efficiency (NUE) as it can 'store' fertilizer-N for short-longer terms

Objectives

- Quantify proportion of starter fertilizer-N into different crop and soil pools: whole soils, MAOM, total dissolved N (TDN), microbial biomass N (MBN), roots, and shoots at V3 and V6 stage of corn using ¹⁵N isotope tracing technique
- Determine the effect of fertilizer type, rate, and placement on crop NUE and storage and cycling in these pools
- Determine the effect of crop rotation on the fate of starter fertilizer-N (study 2)

Methods

- Study 1:** Replicated at New Hampshire (NH) and Nebraska (Neb).
- Study 2:** Monoculture corn vs diverse crop rotation history (2021 soybean/2022 sorghum/ 2023 oat-clover/2024 corn) in Neb

Treatment design: Field microplot, RCBD (4 replicates)

Fert, rate, and placement	InF 1x in-row	InF 2x in-row	UAN 1x band	Both 1x	UAN 2x band	Both 2x	Both 3x
kg N applied ha ⁻¹ (field)	5	10	74	79	148	158	220

- "InF" fertilizer ("InFurrow"-commercial fertilizer containing biostimulant; Ag Spectrum, DeWitt, IA, USA) applied in crop row (see fig. 1)
- 28% UAN applied 4" from crop row ("band")
- "Both" (combination of InF and UAN) applied in respective rows

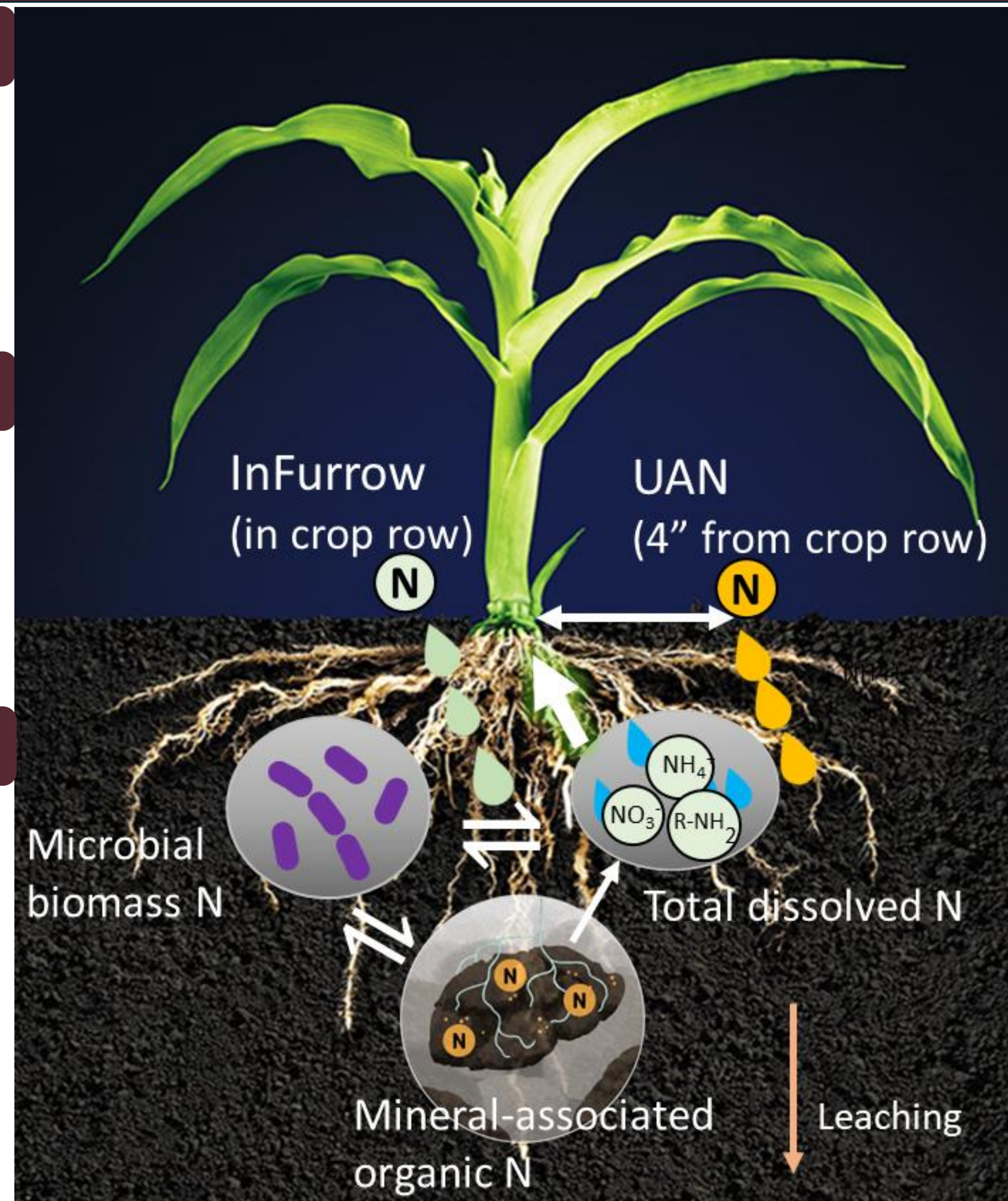


Fig. 1. Starter fertilizer applied at seeding in InF and Band position. Corn plant not to scale. Corn photo from: Jeffrey Marshall

Key findings

1. The majority of shoot N was derived from SOM-N

Regardless of treatment, more than 50% of corn shoot N was derived from SOM at V3, and by V6, increasing fertilizer rate tended to decrease SOM-N utilization

2. Fertilizer N was rapidly stored in mineral-associated organic matter

Within 20 days of fertilizer application in the field, we recovered as much as 37% of fertilizer applied in-row in MAOM

3. Small biostimulating fertilizer applications outperformed large UAN applications

Starter fertilizer (at rates 5, 10 kg N ha⁻¹) had similar or greater recovery in shoots and MAOM than much higher rates of UAN (74, 148 kg N ha⁻¹) fertilizer at the V3 stage

4. Diverse crop rotation history provides an early advantage in corn biomass than monoculture

Regardless of treatment, diverse rotation increased V3, V6 shoot biomass by 1.2 to 2 times

Results and Discussion

Majority of plant N was derived from SOM-N

- By V6, proportionally more N was derived from SOM than fertilizer-N for InF-only treatments
- Adding InF to UAN fertilizer increased shoot N uptake
- 1x were optimal than 2x rates
- A larger proportion originating from SOM-N highlights the need to integrate fertilizer N management with SOM cycling

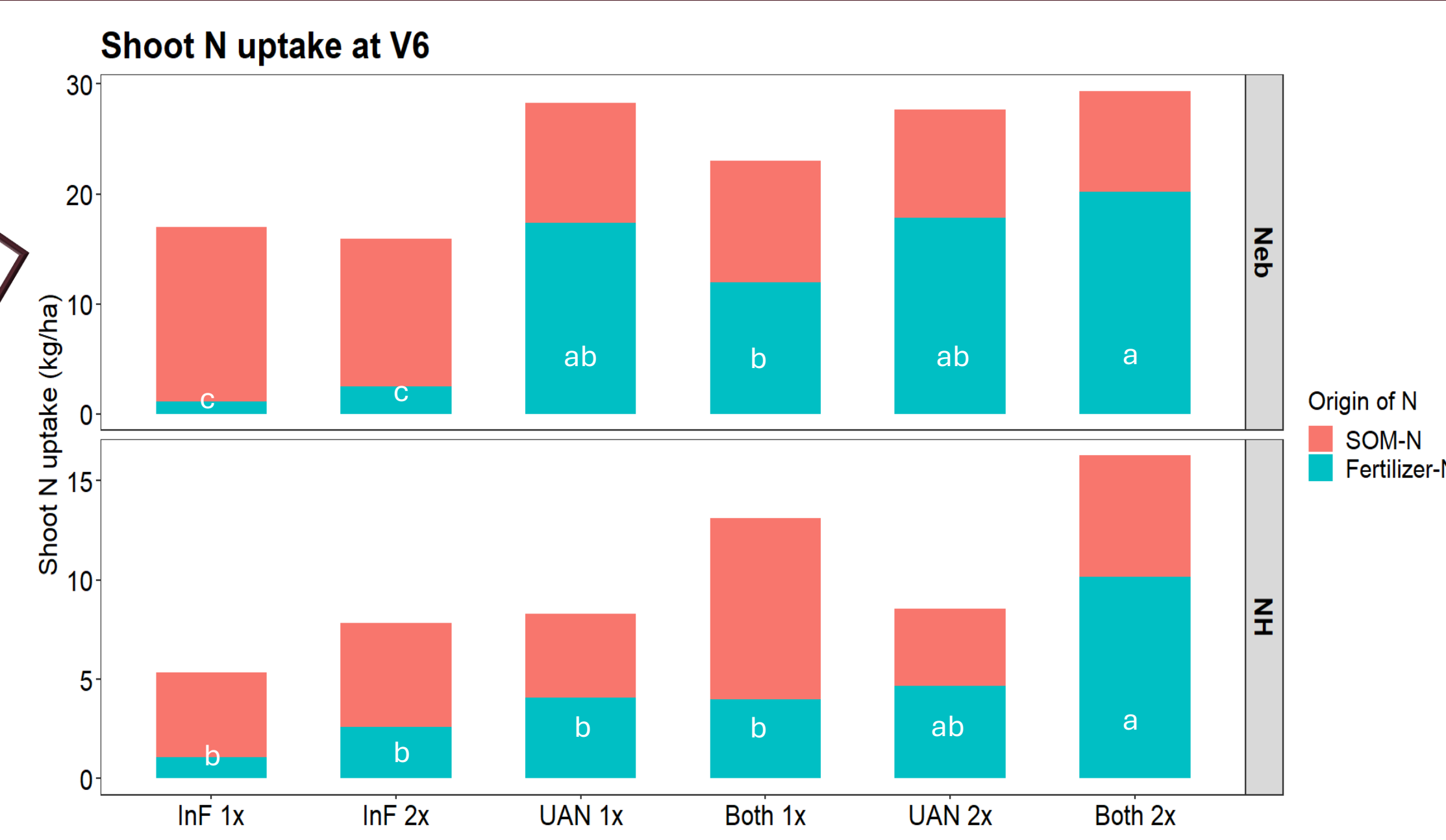


Fig. 2. Shoot N uptake from fertilizer vs SOM-N source at V6 stage. Differences significant at p<0.1

InF fertilizer more efficiently recovered in MAOM, shoots, and roots

- Treatments receiving InF fertilizer had higher N recovery in shoots, roots, and MAOM than UAN
- No difference in V6 shoot biomass regardless of treatments
- Total fertilizer N recovery in MAOM ranged from 0.4% to 37%

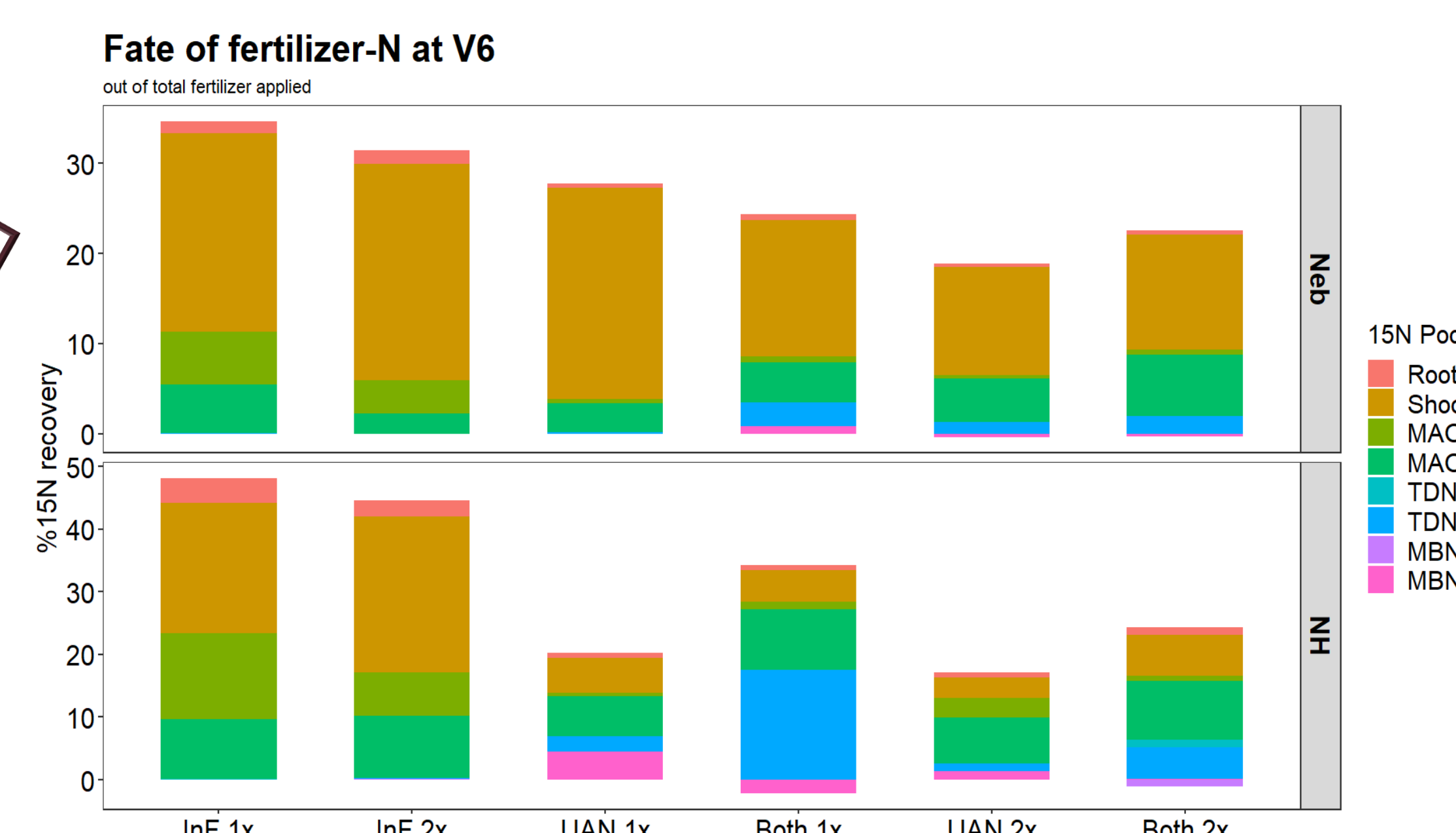


Fig. 4. Average percentage of fertilizer recovered in plant and different soil pools at V6 stage or 38 Days after sowing (DAS)

Shoot N Uptake by Source at V6

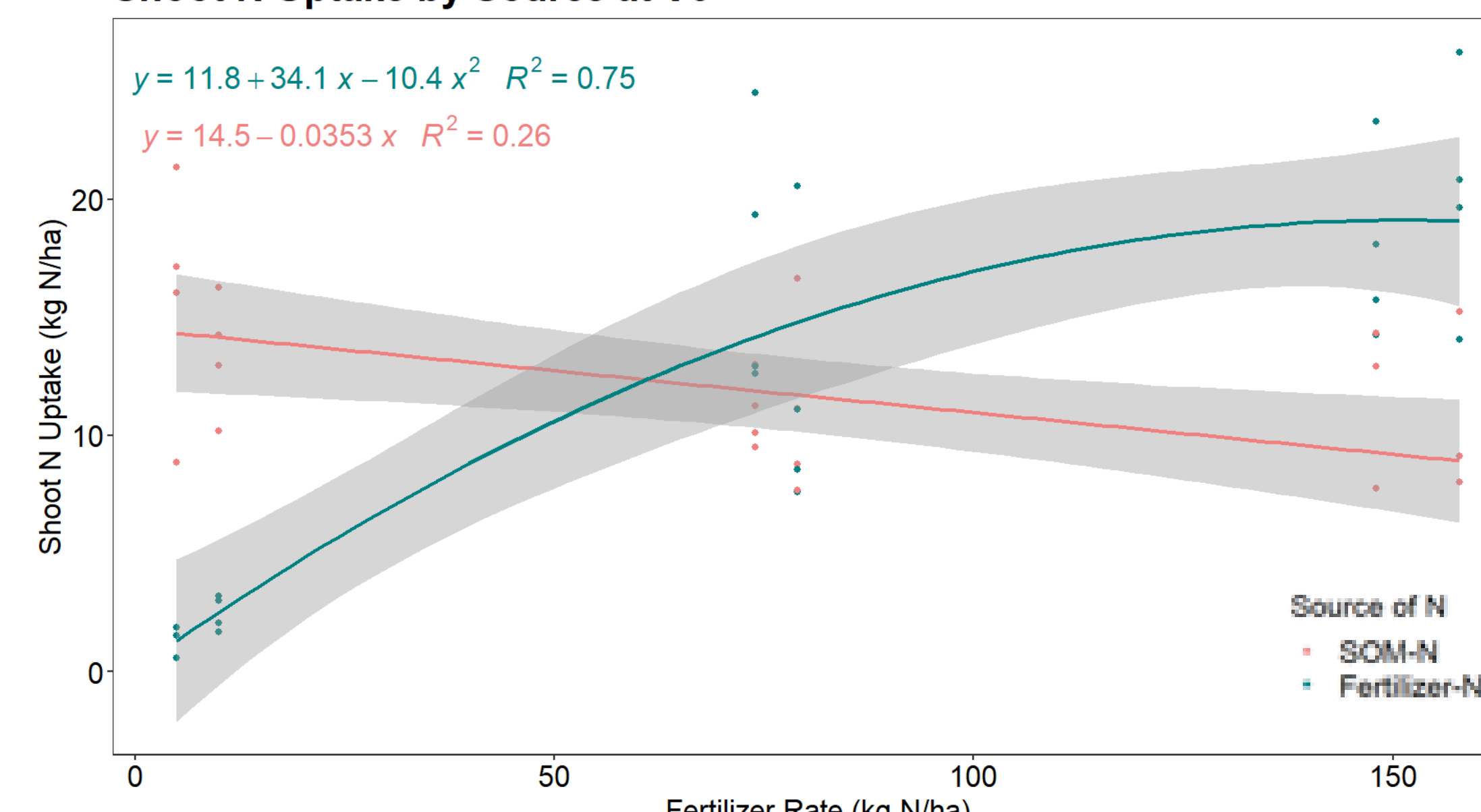


Fig. 3. Regression of shoot N uptake from fertilizer and SOM-N vs application rate in Neb at V6

Table 1. Anova (type 2) and partial eta squared for shoot biomass at V3 and V6 stage of corn in Study 2

	V3		V6	
	Pr(>F)	Partial eta squared (effect size)	Pr(>F)	Partial eta squared (effect size)
Rotation	0.00017	0.451	0.0025	0.31
Treatment	0.00099	0.582	6.57e-07	0.77
Rotation:Treatment	0.495	0.188	0.92	0.071

At V3, crop rotation had more significant effect on shoot biomass but explained less variability than fertilizer treatments at both V3 and V6 stages

Shoot biomass

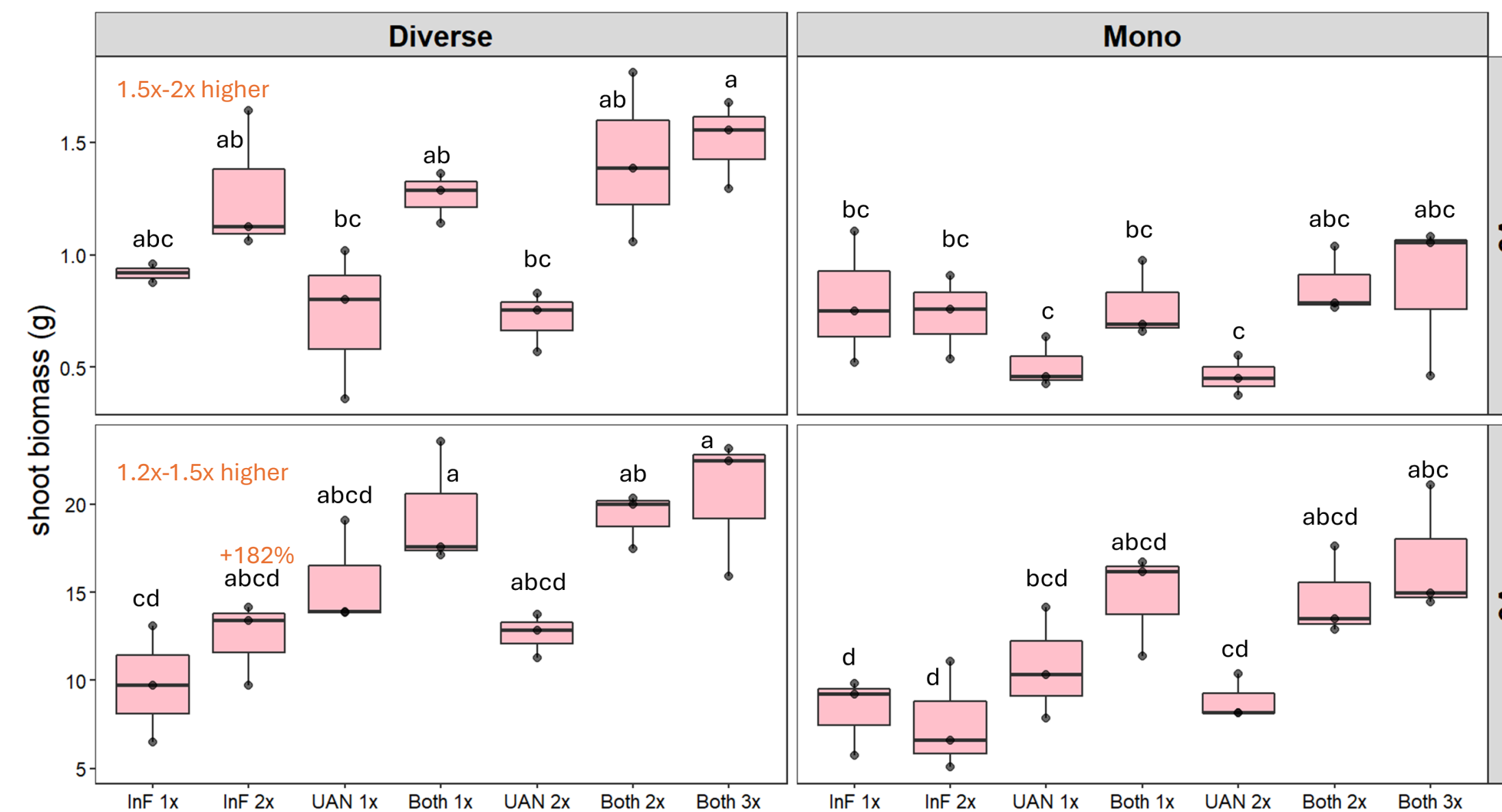


Fig. 4. Shoot biomass in study 2 at V3, or 20 Days after sowing (DAS) and V6 or 38 DAS. Differences significant at p<0.05

Diverse crop rotation increased shoot biomass for all treatments

- No added biomass gain by doubling or tripling fertilizer application rates, suggesting that 1x rates were optimal
- Adding InF fertilizer to UAN increased shoot biomass
- Both 3x produced highest shoot biomass

Methods (contd.)



Fertilizer solutions injected 2 inches deep at planting



SOM size fractionation; <53 μm= MAOM
 Each fertilizer spiked with 10 at% ¹⁵NH₄SO₄

Lab analysis

- Soil cores and plants harvested at V3 and V6 stages of corn
- MBN by chloroform fumigation and extraction
- Equation used:

$$\% \text{ } ^{15}\text{N recovery} = \frac{N_t \times A_s}{Q^{15}\text{N}} \times 100 = \frac{N_s}{N_f} \times 100$$

Where N_t= N content in the pools;
 A_s is the ¹⁵N excess (atom %) of samples;
 Q¹⁵N added is the total amount of ¹⁵N fertilizer added

Table 2. Physicochemical properties of soil at the two sites

Soil properties	Neb	NH
Soil type	Silt loam	Sandy loam
OM%	2.8±0.14	4.8±0.2
MAOM:POM%	85:1	51:49
pH	6.1±0.07	5.7±0.04
Cultivation	No-till	Moldboard plow

Future directions and acknowledgments

In process work: assess ¹⁵N in the pools from crop rotation study
 Next step: determine the stability of newly formed MAOM-N through sequential extractions

Future research should investigate

- the mechanisms driving mobilization of MAOM-N (AMF, enzymes, etc.)
- the efficacy of these pools as both short- and longer-term reserves
- Integrating MAOM-N reserve in fertilizer use recommendations

