Control of Moisture and Rhizosphere in Nutrient Release and Plant Uptake in Two Soil Types of North Dakota using Ion exchange Resin Membrane (PRS® probe)

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Introduction

Nutrient availability in soil depends upon several factors and complex interactions among them. Soil moisture is one of the most important factor in governing plant nutrition by its influence on nutrient movement, solution chemistry and microbial activity (Dunham and Nye, 1976). Available nutrient concentration in soil is generally determined using soil test which is often very poorly correlated because of the rhizosphere effect (Marschner et al. 1987) as well as time and point of sampling. Ion exchange resins buried in soil for a specific period of time may better estimate the nutrient availability in soil as a plant root simulator. The goal of this experiment is to assess how moisture, rhizosphere and time of sampling governs nutrient availability in soil (using ion exchange resin membrane/PRS® probes) and nutrient uptake in plants.

Objective

- Determine the control of soil moisture levels and rhizosphere environment (*Zea mays*) on nutrient availability using the PRS® probes during two growth stages (V3 and V7) in two soils of North Dakota
- Correlate soil availability and plant uptake of nutrients at different soil moisture levels with and without rhizosphere effect.
- Determine the control of soil moisture levels on above ground biomass production and root morphology in two soil types of North Dakota.

Materials and Methods

Preparation and Experiment Design

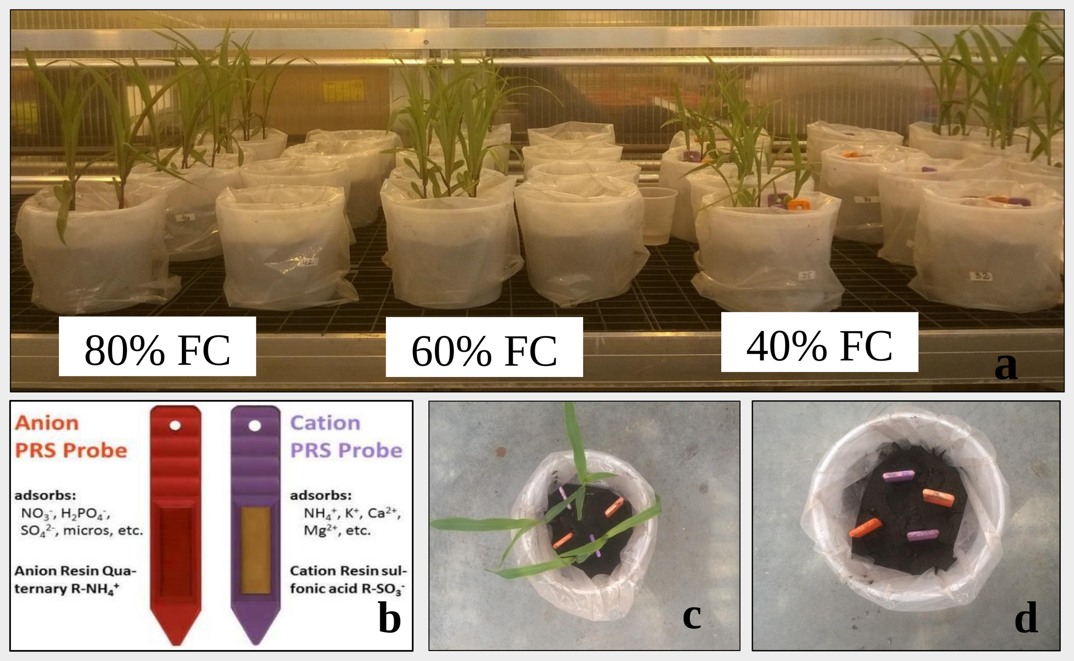
- Surface soil samples (0-30 cm) were collected from **(i)** Inkster series at Inkster, ND (48.16492 N, 97.72025 W) **(ii)** Wyndmere series near Downer, Minnesota (46.843595 N, 96.505495 W).
- Processed (air-dried and 2-mm sieved) soil samples were analyzed for basic soil physical and chemical properties (Table 1).
- Twenty four close bottomed plastic pots were filled with 2 kg processed Inkster soil and another 24 pots were filled with processed Wyndmere soil. Pots were compacted to achieve bulk density of 1.2 g cm^{-3} and supplied with sufficient macro- and micronutrients in water solution. In each soil type each 8 pots were maintained with moisture level of 40%, 60% and 80% FC. Four pots in each moisture level were planted with Corn (*Zea mays*). Moisture levels were checked twice a day using GS1 moisture sensor coupled with Procheck data logger.
- Pots were maintained in a green house at 26°C in a factorial completely randomized design (CRD).

Sampling and Analysis

- Two pairs of fresh anion and cation exchange resin probes (PRS®) were inserted in each pot at a depth of 3 cm at V3 and V7 stage of the corn plant as well as in the pots with similar moisture content and soil without plants. The resin probes were kept buried for 3 days each time and after that collected probes were cleaned thoroughly and sent to the Western Ag Innovations laboratory for complete nutrient analysis.
- Above and below ground plant biomass were recorded at V7 stage and plant samples were analyzed for nutrient uptake.
- Homogenized soil samples of each pot were analyzed for residual N, P, K concentrations.
- Root samples were scanned in EPSON V700 scanner coupled with WinRhizo software.

Statistical Analysis

- ANOVA for factorial CRD (R 3.2.0) to assess the effect of moisture and rhizhosphere on nutrient release, Least significant difference test (R 3.2.0), Correlation analysis (SAS 9.4).



a. Maintenance of pots in greenhouse with different moisture and rhizosphere levels.
b. PRS® probe basics
c. PRS® probes installed at V3 stage with rhizosphere.
d. PRS® probes installed in the pots with same moisture level without rhizosphere.

Table 1: Basic physical and chemical properties of the soil prior to experiment

Site	Soil Series	Textural class	pH	NO_3-N (kg/ha)	P (mg/kg)	K (mg/kg)	S (kg/ha)	OM (%)	Θ_g at FC (g/g)
Inkster	Inkster Sandy loam	Sandy loam	5.8	23.5 L	45 M	352 M	91.8 H	3.0 L	0.18
Sabin	Wyndmere fine sandy loam	Sandy loam	8.1	89.6 H	10 H	83 H	134 H	2.8 L	0.15

H- High, M- Medium, L- Low

References:

1. Dunham, R.J., Nye, P.H. 1976. Influence of soil water content on the uptake of ions by roots. III. Phosphate, potassium, calcium and magnesium uptake and concentration gradients in soil. J. Appl Ecol 13, 967-984.
2. Johnson, D. W., Hungate, B. A., Dijkstra, P., Hymus, G. and Drake, B. 2001. Effects of elevated carbon dioxide on soils in a florida scrub oak ecosystem. J. Environ. Qual. 30, 501–507.
3. Johnson, D.W., Dijikstra, F.A., Cheng, W. 2007. The effects of Glycine max and Helianthus annus on nutrient availability in two soils. Soil. Biol. Biochem. 39, 2160-2163.
4. Marschner, H., Römheld, V., Cakmak, I. 1987. Root-induced changes of nutrient availability in the rhizosphere. J. Plant Nutr. 10, 9-16.
5. Smith, J. H. 1964. Relationship between soil cation exchange capacity and the toxicity of ammonia to the nitrification process. Soil Sci. Soc. Amer. Proc. 28, 640-644.

Results

Table 2: Pearson Correlation between available nutrient (PRS®) probe) with rhizosphere in two growth stages and nutrient uptake after V7 stage

PRS_N (µg/10cm²/3days)	Total N Uptake (g)	Plant N Uptake (g)	Root N Uptake (g)
V3	0.56 **	0.46 *	0.44 *
V7	NS	NS	NS
PRS_P (µg/10cm²/3days)	**Total P Uptake (g)**	**Plant P Uptake (g)**	**Root P Uptake (g)**
V3	0.68 ***	0.68 ***	NS
V7	0.57 **	0.58 **	NS
PRS_K (µg/10cm²/3days)	**Total K Uptake (g)**	**Plant K Uptake (g)**	**Root K Uptake (g)**
V3	0.81 ***	0.89 ***	NS
V7	0.87 ***	0.93 ***	NS
PRS_S (µg/10cm²/3days)	**Total S Uptake (g)**	**Plant S Uptake (g)**	**Root S Uptake (g)**
V3	NS	0.46 *	NS
V7	NS	NS	NS

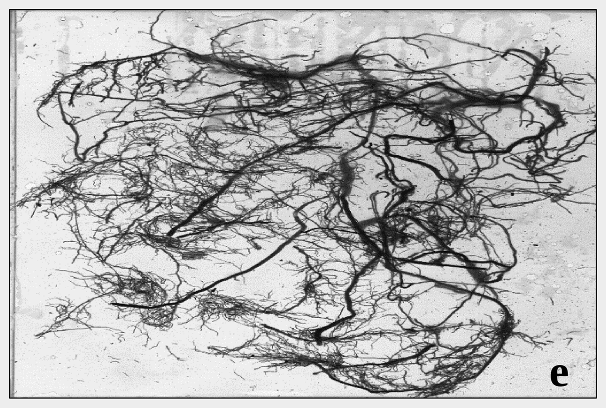
Table 3: ANOVA results for effect of moisture and rhizosphere on available nutrient estimated by ion exchange resins (PRS®) (µg/10cm²/3days)

Growth Stages	V3				V7			
Mineral Nutrient	N	P	K	S	N	P	K	S
Source of Variation	Inkster							
Moisture	*	NS	NS	NS	NS	NS	NS	NS
Rhizosphere	NS	NS	NS	NS	***	***	***	NS
Moisture× Rhizosphere	**	NS	NS	NS	NS	NS	NS	NS
	Wyndmere							
Moisture	*	NS	NS	NS	NS	NS	NS	NS
Rhizosphere	*	NS	NS	NS	***	*	NS	***
Moisture× Rhizosphere	NS	NS	NS	NS	NS	NS	NS	*

Table 4: ANOVA results for Effect of Moisture and Soil on plant biomass and root morphology

Source of Variation	Root Volume (cm^3)	Root Diameter (cm)	Plant dry Biomass (g)
Soil	***	***	***
Moisture	***	*	***
Soil* Moisture	NS	NS	*

*** ($p < 0.001$), ** ($p < 0.01$), * ($p < 0.05$)



e. Root scan image in EPSON V700 root scanner

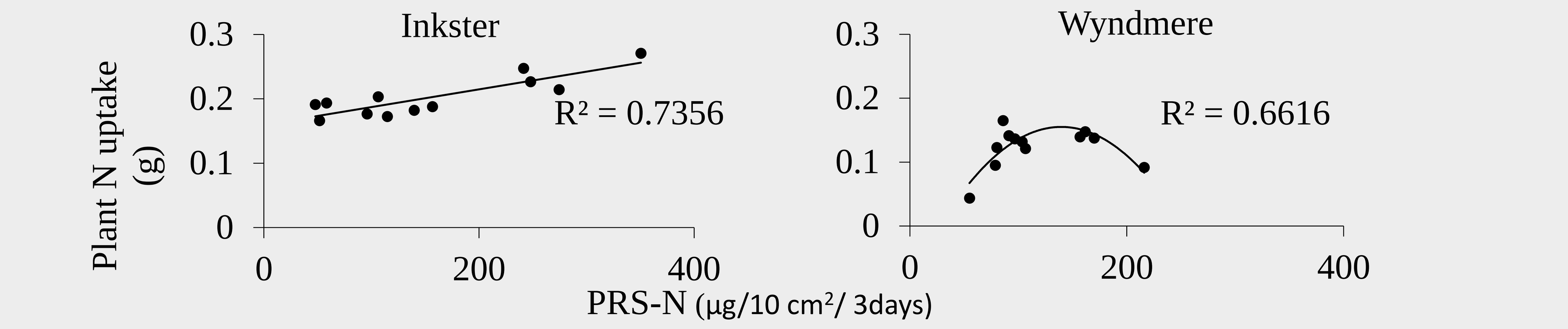


Fig 1. Relationship between available N (PRS®) at V3 stage and plant uptake after V7 stage in two soils

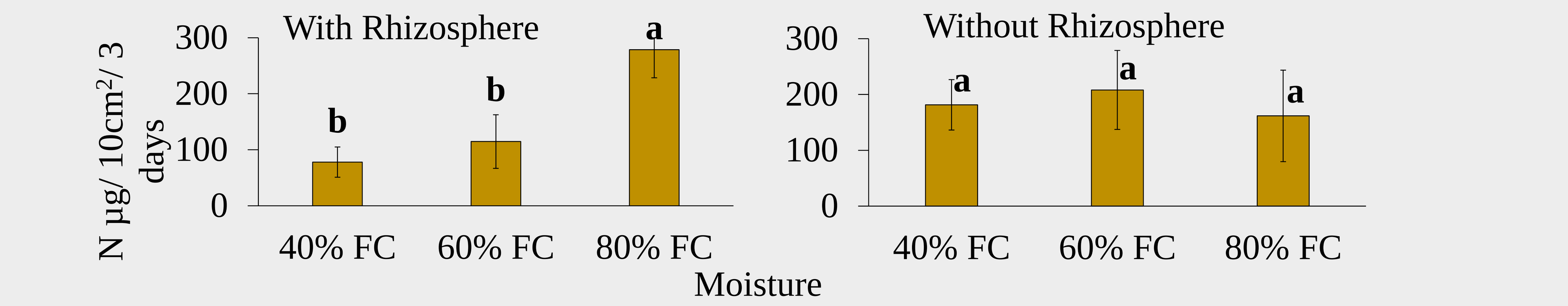


Fig 2. Moisture and rhizosphere interaction effect on available N (PRS®) in Inkster soil at V3 stage

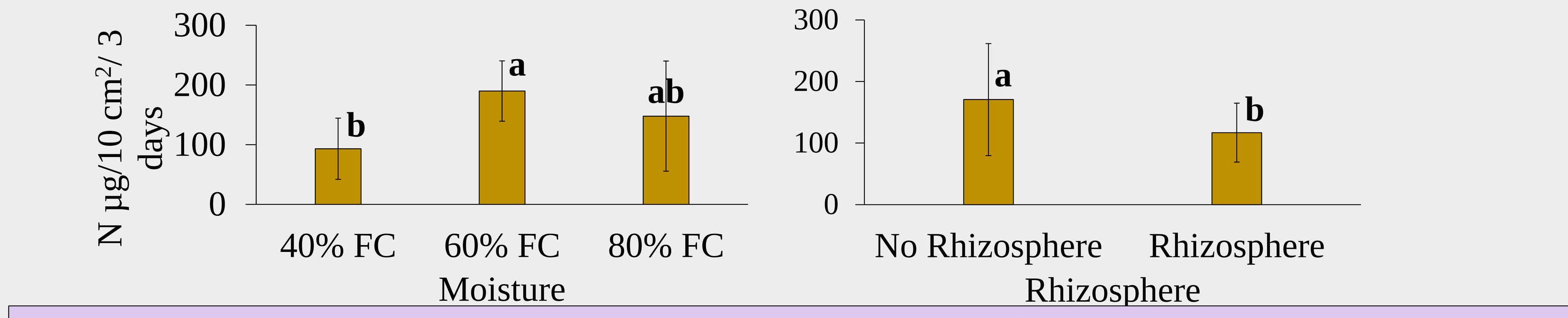


Fig 3. Control of moisture and rhizosphere levels on available N (PRS® probe) in Wyndmere soil at V3 stage

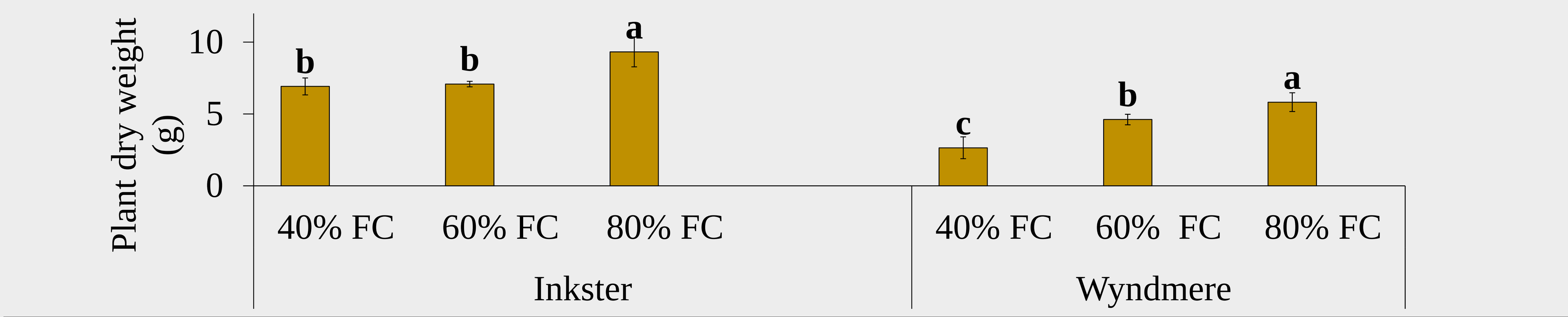


Fig 4. Moisture and soil interaction effects on plant biomass (g) at V7 stage

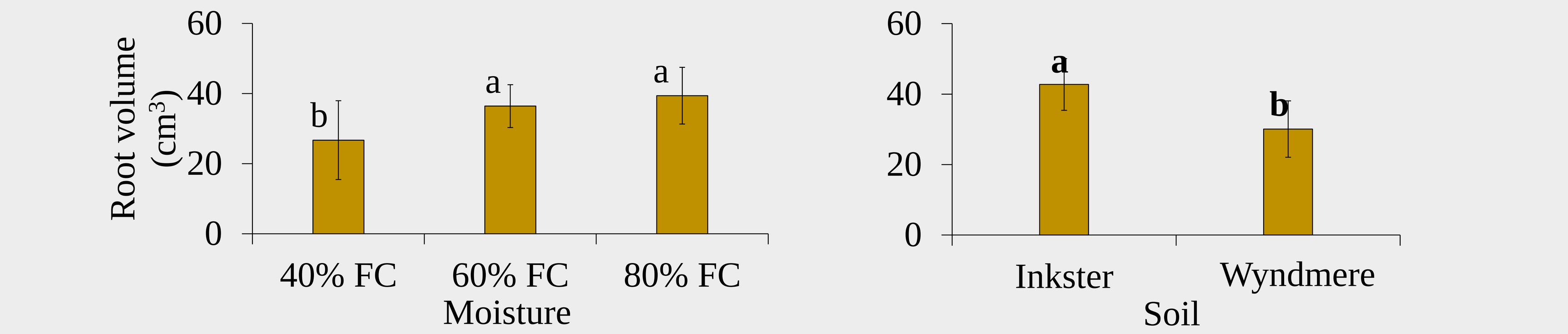


Fig 5. Influence of moisture levels and soil types on root volume (cm^3) at V7 stage

Table 5: Onset of growth stages days after planting (DAP) at different moisture contents in both soils.

Soil	V3			V7		
	40% FC	60% FC	80%FC	40% FC	60% FC	80%FC
Inkster	25	22	19	66	42	34
Wyndmere	25	19	19	66	48	43

Discussion

- Onset of growth stages were rapid with higher moisture contents compared to lower moisture contents (evident from Table 5. and Picture a.).
- Plant nutrient uptake was better correlated with available nutrient (PRS® probe) in the presence of rhizosphere compared to available nutrient in absence of rhizosphere (data not shown) as rhizosphere significantly moderates different nutrient availability differently, depending upon moisture content and soil type.
- Total N uptake was better correlated with available N (PRS® probe) at V3 stage. No correlation observed between PRS-N and plant uptake at V7 stage is because of the negative effect of plant uptake of mineral N (Johnson et al., 2007).
- Poor correlation with available S and plant uptake was possibly due to excess amount of adsorbed S pool in equilibrium with soil solution S.
- The difference in PRS-N availability and plant uptake relationship in two different soils proves the great variability in soil behavior. As the texture and organic carbon of two soils were almost similar, the difference in initial available N, amount of applied fertilizer and pH might have influenced the N availability and uptake pattern in two different soils.
- In Inkster soil with rhizosphere, a decrease in soil N availability compared to soil without rhizosphere was observed at 40% and 60% FC. This decrease either due to plant uptake or due to increased soil CO_2 or root respiration leading to N immobilization to labile organic C (Johnson et al., 2001). However, moisture content in general gradually increased the soil N availability in Inkster soil due increased nitrification and lower NH_4^+ adsorption (Smith, 1964). At 80% FC the negative effect of plant uptake or elevated CO_2 level on N availability was masked by increased N mineralization due to favorable soil moisture for N mineralization
- In Wyndmere soil the decrease in N availability due to rhizosphere effect was either due to plant uptake or negative effect of elevated CO_2 similar to that of Inkster soil.
- The decrease in N availability or the variability (SD) in N availability at 80% FC in Wyndmere soil was possibly due to inhibition of nitrification because of poor aeration as some pots in this treatment lacked sunlight comparatively to others
- Increase in soil moisture increased plant dry biomass and root volume due to increased nutrient availability and metabolism. Inkster soil facilitated better root development and plant growth compared to Wyndmere soil. Web soil survey crop productivity indices also shows that Inkster soil is more productive (rating 73) than Wyndmere soil (rating 66).

Conclusion

- PRS® technology provides reliable prediction of plant nutrient uptake from soil nutrient availability. Time of sampling with PRS® probe should be during early growth stage (V3).
- Moisture content equivalent to 80% FC was most beneficial regarding N availability, plant N uptake and plant growth in both soils.
- Sampling near rhizosphere zone or within-row sampling for nutrient availability should be preferred for better prediction of plant nutrient uptake.