



Factors Affecting Soil Nutrient Supply Rate Measurements with PRS™-Probes.

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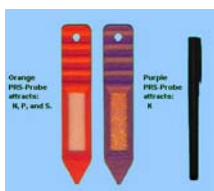
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WHAT IS A PRS™-PROBE?

Plant Root Simulator (PRS™) probes are comprised of an anion or cation exchange resin membrane encapsulated in a plastic holding device.

A high concentration of ion adsorption sites on the resin surface allows the PRS™ membrane to act as an ion sink when buried in soil, similar to a plant root surface.



The PRS™ assesses nutrient supply rates by continuously adsorbing charged ionic species from the soil over the burial period.

Measures soil ion supply rates *in situ* under conditions similar to those in which plant roots grow and absorb nutrients.

Integrates all of the factors that affect nutrient uptake by plants (free ion activities, buffer capacity, mineralization, immobilization, temperature, moisture, crop uptake, diffusion etc.).

WHAT ARE PRS™ ION SUPPLY RATES?

Amount of ion adsorbed per unit surface area per time: $\mu\text{g}/10\text{cm}^2/\text{duration of burial}$

Flux of ions adsorbed from both the soil labile ion pool as well as ions replenished by more slowly supplying pools.

Function of the size of soil ion pools and soil physical, chemical and biological conditions. Therefore all factors of the soil environment must be considered when interpreting PRS™ supply rate data.

Table 1. Relationship between PRS™ supply rates, soil ion concentrations determined by conventional chemical extraction, and plant ion uptake.

Chemical species	PRS™ type	Correlation (R ²) with		References
		Conventional Extraction Method	Plant Uptake	
Nitrate	Anion	0.69	0.86	Qian & Schoenau, 1995
Phosphate	Anion	0.57	0.71	Schoenau et al., 1993
Sulfate	Anion	0.73	0.98	Greer & Schoenau, 1994
Borate	Anion	0.79	NA	Greer & Schoenau, 1994
Chloride	Anion	0.81	NA	Greer & Schoenau, 1994
Potassium	Cation	0.87	0.68	Qian et al., 1996
SAR	Cation	0.95	NA	Greer & Schoenau, 1996
Sodium	Cation	0.86	NA	-
Calcium	Cation	0.68	NA	-
Magnesium	Cation	0.68	NA	-
Ammonium	Cation	NA	NA	-
Chromium	DTPA-Anion	0.58	0.99	Tejwulan et al., 1994
Manganese	DTPA-Anion	0.50	0.68	Tejwulan et al., 1994
Iron	DTPA-Anion	0.61	0.71	Liang & Schoenau, 1995
Nickel	DTPA-Anion	1.00	1.00	Liang & Schoenau, 1995
Copper	DTPA-Anion	0.78	0.75	Tejwulan et al., 1994
Zinc	DTPA-Anion	0.83	0.74	Tejwulan et al., 1994
Cadmium	DTPA-Anion	0.98	0.98	Liang & Schoenau, 1995
Lead	DTPA-Anion	0.97	0.98	Liang & Schoenau, 1995
2,4-D amine	Anion	0.98	NA	Szmigielka & Schoenau, 1994
Metsulfuron	Anion	NA	0.98	Szmigielka et al., 1998
Glucosinolates	Anion	0.98	NA	Szmigielka et al., 2000

WHAT FACTORS INFLUENCE PRS™ NUTRIENT SUPPLY RATES?

DURATION OF BURIAL IN SOIL

The longer a PRS™-probe is buried in the soil, the greater its opportunity to absorb ions, the higher the ion supply rates measured.

The effect of different burial times on nutrient supply rates measured in three soils is shown in Table 2. Supply rates of all nutrients are visibly higher after the 24 vs. 1 hour burials.

Table 2. PRS™ nutrient supplies determined during two burial times in three soils under controlled environmental conditions.

Soil	Burial Time	$\mu\text{g cm}^{-2} \text{ burial time}^{-1}$			
		NO ₃ -N	PO ₄ -P	K	SO ₄ -S
1	1hr	21	0.7	36	4
	24hr	143	1.6	72	16
2	1hr	5	0.1	18	10
	24hr	84	0.2	28	107
3	1hr	6	0.1	21	2
	24hr	22	0.2	31	5

Schoenau et al., 1993

Supply rates would be even higher following a 2 week burial of the PRS™, particularly for ions released through mineralization processes such as N and S.

PRS™-probes should be buried for equivalent time periods among treatments to be compared. Supply rates can not be divided into smaller time units as adsorption may not be linear over time. However, repeated measures in the same soil slot over time can be added together to achieve cumulative supplies (i.e. over the growing season as in Table 3).

"Snapshots" of soil nutrient supplying power are obtained by 1 - 24 hour burial of PRS™-probes, while 1 - 4 week burials are used to measure mineralization or release of soil ions over time.

SOIL TEMPERATURE

Microbial activity is reduced at low soil temperatures, resulting in less organic matter mineralization and lower supply rates of mineralizable ions such as N and S. This is visible in Table 4 in which microbial respiration progressively increases as soil temperature increases. At the same time, N supply rates measured by PRS™-probes also increase.

Although differences may be greater following long duration burials, even during short-term burials (Table 5) there is an effect of temperature on ion movement to the PRS™. This is a function of both microbial activity as well as the physical movement of ions through the soil. At reduced temperatures, ion diffusion decreases and therefore lower supply rates of diffusion limited ions such as PO₄ are measured by the PRS™-probes.

Table 4. Microbial activity and nutrient supplies in triplicate samples of a loamy sand soil (O.M.= 1.8%) incubated for one week at three soil temperatures. (Unpublished data, P>F= 0.02)

Soil temperature (°C)	Nutrient Supply Rate ($\mu\text{g } 10\text{cm}^{-2} \text{ week}^{-1}$)		Cumulative Respiration $\mu\text{g CO}_2\text{-C kg}^{-1} \text{ O.D. soil}$
	N supply rate	P supply rate	
5	62	2.2	37 a
23	90	2.1	189 b
32	300	2.4	337 c

COMPETING SINKS

Organisms in the soil environment, including microorganisms and plant roots, will compete with the PRS™-probes for ions.

The impact of plant root competition on soil nutrient supplies measured over a growing season is shown in Table 3.

Table 3. Impact of plant roots on cumulative NO₃-N ion adsorption by PRS™-probes buried in different pasture systems biweekly (12 times) over a growing season at Lacombe, Alberta, 1999.

Pasture Type	No Roots			Roots			N Uptake			
	$\mu\text{g NO}_3\text{-N } 10\text{cm}^{-2} \text{ 24week}^{-1}$			$\mu\text{g cm}^{-2} \text{ 24week}^{-1}$			kg ha^{-1}			
Old Perennial	1713	237	140	2686	1328	330	2446	895	320	
Alfalfa	2446	895	320	2955	2007	200	1349	262	140	
Mixed Brome/Alfalfa	2955	2007	200	1349	262	140	Significant F	**	**	*
Annual Rye Grass	**	**	*	SE LSM	185	165	40			

Dr. V.S. Baron, unpublished data



Figure 1. Root exclusion cylinder consisting of a PVC pipe inserted to a 10' depth from which plants were removed to isolate the PRS™ from plant root competition.

NO₃-N supplies were much lower in the presence of roots than where the PRS™ were buried inside of "root exclusion cylinders" (Fig. 1). By burying PRS™ both inside and outside of the cylinders, a more complete picture of the soil NO₃-N dynamics were obtained.

SOIL MOISTURE

Soil moisture content has a large influence on physical movement, biological uptake and chemical reaction of ions in the soil which in turn influence ion supplies to plant roots.

An example of how moisture affects PRS™ nutrient supply rates is provided in Table 6 in which PRS™-probes were buried in soil incubated at 5 moisture contents (values represent means of 3 replicates).

Table 6. Influence of soil moisture content on PRS™ soil nutrient supply rates.

Soil Moisture Content	PRS™ soil nutrient supply rate ($\mu\text{g } 10\text{cm}^{-2} \text{ hour}^{-1}$)			
	N	P	K	S
Saturated	282	4.5	218	50
100% F.C.	200	2.7	181	39
70% F.C.	196	1.4	155	37
45% F.C.	113	0.9	93	26
15% F.C.	24	0.3	48	12

Schoenau et al., 1993

At lower soil moisture contents, lower supply rates are measured as microbial activity (and therefore mineralization) is limited and physical ion movement is restricted by greater tortuosity in the path the ions must travel to reach the PRS™ membrane.

Microbial activity may also be limited in very wet soils due to anaerobic soil conditions and N supply rates may be reduced in saturated soils as a result of denitrification.

CONCLUSIONS

The sensitivity of PRS™-probes to soil environmental conditions makes them a powerful tool for measuring soil nutrient supplies under field conditions similar to those in which plants grow.

This sensitivity also means that care must be taken in planning experiments with the PRS™ and when interpreting PRS™ supply rate data. If possible, it is recommended that soil moisture and temperature be measured for the duration of PRS™ burial and that plant root competition be accounted for.

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