Interpreting potential plant availabitily of N based on soil supply indicies

K.J. Greer[1], J.J. Schoenau' and CA. Campbell'
'Saskatchewan Centre for Soil Research, Saskatoon, Sk.
[2]Agriculture and Agrifood Canada Research Station, Swift Current, Sk.

Introduction:

Soil supply of nitrogen is the most intensively studied of all nutrient cycles. Prior to the widespread use of fertilizers, economically viable agriculture was dependent solely on the soils ability to supply N. From 1945 to 1970, relatively cheap and abundant N fertilizer forced the issue of soil N supply to the background. More recently, however, concern about environmental degradation caused by overuse of fertilizer and manure has renewed interest in predicting the soil supply of N.

A Canada-Saskatchewan Greenplan study was undertaken to screen some promising methods of assessing soil N supply. This paper describes the methods and evaluates their performance as compared to plant uptake in the growth chamber. We also discuss the ability of these indices to improve our predictions of optimal N fertilizer requirements.

Materials and Methods:

A total of 44 field soils were sampled in the fall of 1994 and 1995. These fields differed in organic matter, texture and management histories. Twenty six soils from the research plots at Swift Current and Melfort Agriculture and Agrifood Canada Research Stations were also included in the study. The soil N supply was assessed on duplicate sub samples using a 24 week leaching-incubation, 2 M hot KC1 and 2 week N supply rate to a PRS-probe™. These results were then compared to the actual N uptake by canola (Qian et al., 1996).

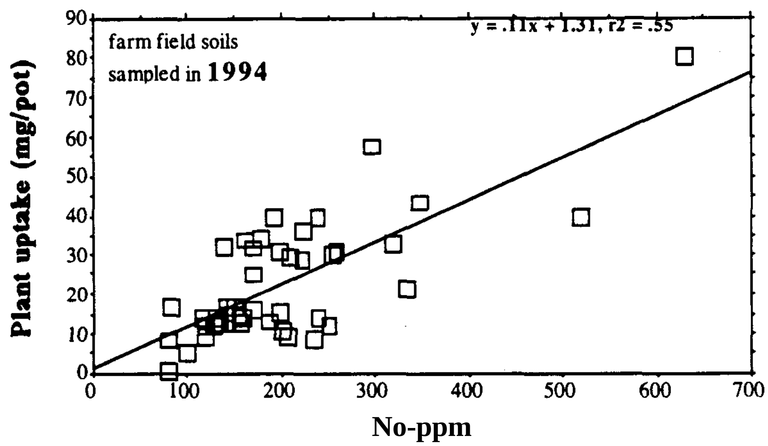
Stanford and Smith (1972) introduced the leaching-incubation method which successfully measured the release of soil N from a functionally determined potentially mineralizable pool. The advantage of this method is the simple description of the release function using a 1st order kinetic equation, When applied in an integrated form, the function can numerically predict the soil N released under conditions similar to the lab. Many studies have been conducted using this method. Most have been designed to improve the predictive ability of this method by adjusting for temperature, moisture, field condition of the soil, plant residue/litter, and contributions from deeper soil horizons (Campbell et al., 1988; Cabrera and Kissel, 1988; Mahli et al., 1992; Stanford, 1982; Ellert, 1990). As well, more fundamental studies have been conducted which deal with the rational of mathematical fitting of the soil release and the extrapolation of this to the field (Ellert and Bettany, 1988). Despite the lab conditions employed in this 24 week test, it has demonstrated utility in describing the N supply from both genetically different soils and those altered by management (Verity and Anderson, 1990; Campbell et al. 1991).

Boiling the soil with 2 M KC1 for 4 hours has evolved as a means of measuring both the "native" ammonium as well as that ammonium which can be easily hydrolyzed (Jalil et al., 1996). A wide range of concentrations and boiling conditions have been investigated since the method was first proposed (Smith and Li, 1993). Hydrolyzable ammonium was found useful in improving the prediction of plant N uptake in the lab (Smith and Li, 1993) and in the field where residue contributions were not large (McTaggart and Smith, 1993). Correlative relationships indicate that Hot KC1 ammonium responds much like the N_o assessment of soil N supply across widely varying soils (Jalil et al., 1996).

Soil N supply was also assessed bv measuring the NO_3^- ion flux to an ion exchange membrane over a 2 wk incubation (Qian and Schoenau, 1995). The integrated flux of nitrate sorbed by the Plant Root Simulator (PRS-probe™) provides a dynamic measure of both the soil intensity (soil solution N concentration) as well as the soils quantity factor or ability to release N. This type of ion sink can also account for the differences in diffusion characteristics which influence the delivery of mobile nutrients to the adsorbing surface.

Results and Discussion:

The relationships between N uptake by canola and the N release measured by each of the three methods is shown in Figs. 1,2 and 3. Potentially mineralizable N (N_o) was derived by fitting the data to a 1st order kinetic equation (Stanford and Smith, 1972). This index was clustered to some degree with the extreme points on both 1994 and 1995 data sets resulting from a heavily manured soil. Dropping the manured soils reduces the extent of the variation explained by N_0 to 36% and 5 1% for the two data sets respectively. In general, it can be seen that the functional release of N under leaching incubation conditions can describe a significant amount of the variation in Canola N uptake. These results confirm those of many others that find N_0 to be a useful indicator of soil N supply especially where N release from residues does not make a significant contribution to N supply.



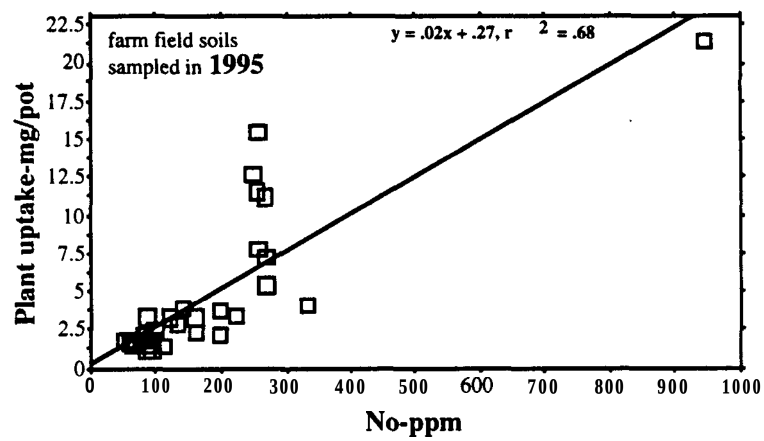


Fig. 1 Canola uptake of N from 1994 and 1995 samples as related to potentially mineralizable N (N,).

Hot KC1 is a chemically assessed N pool which includes mineral ammonium and hydrolyzable organic N. The relationship to Canola uptake (Fig 2) was improved slightly over that seen with the N_o measure of soil N supply. The hot KC1 method has been advanced as a means of estimating the N_o (Jalil et al., 1996). The estimated N_o could then be applied to the 1st order kinetic release model and integrated over time to estimate the soil supply. Other researchers have reported a similarly good relationship between hot KC1 and plant uptake on soils where residues are not contributing to the N supply (McTaggart and Smith, 1993).

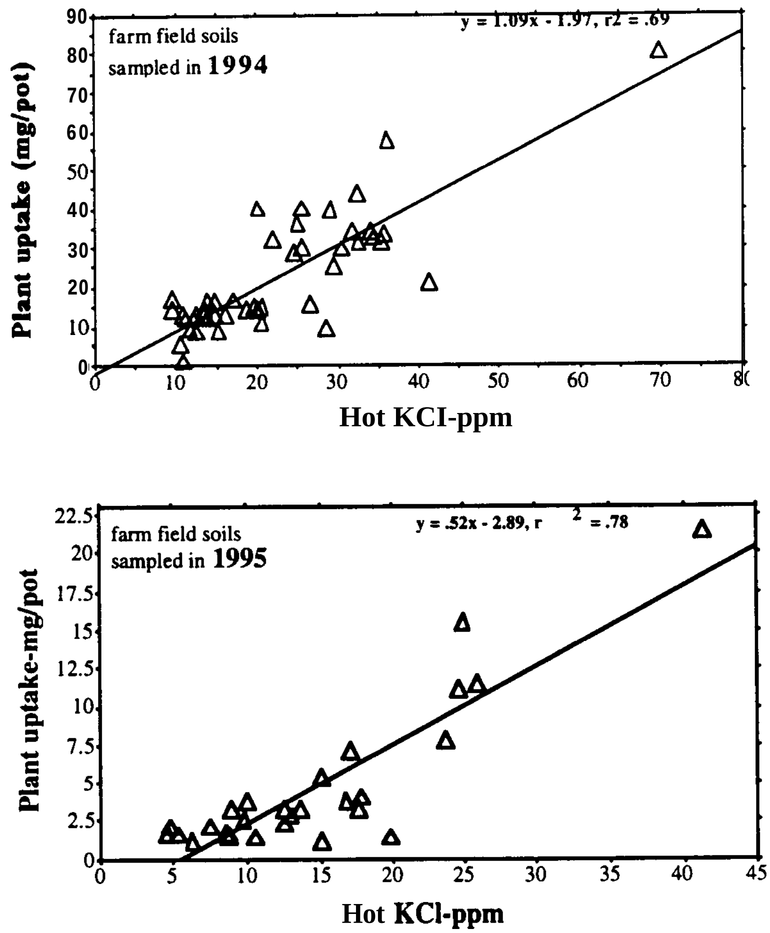


Fig. 2 Canola uptake of N from 1994 and 1995 samples as related to hydrolyzed ammonium using Hot KCl.

Nitrate supply rate assessed by the PRS-probe™ was also a good predictor of the Canola N uptake (Fig. 3). The manured soil in the 1994 samples had a supply rate which was high enough to saturate the probe during the 2 week incubation period. This caused the soil N supply rate to reach a maximum near 1600 $\mu g/10\,cm^2/2wk$ and not show further increase. Removing the manured soils from the 1994 data set increased the r^2 to 0.70. Nitrate supply rate on the 1995 soils was assessed using 2 sequential probes each remaining in the soil for 1 week. Removing manured site from the 1995 data decreased the strength of the relationship similar to that seen for N,.

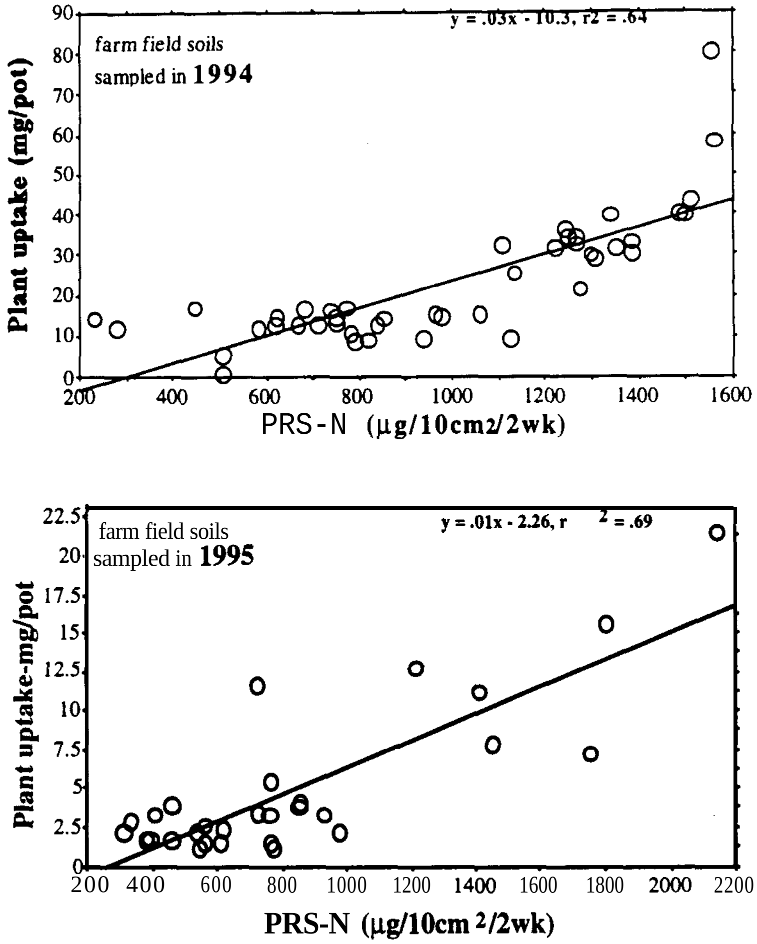


Fig. 3 Canola uptake of N from 1994 and 1995 samples as related to N supply rate to the PRS-probe™

Implications for fertilizer recommendations:

Fertilizer N recommendations are commonly based on the level of extractable mineral N found in the soil at the time of sampling. Using only the extractable mineral N to predict fertilizer needs is a valid approach only where the climate, soils and cropping systems are reasonably static over a given region. Adding the contribution from N mineralization to the initial mineral N extractable provides a more robust way of calculating total plant available N (Stanford, 1982; Rice and Havlin, 1994). This method of estimating the N availability has been applied in simple balance sheet approaches, nomographs and computer models.

Computer models adjust N mineralization to field conditions by moderating the release function for changes in field temperature and moisture (Campbell et al., 1984). The integrated release over the growing season is then compared to plant N uptake. Field validations of the N_o models tend to over predict plant N uptake sometimes as much as 343% (Cabrera et al., 1994). The likely cause of the poor field validations lies in the inherent assumption that all of the N supplied by the soil is taken up by the plant. This simple additive approach to N supply and plant demand is valid only for highly N starved pot studies where the amount of soil available for rooting is greatly restricted. Field validation of N availability requires that the entire soil-plant system be considered (Mengel and Kirkby, 1982).

Nitrogen availability encompasses more than the biological, chemical and physical processes which transform soil organic N to mineral N. The size of the absorbing sink as related to plant root characteristics, is also essential in interpreting how much N uptake will occur. Linking the dynamics of plant root growth to both the initial extractable N and the slowly released N provides the most realistic picture of N accumulation in the plant For this to occur the measures of N supply need to be related not to a mass of soil but instead to the effective size of the root absorbing surface. The N supply to the PRS-probe provides a measure of N supply rate on the basis of absorbing area which should be an advantage in forecasting the N supply to the entire rooting surface.

Conclusions:

A cross section of soils from the Brown, Dark Brown and Black soil zones showed large differences in N supply. Both the chemical index (Hot KCl) and the more functional incubation indices (N_o and PRS-probes) were reasonably well related to canola N uptake in the growth chamber. Because of the need to properly account for the differences in the size of the plant rooting system, simple addition of mineral N release in the laboratory to the initial N extractable may not be an effective predictor of plant N uptake in the field. The N supply rate measured by PRS-probes in the field has potential to provide a useful integrated estimate of N dynamics. Moderating this measured supply rate according to field moisture and temperature, which affects not only the soil release of N but also the rooting area and activity, provides a logical basis for modelling the N accumulation by plants.

References:

Cabrera, M.L., and D.E. Kissel. 1988. . Potentially mineralizable nitrogen in disturbed and undisturbed soil samples. Soil Sci. Soc. Am. J. 52: 1010- 1015.

Cabrera, M.L., D.E. Kissel, and M.F. Vigil. 1994. Potential nitrogen mineralization: Laboratory and field evaluation. IN Soil Testing: Prospects for Improving Nutrient Recommendations. Special Pub. No. 40, SSSA. Madison, WI.

Campbell, C.A., Y.W. Jame and G.E. Winkleman. 1984. Mineraliztion rate constants and their use for estimating nitrogen mineralization in some Canadian prairie soils. Can. J. Soil Sci. 64: 333-343.

Campbell, CA., Y.W. Jame and R. De Jong. 1988. Predicting net nitrogen mineraliztion over the a growing season: Model verification. Can. J. Soil Sci. 68: 537-552.

Campbell, C.A., G.P. LaFond, A.J. Leyshon, R.P. Zentner and H.H. Janzen 199 1. Effect of cropping practices on the initial rate of N mineraliztionin a thin Black Chemozem. Can. J. Soil Sci. 71: 43-53.

Ellert, B.H. 1990. Kinetics of nitrogen and sulfur cycling in gray luvisol soils. Ph.D. Dissertation. University of Sask. Saskatoon, Sk.

Ellert, B.H. and J.R. Bettany. 1988. Comparison of kinetic models for describing net sulfur and nitrogen mineralization. Soil Sci. Soc. Am. J. 52: 1692-1702.

Jalil, A., C.A. Campbell, J.J. Schoenau, Y .W. Jame, J.L. Henry, and G.P. LaFond. 1996. Assessment of two chemical extraction methods as indices of available nitrogen. Soil Sci. Soc. Am. J. 60: 1954-1960.

Malhi, S.S., M. Nyborg, and D.J. Heaney. 1992. Potential for nitrogen mineralization in central Alberta soils. Fert. Res. 32: 32 l-325.

McTaggart, I.P. and K.A. Smith. 1993. Estimation of potentially mineralizable nitrogen in soil by KC1 extraction. II. Comparison with soil N uptake in the field. Plant Soil. 157: 175-184.

Mengel, K. and E.A. Kirkby. 1982. Principles of Plant Nutrition. International Potash Institute. Bern, Switzerland. pp 63.

Qian, P., and J.J. Schoenau. 1995. Assessing nitrogen mineralization from soil organic matter using anion exchange membranes. Fert. Res. 40: 143-148.

Qian, P., J.J. Schoenau and K.J. Greer. 1996. Predicting soil nitrogen supplying power for canola growth. Proc. Soils and Crops Workshop. pp. 541-546.

Rice, C.W. and J.L. Havlin. 1994. Integrating mineralizable nitrogen indices into fertilizer nitrogen recommendations. . IN Soil Testing: Prosnects for Improving Nutrient Recommendations. Special Pub. No. 40, SSSA. Madison, WI.

Smith, K.A. and Li, S 1993. Estimation of potentially mineralizable nitrogen in soil by KC1 extraction. I. Comparison with pot experiments. Plant Soil. 157: 167-174.

Stanford, G. 1982. Assessment of soil nitrogen availability. IN F.J. Stevenson (ed) Nitrogen in Agricultural Soils. Agronomy Monograph No. 22. American Soc. Agron. Madison, WI.

Stanford, G. and K.A. Smith. 1972. Nitrogen mineraliztion potentials of soils. Soil Sci. Soc. Am. J. 36: 465472.

Verity, G.E. and D.W. Anderson. 1990. Soil erosion effects on soil quality and yield. Can. J. Soil Sci. 70: 471-484.