UPDATE ON THE ILLINOIS N TEST

R.G. Hoeft, R.L. Mulvaney, and S.A. Khan[1,2]
University of Illinois- Urbana-Champaign

Introduction

Estimation of plant-available N is complicated enormously by the dynamic nature of soil N, owing largely to the effects of temperature and moisture supply on N-cycle processes. Numerous biological and chemical methods have been proposed as an index of soil N availability (Bremner, 1965; Keeney, 1982; Stanford, 1982; Bundy and Meisinger, 1994), but none has been adopted widely for soil testing. Biological methods are necessarily time-consuming because of the need for incubation, and the results represent the net effect of mineralization-immobilization turnover rather than gross mineralization. Chemical methods of estimating potentially mineralizable soil N have been based on an empirical approach, and their use has been very limited due to low correlations with crop N uptake and/or the production of mineral N during soil incubations.

Soil testing for NO_3^- is currently considered the best option for identifying sites where N fertilization will be ineffective in producing a yield response by corn (Bundy and Meisinger, 1994). Two soil NO_3^- tests have been developed that differ in the time and depth of sampling. With the preplant NO_3^- test (PPNT), profile samples are collected in the early spring to a depth of 2 or 3 feet, to account for carryover of mineral N from previous cropping (e.g., Bundy and Malone, 1988; Roth and Fox, 1990; Schmitt and Randall, 1994). With the presidedress NO_3^- test (PSNT), soil sampling is done to a depth of 1 foot in late spring, so that soil N mineralization can be taken into account and supplemented, if necessary, by sidedressing (e.g., Magdoff et al., 1984; Blackmer et al., 1989; Meisinger et al., 1992). The PSNT has been recommended more widely than the PPNT in the eastern U.S., but usage has been limited by the need to collect soil samples during the growing season, and by the fact that N fertilization must be postponed until after testing, and can be ineffective if adverse weather conditions delay sidedressing. Besides logistical problems, an inherent limitation with the PPNT and PSNT arises from the extensive spatial and temporal variability in soil NO_3^- concentrations, which depend on numerous N-cycle processes, including mineralization, immmobilization, nitrification, denitrification, leaching, and plant uptake. Consequently, a one-time test for soil NO_3^- is apt to be of little value for predicting crop N availability throughout the growing season, particularly in a humid region where these processes occur extensively.

In Illinois, soil testing is used routinely to guide agricultural applications of limestone, P, and K, whereas N applications for corn production are based on a realistic yield goal, with adjustments to account for other N inputs, such as legumes or manure. A yield-based recommendation may have

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[1] **R.G. Hoeft and R.L. Mulvaney are Professors, Department of Crop Sciences and Department of Natural Resources and Environmental Sciences, respectively, and S.A. Khan is a Research Specialist in the Department of Natural Resources and Environmental Sciences, University of Illinois, Urbana-Champaign, IL.**

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merit on a long-term basis, but under- or overfertilization is apt to occur in any given growing season, since soil N availability is not taken into account. Insufficient application of N can have serious economic consequences for the farmer, whereas excessive fertilization increases the risk of environmental pollution.

Reports that corn is sometimes nonresponsive to N fertilization (e.g., Bundy and Malone, 1988; Blackmer et al., 1989; Fox et al., 1989; Roth and Fox, 1990; Meisinger et al., 1992; Brown et al., 1993; Schmitt and Randall, 1994) have stimulated recent work to identify a specific fraction of soil organic N that mineralizes readily, as a means to detect sites where N fertilization is unnecessary. After eliminating major defects in the methodology to fractionate the N in soil hydrolysates (Mulvaney and Khan, 2001), studies showed a much higher concentration of amino sugar-N for nonresponsive than for responsive soils, whereas no consistent difference was detected in their concentrations of total hydrolyzable N, hydrolyzable NH_4^+-N, or amino acid-N (Mulvaney et al., 2001). In subsequent incubation experiments, nonresponsive soils produced a much larger quantity of mineral N than did responsive soils, and mineralization was accompanied by a net decrease in amino sugar-N but not in amino acid-N (Mulvaney et al., 2001).

Based on these findings, a simple soil test has been developed to estimate amino sugar-N, as a means of detecting sites where corn is unlikely to respond to N fertilization (Khan et al., 2001). Our objectives here are to report on recent laboratory developments concerning this new soil test, clarify the measurement of labile organic N as opposed to soil organic matter, and summarize preliminary findings from current field studies to check the reliability of the test and establish protocol for soil sampling.

Laboratory Developments

The Illinois N test requires gentle heating of alkalized samples on a griddle, so as to promote decomposition of amino sugars and other alkali-labile forms of organic N. Experience has shown that data integrity depends on uniform heating, and that not all commercial griddles provide adequate uniformity. Among currently available units, soil test values have been most reproducible when using a model (no. 76220) that was recently introduced by the West Bend Co., West Bend, WI <www.westbend.com>. Although this griddle is large enough to accommodate 15 of the 1-pint jars required, no more than 12 of these jars should be heated concurrently, and the jars should be placed toward the center of the griddle. To improve data quality, samples should be tested in duplicate, and adjacent jars should be exchanged after heating for approximately 2 hours, so as to compensate for the somewhat lower temperatures that tend to occur in corner positions.

A new laboratory has been established in the Department of Crop Sciences at the University of Illinois, for the sole purpose of conducting the Illinois N test in conjunction with field evaluation research.

The Need to Measure Labile N, not Organic Matter

In some states, fertilizer N recommendations have been made on the basis of soil organic matter or total N content, on the assumption that a fixed proportion (typically 1 or 2%) of soil N mineralizes during the growing season. This approach is subject to the inherent limitation that soil organic matter is extremely heterogeneous in chemical composition, with the majority being essentially inert toward microbial decomposition.

The Illinois N test was not designed to measure soil organic matter content, but a labile fraction of organic N that supplies the plant through mineralization. Figure 1 demonstrates that this test is consistent with the yield response of corn to N fertilization, in that higher N test values were obtained for six nonreponsive sites than for six responsive sites. In contrast, these sites were not distinguishable on the basis of organic matter content, which was higher for some of the responsive soils than for others that were nonresponsive. Of particular interest is that organic matter content was higher for the lowest testing responsive soil (Varna) than for five of the six nonresponsive soils. Not surprisingly, the correlation between these two parameters was virtually nonexistent.

Temporal Variability

If the Illinois N test measures a mineralizable form of soil N, then test values should vary considerably with time. A decrease would be expected during the growing season because of crop N uptake, followed by an increase associated with production of microbial biomass in the absence of plant competition for mineral N. Figure 2 shows evidence of these trends for three sites under different management practices near Mansfield, IL, which are being sampled at weekly intervals to a depth of 12 inches. In each case, monthly mean values increased from November 2001 to March 2002, and subsequently decreased until July 2002, during which very little precipitation was received.

The value of the Illinois N test for detecting management effects is evident from the consistent difference in test values that was observed among the three sites studied. The highest test values were always obtained for a manured soil in a corn-soybean rotation, where the crop showed no visual response to N fertilization. Of two nonmanured sites on different soils, test values were higher when corn followed soybean, as opposed to continuous corn, with much less visual indication of N deficiency.

Sampling Time

Given the sort of temporal variability indicated by Fig. 2, the time of sampling is clearly a critical variable in using the Illinois soil N test. Figure 3 compares soil test values for samples collected in late November 2001 and early April 2002, from five sites under continuous corn. Test values were 3.5 to 12.6% higher for spring sampling, presumably owing to microbial decomposition of crop residues during a mild winter. To reduce the risk that a responsive soil could be erroneously identified as nonresponsive on the basis of an elevated test value, current indications are that soil sampling for the Illinois N test is best done in the fall after harvest.

Sampling Depth

Depth of sampling is an important consideration for reliable soil testing, so as to ensure valid calibration of plant response relative to nutrient supply within the soil profile. In the case of the

Illinois N test, the quantity of interest is a labile fraction of soil N associated with organic matter, and because of limited leaching, accumulation would be expected near the soil surface following addition of aboveground plant residues or manure. This is confirmed by Fig. 4, which shows that this test was much more effective for differentiating responsive from nonresponsive sites on the basis of surface samples (0-6 or 0-12 inches), as compared to profile sampling (0-24 inches). Figure 4 provides further evidence that the new N test would be compatible with routine soil testing for pH, P, and K, because nonresponsive sites were detected equally well by testing 6- instead of 12-inch samples, provided the critical test level was increased by 30 ppm. As indicated by a lack of correlation between soil N test values and crop N response, a serious loss of resolution occurred when sampling was done to 24 inches, which can be attributed to profile dilution of the labile N fraction.

Spatial Variability

Cropping and management practices necessarily lead to spatial variability in soil fertility, particularly with a biologically active nutrient such as N. If the Illinois N test is sensitive to these practices, spatial variability should be more extensive for a corn-soybean rotation than for continuous corn, and should be markedly affected by tillage or the application of manure. As shown by Fig. 5, this is precisely what has been observed for the three Mansfield sites previously mentioned in connection with temporal variability, from which 540 soil samples were collected on 21 March 2002. Spatial variability was least extensive for a site under continuous corn that had been chisel-plowed after harvest, more extensive for a corn-soybean site that had not yet been tilled, and most extensive for a manured site where corn follows soybean. The variability observed in the latter case is no doubt largely due to uneven spreading of solid beef manure, but is of limited significance in regard to N fertilization given the magnitude of the test values for this site. The limited spatial variability observed for the continuous corn site has practical implications if this test is to be utilized in making quantitative N recommendations for responsive soils.

Summary

The Illinois soil N test estimates potentially mineralizable N to detect sites where corn does not respond to N fertilization. This test does not measure total organic matter, but a fraction of soil organic N that decomposes when heated under strongly alkaline conditions. Although originally developed using soil samples collected to a depth of 1 foot, subsequent studies in 2001 have shown 6-inch samples to be equally satisfactory for detecting nonresponsive sites, provided the critical test level is increased. Somewhat higher test values have been obtained for spring than for fall sampling, which is consistent with crop removal during the growing season. The sensitivity of this test is apparent from the range in test values obtained for sites under different cropping and management practices.

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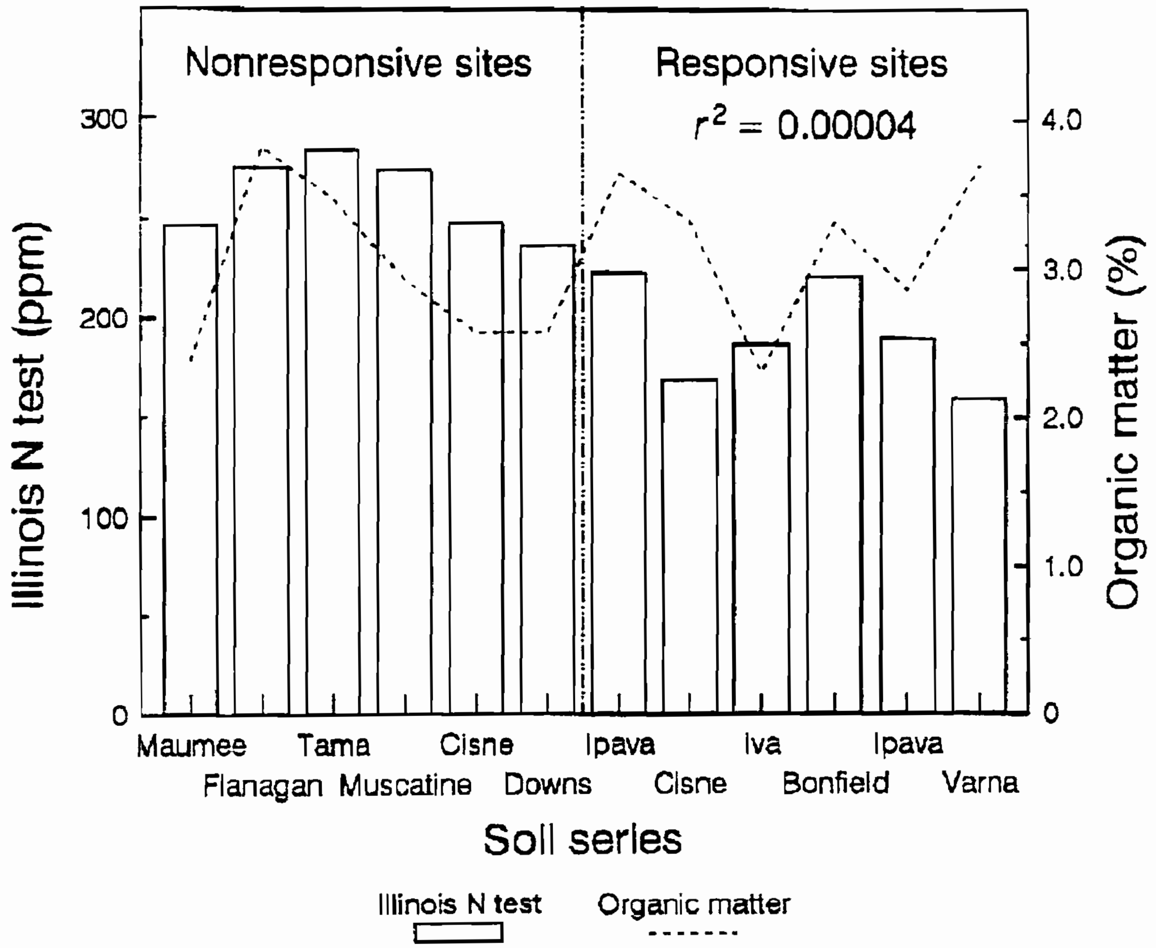

Fig. 1. Comparison of Illinois N test versus soil organic matter content for detection of nonresponsive sites.

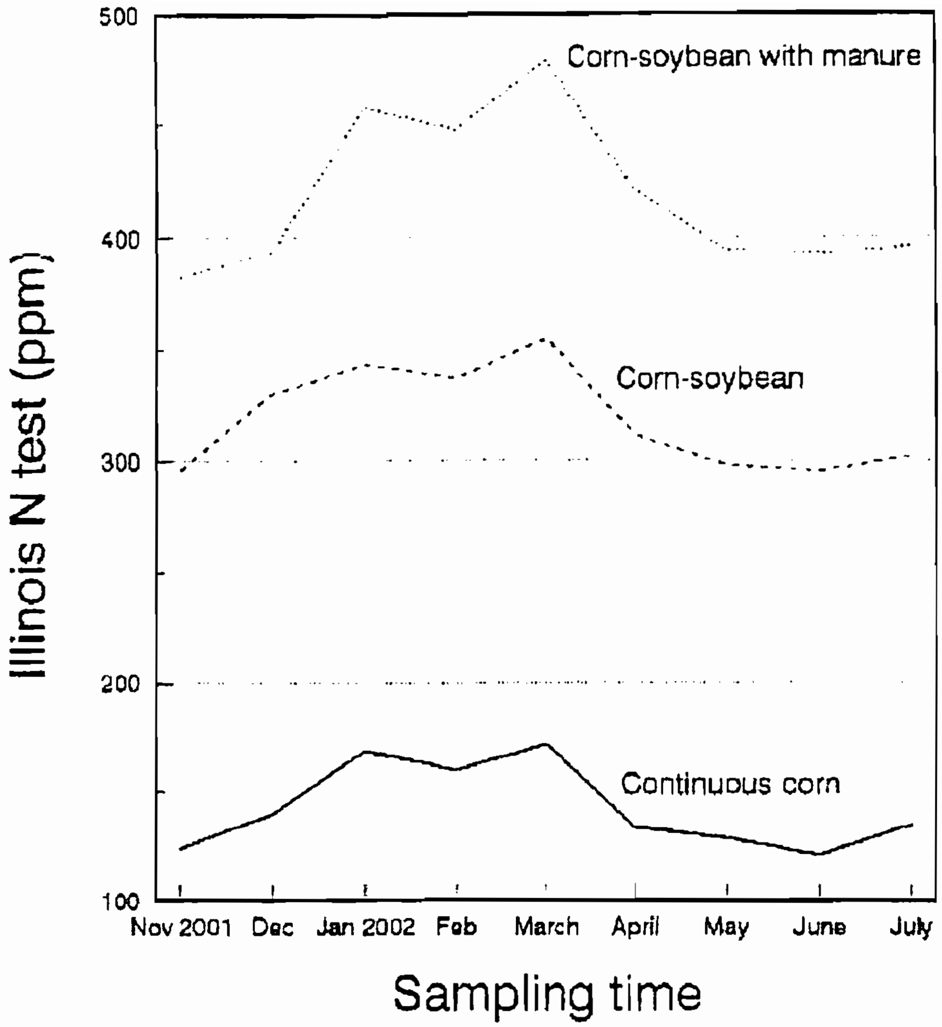

Fig. 2. Temporal changes in Illinois N test at three sites near Mansfield, IL. Soil samples were collected to a depth of 12". Data are plotted as monthly mean values for eight replicate subplot.

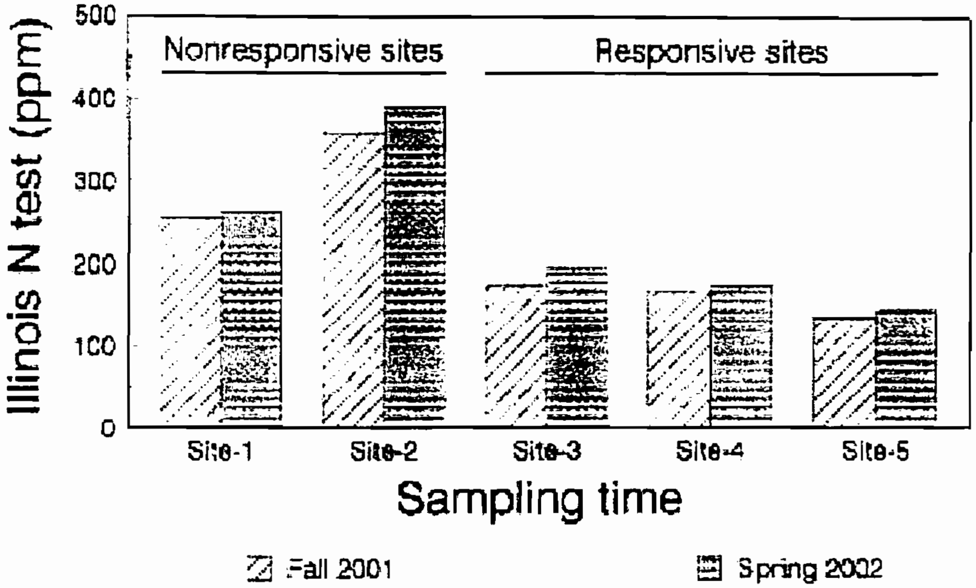

Fig. 3. Comparison of Illinois N test values for fall vs. spring sampling (0-12").

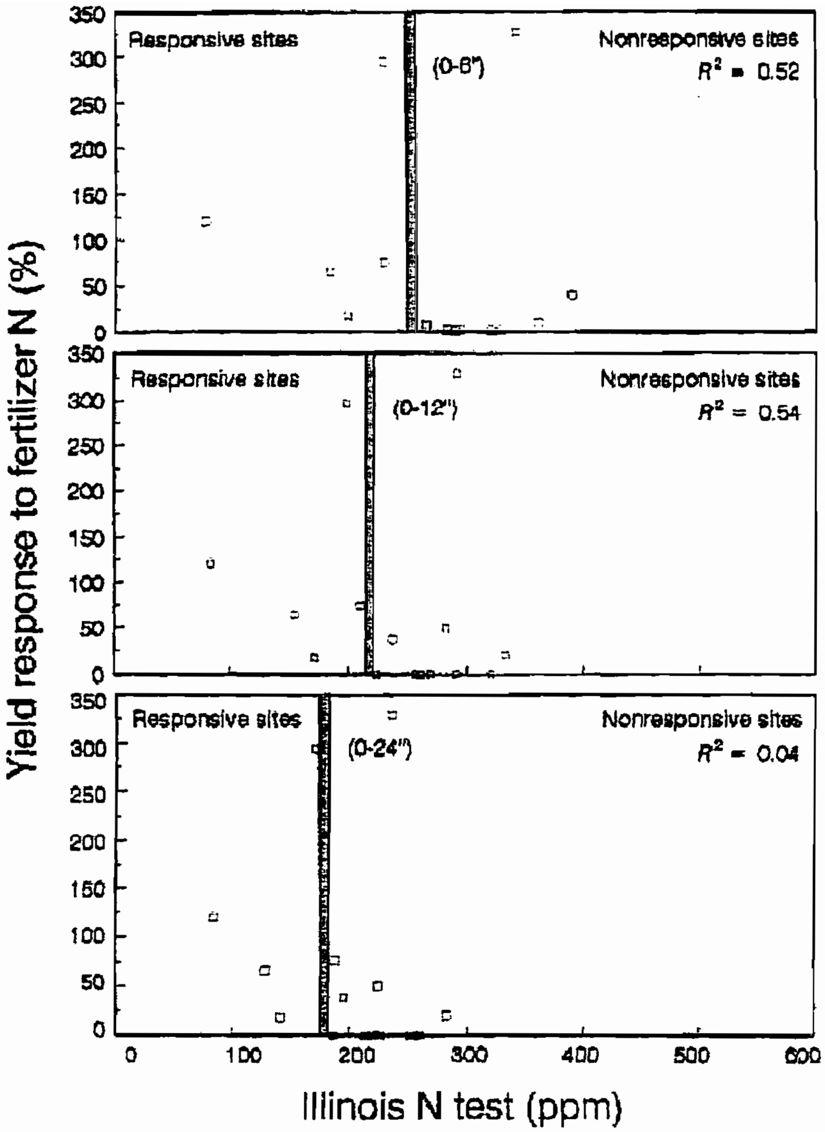

Fig. 4. Effectivness of the Illinois N test for detecting nonresponsive sites when applied to soil samples collected to depths of 6, 12 or 24".

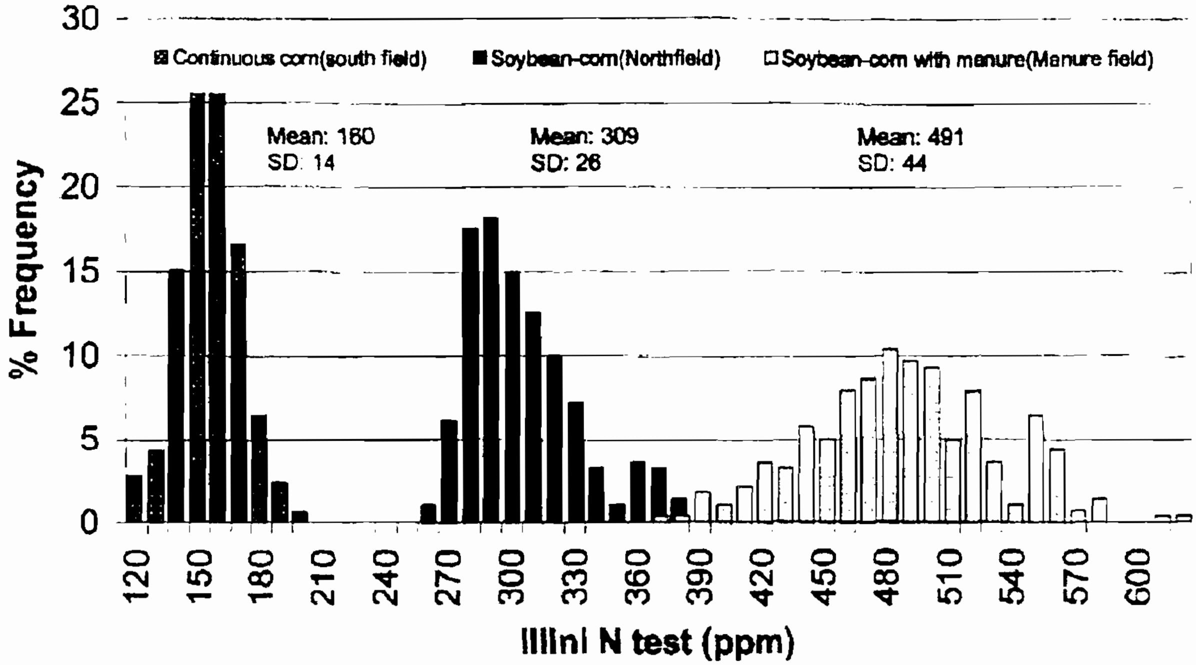

Fig. 5. Spatial variability in the Illinois N test for the three sites near Mansfield, IL, under different cropping and management practicing. At each of other site, 260 samples were collected to 7 inches. At each of other site, 140 samples were collected within 0.04 acre. Soil testing was done in duplicate.

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Program Chair:
Larry Bundy
University of Wisconsin
Madison, WI 53706
(608) 263-2889

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772 – 22nd Avenue South
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(605) 692-6280
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