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## Nutrients Removed in Harvested Portion of Crop by Continuous Corn Receiving Organic and Inorganic Fertilizers

M.F. Hossain

Natural Resources Canada, CCRS/EMS/AD,  
588 Booth Street, Ottawa, ON, Canada K1A 0Y7

**Abstract:** A study was conducted to examine patterns of macro- and micro nutrient accumulation in corn grains in response to seven different levels of N amendments: no amendments, fertilizer ( $\text{NH}_4\text{NO}_3$ ) at 100 and 200 kg N  $\text{ha}^{-1}$ , stockpiled and rotted manure at 50 and 100 Mg  $\text{ha}^{-1}$  (wet weight) application. Results indicate that over the study periods manure application increased most of biomass macro- and micro nutrient concentrations. There was no significant positive relationship between grain yield and macro- and micro nutrient concentrations. Data showed at 11 t  $\text{ha}^{-1}$  yield level, corn grain would remove on average the following amounts of nutrient elements: N, 126.5 to 174.9; P, 31.9 to 35.2; K, 34.43 to 37.62; S, 12.21 to 14.96; Mg, 10.08 to 10.65; Ca, 0.81 to 0.97; Fe, 0.24 to 0.33; Zn, 0.20 to 0.23; Mn, 0.048 to 0.054; Cu, 0.027 to 0.042 kg  $\text{ha}^{-1}$ , which are comparable to those reported in the literature: N, 120.8; P, 36.7; K, 44.7; S, 9.9; Mg, 14.4; Ca, 2.6; Fe, 0.33; Zn, 0.25; Mn, 0.045; Cu, 0.03 kg  $\text{ha}^{-1}$ . These values, however, do not take into account the quality and availability of nutrient reserves already in the soil. Because of this limitation, soil testing should still be the cornerstone of all fertility programs. Removal rates can be used in conjunction with soil testing to estimate the depletion of macro- and micro nutrient reserves. These data are very useful in comparing the nutrient demands of different crops.

**Key words:** Corn (*Zea mays* L.), Biomass, macro-and micro nutrient, stockpiled and rotted manure, organic and inorganic fertilizer

### Introduction

In the efforts to achieve sustainable agricultural production while maintaining and preserving the environment, we have come to face crucial macro- and micro nutrient for life (Marschner, 1995). Agricultural producers increasingly rely on application of large quantities of inorganic and organic amendments to maximize yields, which may lead to potential macro-and micro nutrient crisis (Heckman *et al.*, 2003). Therefore, an ideal nutrient management should provide a balance nutrient between inputs and outputs in the plant-soil-atmosphere ecosystem over the long-term (Bacon *et al.*, 1990; Heckman *et al.*, 2003). To do so, nutrient removed by crop harvest must be replaced annually or at least within the crop rotation cycles. If, nutrient inputs as a fertilizer, manure or any other sources like waste materials exceed crop removal over growing seasons, soils become an environmental concern (Daniel *et al.*, 1998). An accurate measurement for macro- and micro nutrients removal by biomass part of crop is an important component for sustainable crop production and nutrient management. Macro-and micro nutrient fertilizers must be applied annually to avoid nutrient deficiencies, maintain a medium level of soil fertility and produce high-yielding crops.

Nutrient removal values are a key component of nutrient management planning as manure and fertilizer applications are being limited based on the expected level of crop potential yield of corn (Heckman *et al.*, 2003; Sims, 1999; Sims *et al.*, 1998). Ontario Ministry of Agriculture and Food

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**Corresponding Author:** M.F. Hossain, Natural Resources Canada, CCRS/EMS/AD, 588 Booth Street, Ottawa, ON, Canada K1A 0Y7 Tel: +1 613 943 1179 Fax: +1 613 947 1385

regularly publishes values for crop nutrient removal through agronomy guide for field crops. Also, the values that were established in the past may reflect progress in current agronomic technologies such as improved hybrids, with higher plantation; yield potential, precision fertilizer management according to land type and soil conditions. In additions, the soils on the ECORC experimental station are typical of the Eastern Ontario crop area in regards to soil series, chemical and physical properties and crop rotations making it an ideal site for soil fertility research in relation with biomass nutrient uptake. Therefore, it is urgently need to evaluate biomass macro- and micro nutrients removal by corn for expected yield.

Many of the soils used for corn, soybean and wheat production in Eastern Ontario have high pH, low organic matter and low to medium levels of plant available nutrients (Baute, 2002). There is emphasis on short and long-term fertilization studies are conducted at the central experimental farm to examine corn crop physiology, rotation, hybrids, growth and yield response to N amendments (Ma and Dwyer, 2001, 1998; Ma *et al.*, 1999, 2003). Crop nutrients removal has not been received greater attention. The objective of this study was to assess soil N amendments effects on corn grain and stover accumulation of macro- (N, P, K, S, Ca and Mg) and micro- (Fe, Mn, Zn and Cu) nutrients.

## Materials and Methods

### The Experiment

A long-term experiment on corn from 1992 to 2002 was conducted on Brandon loam soil (Orthic Humic Gleysol, in the Canadian classification) on the Central Experimental Farm at Ottawa, Ontario (45°22'N, 75°43'W) to evaluate the N changes in soil and plant after ten years of continuous corn receiving fertilizer and manure. The soil contained an average of 34% clay, 27% silt and 39% sand with a pH of 6.5 (1:1 in water). The treatment and design has been reported previously (Ma *et al.*, 1999). Briefly, a randomized complete block design arranged with two factors. Seven different treatments (no amendments, N fertilizer (NH<sub>4</sub>NO<sub>3</sub>) at 100 and 200 kg N ha<sup>-1</sup>, stockpiled manure at 50 and 100 Mg ha<sup>-1</sup> (wet weight) and well rotted manure at 50 and 100 Mg ha<sup>-1</sup> (wet weight) were assigned to the whole plot. Two corn hybrids, an older lower yielding hybrid (Pride 5) with demonstrated intolerance to stress conditions and a modern hybrid of the same maturity (Pioneer 3902), were the subplot. Each subplot was 8 m long and consisted of 12 rows with 0.762 m spacing. This study was focused on the modern hybrid plots.

Table 1: Chemical composition of stockpiled and rotted manure applied from 1998 to 2001

| Year              | Total C<br>g kg <sup>-1</sup> | Total N<br>g kg <sup>-1</sup> | Dry<br>matter <sup>†</sup><br>Mg ha <sup>-1</sup> | Total mineral N <sup>†</sup><br>kg N ha <sup>-1</sup> | Total N <sup>†</sup><br>kg N ha <sup>-1</sup> | C:N |
|-------------------|-------------------------------|-------------------------------|---------------------------------------------------|-------------------------------------------------------|-----------------------------------------------|-----|
| Stockpiled manure |                               |                               |                                                   |                                                       |                                               |     |
| Spring 1998       | 427                           | 22                            | 12                                                | 60                                                    | 260                                           | 20  |
| Spring 1999       | 419                           | 18                            | 11                                                | 24                                                    | 190                                           | 23  |
| Spring 2000       | 401                           | 19                            | 14                                                | 43                                                    | 260                                           | 21  |
| Fall 1998         | 407                           | 21                            | 12                                                | 35                                                    | 250                                           | 19  |
| Fall 1999         | 443                           | 21                            | 11                                                | 46                                                    | 220                                           | 21  |
| Fall 2000         | 419                           | 20                            | 10                                                | 42                                                    | 198                                           | 21  |
| Fall 2001         | 419                           | 20                            | 12                                                | 85                                                    | 308                                           | 21  |
| Mean              | 419                           | 20                            | 12                                                | 48                                                    | 236                                           | 21  |
| Rotted manure     |                               |                               |                                                   |                                                       |                                               |     |
| Spring 1998       | 427                           | 22                            | 12                                                | 60                                                    | 260                                           | 20  |
| Spring 1999       | 326                           | 24                            | 14                                                | 52                                                    | 330                                           | 14  |
| Spring 2000       | 392                           | 19                            | 13                                                | 44                                                    | 250                                           | 21  |
| Fall 1998         | 362                           | 22                            | 20                                                | 58                                                    | 440                                           | 16  |
| Fall 1999         | 385                           | 25                            | 15                                                | 82                                                    | 390                                           | 15  |
| Fall 2000         | 378                           | 20                            | 13                                                | 55                                                    | 266                                           | 19  |
| Fall 2001         | 378                           | 22                            | 18                                                | 13                                                    | 387                                           | 17  |
| Mean              | 378                           | 22                            | 15                                                | 52                                                    | 333                                           | 17  |

<sup>†</sup>Total amount in the manure applied at 50 Mg ha<sup>-1</sup> (wet weight) and double the values to obtain the total amount applied at 100 Mg ha<sup>-1</sup> (wet weight)

The fertilizer N ( $\text{NH}_4\text{NO}_3$ ) was broadcast and incorporated into the soil shortly after planting each year. During the first year of the experiment stockpiled manure was the only manure applied. Manures were spread in the spring, before planting from 1998 to 2001, then prior to fall ploughing from 1998 to 2001. Manure characteristics are shown in Table 1. The year 1998 and 2002 was used to evaluate the changes in macro and micronutrient removed by harvested portions. These year 1998 and 2002 has been selected based on samples are available and the weather, which means there is no considerable influence on nutrient removal due to weather.

#### *Sampling and Statistics*

Ten consecutive plants from an area marked shortly after harvests were taken from each plot and these separated into leaves, stalks, other reproductive components and kernels. An additional 40 plants were harvested in each plot for determination of grain yield. All the components were dried at  $70^\circ\text{C}$  to a constant and dry weights were recorded prior to being chopped. Sub samples (kernel and stover) were taken and ground to pass a 1 mm screen for macro- and micro nutrient analysis. The kernel and stover samples digestion for total N was performed using a block digester. The total N in the digest was determined using the automated colorimetric method. Concentrations of macro-nutrients (K, Ca and Mg) and micro-nutrients (Fe, Mn, Zn and Cu) in kernel and stover samples were determined by atomic absorption spectroscopy (AAS) after samples were digested with nitric and perchloric acid ratio 2:1 (Jackson, 1975; Anderson and Ingram, 1993). Measurement of P (Olsen and Sommers, 1982) and  $\text{SO}_4\text{-S}$  concentration in the extracts by a turbidimetric procedure using barium chloride (Anderson and Ingram, 1993). All macro- and micro nutrient concentrations are expressed on a dry weight basis.

All the data were subject to analysis of variance. The treatment means were separated according to the *F*-protected LSD test ( $p < 0.05$ ). Regression analysis also used to examine between yield and plant nutrient concentration and co-relation between corn yield and grain nutrient concentration.

## **Results**

### *Macro Nutrients*

#### *Nitrogen, Phosphorus and Potassium*

The concentrations of biomass (corn and stover) N across both years under different N amendments varied significantly within different N levels but manure (both stockpiled and rotted manure at  $100 \text{ Mg ha}^{-1}$ ) application remarkably increased biomass N concentrations. Surprisingly there is no difference between 100 and  $200 \text{ kg N ha}^{-1}$  but biomass N concentration significantly increased in 2002 (Table 2 and 3) with no relationship of yield (Fig. 1), suggesting that a significant amount of N accumulated in biomass part which was not responding in yield. Compared to high rated of mineral fertilizer treatment, a large portion of the N uptake by the crop was derived from the native soil organic

Table 2: Comparison between 1998 and 2002 macro-micro nutrients concentration in corn grain under different levels of N amendments

|                           | N                                      |       | P     |       | K     |       | S     |       | Mg     |        | Ca     |        |
|---------------------------|----------------------------------------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|
|                           | 1998                                   | 2002  | 1998  | 2002  | 1998  | 2002  | 1998  | 2002  | 1998   | 2002   | 1998   | 2002   |
|                           | Macro-nutrients ( $\text{g kg}^{-1}$ ) |       |       |       |       |       |       |       |        |        |        |        |
| *Soil N amendments        |                                        |       |       |       |       |       |       |       |        |        |        |        |
| Unfertilized              | 012.3a                                 | 10.8a | 2.96a | 3.11a | 3.27a | 3.31a | 0.97b | 1.23a | 0.926a | 0.930a | 0.766b | 0.100a |
| 100 kg N $\text{ha}^{-1}$ | 14.1b                                  | 16.9a | 2.69b | 3.28a | 2.92b | 3.46a | 1.22a | 1.10b | 0.916a | 1.02a  | 0.076a | 0.083a |
| 200 kg N $\text{ha}^{-1}$ | 13.5b                                  | 17.6a | 2.64a | 3.10a | 3.07a | 3.19a | 1.23b | 1.49a | 0.896a | 0.936a | 0.080a | 0.076a |
| SM50                      | 12.5a                                  | 14.6b | 2.86b | 3.39a | 3.28b | 3.69a | 1.22b | 1.40a | 0.893a | 1.02a  | 0.076b | 0.093a |
| SM100                     | 15.6a                                  | 16.2a | 2.76b | 3.33a | 2.89b | 3.59a | 1.26a | 1.26a | 1.03a  | 0.940a | 0.070a | 0.076a |
| RM50                      | 13.3a                                  | 11.9a | 2.66b | 3.43a | 3.12b | 3.74a | 1.23a | 1.24a | 0.983a | 0.813a | 0.076a | 0.083a |
| RM100                     | 14.0b                                  | 16.6a | 2.88b | 3.56a | 3.24a | 3.56a | 1.20a | 1.22a | 0.976a | 0.956a | 0.076a | 0.066a |
| Mean                      | 13.6                                   | 14.9  | 2.78  | 3.31  | 3.1   | 3.5   | 1.19  | 1.28  | .946   | 0.945  | 0.076  | 0.083  |

Table 2: Continue

|                           | Fe                                     |       | Zn    |       | Mn    |       | Cu    |       |
|---------------------------|----------------------------------------|-------|-------|-------|-------|-------|-------|-------|
|                           | 1998                                   | 2002  | 1998  | 2002  | 1998  | 2002  | 1998  | 2002  |
| *Soil N amendments        | Micro-nutrients (mg kg <sup>-1</sup> ) |       |       |       |       |       |       |       |
| Unfertilized              | 23.6a                                  | 20.4b | 19.6a | 21.7a | 4.00b | 4.81a | 1.50b | 3.31a |
| 100 kg N ha <sup>-1</sup> | 24.7b                                  | 29.9a | 19.7a | 19.7a | 3.92b | 5.64a | 1.37b | 4.05a |
| 200 kg N ha <sup>-1</sup> | 27.2a                                  | 28.0a | 17.5a | 18.6a | 4.03b | 5.83a | 2.77b | 4.92a |
| SM50                      | 23.7a                                  | 24.5a | 17.9b | 21.1a | 3.76b | 4.97a | 2.08b | 4.03a |
| SM100                     | 33.5a                                  | 27.0b | 18.2b | 20.3a | 4.69a | 4.89a | 1.12b | 6.31a |
| RM50                      | 31.9a                                  | 22.5b | 19.5b | 21.8a | 3.73b | 5.14a | 1.83b | 4.13a |
| RM100                     | 34.6a                                  | 26.2b | 17.4b | 19.4a | 4.45b | 4.58a | 1.78b | 4.42a |
| Mean                      | 28.5                                   | 25.5  | 18.5  | 20.3  | 4.1   | 5.1   | 1.8   | 4.4   |

\*Soil N amendments: 100 and 200 kg N ha<sup>-1</sup> applied as NH<sub>4</sub>NO<sub>3</sub>; SM50 = stockpiled manure at 50 Mg ha<sup>-1</sup> (wet weight); SM100 = stockpiled manure at 100 Mg ha<sup>-1</sup> (wet weight); RM50 = rotted manure at 50 Mg ha<sup>-1</sup> (wet weight); RM100 = rotted manure at 100 Mg ha<sup>-1</sup> (wet weight). Under each nutrient element, means within soil N amendments followed by the same letter are not significantly different at p<0.05 according to LSD test

Table 3: Comparison between 1998 and 2002 macro-micro nutrients concentration in corn stover under different levels of N amendments

|                           | N                                     |       | P     |       | K     |       | S     |       | Mg    |       | Ca    |       |
|---------------------------|---------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                           | 1998                                  | 2002  | 1998  | 2002  | 1998  | 2002  | 1998  | 2002  | 1998  | 2002  | 1998  | 2002  |
| *Soil N amendments        | Macro-nutrients (g kg <sup>-1</sup> ) |       |       |       |       |       |       |       |       |       |       |       |
| Unfertilized              | 4.52a                                 | 4.39a | 2.08b | 2.40a | 11.1a | 7.84b | 1.24a | 1.33a | 1.08b | 1.25a | 2.72b | 3.32a |
| 100 kg N ha <sup>-1</sup> | 4.63b                                 | 5.81a | 0.97a | 0.79b | 8.67a | 8.45a | 1.23a | 1.20a | 1.21b | 1.55a | 3.28b | 3.88a |
| 200 kg N ha <sup>-1</sup> | 4.90b                                 | 7.46a | 0.63a | 0.61a | 9.00b | 10.9a | 1.19b | 1.27a | 1.16b | 1.59a | 3.19b | 3.90a |
| SM50                      | 4.58a                                 | 5.07a | 1.37b | 2.00a | 11.2a | 11.7a | 1.25b | 1.32a | 0.93b | 1.11a | 2.88b | 3.52a |
| SM100                     | 5.31b                                 | 6.08a | 0.66b | 0.97a | 10.9b | 12.0a | 1.22b | 1.57a | 1.16b | 1.23a | 3.59b | 3.91a |
| RM50                      | 5.14a                                 | 4.50a | 1.18b | 2.44a | 10.7a | 11.4a | 1.19b | 1.30a | 1.41a | 1.27b | 3.42a | 3.57a |
| RM100                     | 5.29b                                 | 6.12a | 0.66b | 1.46a | 9.9b  | 14.0a | 1.21b | 1.31a | 1.09b | 1.20a | 3.34a | 2.26a |
| Mean                      | 4.9                                   | 5.6   | 1.08  | 1.52  | 10.2  | 10.9  | 1.22  | 1.33  | 1.15  | 1.31  | 3.2   | 3.5   |

Table 3: Continue

|                           | Fe                                     |      | Zn    |       | Mn    |       | Cu    |       |
|---------------------------|----------------------------------------|------|-------|-------|-------|-------|-------|-------|
|                           | 1998                                   | 2002 | 1998  | 2002  | 1998  | 2002  | 1998  | 2002  |
| *Soil N amendments        | Micro-nutrients (mg kg <sup>-1</sup> ) |      |       |       |       |       |       |       |
| Unfertilized              | 327b                                   | 599a | 29.6b | 56.8a | 16.3b | 28.3a | 4.17b | 5.92a |
| 100 kg N ha <sup>-1</sup> | 408b                                   | 602a | 26.9b | 38.5a | 20.5b | 36.9a | 5.20b | 7.06a |
| 200 kg N ha <sup>-1</sup> | 410a                                   | 432a | 14.1b | 20.7a | 22.0b | 33.1a | 4.23b | 8.16a |
| SM50                      | 218b                                   | 325a | 19.6b | 39.9a | 45.4a | 21.2b | 3.54b | 6.86a |
| SM100                     | 300a                                   | 227b | 17.0a | 16.2a | 25.3a | 17.9b | 6.12b | 7.72a |
| RM50                      | 473a                                   | 302b | 24.7b | 46.5a | 22.4a | 18.9a | 4.24b | 8.08a |
| RM100                     | 187a                                   | 257b | 13.6b | 22.2a | 13.2a | 13.9a | 4.36b | 7.15a |
| Mean                      | 332                                    | 392  | 21.2  | 34.4  | 23.6  | 24.3  | 4.6   | 7.3   |

\*Soil N amendments: 100 and 200 kg N ha<sup>-1</sup> applied as NH<sub>4</sub>NO<sub>3</sub>; SM50 = stockpiled manure at 50 Mg ha<sup>-1</sup> (wet weight); SM100 = stockpiled manure at 100 Mg ha<sup>-1</sup> (wet weight); RM50 = rotted manure at 50 Mg ha<sup>-1</sup> (wet weight); RM100 = rotted manure at 100 Mg ha<sup>-1</sup> (wet weight). Under each nutrient element, means within soil N amendments followed by the same letter are not significantly different at p<0.05 according to LSD test

N when sub-optimum N (100 kg N ha<sup>-1</sup>) was applied. Which also tends to confirm the indication above that yield was limited by a factor other than nitrogen as increase in very large biomass N concentration. The mean value we estimated for P and K varied more than twofold for P and by twofold for K, which was similar to report from different studies (Heckman *et al.*, 2003; Sims, 1999; Sims *et al.*, 1998; Lander *et al.*, 1998; Zublena, 1991). However, compared to those in 1998, biomass P and grain K concentration was significantly increased in 2002 (Table 2 and 3), while within N amendments significant different observed only in manure treatment when compared with unfertilized treatments (Table 4 and 5).

Table 4: Comparison of macro-micro nutrients concentration in corn kernel within different levels of N amendments (mean of 1998 and 2002)

| *Soil N amendments        | Macro-nutrients (g kg <sup>-1</sup> ) |       |          |         |         |          | Micro-nutrients (mg kg <sup>-1</sup> ) |        |       |       |
|---------------------------|---------------------------------------|-------|----------|---------|---------|----------|----------------------------------------|--------|-------|-------|
|                           | N                                     | P     | K        | S       | Mg      | Ca       | Fe                                     | Zn     | Mn    | Cu    |
| Unfertilized              | 11.5c                                 | 2.9b  | 3.30abcd | 1.11c   | 0.9283a | 0.0883a  | 21.96b                                 | 20.6a  | 4.41a | 2.41a |
| 100 kg N ha <sup>-1</sup> | 15.5a                                 | 3.0ab | 3.20cd   | 1.19bc  | 0.9683a | 0.0800ab | 27.28ab                                | 19.7ab | 4.78a | 2.71a |
| 200 kg N ha <sup>-1</sup> | 15.6a                                 | 3.0ab | 3.13d    | 1.36a   | 0.9166a | 0.0733ab | 27.58ab                                | 18.0b  | 4.93a | 3.85a |
| SM50                      | 13.6abc                               | 3.1ab | 3.49a    | 1.31ab  | 0.9566a | 0.0850ab | 24.08ab                                | 19.5ab | 4.37a | 3.06a |
| SM100                     | 15.9a                                 | 3.0ab | 3.24bcd  | 1.26abc | 0.9850a | 0.0733b  | 30.25a                                 | 19.2ab | 4.79a | 3.71a |
| RM50                      | 12.6bc                                | 3.0ab | 3.42ab   | 1.23abc | 0.9166a | 0.0800ab | 27.16ab                                | 20.6a  | 4.44a | 2.98a |
| RM100                     | 15.3ab                                | 3.2a  | 3.40abc  | 1.21abc | 0.9667a | 0.07167c | 30.39a                                 | 18.4ab | 4.51a | 3.01a |

\*Soil N amendments: 100 and 200 kg N ha<sup>-1</sup> applied as NH<sub>4</sub>NO<sub>3</sub>; SM50 = stockpiled manure at 50 Mg ha<sup>-1</sup> (wet weight); SM100 = stockpiled manure at 100 Mg ha<sup>-1</sup> (wet weight); RM50 = rotted manure at 50 Mg ha<sup>-1</sup> (wet weight); RM100 = rotted manure at 100 Mg ha<sup>-1</sup> (wet weight). In column within N amendments by the same letter are not significantly different at p<0.05 according to LSD test

Table 5: Comparison of macro-micro nutrients concentration in corn stover within different levels of N amendments (mean of 1998 and 2002)

| *Soil N amendments        | Macro-nutrients (g kg <sup>-1</sup> ) |       |         |        |        |        | Micro-nutrients (mg kg <sup>-1</sup> ) |        |       |      |
|---------------------------|---------------------------------------|-------|---------|--------|--------|--------|----------------------------------------|--------|-------|------|
|                           | N                                     | P     | K       | S      | Mg     | Ca     | Fe                                     | Zn     | Mn    | Cu   |
| Unfertilized              | 4.46c                                 | 2.24a | 9.45bc  | 1.29ab | 1.17ab | 3.02bc | 463a                                   | 43.1a  | 22.3a | 5.0a |
| 100 kg N ha <sup>-1</sup> | 5.22abc                               | 0.88b | 8.56c   | 1.22b  | 1.38a  | 3.58ab | 505a                                   | 32.7ab | 28.7a | 6.1a |
| 200 kg N ha <sup>-1</sup> | 6.18a                                 | 0.62b | 9.94abc | 1.23b  | 1.37a  | 3.54ab | 421ab                                  | 18.9cd | 27.5a | 6.2a |
| SM50                      | 4.83bc                                | 1.69a | 11.41ab | 1.28ab | 1.02b  | 3.20ab | 272bc                                  | 29.7bc | 33.3a | 5.2a |
| SM100                     | 5.70ab                                | 0.82b | 11.4ab  | 1.40a  | 1.19ab | 3.75a  | 264bc                                  | 16.6d  | 21.6a | 6.9a |
| RM50                      | 4.82bc                                | 1.81a | 11.02ab | 1.25b  | 1.34a  | 3.50ab | 387abc                                 | 35.6ab | 20.6a | 6.2a |
| RM100                     | 5.71ab                                | 1.06b | 11.97a  | 1.27ab | 1.15ab | 2.80c  | 222c                                   | 17.8cd | 13.5a | 5.8a |

\*Soil N amendments: 100 and 200 kg N ha<sup>-1</sup> applied as NH<sub>4</sub>NO<sub>3</sub>; SM50 = stockpiled manure at 50 Mg ha<sup>-1</sup> (wet weight); SM100 = stockpiled manure at 100 Mg ha<sup>-1</sup> (wet weight); RM50 = rotted manure at 50 Mg ha<sup>-1</sup> (wet weight); RM100 = rotted manure at 100 Mg ha<sup>-1</sup> (wet weight). In column within N amendments by the same letter are not significantly different at p<0.05 according to LSD test

It was noted that surprisingly no difference observed in P concentrations but a significant different observed in K concentrations between the two levels N fertilization treatment. This may be attributed to the higher composition of macro- and micro nutrient concentrations in stockpiled and rotted manures. Moreover, organic manures reduce the capacity of soil minerals to fix P and increase its availability through release of organic acids. Increase in biomass P concentration due to manure application was reported by Sims (1993) and Sims *et al.* (1998). The biomass K concentration was also significantly higher in the N amendments that had received fertilizer and manures. The manures supply K and solubilize K from K-bearing minerals by the organic acids released from the manures. Similar results were reported by Gill (1995). The positive effect of organic manures on uptake of P and K by the crop may be attributed to the chelation of Fe, Al, Mn, Zn, Ca and Mg preventing them from fixing P and K into soluble compounds (Antil *et al.*, 1995).

Application of stockpiled and rotted manure application increased significant amount of K concentration in kernel (Table 2). The increase was more pronounced in the plants supplied with manure than in the plant supplied with N fertilizer. Maintenance of high K levels in kernel and stover could be an important factor influencing kernel and stover growth by acting as an osmoticum to maintain the tissue turgor pressure, regulating the opening and closing of the stomata and water uptake of roots (Marschner, 1995).

#### *Calcium, Magnesium and Sulphur*

There was no significant effect of corn kernel Ca and Mg concentration between 1998 and 2002, even within different N amendments with some exception of Ca but corn stover Ca and Mg concentration significant increased within year between 1998 and 2002, even within different N amendments as well. The results indicate that application of fertilizer and manure led to accumulating

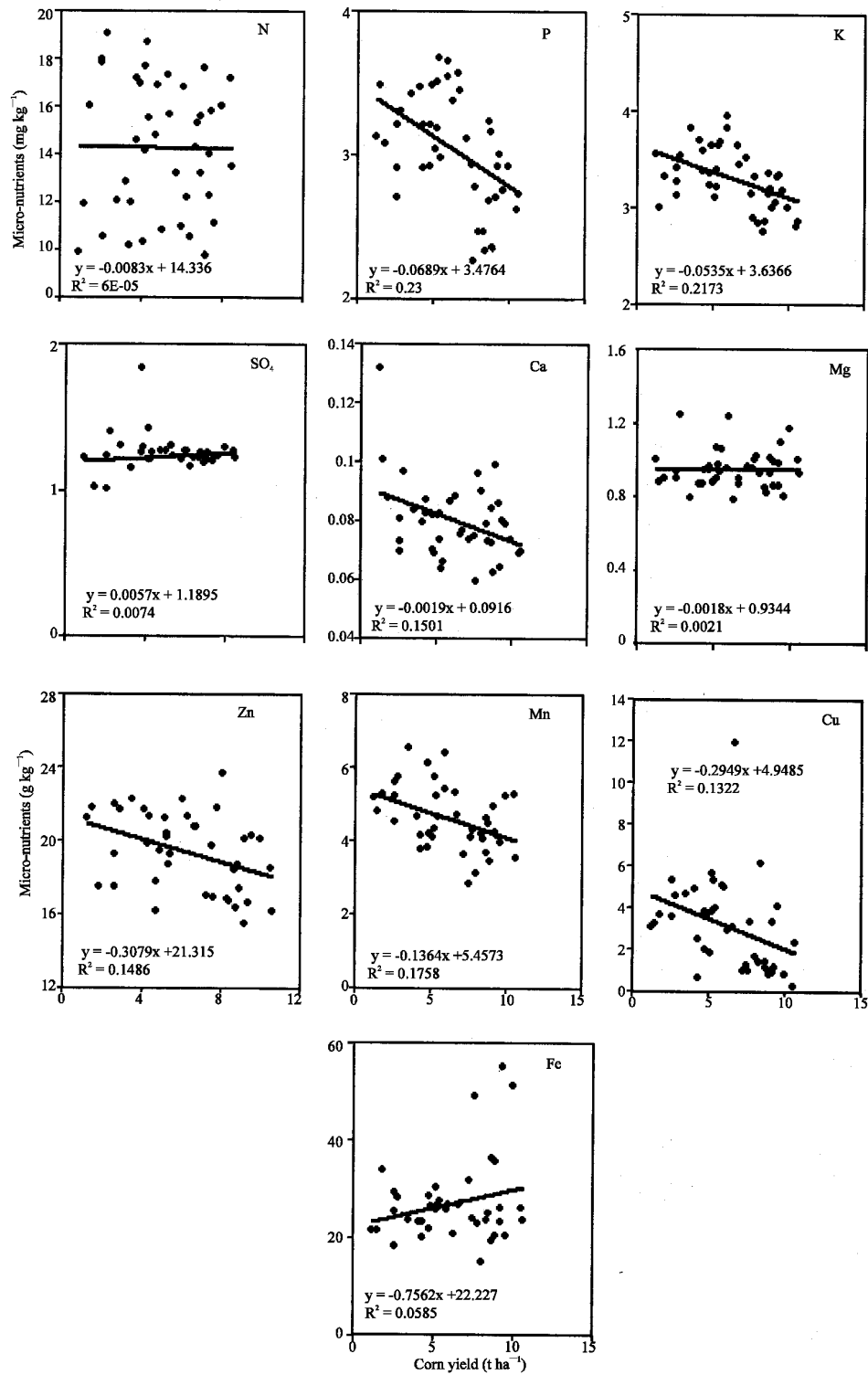


Fig. 1: Relationship between nutrient concentrations in corn grain and yield level

of significant amount of Ca and Mg in stover, not in grain. This result concerns with the report that application of Ca and Mg alone had no significant effect on yield, elemental composition of plant and uptake of macro- and micronutrients at harvest (Sahrawat *et al.*, 1999). Plants in about the same quantity as phosphorus require Sulphur. Our results showed significant differences of sulphur in corn grain within N amendments but no difference within between 1998 and 2002 (Table 2 and 5). Literature shows about 10 pound S per acre is deposited annually by rainfall in surface soils is associated with organic matter (Zublena, 1991).

#### *Micro Nutrients*

##### *Manganese and Iron*

The concentration of Mn in the kernel of the corn plants grown in different N amendments was significantly increased in 2002 with some exception but no effect was observed within N amendments (Table 2 and 5). On the other hand, significant decreased stover N in 2002, where stockpiled manure was applied (Table 3) but difference was observed within N amendments (Table 5). In 2002, Fe concentration significantly increased in the kernel and stover portion of corn (Table 2 and 3) also significant difference was observed within different N amendments as well (Table 4 and 5).

##### *Zinc and Copper*

The concentration of Zn and Cu in the kernel and stover were significantly affected by manure application over the growing periods (Table 2 and 3), which is also reflected within different N amendments (Table 4 and 5). Accumulation of Zn and Cu in the corn plants increased by addition of potassium through organic manure or residue plant materials (Vasanthi and Kumaraswamy, 2000). Results indicated that the increase in the accumulation of Zn and Cu was negatively correlated with yield, although it was not significant.

## **Discussion**

Grain yield ranged from 4 to 11 t ha<sup>-1</sup> among all N amendments as reported elsewhere (Ma *et al.*, 1999). Nutrient concentrations were not positively associated with yield (Fig. 1), may be yields were not reflecting the favorability of the growing environment; it is possible that sites were not favourable condition for corn growth also had no suitable conditions for the diffusion of nutrients from the soil to the root zone. The correlation co-efficient between P, K, Ca, Zn, Mn and Cu concentrations in grain and yield were negative, though it was not statistically significant (Fig. 1). Regression equations shown significant relationships only for Fe ( $p < 0.05$ , Fig. 1).

The value represents in the Table 3 are estimates of nutrient removal or the quantity of nutrients removed in the harvested biomass portion of the crop. Based on these nutrient concentrations, if a corn grain harvest 11 t ha<sup>-1</sup> would remove on average range within different N amendments the following nutrients amounts: N, 126.5 to 174.9; P, 31.9 to 35.2; K, 34.43 to 37.62; S, 12.21 to 14.96; Mg, 10.08 to 10.65; Ca, 0.81 to 0.97; Fe, 0.24 to 0.33; Zn, 0.20 to 0.23; Mn, 0.048 to 0.054; Cu, 0.027 to 0.042 kg ha<sup>-1</sup>. These values are comparable to literature values (Heckman *et al.*, 2003): N, 120.8; P, 36.7; K, 44.7; S, 9.9; Mg, 14.4; Ca, 2.6; Fe, 0.33; Zn, 0.25; Mn, 0.045; Cu, 0.03 kg ha<sup>-1</sup>. However, in this stage it is very difficult to make a recommendation because lack of soil fertility status. Even though the existing values of corn grain macro- and micro nutrient removal in this study are similar to existence reference values, the variability seen in this study raises questions about the usefulness of average values for estimating crop nutrient removal across a range of conditions. It should not be confused with nutrient uptake, which refers to the total nutrients absorbed by the growing crop. Actual nutrient removal may vary by 30% or more depending on the specific growing conditions of the crop such as soil fertility, yield, soil moisture, crop vigor and limiting nutrients (interactions) as well as the actual crop variety and fertilizer program (Potash and Phosphate Institute, 2001). Changes of soil fertility

may differ from the amount removed by the crop. In some instances, weathering of soil minerals and organic matter may compensate for part of the nutrient removal by crops. In other instances, nutrient may be chemically fixed by the soil or lost by leaching and loss of nutrients will exceed crop removal.

Phosphorus is evolved in the energy dynamics of plants, where as K is evolved in photosynthesis, sugar transportation, water and nutrient movement and protein synthesis. Phosphorus and potassium is not only the nutrients that may accumulate in soil from regular application of manure. Mineral supplementation of livestock feeds often enriches manures and soils to which they are applied with Cu and Zn (Mikkelsen, 2000). Nutrient removal values for Cu and Zn are relatively low compared with amounts of these nutrients that may be applied in the typical manure application. P is relatively immobile in soil, which quantity of available P in soils is the fraction that was also affected by plant removal.

Nutrients in plants that were left in the field will partially resupply nutrient reserves in the soil as they decompose. Estimates of nutrient depletion, therefore, should take into account only the nutrients removed with the harvested portion on the plant. Table 2 and 3 showed the mean concentration of various nutrients of both 1998 and 2002 that are removed by the corn crop for the yield level indicated. Values are not reported for B, Mo and Cl, because they were omitted due to lack of facilities, it does not mean that they were not removed or that they are unimportant.

## **Conclusions**

Large variation of macro- and micro nutrient concentration implies that farmers may need regularly to obtain an analysis of their harvested crop to accurately assess nutrient removal. Nutrient management planners should take into account the increased crop removal of macro- and micronutrients at higher soil test levels and higher yield levels.

The current study provided baseline information on macro- and micro nutrient accumulation under different soil N amendments. These macro- and micro nutrient removal rates are useful in comparing the nutrient demands of different crops. These values, however, do not take into account the quality and availability of nutrient reserves already in the soil. Because of this limitation, soil testing should still be the cornerstone of all fertility programs. Removal rates can be used in conjunction with soil testing to estimate the depletion of macro- and micro nutrient reserves.

The macro- and micro nutrient concentrations variability of this study raises questions about the usefulness of average values for estimating crop nutrient removal across a range of conditions. Future research on nutrient removal should focus on identifying sources of variation in nutrient concentrations in corn grain to enable better monitoring of crop nutrient removal. Because the application of macro- and micro nutrients through fertilizer and manure varied from field to field and year to year, therefore, we could not evaluate whether any relationship existed between soil test level and concentrations of these nutrients in grain.

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## **References**

- Anderson, J.M. and J.S.I. Ingram, 1993. Tropical Soil Biology and Fertility. A Handbook of Methods. 2nd Edn. CABI, Wallingford, Oxon OX10 8DE, UK.
- Antil, R.S., B. Singh and A.P. Gupta, 1995. National Seminar on Developments in Soil Science. Indian Soc. Soil Sci., New Delhi, India, pp: 6-7.

- Bacon, S.C., L.E. Lanyon and R.M. Jr. Schlander, 1990. Plant nutrient flow in the managed pathways of an intensive dairy farm. *Agron. J.*, 82: 755-761.
- Baute, T., 2002. Agronomy Guide for Field Crops. Publication 811, Ministry of Agriculture, Food and Rural Affairs, Toronto, Canada.
- Daniel, T.C., A.N. Sharpley and J.L. Lemunyon, 1998. Agricultural phosphorus and eutrophication: A symposium overviewed: *J. Environ. Qual.*, 27: 251-257.
- Gill, M.P.S., 1995. National Seminar on Developments in Soil Science. Indian Soc. Soil Sci., pp: 146-147.
- Heckman, J.R., J.T. Sims, D.B. Beegle, F.J. Coale, S.J. Herbert, T.W. Bruulsema and W.J. Bamka, 2003. Nutrient removal by corn grain harvest. *Agron. J.*, 95: 587-591.
- Jackson, M.L., 1975. Advanced Soil Chemical Analysis. Published by Prentice Hall of India Pvt Ltd. New Delhi, India.
- Lander, C.H., D. Moffitt and K. Alt, 1998. Nutrients available from manure relative to crop growth requirements. Resource Assessment and Strategies Planning Working Paper 98-1. USDA-NRCS, Washington, DC.
- Ma, B.L. and L.M. Dwyer, 1998. Nitrogen uptake and utilization of two contrasting maize hybrids differing in leaf senescence. *Plant and Soil*, 199: 283-291.
- Ma, B.L., L.M. Dwyer and E. Gregorich, 1999. Soil N amendment effects on N uptake and grain yield of maize. *Agron. J.*, 91: 650-656.
- Ma, B.L. and L.M. Dwyer, 2001. Maize kernel moisture, carbon and nitrogen concentrations from silking to physiological maturity. *Can. J. Plant Sci.*, 81: 225-232.
- Ma, B.L., L.M. Dwyer. and C. Costa, 2003. Row spacing and fertilizer nitrogen effects on plant growth and grain yield of maize. *Can. J. Plant Sci.*, 83: 241-247.
- Marschner, H., 1995. Mineral Nutrition of Higher Plants. Academic Press, UK., pp: 229-312.
- Mikkelsen, R.L., 2000. Nutrient management for organic farming: A case study. *J. Natl. Resour. Life Sci. Educ.*, 29: 88-92.
- Olsen, S.R. and L.E. Sommers, 1982. Phosphorus. In: Page *et al.* (Eds.). Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, American Society of Agronomy, Madison, WI.
- Potash and Phosphate Institute., 2001. Nutrients removed in the harvested portion of a crop (Online). A <http://www.ppi-ppic.org/> (verified 15 Jan 2003). Potash and Phosphate Instit., Nor-cross, GA.
- Sahrawat, K.L., M.P. Jones and S. Datta, 1999. Phosphorus, Calcium and Magnesium Fertilization Effects in Upland Rice in an Ultisol. *Commun. Soil Sci. Plant Anal.*, 30: 1201-1208.
- Sims, J.T., 1998. Phosphorus soil testing: Innovations of water quality protection. *Commun. Soil Sci. Plant Anal.*, 29: 1471-1489.
- Sims, J.T., R.R. Simard and B.C. Joern, 1998. Phosphorus loss in Agricultural drainage: Historical perspective and current research. *J. Environ. Qual.*, 27: 277-293.
- Sims, J.T., 1999. Overview of Delaware's 1999 Nutrient Management Act. Fact Sheet NM-02. College of Agriculture and Natural Resources, University of Delaware, Newark.
- Vasanthi, D. and K. Kumaraswamy, 2000. Effects of manure-fertilizer schedule on the yield and uptake of nutrients by cereal fodder crops and on soil fertility. *J. Indian Soc. Soil Sci.*, 48: 510-515.
- Zublena, J.P., 1991. Nutrient removal by crops in North Carolina. Soil Facts. The North Carolina Coop. Ext. Serv., Raleigh.