# INFLUENCE OF DAIRY MANURE APPLICATIONS ON CORN NUTRIENT UPTAKE

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## ABSTRACT

Corn silage is the predominant crop in Idaho used for recovering phosphorus (P) that has accumulated in soils from dairy manure applications. However, little is known about how much phosphorus and other nutrients are being recovered under Idaho conditions. The objective of the study is to estimate phosphorus removal by irrigated corn silage crops cultivated throughout Southern Idaho with variable soil test P concentrations, and to identify effects of increasing soil test P on potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and manganese (Mn). . Forty-two different corn silage fields in 2008 and 2009 were selected throughout Southern Idaho for soil and whole plant sampling at harvest. Soils were analyzed for Olsen P, plant tissue was measure for total P content, and dry and wet yields were calculated based on field weights and drying of plant tissue. Average phosphorus concentration in the whole plant tissue at harvest was 0.2078 % (table 2), with 39 of the 42 fields sampled between 0.15 and 0.25 % (figure 1). Increasing Olsen P in the soil from 3 to 200 ppm had no significant effect on tissue P over 20 ppm, Increasing Olsen P in the soil also did not appear to affect K or Zn concentrations in the tissue. However, it appears that Mg, Ca, and Mn plant tissue concentrations may be decreasing with increased Olsen P, especially on silt-textured soils for Ca and Mn. Controlled studies are needed to verify these relationships. Other factors such as manure source and irrigation method will be incorporated in future analyses of this dataset.

## INTRODUCTION

With increased applications of phosphorus-rich dairy manures to agricultural lands in Southern Idaho, growers need to be confident that the current P removal rate estimates for specific crops are accurate. Corn silage is of particular interest, as these crops receive more dairy manure than any other crop in Idaho. The maximum acceptable concentration of soil test P in Idaho is 40 ppm Olsen P per growing season, with the expectation that agricultural crops, including corn silage crops, are unable to recover more than 35 ppm of extractable P in a growing season. Nutrient management planners and Natural Resources Conservation Service representatives in Idaho have begun questioning the use of these P recovery rate recommendations. Because most P recovery estimates are based on data from crops grown in the Midwestern and Eastern regions of the United States, it is quite possible that the unique characteristics of Southern Idaho calcareous soils would have an effect on phosphorus movement and root adsorption rates, thus potentially altering the expected target for P recovery in this region. To accurately estimate how much P is removed by corn silage crops in Southern Idaho, P movement from soils to plants needs to be evaluated.

A major concern with P accumulations in soils is the potential for deficiencies and toxicities of other nutrients. For example, several research studies have shown that zinc deficiencies can be induced with excessively high concentrations of phosphorus fertilizer in the soil. There is also concern that the high concentrations of potassium in manure will cause cation competition with magnesium and calcium, thus reducing the uptake of these nutrients by the plant.

The objective of the study is to 1) estimate phosphorus removal by irrigated corn silage crops cultivated throughout Southern Idaho with variable soil test P concentrations, and 2) identify effects of increasing soil test P on potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and manganese (Mn).

## METHODS

For soil and tissue testing as well as yield estimates, we selected 21 corn silage fields in 2008 and 21 corn silage fields in 2009 throughout Southern Idaho to represent predominate soil types in the region (Table 1). Fields sampled in 2008 were not resampled in 2009. Efforts were made to select fields ranging widely in soil test P levels by asking growers and dairymen about their manure application histories, and selecting sites that had either low, moderate, high, or excessively high rates of manure applied to their fields in the past. A small percentage (9-19%) of the fields did not have a history of manure applications, allowing us to include lower and possibly limiting P soil test levels in the study.

Soil, whole plant, and tissue sampling was conducted within a week of harvest. For consistency, fields were sampled once the kernels had reached the ½ - 2/3 milk line stage, which is the ideal dryness for harvesting corn for silage use.  Fields were sampled in the fall at three subplots locations throughout the field. Soils were sampled by retrieving 10 soil cores to a 12 inch depth from a 10-ft. length of two full rows (row width documented and used to estimate yield), and analyzed for Olsen P. All stalks were cut 4 inches from the ground, counted, and weighed in the field. Three plants were sub-sampled from the yield sample and dried, ground, and analyzed for nutrient content using nitric acid digestion and Inductively Coupled Plasma analysis.

**Table 1. Locations of corn silage fields in Southern Idaho selected for sampling, by county.**

| County | Jerome | Twin Falls | Lincoln | Canyon | Cassia | Franklin | Gooding | Payette | Total |
|---|---|---|---|---|---|---|---|---|---|
| of Fields sampled in 2008 | 3 | 4 | 3 | 3 | 3 | 2 | 2 | 1 | ***21*** |
| # of Fields sampled in 2009 | 4 | 4 | 2 | 2 | 2 | 2 | 5 | 0 | ***21*** |

## RESULTS AND DISCUSSION

Time did not appear to have a significant effect on yield, dry matter percent, nutrient concentrations in the corn plant tissue, or nutrient uptake, therefore the results from 2008 and 2009 have been combined for this discussion (table 2, figure 1).  Average dry yield, wet yield, and dry matter % were similar to current averages for Idaho. Yield (on a dry matter basis) was also not effected by increasing Olsen P from 3 to 200 ppm, therefore the effect of nutrient uptake relationship to increasing Olsen P were similar to the concentration of nutrients in the tissue.

**Table 2. Whole plant tissue analysis, yield, dry matter, and uptake for corn silage harvested from 21 fields in 2008 and 21 fields in 2009 throughout Southern Idaho with varying fertilizer and manure application histories. Soil test P varied from 3 to 300 ppm Olsen P.**

| Variable | Mean | Std. Dev | Minimum | Maximum |
|---|---|---|---|---|
| Yield (wet ton/acre) | 31.7 | 7.0 | 15.7 | 47.2 |
| Yield (dry ton/acre) | 11.2 | 2.6 | 5.2 | 17.4 |
| % dry matter | 33.8 | 6.4 | 23.8 | 54.5 |
| Tissue P (ppm) | 2078 | 361 | 1163 | 3067 |
| Tissue K (ppm) | 8885 | 2862 | 4385 | 16839 |
| Tissue Mg (ppm) | 965 | 290 | 596 | 1660 |
| Tissue Ca (ppm) | 1380 | 670 | 531 | 2791 |
| Tissue Zn (ppm) | 12.7 | 4.1 | 6.2 | 27.3 |
| Tissue Mn (ppm) | 24.7 | 12.0 | 8.5 | 57.2 |
| Tissue B (ppm) | 4.6 | 1.8 | 2.5 | 12.4 |
| P uptake (lb/acre) | 43.7 | 11.7 | 17.0 | 76.3 |
| K uptake (lb/acre) | 187 | 73.2 | 69.4 | 339 |
| Mg uptake (lb/acre) | 20.6 | 8.3 | 8.3 | 36.7 |
| Ca uptake (lb/acre) | 30.0 | 18.0 | 6.8 | 73.2 |

Average phosphorus concentration in the whole plant tissue at harvest was 0.2078 % (table 2), with 39 of the 42 fields sampled between 0.15 and 0.25 % (figure 1). Increasing Olsen P in the soil from 3 to 200 ppm had no significant effect on tissue P over 20 ppm, therefore it is not necessary to account for soil test P when estimating P tissue concentrations and P uptake for corn silage. Based on our findings, it appears that the current recommended value (includes all plans written after June 2007) by the Idaho OnePlan for tissue P % for corn (0.185 %) will tend to cause producers to underestimate P removal by corn silage more often than overestimate. As NRCS has agreed to change the values based on our findings, these producers will be able to account for more P removal from corn silage, and therefore apply more manure to their fields. However, producers that have nutrient management plans that were written before June 2007 have been grandfathered in with P uptake based on a tissue P of 0.26 %. As only 3 of the 42 fields measured at or above 0.26 % tissue P, producers using this estimate for P removal are most likely overestimating the potential for P uptake by corn silage, and therefore over-applying manure. Producers with older nutrient management plans should be required to use the 0.21 % value for tissue P supported by this study when estimating P removal by corn silage.

The effect of increasing soil test P on K, Ca, Mg, Mn, and Zn concentrations in the plant tissue is illustrated in figure 1. As samples were collected from cooperators' fields that also varied in irrigation method, variety, cultural practices, manure source, and manure application history, variability tends to be higher than in controlled plot studies, however trends can still be identified at this scale. In addition to tissue P, increasing Olsen P in the soil does not appear to affect K or Zn concentrations in the tissue. These results suggest that 1) corn is not a luxury consumer of K, and 2) high P levels in the soil may not be inducing a Zn deficiency. Zinc deficiencies induced by high soil test P has been illustrated in a large number of studies (Christensen, 1972; Christensen and Jackson, 1981; Soltanpour, 1969). However it has been suggested that this is less common on manured soils, as manure is a rich source of Zn as well as P.

Based on our results, it appears that Mg, Ca, and Mn plant tissue concentrations may be decreasing with increased Olsen P (figure 1). One common explanation for Ca and Mg deficiencies on heavily manured soils is cation competition in the soil between K, Ca, and Mg. It should be mentioned that Olsen P values above 30 ppm were generally a result of manure applications. Therefore, at high Olsen P levels, one can assume that K and other nutrients are also being applied at very high levels. It is difficult to determine if there was cation completion between K and Ca and Mg, as K uptake did not appear to increase with increasing Olsen P, and because manures contain large amounts of Ca and Mg in addition to K. Calcium concentrations also appeared to decrease with increasing Olsen P concentration on silty soils more than sandy soils (figure 1). This could be related higher cation exchange capacity associated with silty soils, which would allow for more Ca to attach to the soil particles than on a sandy soil. With increasing soil test P, there would be more Ca available to bind to phosphate ions, which would decrease the amount of Ca available to the plant for uptake.

Decreasing Mn concentrations has been associated with increased soil P in a few studies (Ducic and Polle, 2007; Nogueira et al., 2004; Neilsen et al., 2004). In our study, we found this relationship to be more common on silty soils than on sandy soils (figure 1). As Mn deficiencies have been shown to increase under cooler and wetter conditions, it is possible that the higher water holding capacity of the silty soils created a greater Mn response to increased soil test P than sandy soils. More investigation on possible interactions between Mn uptake, soil texture, high P, and heavily manured soils is needed.

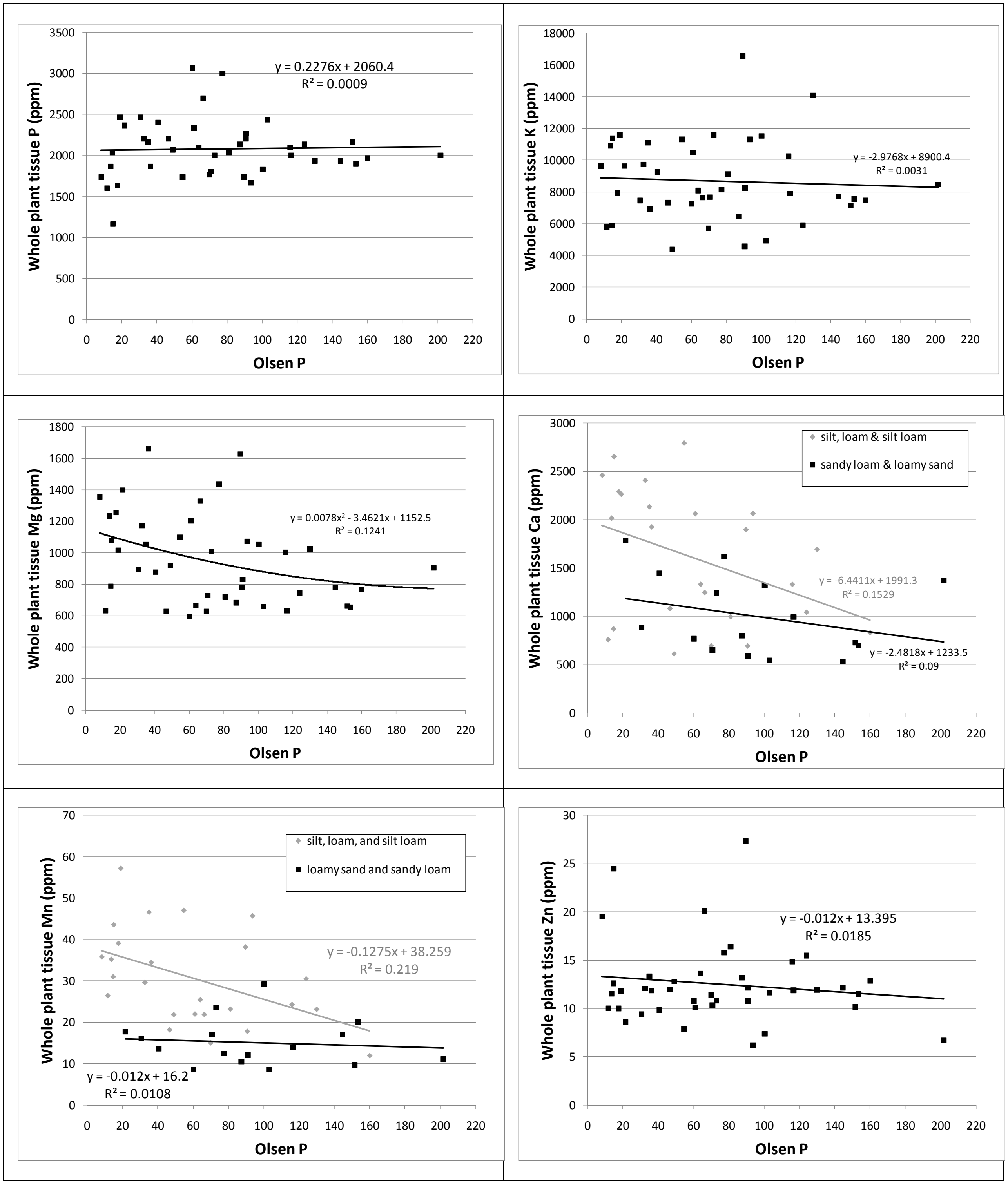


**Figure 1. Whole plant tissue analysis related to Olsen P for corn silage harvested from 21 locations in 2008 and 21 locations in 2009 throughout Southern Idaho.**

## SUMMARY

Based on soil and whole plant samples collected from 42 fertilized and manured corn silage fields in Southern Idaho over a two-year period, we would recommend that NRCS change the tissue P concentration used in Idaho OnePlan nutrient management software to 0.21 %, which represents the average P uptake potential of corn silage grown under Southern Idaho conditions. We would also like to mention that this study has been useful for identifying potential trends between Olsen P, manure applications, and tissue nutrient concentrations, however it is clear that controlled studies are needed to explore and understand these relationships further. Other factors in addition to soil type, such as manure source and irrigation method, will be incorporated in future analyses of this dataset.

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# PROCEEDINGS

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