2013 Research report to the Oregon Processed Vegetable Commission

Improving fertilizer P and N use efficiency in sweet corn

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Contents

1 Executive Summary

1.1 <u>Enhanced efficiency fertilizers</u>

The enhanced efficiency (EEF) products we tested in our study hold the potential to increase the nitrogen utilization efficiency of sweet corn as well as reduce nitrate leaching when all N fertilizer is applied before planting. However, this potential is limited by weather (i.e. large early season rainfall events), irrigation management, and soil conditions (i.e. sandy soils). In most years and at most sites these products will likely not increase yield. But, for early spring plantings on sandy soils, use of these products add extra insurance against nitrate loss in the event of large storm events occurring within 4 weeks after planting.

With the exception of one product (Duration 45), the fertilizers evaluated could consistently protect 20-40 lbs N/A (15-30% of applied N) from leaching in the first 2-6 wks after planting (i.e. before maximum crop N uptake begins).

All enhanced efficiency (EEF) products reduced nitrate concentrations relative to straight urea in the first 2-wks of the study. **With less nitrate in the soil profile early in the growth cycle when seeds are germinating and when no N uptake is occurring, these products have the potential to reduce nitrate leaching in the event of high early season rainfall.** After 2-wks, the ability to reduce nitrate concentrations varied by product. Generally by week 8, there were few if any differences between straight urea and the EEF products. **From our data, these products appear to be most effective at reducing soil nitrate concentrations in the first month after application.**

No difference in gross ear yield or ear quality between fertilizers or fertilizer rates was observed at either trial. The likely reason for this is that the low fertilizer rate was sufficient to achieve maximum yield. Even though these products retained 20-40 lb/A more N in the soil, soil mineral N levels were already high enough that this did not make a difference. To have been able to effectively evaluate these products on ear yield, higher leaching conditions 2-6 wks into the trial would have likely been needed to reduce nitrate concentrations.

Performance data for individual EEF products

Only the soil mineral N results will be discussed in this section because no difference in yield was observed between the EEF products and straight urea. Timing and amount of rainfall are critical factors influencing the performance of these products.

1. ***ESN:*** Across two field trials, this product (polymer coated urea) was the most consistent at reducing soil nitrate levels for 4+ wks. At 15 days after application, we found that 7% of prills were completely empty (just the polymer husk remained), 47% were partially intact (i.e. some urea remained in the prill), and 46% were fully intact. Based just on this data, the ESN is protecting almost half of the urea from being released into the soil in the first two weeks after application, thus preventing the N from being lost should a large rainfall or irrigation event occur early in the crop cycle. In both trials, approximately 30% of urea had not been released at week 4.
2. ***Duration 45:*** In general this product (same polymer coated urea as ESN but thinner and designed to release more rapidly) was able to reduce nitrate concentrations at 2 wks after application, but after 2 wks was consistently no different than straight urea. This product likely releases too fast to be useful for early planted sweet corn, especially if a large rain event were to occur >2 weeks after planting. Duration 45 has been shown to be most effective for small seeded crops that are shallowly planted and receive large pre-emergent irrigations (i.e. lettuce and spinach).

3. ***Super-U:*** This product (containing a urease and nitrification inhibitor) was able to consitently reduce nitrate in the first 4 wks after application and also had the highest ammonium levels of all the products. This product appears to only be effective for ~6 wks on.
4. ***Nitrapyrin:*** The formulation we tested is very similar to the commercially avialable product Instinct II. The nitrapyrin (nitrification inhibitor) was coated onto urea and was used in only one trial. This product was only used in one trial. **Nitrapyrin prevented the conversion of ammonium to nitrate over the entire 8 wks. On average 32, 43, and 35% of total fertilizer N applied remained as ammonium-N at wk 4, 6, and 8 wks, respectively**. Along with ESN, this product had the longest effect. This product is registered for use in sweet corn in Oregon and has the following replant restrictions: "Corn (field, sweet, pop), sorghum, wheat, other cereals, oilseed crops (including soybeans), and leafy vegetables, may be rotated 120 days from the last application of N-Serve 24 [a formulation of nitrapyrin]. All other crops are not to be rotated in less than one year after the last application."

1.2 Presidedress nitrate test (PSNT) and soil nitrogen mineralization (Nmin)

This is the third and final year of field and laboratory measurements of soil N mineralization rate. **We measured soil N mineralization rate in order to understand how to better forecast N fertilizer needs**.

Use of a Presidedress nitrate test (PSNT) "Quick Test" to eliminate need for a lab analysis. We compared nitrate values obtained from a nitrate "Quick Test" (QT) with results from a North American Proficiency Testing (NAPT) certified laboratory. The QT is comprised of easily obtainable supplies, provides **semi-quantitative** results with minutes, and is much cheaper than a laboratory analysis ($0.75/sample vs. $6-13/sample +shipping depending on the lab). The test can easily be done by the farmer and requires no specialized training (other than how to collect a representative sample from a field). **Our results showed that the QT nitrate values were equivalent to the laboratory values. Therefore, by using the QT growers can make immediate PSNT fertilizer decisions without the need to send samples to a commercial lab.**

Forecasting N fertilizer need with at-planting soil nitrate test. The Pre-SideDress Nitrate Test (PSNT) is used to forecast N fertilizer need in the OSU Nutrient Management Guide for Sweet Corn (EM9010; 2010). The PSNT test was shown to be a good predictor of the rate of N fertilizer needed for sweet corn in our N-rate field trials in 2010 and 2011. In 2012-13, we did not have PSNT trials with N fertilizer rates (to measure crop response to N fertilizer rate). Instead, we measured at-planting soil nitrate-N (NO3-N) and soil NO3-N at 6-leaf stage (PSNT) at seven field sites (same fields where we measured N mineralization in the field; see above). The objective was to determine whether at-planting soil testing could provide useful information to predict N fertilizer needs, which would be especially useful for farmers who apply their N fertilizer preplant. **Over two years, we found that soil NO3-N was always higher in the PSNT samples compared to the at-planting samples.** We found that soil nitrate increased by an average of 28 lb and 37 N/acre between planting date and PSNT sampling date (corn at six leaf stage) in 2012 and 2013, respectively. **Growers who are applying all their fertilizer N preplant and who are using the at-planting soil nitrate value with the current PSNT interpretive guidance (Table 10 in EM9010) should apply ~30 lbs less N/A than the PSNT recommendations to account for soil N mineralization.**

Nitrogen mineralization in the field. From 2011-13, corn was grown on small plots within 27 cooperator fields that did not receive current season N fertilizer application. At 1200 GDD after planting (silking) plants were harvested to determine plant N uptake with zero N fertilizer applied. Plants were also harvested from corn rows nearby that were fertilized by the cooperating farmer. All of the plant N in the zero-N plots came from soil (decomposition of soil organic matter to release plant-available nitrate-

N). These field measurements are realistic, but not always precise, because many site variables (not just soil N mineralization rate) affect plant N uptake. **Over three years of measurement (2011-13), we found that sweet corn obtained at least 40% of its N from mineralization, with fertilizer supplying the rest. However, on average 2/3rds of N was supplied by N mineralization.** Over a full season, corn plants usually take up about 150 to 200 lb N/acre. Our measurements showed that N mineralization of soil organic matter (to silking growth stage) supplied an average of 88 lb/acre from 2011-13.

N mineralization in the laboratory vs. the field. Over three years and 29 sites, soil mineralized on average 1.1% (range 0.4-1.7) of total soil N (23C for 42d). Of these soils, 62% mineralized ≥1.0% of their total N. But over three years, we observed no strong correlations between laboratory N mineralization tests and N uptake in zero N plots. Likely field conditions (i.e. wetting/drying cycles, interaction of the soil with plant roots, and changing soil temperatures) are variable enough that lab incubations using sieved soil at constant temperature and moisture are unable to predict N mineralization of soil under field conditions.

1.3 Phosphorus trials

- **In two field trials, gross ear yield did not increase with P fertilization.** Phosphorus fertilizer was banded at rates up to 120 lb P2O5/acre at planting. On trial was on farm and the other conducted at the OSU Vegetable Research. This data is consistent with the 4 field trials conducted in 2012, were no P yield response was observed regardless of planting date (early vs. late). **In the on-farm trial, which had the lowest P concentration of all sites (42 ppm Bray 1P), there appeared to be an increase in husked ear weight, length, and width for treatments receiving ≥60 lb P2O5/A** (which is what is recommended in OSU's Nutrient Management Guide for Sweet Corn-Western Oregon (publication EM 9010-E).
- OSU's Nutrient Management Guide for Sweet Corn-Western Oregon (publication EM 9010-E) recommends that when the Bray 1 P concentration is >50 ppm, no fertilizer P is usually necessary for maximum growth except when conditions could lead to a deficiency (i.e. cold spring soil temps). In 2012 the average soil test P (STP) level across 4 sites was 90 ppm (range 77-108), and no P yield response was observed regardless of planting date. In 2013, the farm-scale field had a STP of 135 ppm and the research-farm field had 42 ppm. Even though the research-farm field was below the recommended threshold of 50 ppm and was planted early when cold soil conditions could limit P availability, at harvest no gross ear yield response was observed. **The lack of benefit from P fertilizer addition at these sites not only supports current OSU recommendations: zero P or low rate P application when soil test P is above 50 ppm, but also demonstrates that the 50 ppm threshold is conservative.**
- **Our data suggest that sweet corn may be able to outgrow an early season P deficiency as long as the deficiency was not too severe and sufficient P is available when maximum P uptake occurs.** Although there were differences in plant growth and P uptake early in the growth cycle (V5) at the research-farm field, which had 44 ppm Bray 1 P, the plants were able to outgrow the early season deficiency and no differences between P fertilizer rates were observed in yield or ear quality. Early in the season cool soil temperatures may limit P availability, but as the soil warms, the root system expands, and the P demand increases, there may be sufficient P to overcome an early season deficiency.

2 Background

2.1 Enhanced efficiency fertilizers

In recent years farmers in Oregon have been experimenting with newly available enhanced efficiency fertilizer (EEF) technologies to manage nitrogen (N) in their production systems. Research has shown that EEFs can improve the crop N use efficiency (NUE) as well as minimize negative environmental losses compared to conventional fertilizers (Guertal, 2009; Shoji et al., 2001). As a result of increased efficiency, these products have the potential to reduce fertilizer use, which may improve the profitability and sustainability of farming operations, especially as fertilizer N costs increase. They work by slowly releasing nitrogen to the crop and/or by inhibiting the conversion of urea and/or ammonium fertilizers to nitrate. Once fertilizer N has converted to nitrate it is susceptible to leaching with irrigations or rainfall.

By keeping the fertilizer in the rootzone early in the season when crop N uptake is minimal, there is the potential to reduce N applications thereby increasing the crop N use efficiency.
Although some EEF products have been around for decades, their effectiveness at increasing the NUE of corn in Western Oregon has been variable (Hart et al., 2010). In a few years with wet springs, yields were increased by the application of a nitrification inhibitor to the preplant fertilizer compared to the preplant alone. But, in other experiments EEF products have been found to be ineffective regardless of weather conditions (Hart et al., 2010). Recently there have been new products have come into the marketplace that show promise in increasing the NUE efficiency of corn. These products use new chemistries and formulations which have been shown to be more effective than some of the older products released decades ago.

Currently several sweet corn growers are experimenting with EEFs by applying all fertilizer N at planting instead of splitting their applications into a pre-plant and midseason application as is traditionally done. Although EEF are more expensive than conventional fertilizers, farmers like this strategy because it eliminates a pass through their fields in the middle of summer when they are busiest and also must work around irrigation schedules and equipment. Also, when the fertilizer is broadcast at midseason, any urea that falls into the whorls can potentially injure the young plants if moisture conditions are right. And if the broadcasted urea is not irrigated in within 24 hrs, significant N loss through ammonia volatilization may occur.

Despite the benefits of applying all the N fertilizer at planting there is a potential risk of doing so. Early in the growing season crop N uptake is minimal and rainfall is likely. If the EEF products releases N too rapidly or fail to prevent the conversion of urea and ammonium into nitrate, there can be a high nitrate leaching potential. Should this happen, the crop may experience N deficiency at early development stages which sacrifices yield that cannot be recovered with additional N later in the season. Conversely, if the fertilizer releases N too slowly when N uptake is at its greatest, insufficient N will be available to maintain maximum crop growth. Although there have been many studies with newer EEF products (especially in the Midwest), there are few studies that have been conducted in the Willamette Valley with these new products. Under cool wet springs conditions their performance may be different than in other regions of the country (Golden et al, 2011). This project is aimed at evaluating new EEF products that may be useful for sweet corn production in western Oregon and, if they are successful, developing strategies to help sweet corn growers reap the maximum benefit of EEF by developing timing and rate guidelines.

2.2 Nitrogen: Predicting N mineralization and fertilizer needs

Land planted to sweet corn and other row crops (vegetables) can make a substantial contribution of nitrate-N to groundwater and nitrous oxide-N to the atmosphere. Failure to accurately forecast the amount of nitrogen needed to produce a crop not only increases the risk of loss, but it also reduces profitability for growers. Excess N fertilizer application increases the rate of soil acidification and future liming expense. Nitrogen fertilizer prices spiked several years ago, and threatened profitable current sweet corn production in the Willamette Valley. Sustained higher N fertilizer costs are expected in the future because energy (natural gas) is approximately 90% of the cost of producing N fertilizers. Much of domestic N fertilizer use is supplied from sources outside the US. Practical tools are needed to reliably predict the amount of N fertilizer that is needed for sweet corn to maintain profitable production and to reduce the potential losses of unused nitrogen to groundwater or the atmosphere.

In spite of the demonstrated accuracy of PSNT test, alternative N tests to guide N management are needed because growers don't always find PSNT logistics easy to fit into management programs. There is usually only a 1 to 2-wk window between collection of soil samples for the PSNT and application of sidedress N fertilizer. An alternative approach to the PSNT test is to collect soil samples preplant, and forecast sidedress N needs using a soil test for nitrogen mineralization potential (N min test; Fig. 2-1). The preplant N min test allows producers more time to make sidedress N fertilizer decisions, and to arrange for application. Soil tests for N mineralization potential have been slow to be adopted by commercial soil testing laboratories for N fertilizer recommendation. A major barrier to Nmin test adoption is the lack of locally relevant test calibration data. Calibration is needed to verify the relationship between N min test values and crop response to N fertilizer.

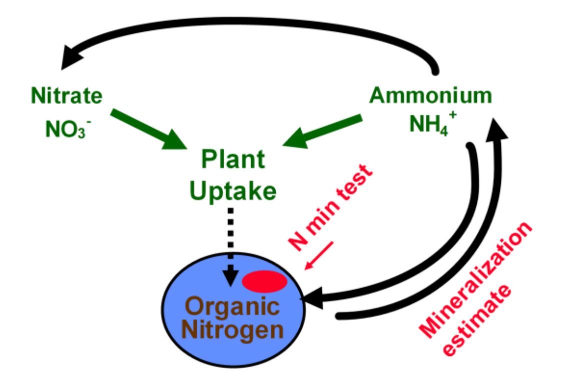

Figure 2-1. A spring soil test for N mineralization potential measures a fraction of total soil organic matter that is active. Results for useful soil Nmin tests are strongly correlated with the amount of plant available N (ammonium + nitrate N) produced by decomposition of soil organic matter during the crop growing season

2.3 Improving P fertilizer use

Determination of P sufficiency via soil testing is difficult, since the ability of sweet corn to obtain P from the soil is influenced by soil temperature, biological activity, and root diseases. Ensuring an adequate P supply for sweet corn production is complicated by the insolubility and immobility of biologically available P forms. Phosphorus moves only a short distance from where it is placed in the soil, so it is commonly banded near the seed where seedling roots proliferate. Root growth and P solubility are both reduced in cold soils, thereby limiting plant P uptake. Low soil temperature also reduces the rate at which soil organic P is mineralized to soluble plant-available P (orthophosphate, $H_2PO_4^-$). Research from California showed a 40 percent reduction in available P with a 20°F decrease in soil temperature. In western Oregon, the minimum soil temperature at the 4-inch depth increases approximately 20°F between mid-April and early July. Thus, soil P is less available at early planting dates. Band application of P fertilizer at planting can increase yield, but does not completely overcome the effect of low soil temperatures. Past field research in western OR showed no consistent advantage to banded P application when corn was planted in early May and soil test P (Bray P-1 method) was near 100 ppm (MacAndrew, 1983). The OSU Nutrient Management Guide for Sweet Corn (EM9010; Hart et al., 2010) recommends that starter P application be omitted or reduced to the lowest rate that can be applied with the planter when Bray soil test P is above 50 ppm.

3 Research Objectives

3.1 Enhanced Efficiency Fertilizers

1. **Evaluate the performance and economics of EEF products that have the most potential to work in Oregon compared to conventional fertilizers for yield and crop N use efficiency (NUE).** If EEFs can keep fertilizer N in the rootzone and reduce nitrate loss relative to conventional fertilizers, environmental impacts are minimized and the NUE is maximized. If effective, we would develop guidelines (rate and timing) for the use of EEF to reap the maximum benefit from these products.

3.2 Phosphorus trials

1. **Improve P fertilizer utilization efficiency by corn**. We continued to evaluate corn yield response to banded starter P fertilizer rate on two sites; one with a moderate and one with a high soil test P level.
2. **Determine the effect of banded P fertilizer rate on crop yield for early season planting dates.**
3. **Measure P supply to roots under actual field conditions using Plant-Root Simulator probes.** The PRS measurements assessed P supply as affected by prevailing soil moisture, temperature, physical and biological conditions at each site.

3.3 Presidedress nitrate test (PSNT) and soil nitrogen mineralization Nmin

1. **Determine the utility of an at-planting soil nitrate test vs. the standard PSNT done at V5.**
2. **Determine if a Nitrate Quick Test is accurate enough to be able to eliminate the need to send a soil sample to a commercial lab.**
3. **Quantify the soil's ability to supply sweet corn with nitrogen.** This is done by measuring crop N uptake in the field (with zero N fertilizer applied).
4. **Measure N mineralization rate potential in the laboratory using a variety of testing protocols.**
5. **Determine the effect of soil incubation temperature on rate of N mineralization in the laboratory, using an aerobic incubation method.**
6. **Relate lab measurements of soil N mineralization potential to N uptake by corn in zero N field plots**.

4 Methods

4.1 Enhanced Efficiency Fertilizers

Determine the effect of enhanced efficiency fertilizers (EEF) on N uptake, N use efficiency, and ear yield, and ear quality. Two field sites, one on-farm (Monroe) and one at the OSU Vegetable Research

Farm (VF), were selected because they had sandy soils and early planting dates. These conditions allowed us to assess the worst case scenario for nitrate leaching, wet spring conditions on a soil with good drainage. Both sites were set up in a randomized complete block design (RCBD) with 4 replicates.

On-farm experiment- Fertilizer was broadcast on April 22 and incorporated on April 23. Treatments and fertilizer rates are given in Table 4-1. All plots received 120 lb/A K2O applied using a belly grinder. The field was seeded on April 26. Crop N uptake was measured a week prior to ear harvest by harvesting aboveground biomass from 10 ft of row, grinding it with a chopper, then measuring dry matter, and %N. Crop N uptake was calculated as: Above-ground plant dry matter (lb/acre) x plant N%/100. Ears from twenty feet of row were hand harvested. Ear harvest weight, dry matter, and other parameters (tip fill, length, width, etc.) were measured. Nitrogen use efficiency (NUE) could not be estimated at this site because we were unable to exclude the at-planting banding of 30 lb N/A.

Table 4-1. Rates of fertilizer applied to experimental plots at the on-farm trial (Monroe)

				Pre-plant[1]	At-planting[2]	Midseason[3]	Total
Trt	Fertilizer	Company	%N	---------------------- lbs N/A	------------------------		
1	Control	NA	NA	0	33	0	33
2	Urea	NA	46	0	33	150	183
3	Urea	NA	46	100	33	0	133
4	Urea	NA	46	150	33	0	183
5	ESN	Agrium	44	100	33	0	133
6	ESN	Agrium	44	150	33	0	183
7	Super-U	Koch	46	100	33	0	133
8	Super-U	Koch	46	150	33	0	183
9	Duration 45	Agrium	44	100	33	0	133
10	Duration 45	Agrium	44	150	33	0	183

1- broadcast an incorporated; 2- 250 lb/A of 13-39-0 banded; 3- banded

OSU Vegetable Research Farm (VF)- Fertilizer was broadcast and incorporated with a Kuhn Power harrow on May 9. Incorporation depth was approximately 4 inches deep. Treatments and fertilizer rates are given in Table 2. All plots received 50 lb/A K2O and 50 lb/A P2O5 banded at planting. The field was seeded on May 10. Treatment 2 received a split application of urea, urea broadcast and incorporated at planting, and a midseason application banded next to the seedline (Table 4-2). Crop N uptake was measured a week prior to ear harvest by harvesting aboveground biomass from 20 ft of row, grinding a subsample with a chopper, then measuring dry matter, and %N. Crop N uptake was calculated as: previously described. Ears from forty feet of row were hand harvested. Ear harvest weight, dry matter, and other parameters (tip fill, length, width, etc.) were measured.

The N use efficiency (NUE) was measured as NUE= (Ntrt – Ncontrol)/Nfert where Ntrt is N uptake for each fertilizer treatment, Ncontrol is the N uptake by the no N fertilizer treatment, and Nfert is the total N fertilizer applied in a given treatment. NUE can help assess how much of the applied fertilizer actually ended up in the aboveground biomass.

Table 4-2. Rates of urea and enhanced efficiency fertilizers applied to experimental plots at OSU Vegetable Research Farm (VF).

Trt	Fertilizer	Manufacturer	%N	Pre-plant[1]	Midseason[2]	Total
				lbs N/A		
1	Control	NA	NA	0	0	0
2	Urea	NA	46	30	130	160
3	Urea	NA	46	80	0	80
4	Urea	NA	46	160	0	160
5	ESN	Agrium	44	80	0	80
6	ESN	Agrium	44	160	0	160
7	Super-U	Koch	46	80	0	80
8	Super-U	Koch	46	160	0	160
9	Duration 45	Agrium	44	80	0	80
10	Duration 45	Agrium	44	160	0	160
11	Instinct	Dow	46	80	0	80
12	Instinct	Dow	46	160	0	160

1- broadcast an incorporated; 2- banded

A description of each EEF product is given below:

- **ESN®** and **Duration 45** are manufactured by Agrium Advanced Technologies, Inc. This product is a polymer coated urea and contains 44%N. The coating allows water in the soil to move into the granule and dissolve the urea, which then diffuses into the soil. The rate at which the urea solution moves out through the coating is determined by soil, temperature, and moisture. In cool soils when the crop is growing slowly and N demand is minimal, N release is slow, but as the soil warms and crop growth increases, the granules release N more rapidly. Duration 45 has a thinner polymer coating than ESN and releases N faster. At current urea market prices, using ESN costs an additional $0.15/lb N.
- **SuperU®** is manufactured by Agrotain International (a subsidiary of Koch Agronomic Services). This product is a granular urea product containing both a urease inhibitor and nitrification inhibitor, and contains 46%N. The combined action of the inhibitors can reduce ammonia volatilization losses and slow the conversion of ammonium into nitrate. As a result, the fertilizer should be less susceptible to leaching in the early part of the season when crop N uptake is minimal. This product is currently available from Wilbur Ellis.
- **Nitrapyrin (formulation used very similar to Instinct™ II**) is manufactured by Dow Agrosciences. It contains the nitrification inhibitor nitrapyrin in an encapsulated form. This encapsulation is designed to prevent loss from volatilization and fixation on clay particles and organic matter, which allows it to remain on the soil surface longer before incorporation. This product is registered for use in sweet corn in Oregon and has the following replant restrictions: "Corn (field, sweet, pop), sorghum, wheat, other cereals, oilseed crops (including soybeans), and leafy vegetables, may be rotated 120 days from the last application of N-Serve 24 [a formulation of nitrapyrin]. All other crops are not to be rotated in less than one year after the last application."

Soil mineral N monitoring and nitrate leaching. At each field site, soil mineral N (NO3-N and NH4-N) concentrations were monitored in the surface 8" approximately every 2 wks from planting to week 8. This sampling allowed us to evaluate the performance of each EEF product during a period when the leaching potential was high and plant uptake was low. Eight soil samples from each plot were taken from the middle of the row to minimize the influence of roots, then sieved and extracted in the field with 2M KCl, and sent to OSU's Central Analytical lab for analysis. Following ear harvest, each plot was sampled at 1 ft intervals to a depth of 4 ft using a mechanical auger. Three samples from each plot were collected and composited. Only depths 2, 3, and 4ft were analyzed for nitrate. Soil temperature and rainfall/irrigations were monitored during the first 8 wks of the cropping cycle.

4.2 PSNT and N mineralization

Crop nitrogen (N) uptake in the field (no N fertilizer). Crop N uptake in aboveground biomass at ~1200 growing degree days (GDD) was measured by harvesting aboveground biomass, grinding it with a chopper, then measuring dry matter, and %N. Crop N uptake was calculated as: Above-ground plant dry matter (lb/acre) x plant N%/100. Plants were also harvested from corn rows nearby that were fertilized by the cooperating farmer. The relative amount of crop N uptake (%) from mineralization was calculated as: Crop N uptake with no N fertilizer (in zero N plot)/crop N uptake with farmer fertilization (in adjacent field area) x 100.

Nitrogen mineralization rate potential in the laboratory. Soil samples were collected and sieved to pass a 4.75mm screen at-planting. Samples were frozen for approximately 4 months prior to being incubated in the laboratory to measure N mineralization potential. This measurement is called "potential" because soil is given optimum physical and moisture conditions for N mineralization (it is sieved and moistened to near field capacity). To measure soil N mineralization (the conversion of soil organic N to mineral N), 300 g of soil was aerobically incubated at 23 or 35C in our laboratory. Before incubation soil moisture was adjusted to near field capacity: approximately 25 to 30% gravimetric moisture for the silt loam and silty clay loam soils present at 2013 field sites. On day 0, 7, 21 and 42, an ~10 g subsample was taken from each bag and analyzed for nitrate. N mineralized during the incubation was calculated as: Nmin = Nfinal – Ninitial, where Nmin is the net increase in NO3-N during incubation, and Nfinal is NO3-N at termination of incubation, and Ninitial is the NO3-N present at the start of laboratory incubation (the "as-is" NO3-N present in the sample as collected from the field).

Effect of soil incubation temperature on rate of N mineralization in the laboratory. We evaluated soil N mineralized (in aerobic incubation) at 23 and 35C. The increase in N mineralization rate due to temperature was calculated as Nmin increase = (net N min at 35C)/(net N min at 23 C). This data is of importance when forecasting N mineralization in the field, based on a laboratory soil test of Nmin potential. From a lab test expediency standpoint, faster results (from high temperature incubation) are desired. However, it is important to know how the lab result (high temperature) relates to N mineralization at summer field soil temperatures (field temperatures are closer to 23 C).

Relating lab measurements of soil N mineralization potential to N uptake by corn in zero N field plots. We compared the amount of N mineralized in the laboratory incubations to the amount of N uptake by the crop in the field. Laboratory tests that correlate to field data are considered more useful.

Utility of an at-planting soil nitrate test. We collected soil samples from 6 cooperator fields at planting and at the PSNT sample timing (~V6 growth stage). Net N mineralized between sample dates (at-plant and PSNT sampling times) was calculated. The basic idea here is to see how much soil NO3-N accumulated between planting and V-6, and how much N fertilizer recommendations (using OSU EM 9010) were affected by soil sample collection date. We measured soil temperatures between sampling to assess how temperatures affected soil N mineralization.

Utility of a nitrate "Quick Test". Using the methods and materials given by Tim Hartz (UC Davis), we compared the utility of an on-farm nitrate test with that of a traditional laboratory analysis (samples extracted with 2M KCl and sent to OSU CAL lab for analysis. The procedure for performing the Quick Test is given below.

1) Make the extracting solution by dissolving approximately 6 grams of calcium chloride (~1 teaspoon) in a gallon of distilled water. The calcium will help to settle out the suspended clay particles.
2) Fill a volumetrically marked tube or cylinder to the 30 ml level with the extracting solution. Any volumetrically marked tube or cylinder will work, but 50 ml plastic centrifuge tubes are convenient and reusable.
3) Add well homogenized soil to the tube until the solution rises to 40 ml. Cap tightly and shake vigorously until all soil clods are broken down and dispersed. For moist clay soils that may be difficult to blend, pinch off small pieces of each soil core to get a representative sample.
4) Let the samples sit until a clear zone at the top of the tube forms. This may take a few minutes for a sandy soil up to an hour for clay soils.
5) Dip an EM Quant ™ nitrate test strip into the clear zone of the solution, shake off excessive solution, and wait 60 seconds. The strip color will continue to darken with time, so make the determination between 60-70 seconds after dipping the strip. Compare the color that has developed on the test strip with the color chart provided. When the strip color is between two color samples on the chart, interpolate the nitrate concentration of the strip as closely as possible. When in doubt, be conservative and go lower than higher.
6) The nitrate test strips are calibrated in parts per million (ppm) NO3. Conversion to ppm NO_3-N in dry soil requires dividing the strip reading by a correction factor based on soil texture and moisture content:

   strip reading ÷ correction factor = ppm NO_3-N in dry soil

	Correction factor	
Soil texture	**Moist Soil**	**Dry soil**
sand	2.3	2.6
loam	2.0	2.4
clay	1.7	2.2

Once you have the corrected value, use Table 10 in OSU's nutrient management guide EM 9010-E (Sweet Corn- Western Oregon) to determine the sidedress rate

4.3 Phosphorus

Determine the effect of banded P fertilizer rate on crop yield and quality for early season planting dates. Two P trials were conducted; one at OSU's Vegetable Research Farm in Corvallis (Corvallis I) and one on-farm (Corvallis II). P fertilizer treatments of 0, 15, 30, 60 and 120 lb P2O5 per acre were banded at planting time. Each on-farm trial contained 20 field plots (4 replications per P fertilizer treatment). Each treatment plot measured 15 x 60 ft. All treatments received the same N and K applications, only the P varied. The on-farm and OSU Farm field experiments were established on June 3 and May 14 so that the "worst case" (cold soils that limit P solubility) could be evaluated. At the Corvallis I site, ears were hand harvested from 40 ft of row. At the on-farm site, ears were harvested with commercial headers from 6 rows by 50'. Ear harvest weight, dry matter, and other parameters (tip fill, length, width, etc.) were measured.

Determine the effect of banded P fertilizer rate on plant growth and P uptake. Ten plants per plot were collected at ~V5 and V7 for the on-farm and VF experiment sites, respectively. Crop P uptake was measured by harvesting aboveground biomass, grinding it with a chopper, then measuring dry matter, and %P. Crop P uptake was calculated as: above-ground plant dry matter (lb/acre) x plant P%/100.

Measure P supply to roots under actual field conditions using Plant-Root Simulator probes. The PRS measurements assessed P supply as affected by prevailing soil moisture, temperature, physical and biological conditions at each site. At both on-farm and OSU field sites, P flux (estimate of amount of P supplied to root surfaces) was measured quantitatively using Plant-Root Simulator Probes (Western Ag Innovations, Inc., Saskatoon, SK, Canada). Each PRS probe consists of an anion exchange membrane mounted on a flat plastic stake. The PRS probes were allowed to adsorb P from soil solution on the zero P plots to get a measure of the cumulative effects of temperature, moisture, and soil test P on phosphorus solubility. PRS probes were buried in soil for 2-week intervals (2-wk exposure time for each burial) starting at planting, and ending at the 6-8 leaf stage to determine changes in P supply in response to soil temperature and other environmental factors. Each 2-wk PRS probe burial generated a measurement of P supply. Preplant soil samples (0-12 inches) from each site were analyzed via routine procedures to measure soil test nutrients as per OSU recommended protocols. Additional PRS probes were installed in the Nmin plots (as well as plots in bean fields from another trial). PRS probes were buried in soil for 2-week intervals (2-wk exposure time for each burial) starting at planting and ending 4 weeks later (~V5).

5 Results

5.1 Results for enhanced efficiency fertilizer trials

***On-farm experiement*:**

Results from the biomass sampling are in Table 5-1. Although there was a significant difference in tissue N between the low and high rate N applications, there was no significant differences between any of the fertilizer treatments for biomass or N uptake. This shows that the low rate fertilizer application (130 lb N/A) was too high to be able to evaluate if the EEF products could increase the fertilizer use efficiency.

Results from the ear harvest are given in Table 5-2. There were no differences between fertilizer treatments. This shows that the low rate fertilizer application (130 lb N/A) was too high to be able to evaluate if the EEF products could increase the fertilizer use efficiency.

Soil mineral N concentrations are given in Figure 5-1 and Figure 5-2. For ease of viewing, the split urea application was excluded from the graphs because concentrations were no different than the no fertilizer control plot. **In general, all products were able to significantly reduce nitrate concentrations at the first sampling date 12 days after application compared to the straight urea application.** But by week 4 after aplication, only ESN and Super-U had less nitrate than the urea. On the last two sampling dates 6 and 8 wks after application, no treatment was significantly different than the straight urea.

Deep soil sampling after harvest showed a statistical increase in soil nitrate for the ESN and Super-U 130 lbN/A rate (Figure 5-3). A possible explaination for this is that the ESN and Super-U products prevented nitrate leaching early in the season, which then moved deeper into the soil profile later in the season. The soil at this site was very sandy and nitrate may have leached below 4 feet. But, if this were happening, then we would expect to see the same results for the high N rate treatments also. In general, deep soil sampling at this site was not useful in predicting the ability of these products to prevent nitrate leaching.

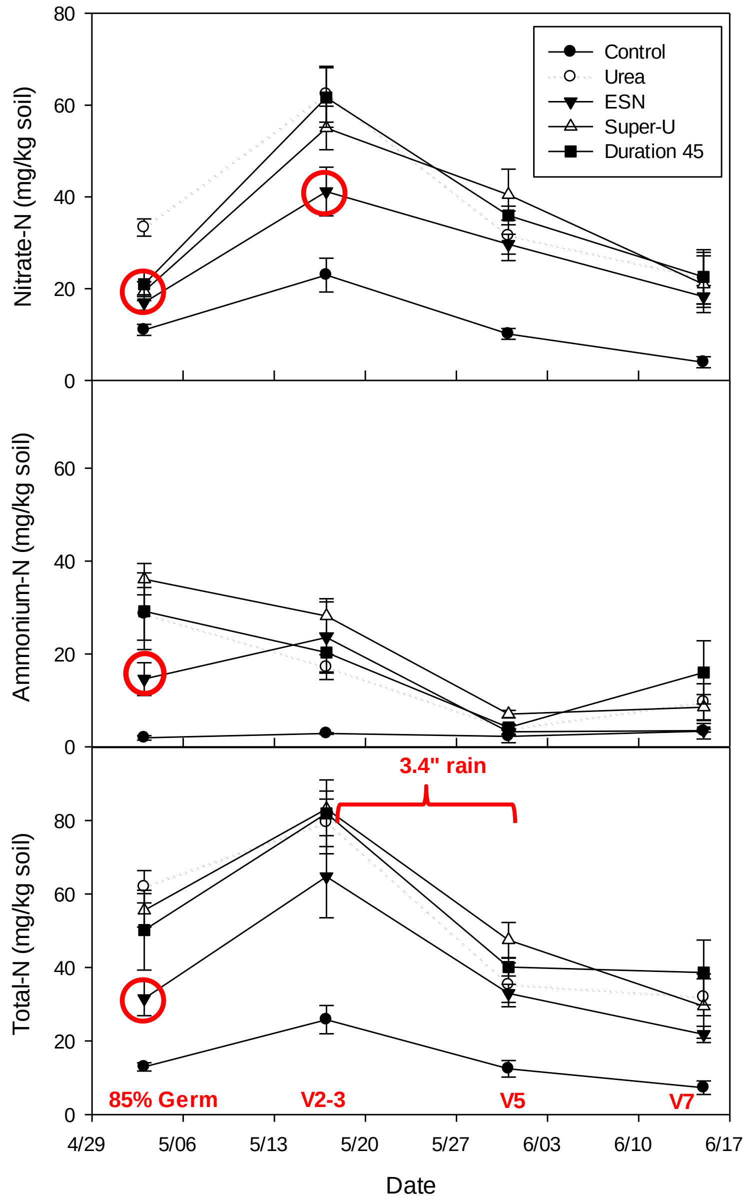

Figure 5-1. **On-farm** soil mineral N concentrations for treatments receiving **130 lb N/A** fertilizer application broadcast and incorporated prior to planting. Soil was sampled at ~2 wk intervals after planting from 0-8”. The circled values represent a statistical difference ($p<0.05$) between an enhanced efficiency fertilizer (EEF) treatment compared to straight urea. The Control received 30 lb N/A banded at planting. Growth stage of the crop is given at the bottom of the graphs. Between May 17 and May 31, 3.4” of rain was recorded at the site. Error bars represent the SEM (n=4). Treatment 2 (split application of urea) is not shown as soil mineral N values were no different than the Control (soil sampling did not pick up the fertilizer N after application due to it being banded)**.**

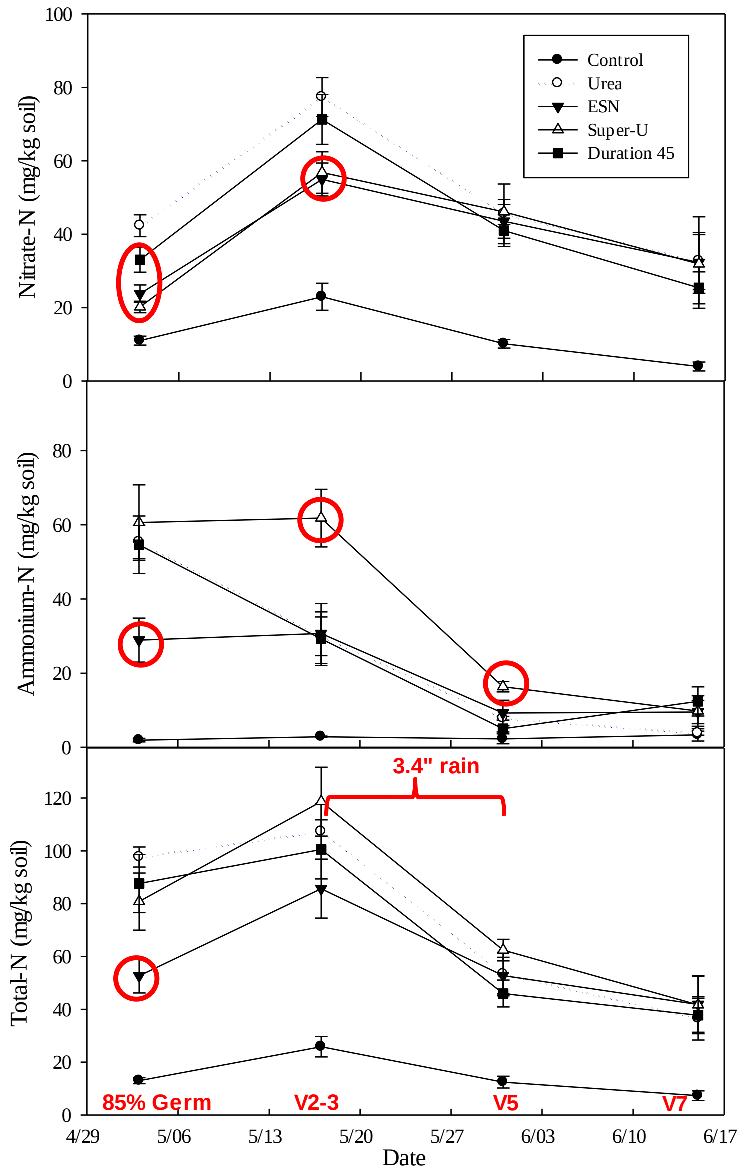

Figure 5-2. **On-farm** soil mineral N concentrations for treatments receiving **180 lb N/A** fertilizer application broadcast and incorporated prior to planting. Soil was sampled at ~2 wk intervals after planting from 0-8”. The circled values represent a statistical difference ($p<0.05$) between an enhanced efficiency fertilizer (EEF) treatment compared to straight urea. The Control received 30 lb N/A banded at planting. Growth stage of the crop is given at the bottom of the graphs. Between May 17 and May 31, 3.4” of rain was recorded at the site. Error bars represent the SEM (n=4). Treatment 2 (split application of urea) is not shown as soil mineral N values were no different than the Control (soil sampling did not pick up the fertilizer N after application due to it being banded)**.**

Table 5-1. On-farm biomass, tissue N, and N uptake from 10 linear ft.

	Obs.	Plant wt.		Fresh biomass		Tissue N		-------- N Uptake -------		
		lb	Stdev	ton/A	Stdev	%	Stdev	lb N/A	Stdev	CV
Control (30)	4	1.8	0.2	23.5	2.1	0.86	0.07	76	5	6
Urea split (180)	4	3.0	0.4	33.8	2.3	1.45	0.13	169	16	9
Urea (130)	4	2.8	0.5	34.7	4.8	1.32	0.12	160	19	12
Urea (180)	4	3.1	0.3	38.0	6.6	1.41	0.07	193	56	29
ESN (130)	4	2.9	0.4	34.4	3.6	1.25	0.07	157	18	11
ESN (180)	4	2.9	0.7	32.7	11.5	1.50	0.11	160	48	30
Super-U (130)	4	2.7	0.6	34.7	4.6	1.17	0.22	150	31	21
Super-U (180)	4	3.1	0.5	36.1	3.3	1.44	0.11	177	8	5
Duration 45 (130)	4	3.1	0.3	32.6	8.4	1.36	0.06	155	26	16
Duration 45 (180)	4	2.8	0.4	31.5	4.0	1.43	0.05	153	20	13
LSD(0.05)		0.25		7.0		0.16		39		

Table 5-2. On-farm Ear harvest yield and quality parameters (n=4) from 20 linear feet in each plot.

Treatment	Ears		Gross ear yield		Ear wt.		Husked ear wt.		Length		Tip fill		Width	
	#/A	Stdev	ton/A	Stdev	lb	Stdev	lb	Stdev	in	Stdev	%	Stdev	in	Stdev
Control (30)	21,998	3,289	7.9	1.0	0.72	0.03	0.63	0.06	7.9	0.3	86.1	3.4	2.0	0.0
Urea split (180)	32,888	6,217	14.1	1.9	0.86	0.05	0.74	0.04	8.3	0.3	86.2	1.5	2.1	0.0
Urea (130)	27,443	4,745	12.1	1.8	0.88	0.02	0.72	0.03	8.2	0.3	87.1	3.8	2.1	0.1
Urea (180)	30,928	3,374	13.1	1.8	0.85	0.04	0.73	0.06	8.3	0.2	85.9	2.0	2.1	0.1
ESN (130)	27,443	1,125	11.6	0.5	0.85	0.04	0.76	0.05	8.4	0.2	88.5	1.8	2.1	0.1
ESN (180)	28,314	4,414	12.4	2.0	0.88	0.03	0.76	0.05	8.4	0.3	86.7	2.4	2.1	0.1
Super-U (130)	25,483	4,047	11.1	0.5	0.88	0.11	0.69	0.04	8.1	0.4	85.9	3.3	2.1	0.0
Super-U (180)	25,700	3,864	11.3	2.0	0.88	0.03	0.72	0.07	8.4	0.1	84.4	3.4	2.1	0.1
Duration 45 (130)	26,572	4,055	11.8	2.9	0.88	0.12	0.70	0.02	8.1	0.1	87.0	3.1	2.1	0.0
Duration 45 (180)	27,878	4,148	12.4	1.4	0.90	0.10	0.73	0.09	8.2	0.4	87.1	4.8	2.1	0.1
LSD(0.05)	5,296		2.3		NS		NS		NS		NS		NS	

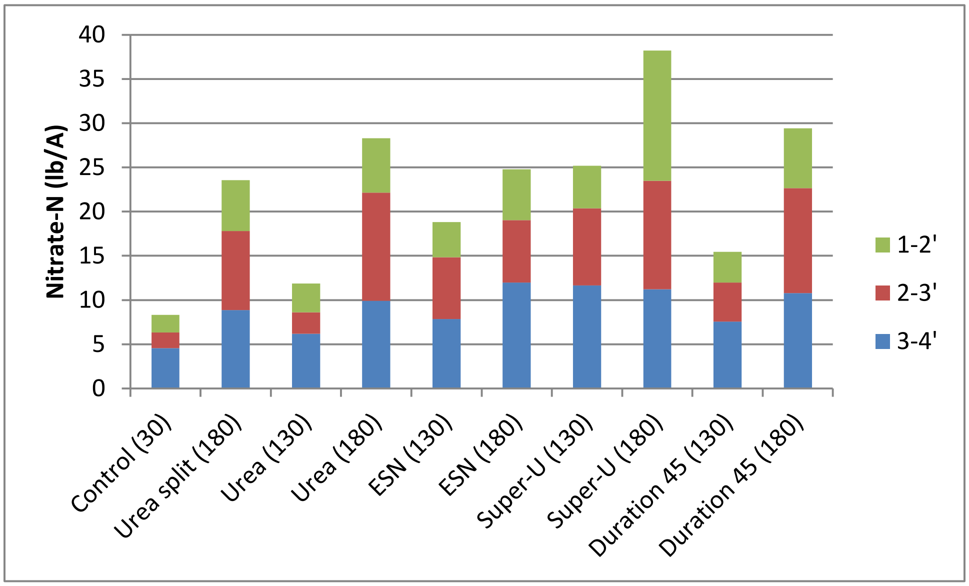

Figure 5-3. On-farm soil nitrate-N concentrations at 1 foot intervals from 2' to 4'. To convert nitrate from mg/kg, we assumed a bulk density of 1.4 g/cm3.

***Research-farm experiement*:**

Results from biomass sampling are in **Table 5-3**.Although there were significant difference in all measured parameters between the low and high rate N applications, there was no significant differences among any of the EEF products and straight urea (split or pre-plant incorporated) for each N fertilizer N rate.

Results for the ear harvest are give in Table 5-4. There were no significant differences significant differences among any of the EEF products and straight urea (split or pre-plant incorporated) for each N fertilizer N rate. There were also no significant differences between fertilizer rates (80 and 160 lb N/A), indicating that the lower rate fertilizer treatment was sufficient to maximize yields. Although N uptake was higher for the plots receiving 160 lb N/A (**Table 5-3**), the extra N uptake did not contribute to a yield increase and was likely the result of luxery consumption. Looking at the N uptake and ear yield response curve (Figure 5-4), N uptake was likely at its maximum for a N fert rate of around 120 lb N/A, but gross ear yield maxed out around 80 lb N/A. The average nitrogen use efficiency (NUE) was 89 and 67% for the plots receiving 80 and 160 lb N/A, respectively. At this field, the ear yield and NUE could be maximized by applying only 80 lb N/A.

Soil mineral N concentrations are given in **Figure 5-5** and Figure 5-6. For ease of viewing, the split urea application was excluded from the graphs because concentrations were no different than the no fertilizer control plot (i.e. soil sampling did not pick up the banded fertilizer N application**)**. **In general, all products were able to significantly reduce nitrate concentrations at the first sampling date 2 weeks after application compared to the straight urea application.** By week 4, all products except Duration 45 still had less nitrate than the urea. For the 80 lb/A rate, ESN and Instinct were able to reduce nitrate concentrations all the way to week 8 (**Figure 5-5**). However, at the 160 lb/A rate, no product was able to reduce nitrate concentrations after week 4, but all products had higher ammonium concentrations at wk 4 and 6 (Figure 5-6). Therefore, if heavy irrigations or rainfall occurred in this period less leaching would occurr with these products.

Why didn't we pick up the same trends in ammonium between the 80 and 160 lb/A treatments? Ammonium is not mobile in soil like nitrate. Therefore, with the higher rate treatments, there was a higher liklihood of collecting a sample near a fertilizer prill, thus being able to observe the differences in ammonium. Once the ammonium is nitrified to nitrate, the nitrate is mobile and can diffuse, making picking up differences in nitrate concentrations more likely, especially for the lower rate fertilizer treatment.

At 15 days after application, we ecavated a small area of soil in the high rate ESN plots (n=4) and quantified the number of empty, partially intact, and full intact fertilizer prills. What we found was that 7% of prills were completely empty (just the polymer husk remained), 47% were partially intact (i.e. some urea remained in the prill), and 46% were fully intact. Based just on this data, the ESN is protecting almost half of the urea from being released into the soil, thus preventing the N from being lost should a large rainfall or irrigation even occur early in the crop cycle.

Deep soil sampling after harvest showed a statistical differences between fertilizer rates (80 vs 160 lb N/A) but no significant differences among treatments for each rate at any depth (Figure 5-7). In general, deep soil sampling at this site was not useful in predicting the ability of these products to prevent nitrate leaching. Compared to the on-farm trial, there was approximately half the nitrate in the soil profile for each treatment, which may be due to the lower N rate applied in the research farm trial. For both trials, there was an increase in soil nitrate in the profile for Super-U. Although not statistically significant, the Super-U could possibly be preventing nitrate leaching early in the season, which results in more avialable N at the end of the season.

Table 5-3. Research-farm biomass, tissue N, N uptake, and nitrogen use efficiency (NUE)**.** NUE= (Ntrt – Ncontrol)/Nfert where Ntrt is uptake for each fertilizer treatment, Ncontrol is the uptake by the no N fertilizer treatment, and Nfert is the total N fert. applied in a given treatment. From 20 linear ft of row.

Treatment	Obs.	Plant wt.		Fresh biomass		Tissue N		N Uptake		NUE
		lb	Stdev	ton/A	Stdev	%	Stdev	lb N/A	Stdev	%
Control (0)	4	2.36	0.34	22.9	3.5	1.10	0.12	89	13	NA
Urea split (160)	4	4.23	0.40	36.7	6.7	1.82	0.15	211	48	76
Urea (80)	4	3.54	0.15	35.3	3.9	1.38	0.11	157	12	84
Urea (160)	4	4.09	0.88	36.1	2.2	1.51	0.07	181	25	57
ESN (80)	4	3.63	0.13	33.3	1.2	1.43	0.09	165	11	94
ESN (160)	4	4.13	0.26	38.5	2.9	1.65	0.15	201	22	70
Super-U (80)	4	3.95	0.41	32.3	2.6	1.51	0.13	165	30	95
Super-U (160)	4	4.13	0.24	37.9	2.7	1.64	0.14	197	32	67
Duration 45 (80)	4	3.55	0.39	32.8	3.2	1.43	0.19	148	29	73
Duration 45 (160)	4	4.84	0.76	35.9	1.4	1.76	0.22	211	31	76
Instinct (80)	4	3.83	0.41	33.0	3.3	1.58	0.05	170	32	100
Instinct (160)	4	3.88	0.19	36.1	1.5	1.62	0.21	185	29	60
	LSD(0.05)	0.62		4.8		0.21		42		NA
Contrast (80 vs. 160 lb/A) p=		<0.001		0.002		0.001		<0.001		NA

Table 5-4. Research-farm ear harvest yield and quality parameters (n=4) from 40 linear ft of row.

Treatment	Ears		Gross ear yield		Ear wt.		Husked ear wt.		Length		Tip fill		Width	
Product (N rate)	#/A	Stdev	ton/A	Stdev	lb	Stdev	lb	Stdev	in	Stdev	%	Stdev	in	Stdev
Control (0)	15,464	1,488	7.3	1.1	0.94	0.06	0.74	0.04	8.2	0.1	97.3	0.8	2.06	0.05
Urea split (160)	18,513	1,354	10.4	0.7	1.13	0.03	0.83	0.03	8.5	0.2	97.6	1.0	2.17	0.05
Urea (80)	18,077	1,932	10.4	1.0	1.15	0.03	0.84	0.06	8.6	0.1	97.4	1.1	2.18	0.06
Urea (160)	17,533	2,232	9.9	1.1	1.13	0.03	0.85	0.02	8.4	0.1	97.3	0.8	2.19	0.04
ESN (80)	18,404	1,682	10.6	0.7	1.15	0.04	0.85	0.04	8.7	0.4	98.1	0.9	2.18	0.02
ESN (160)	19,602	871	11.1	0.4	1.13	0.05	0.84	0.05	8.3	0.3	97.7	1.9	2.18	0.02
Super-U (80)	18,077	1,831	10.2	0.8	1.13	0.03	0.81	0.02	8.4	0.1	99.1	0.8	2.17	0.05
Super-U (160)	18,949	562	10.8	0.4	1.14	0.04	0.83	0.06	8.4	0.1	96.9	2.4	2.18	0.06
Duration 45 (80)	18,840	1,089	10.7	0.5	1.13	0.02	0.82	0.05	8.5	0.2	97.2	1.9	2.18	0.07
Duration 45 (160)	18,186	2,115	10.1	1.1	1.12	0.03	0.80	0.02	8.4	0.2	96.7	2.0	2.16	0.03
Instinct (80)	17,969	1,146	10.2	0.7	1.13	0.05	0.85	0.03	8.5	0.2	97.4	2.2	2.19	0.04
Instinct (160)	20,582	218	11.4	0.2	1.11	0.02	0.78	0.03	8.2	0.1	97.3	2.2	2.14	0.03
ANOVA p=	0.015		<0.001		<0.001		0.006		0.833		0.070		0.029	
LSD(0.05)	2,117		1.1		0.05		0.06		NS		NS		0.07	
Contrast '80 vs 160' p=	0.144		0.267		0.278		0.305		0.011		0.221		0.574	

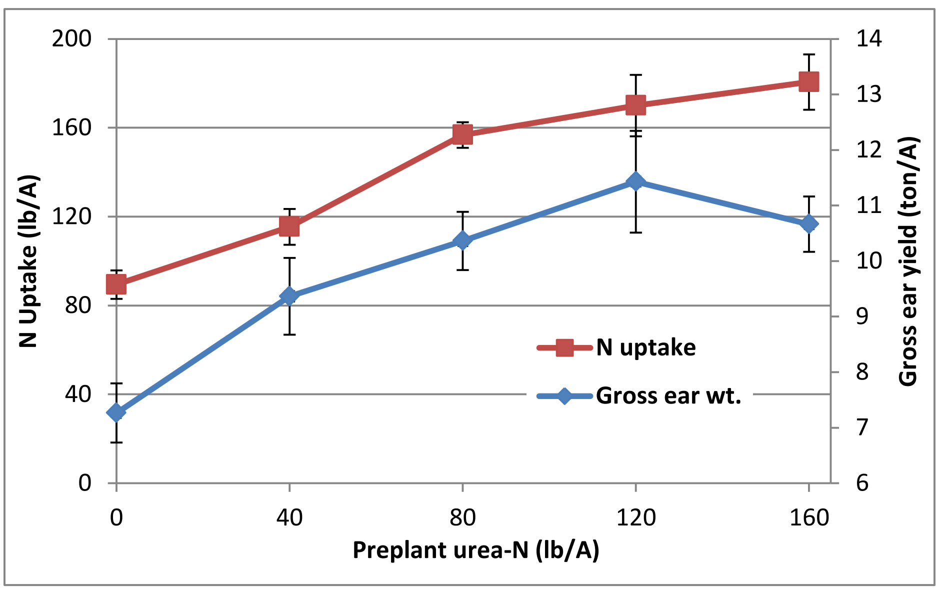

Figure 5-4. Fertilizer N response curve for preplant broadcast and incorporated urea. For the 40 and 120 lb N/A rates, there were only 3 reps and only half the area was harvested for both the biomass and ear yield compared to the other rates, resulting in higher variability (i.e. larger error bars).

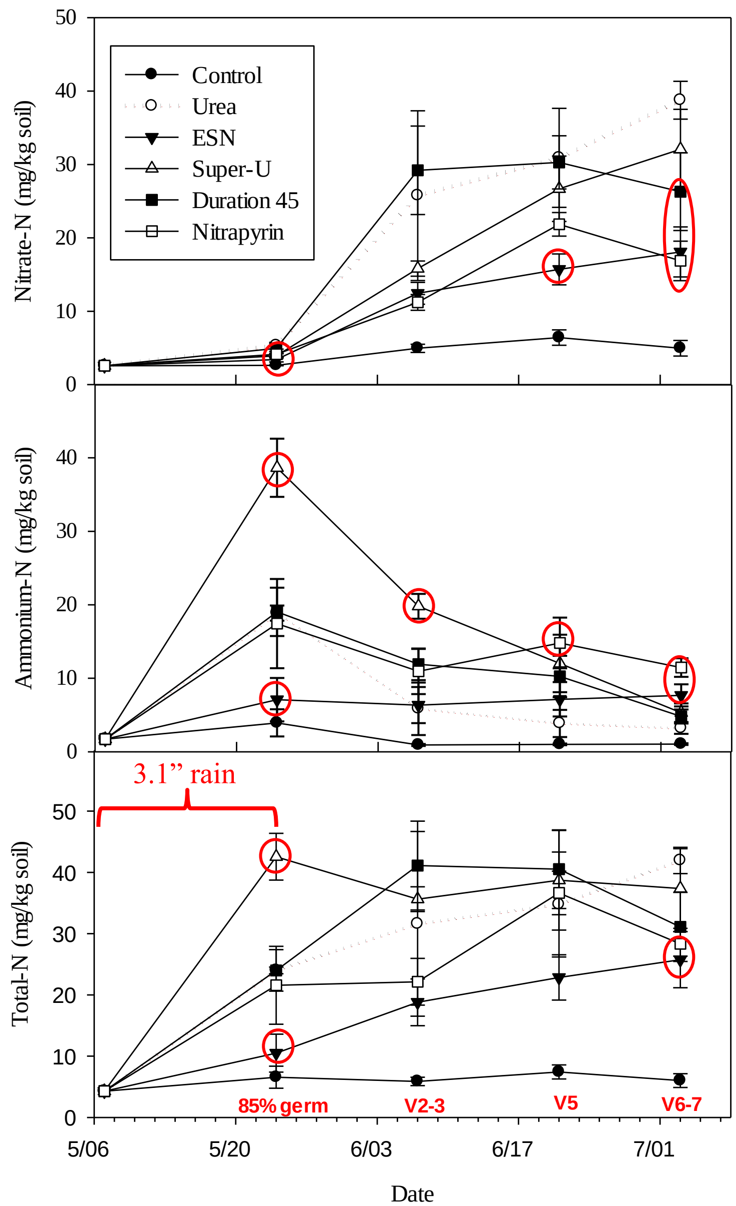

Figure 5-5. Research-farm soil mineral N concentrations for treatments receiving 80 lb N/A fertilizer application broadcast and incorporated prior to planting. Soil was sampled at 2 wk intervals after planting from 0-8”. The circled values represent a statistical difference ($p<0.05$) between an enhanced efficiency fertilizer (EEF) treatment compared to straight urea. 3.1” of rain and irrigation occurred in the first 2 weeks. Growth stage of the crop is given at the bottom of the graphs. Error bars represent the SEM (n=4). Treatment 2 (split application of urea) is not shown as soil mineral N values were no different than the Control (soil sampling did not pick up the banded fertilizer N application)**.**

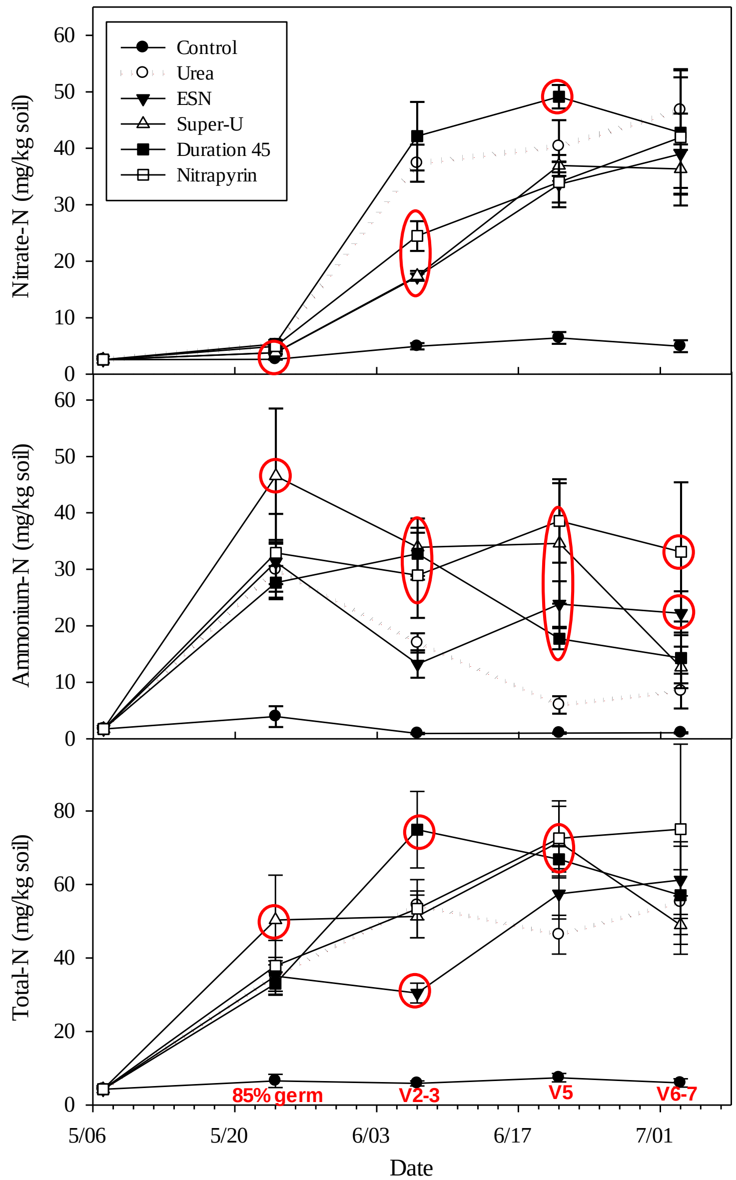

Figure 5-6. **Research-farm** soil mineral N concentrations for treatments receiving 160 lb N/A fertilizer application broadcast and incorporated prior to planting. Soil was sampled at 2 wk intervals after planting from 0-8”. The circled values represent a statistical difference ($p<0.05$) between an enhanced efficiency fertilizer (EEF) treatment compared to straight urea. 3.1” of rain and irrigation occurred in the first 2 weeks. Growth stage of the crop is given at the bottom of the graphs. Error bars represent the SEM (n=4). Treatment 2 (split application of urea) is not shown as soil mineral N values were no different than the Control (soil sampling did not pick up the banded fertilizer N application).

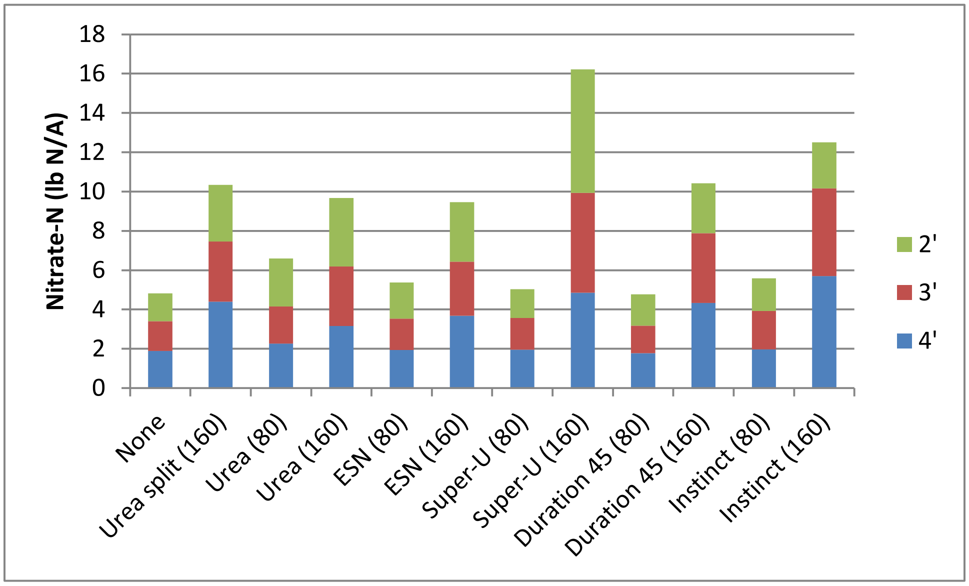

Figure 5-7. Research-farm soil nitrate-N concentrations at 1 foot intervals from 2' to 4'. To convert nitrate from mg/kg, we assumed a bulk density of 1.4 g/cm3. There was a significant difference between fertilizer rates (80 vs 160 lb N/A) but no significant differences among treatments for each rate for any depth were observed. The top foot of soil was not analyzed for nitrate because experience has shown that usually no differences between treatments can be found by the end of the season.

Individual product evaluations for each trial under 2 scenarios.

Scenario 1- minimal leaching in first 4 weeks of trial:

In the first two weeks of the on-farm trial the field received 0.71" of irrigation. Although the soil was sandy, minimal leaching likely occurred over this period because almost 100% of added urea-N (in the form of NO3-N + NH4-N) could be accounted for in the top 8" of soil. There was approximately 3.4" of rain between weeks 2 and 4, which leached an estimated 50% of soil nitrate in the straight urea treatment below the sampling depth of 8".

Performance of EEF products in Scenario 1:

Environmentally Smart Nitrogen (ESN): ESN is a polymer coated urea manufactured by Agrium with an estimated 100% release of urea in 80-d. At week 2, there was 46% less nitrate in the soil relative to straight urea and 60% of the fertilizer N in ESN had not been released yet. Supporting this value is the prill data collected at week 2. We found that 7% of prills were completely empty (just the polymer husk remained), 47% were partially intact (i.e. some urea remained in the prill), and 46% were fully intact. At week 4 there was 31% less nitrate in the soil relative to straight urea and 29% of fertilizer the N in ESN had not been released yet. After 4 weeks, there were no significant differences in soil mineral N between ESN and straight urea. We would have expected to see more NO3-N and NH4-N in the soil at week 6 after 3.4" of rain fell between wk 2 and 4 because 31% of the urea in the ESN prills had not yet released, however we were unable to detect a difference.

Duration 45: Duration 45 is also a polymer coated urea manufactured by Agrium. The coating is thinner than ESN and has an estimated 100% release of urea in 45-d. At week 2, there was 29% less nitrate in the soil relative to straight urea and 18% of the fertilizer N in Duration had not been released yet. After week 2, there were no significant differences between Duration and straight urea.

Super-U: Super-U is a granular urea product containing both a urease inhibitor and nitrification inhibitor (the same inhibitors used in the product Agrotain Plus) and is manufactured by Agrotain International. At week 2, there was 47% less nitrate in the soil relative to straight urea and an estimated 18% of the fertilizer likely was still in the form of urea (the result of the urease inhibitor). There was also 18% more ammonium in the soil than urea (the result of the nitrification inhibitor). At week 4, all the added fertilizer had released but there was 19% less soil nitrate and 85% more ammonium than straight urea. After 4 weeks, there were no significant differences in soil mineral N between Super-U and straight urea.

Scenario 2- leaching in first 3 weeks of trial:

At the research farm trial, the field received a total of 3.1 inches of water (2.2" irrigation and 0.9" rain) in the first 2 weeks followed immediately by an additional inch in the first 5 days of the second 2-wk sampling interval. Unlike the on-farm trial where we could account for 100% of urea-N applied, we could only account for ~40% of the straight urea applied in the top 8" of soil, suggesting that 60% of urea-N (in the form of nitrate) likely leached below 8". The small nitrate levels at week 2 (avg 4.2 ppm) support this data, especially given the high nitrate levels at week 2 in the on farm trial (avg 26.3 ppm) and the fact that soil temperatures over this interval were similar at both sites (61.1 vs. 62.5 F @4" for research- and on-farm trials, respectively).

Performance of EEF products in Scenario 2: In this trial, performance was highly variable between fertilizer rates, which made interpretation of the data more difficult.

Environmentally Smart Nitrogen (ESN): Although there was 32% less soil nitrate than straight urea at week 2, the absolute difference was small (only ~4 lbs N/A). But, by week 4 there was 53% less soil nitrate than straight urea (~22 lbs N/A) and an estimated 31% of ESN-N had not yet released, which is consistent with results from the on-farm trial. Unlike the on-farm trial, ESN continued to have lower soil nitrate and higher ammonium concentrations (1.5-2x greater; absolute amount ~20 lbs) compared to straight urea to week 8.

Duration 45: Throughout the trial, there was no difference in soil nitrate between Duration and straight urea. Although our nitrogen budget showed that all of the Duration-N had released by week 2, at 4 and 6 weeks Duration had higher ammonium concentrations (equivalent to ~20 lb N/A at each date) indicating that some Duration prills may have been still releasing N.

Super-U: Although there was 27% less soil nitrate than straight urea at week 2, the absolute difference was small (only ~3 lbs N/A). But, at week 4 there was 46% less soil nitrate (~30 lb N/A) relative to straight urea. After week 4 there were no significant differences in soil nitrate concentrations relative to straight urea. From week 2 through 6, soil ammonium levels were significantly higher than straight urea, averaging 36, 31, and 36 lb N/A at each 2 wk sampling interval. Because there was 33% more N (NO3-N+NH4-N) compared to straight urea at wk 2, the Super-U likely reduced leaching over this period by inhibiting ammonium and retaining the fertilizer N as ammonium. This product appears to be effective for up to 6 weeks.

Nitrapyrin: Nitrapyrin is a nitrification inhibitor manufactured by Dow Agrosciences. The formulation used in the study is similar to the commercially available product Instinct™ II. In this formulation, the nitrapyrin is in an encapsulated form. This encapsulation is designed to prevent loss from volatilization and fixation on clay particles and organic matter, which allows it to remain on the soil surface longer before incorporation. In this trial, the product was coated onto urea prills prior to application. Although results were variable depending on the N rate, over the first 6 wks of the trial, nitrapyrin performed as well as Super-U and ESN in reducing soil nitrate concentrations relative to straight urea. In the first 2 wks, there were no differences in ammonium concentrations between nitrapyrin and straight urea, but from wk 4 to 8, the nitrapyrin consistently maintained the fertilizer N in the ammonium form (equivalent to 17, 43, and 33 lb N/A more than straight urea at weeks 4, 6, and 8, respectively; this also corresponds to 32, 43, and 35% of total fertilizer N applied remained as ammonium-N). This product appears to be effective for at least 8 weeks after application.

5.2 Results from PSNT and N mineralization

Crop N uptake from soil N mineralization (field). Figure 5-8 and

Figure **5-8**. Crop response to fertilizer application at field sites (same data as Table 2).

Table 5-5 show crop N uptake in aboveground biomass at ~1200 growing degree days (GDD). In the zero N plot (no N fertilizer applied) and the adjacent grower fertilized soil, crop N uptake averaged 87 lb N/A and 126 lb N/A, respectively. The farmer at site 2 accidentially applied fertilizer to the zero N plot when sidedressing. With addition of fertilizer (by cooperating growers), crop N uptake increased by an average of 38 lb N/A in 2013. The soil (N mineralization) at 2013 sites supplied 74% (range 46-94%) of measured crop N uptake. The N use efficency at the sites in 2013 was very low due to soil supplying a large fraction of the corn's N needs as well as high N fertilization rates. **Over 3 yrs and 27 sites, we found that on average sweet corn obtained about 2/3rds of its N from mineralization**. Our measurements showed that mineralization of N from soil organic matter (to silking growth stage) supplied an average of 88 lb N/acre (2011-13).

Nitrogen mineralization in the laboratory

Table 5-6 and Table 5-7 show nitrogen mineralization estimates for various anaerobic and aerobic N mineralization tests. Although there was high variability of the absolute amount of N mineralized (42d @ 23C) over the three years of the study, the soil consistently mineralized 1.1% of total soil N.

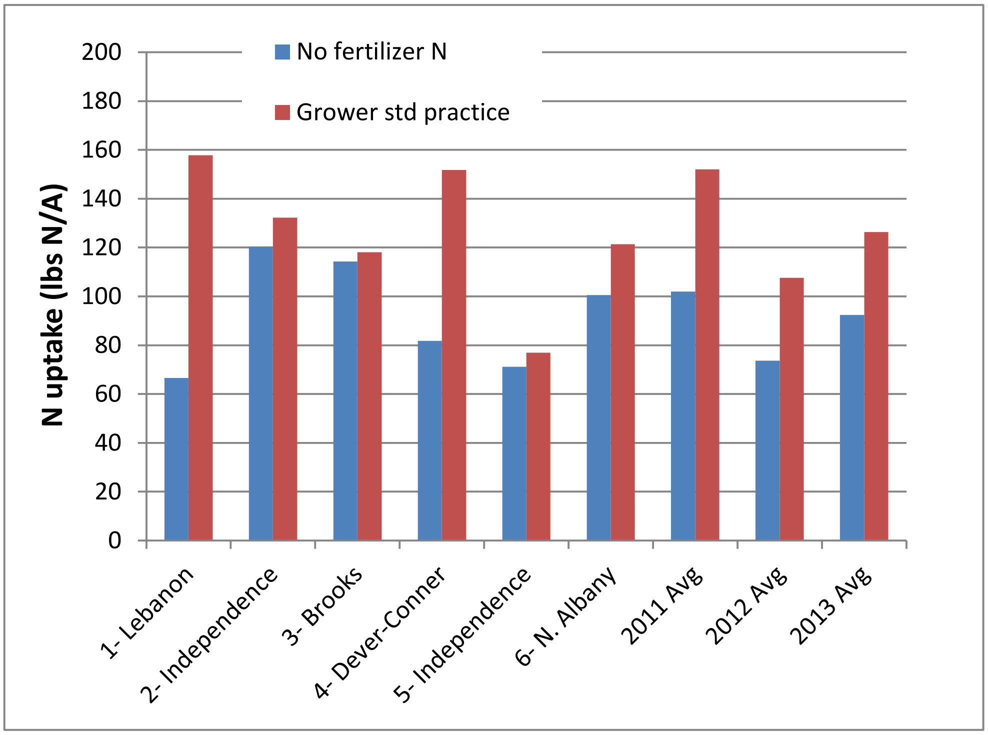

Figure 5-8. Crop response to fertilizer application at field sites (same data as Table 2).

Table 5-5. Corn N uptake in aboveground biomass measured at ~1200 growing degree days (GDD) for zero N plot (no fertilizer N applied) vs. adjacent field area fertilized by the cooperating grower.

Site	Location	Variety	Crop biomass date (~1200 GDD)	Crop N uptake in zero N plot	Crop N uptake in adjacent grower field	Increase in crop N uptake with grower N fertilization	Fraction of crop N uptake suppled by soil Nmin	N use efficiency	N applied
				lb N/A	lb N/A	lb N/A	zero N/ grower N	%	lb N/A
1	Lebanon	Serendipity	22-Jul	67	158	91	0.42	NA	NA
2	Independence	Coho	9-Aug	NA	132	NA	NA	NA	201
3	Brooks	Coho	13-Aug	114	118	4	0.97	2	198
4	Dever-Conner	Kokanee	13-Aug	82	152	70	0.54	43	162
5	Independence	Samurai	22-Aug	71	77	6	0.93	5	111
6	N. Albany	AC1138Y	27-Aug	101	121	21	0.83	20	105
			2013 Average	87	126	38	0.74	18	155
			2012 Average	74	108	34	0.69		
			2011 Average	95	160	66	0.60		
			All years (n=27)	88	139	52	0.65		

Table 5-6. Nitrogen mineralized from soil samples (0-12 inches), using anaerobic or aerobic N mineralization test methods. Also shown is crop N uptake from zero N field plots (full data set in Table 2). Assumed bulk density = 1.3 g/cm3. **Units = lb N/acre.**

Site	Location	Soil total N (0-12" @BD of 1.3 g/cm3)	Anaerobic Nmin, 7d @ 40C	Aerobic 42d net Nmin @ 23C	Aerobic 7d net Nmin @ 35C	Aerobic 42d net Nmin @ 35C	Nmin estimate based on zero N plot crop N uptake	Increase in mineralization w/increase in temp from 23 to 35 C @ 42-d
		--- lb N/acre -----------------------------------						Nmin(@35/@23)
1	Lebanon	5,950	132	59	52	146	67	2.5
2	Independence	7,350	163	61	69	184	NA	3.0
3	Brooks	4,900	157	79	63	190	114	2.4
4	Dever-Conner	4,550	153	76	70	182	82	2.4
5	Independence	4,200	132	43	21	94	71	2.2
6	N. Albany	4,900	94	76	56	147	101	1.9
	2013 Average	5,308	139	66	55	157	87	2.4
	2012 Average	6,050	132	75	68	164	74	2.2
	2011 Average	4,681	66	39	NA	123	95	3.2
	All years (n=27)	5,224	100	57	62	143	88	2.8

Table 5-7. Nitrogen mineralized from soil samples (0-12 inches), using anaerobic or aerobic N mineralization test methods. Also shown is crop N uptake from zero N field plots (full data set in Table 2). **Units: N mineralized as percentage of total soil N.**

Site	Location	Soil total N	Anaerobic Nmin, 7d @ 40C	Aerobic 42d net Nmin @ 23C	Aerobic 7d net Nmin @ 35C	Aerobic 42d net Nmin @ 35C	Nmin estimate based on zero N plot crop N uptake
		%	----------------------------	----------------------------	% of total soil N	----------------------------	----------------------------
1	Lebanon	0.17	2.2	1.0	0.9	2.5	1.1
2	Independence	0.21	2.2	0.8	0.9	2.5	NA
3	Brooks	0.14	3.2	1.6	1.3	3.9	2.3
4	Dever-Conner	0.13	3.4	1.7	1.5	4.0	1.8
5	Independence	0.12	3.2	1.0	0.5	2.2	1.7
6	N. Albany	0.14	1.9	1.5	1.1	3.0	2.1
	2013 Average	0.15	2.7	1.3	1.0	3.0	1.8
	2012 Average	0.17	2.1	1.3	1.1	2.7	1.2
	2011 Average	0.13	1.4	0.9	NA	2.7	2.3
	All years (n=27)	0.15	1.9	1.1	1.1	2.7	1.7

N mineralization rate in the laboratory vs. the field (Table 5-6 and Table 5-7**).** We measured soil N mineralization rate in the laboratory in an effort to use a laboratory test to forecast N mineralization rate in the field. Consistent with results from 2011 and 2012, the anaerobic N mineralization test (7 days incubation at 40C) was about 1.6X greater than crop N uptake in the field. Based on three years of data, we observed no strong correlations between laboratory N mineralization tests and N uptake in zero N plots. Likely field conditions (i.e. wetting/drying cycles, interaction of the soil with plant roots, and changing soil temperatures) are variable enough that lab incubations using sieved soil at constant temperature and moisture are unable to predict N mineralization of the soil under field conditions.

Effect of soil incubation temperature on rate of N mineralization in the laboratory, using an aerobic incubation method. We conducted aerobic N mineralization tests at two temperatures, 23 and 35C to evaluate the effect of temperature on the mineralization rate. At 23C, N mineralization was mostly complete by day 21 while at 35C, the soil was still mineralizing N at day 42. Soil N mineralized (after 42 d) at 35C was 2.4X greater than at 23C. Existing models typically predict a mineralization rate increase of 2 to 3X when temperatures increase by 10C, so our data falls within the expected range.

Utility of an at-planting soil nitrate test.

Soil NO3-N was always higher in the PSNT samples compared to the at-planting samples (Table 5-8). We found that soil nitrate increased by an average of 28 lb N/acre between planting date and PSNT sampling date (corn at V6), which is consistent with results from last year. Using the at-planting soil nitrate value with the current PSNT interpretive guidance (Table 10 in EM9010) would result in an over-application of N fertilizer by ~29 lb N/acre. This information is most useful for growers who apply all their fertilizer pre-plant broadcast and incorporated. Using a preplant soil nitrate test, these growers could use the recommended fertilizer rate from Table 10 in the Sweet Corn Fertility Guide (EM9010) and subtract ~30 lbs N/A when calculating their fertilizer rates.

Based on 3 yrs of data, the variable that best predicted potential N uptake (N uptake by zero N plot/N uptake by grower plot) was soil nitrate taken at planting (Figure 5-9). **When nitrate-N values are ≥15**

ppm (equivalent to ≥53 lb N/A in the top 12”), this is likely indicative of a soil with a high N supplying potential and thus less fertilizer is needed to achieve maximum N uptake. This shows that an at-planting soil test could be used in lieu of a PSNT soil test taken at V5 to calculate N application rates as long as the rate is reduced by ~30 lb N/A to account for N mineralization (see discussion above).

Determine if a Nitrate Quick Test is accurate enough to be able to eliminate the need to send a soil sample to a commercial lab. The Quick Test results were highly correlated with laboratory results (Figure 5-10). At nitrate concentrations >25 ppm, the Quick Test tended to underestimate nitrate concentrations, which could result in a slight over-application of N when using OSU’s nutrient management guide EM 9010-E (Sweet Corn- Western Oregon) to determine the sidedress rate. Compared to a traditional laboratory test, using the Quick Test is cheaper (~$0.75/sample vs. ~$7-13/sample + shipping) and test results can be obtained within hours of collection, eliminating the need to mail samples. On average, there was a 12% difference between the lab and QT values (8% for values <25 ppm and 16% for values >25 ppm). These results show that the Quick Test is reliable enough to be able to base fertilizing decisions on the results.

Table 5-8. Soil nitrate concentrations (0-12 inches) in zero N plots (no fertilizer N applied). Soil samples were collected at time of planting or at ~V6 (as recommended for PSNT test).

Site	Location	Previous summer crop	Winter Cover Crop	Sampling date	Sampling date	NO3-N	NO3-N	Est Nmin between planting and PSNT	PSNT fertilizer N recommendations		Additional N over recommended rate	Avg soil temp between planting and PSNT sampling
				@ planting	@ PSNT	@ planting	@ PSNT		@ planting	@ PSNT		
						ppm	ppm	lb N/A	lb N/A	lb N/A	lb N/A	°F@4"
1	Lebanon	Beans	Oat/vetch	24-Apr	11-Jun	5.1	10.5	19	160	135	25	65.4
2	Independence	Sweet Corn	None	15-May	28-Jun	9.5	21.4	42	145	100	45	66.7
3	Brooks	Cauliflower	Oat/vetch	31-May	2-Jul	15.0	19.5	16	120	105	15	70.7
4	Dever-Conner	Radish seed	Oat	31-May	2-Jul	12.6	25.8	46	130	85	45	72.6
5	Independence	Corn	None	14-Jun	17-Jul	14.2	21.8	27	125	100	25	75.9
6	N. Albany	Radish seed	vetch/phacelia	17-Jun	15-Jul	19.4	24.2	17	110	90	20	77.1
					2013 Average	13	21	28	132	103	29	71
					2012 Average	12	23	37	131	96	35	NA

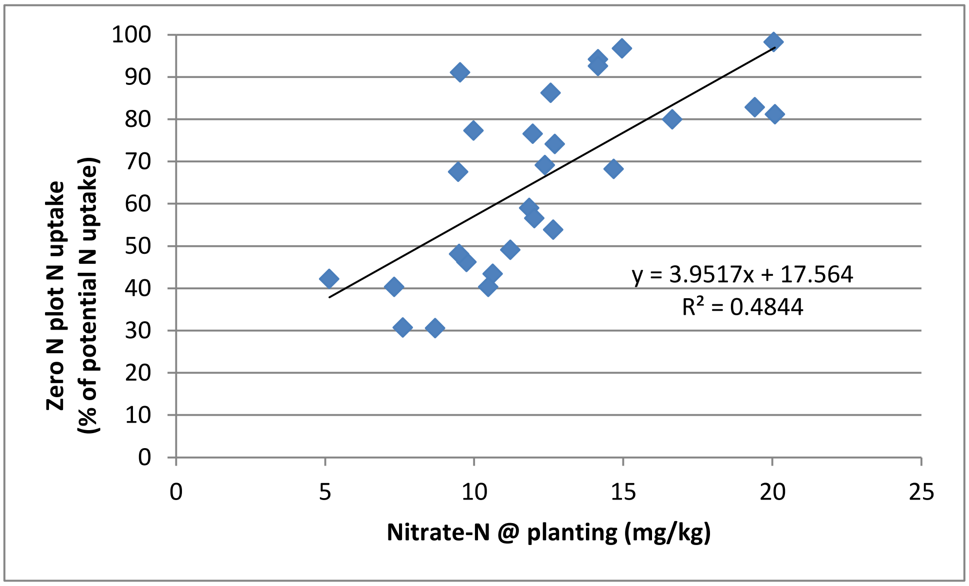

Figure 5-9. Relationship between nitrate-N at planting and N uptake of the zero N plot expressed as a percentage of N uptake in the fertilized grower field.

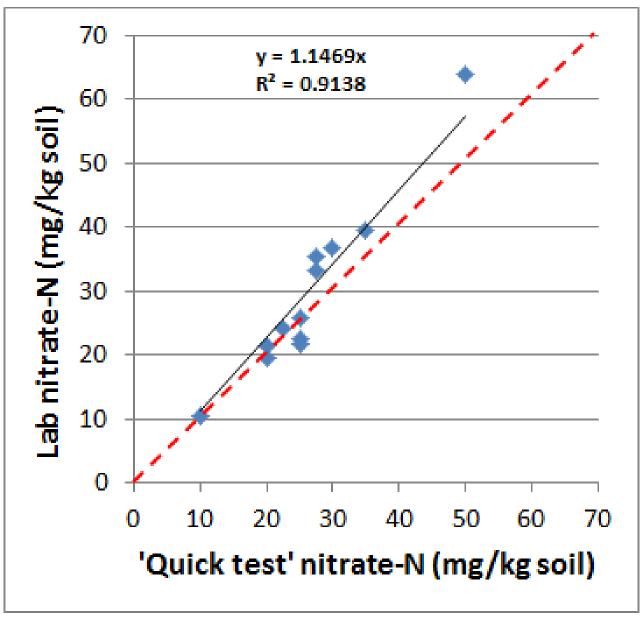

Figure 5-10. Correlation between 'Quick Test' (QT) and laboratory nitrate concentrations for 2013 PSNT samples (n=14). The red dashed line is the 1:1 line. At higher concentrations, the QT tended to overestimate nitrate concentrations.

5.3 Results for Phosphorus

Effect of banded P fertilizer rate on crop yield and quality for early season planting dates.

Table 5-9 shows the soil characteristics for the field sites used in the P studies. The OSU Farm site (Corvallis I) had a P concentration in a range where we might expect to see a P yield response, but the on-farm site (Corvallis II) had a high enough P concentration that we would not expect to see a yield response. OSU's Nutrient Management Guide for Sweet Corn-Western Oregon (publication EM 9010-E) recommends that when the Bray 1 P concentration is >50 ppm, no fertilizer P is usually necessary for maximum growth except when conditions could lead to a deficiency (i.e. cold soil temps and tillage history). Root growth is governed by temperature and can be minimal early in the season, limiting crop P uptake. Low soil temperature also reduces the rate at which organic P is converted to soluble plant-available P. We hypothesized that for early spring plantings when soil temperatures were low that the crop would respond to P fertilization even if initial soil P test levels were high.

Table 5-9. At-planting soil characteristics for P field sites (0-12") as analyzed by Brookside Laboratories. Values are an average of four replicates.

Site	NRCS mapped soil	pH	Total N %	OM[1] %	Bray I P ppm	K[2] ppm
Corvallis I	Chehalis sicl	6.1	0.08	1.7	42	227
Corvallis II	Chehalis sicl	6.2	0.19	3.4	135	252

1- estimated by 1.7 x total C (assumes SOM contains 58%C); 2-Mehlich III extractant

At harvest, there was no gross ear yield response for the trials in 2013 (Table 5-10 and Figure 5-11), which is consistent with our results from last year over (Figure 5-11). Although gross yield was not different among treatments, at the Corvallis I site (which had low initial P), there was an increase in the husked ear weight, length, and width with increasing P up to 60 lb P2O5/A (Table 5-10). This would likely translate into increased kernel yield. For the Corvallis II site, no differences in ear quality parameters were observed.

Tissue P concentrations were in the range considered to be sufficient for optimal growth (Table 5-11). For the Corvallis I site, there were no differences in tissue P among treatments, but due to differences in plant growth, there were differences in P uptake (Figure 5-12). Despite the difference in early season plant growth and P uptake, gross ear yield was unaffected. Because sweet corn can uptake 60 lb P2O5/A or more (Figure 5-13) by harvest, P uptake measured early in the season only represents a small fraction (<13%) of total uptake. Therefore, in this study it appears that as the plant's root system grew and the soil's temperature increased (increasing P availability), the plants in the lower rate P2O5 treatments were able to recover from an early season P deficiency. At the Corvallis II site, which had a high initial soil test P level, there was no difference in P uptake between treatments.

Table 5-10. Sweet corn yield and ear quality response to P2O5 treatments at 2 sites in the Willamette Valley, 2013.

P2O5 (lb/A)	Obs	Ear no./A	Gross yield (t/A)	Avg. fresh ear wt (lbs)	Avg. husked ear wt (lbs)	Avg ear length (in)	% tip fill	Avg ear width (in)	Moisture (%)
Corvallis II, planted May 14, Var. Captain, hand harvested									
0	4	19,275	9.8	1.02	0.74	8.18	94.3	2.08	76.1
15	4	17,206	9.1	1.06	0.74	8.08	95.4	2.04	75.4
30	4	19,493	10.1	1.04	0.77	8.28	94.5	2.09	74.8
60	4	17,751	9.7	1.09	0.82	8.35	95.5	2.15	74.3
120	4	19,058	10.4	1.09	0.82	8.38	94.9	2.12	74.2
	LSD (0.05)	NS	NS	NS	0.07	0.25	NS	0.07	NS
Corvallis II, planted June 3, Var. Kokanee, machine harvested									
0	4	21,809	10.0	0.92	0.80	8.50	96.8	2.12	67.4
15	4	22,767	10.2	0.89	0.79	8.40	95.0	2.17	67.6
30	4	23,203	10.1	0.87	0.77	8.50	96.2	2.11	68.2
60	4	20,531	9.4	0.92	0.79	8.45	96.7	2.18	67.3
120	4	23,435	10.2	0.88	0.78	8.38	96.1	2.13	67.9
Grower[1]	2	23,464	10.5	0.90	0.82	8.45	97.6	2.18	65.8
	LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

1- Grower standard practice. Not included in the statistical analysis; data provided for comparison.

Table 5-11. Tissue P concentration and P uptake. Growth stage at the time of sampling for Corvallis I and II was V6-7 and V5, respectively. Different letters in a column indicate a significant difference (p>0.05).

	Tissue P			P uptake		
Treatment	Corvallis I	Corvallis II		Corvallis I		Corvallis II
lb P2O5/A	--------- % -----------			------- lb P2O5/A ------		
0	0.298	0.299	b	4.3	c	3.2
15	0.297	0.283	b	6.1	cb	2.4
30	0.271	0.297	b	5.5	cb	2.6
60	0.272	0.297	b	7.4	ab	2.8
120	0.295	0.335	a	8.3	a	3.3
LSD(0.05)	ns	0.035		2.0		ns

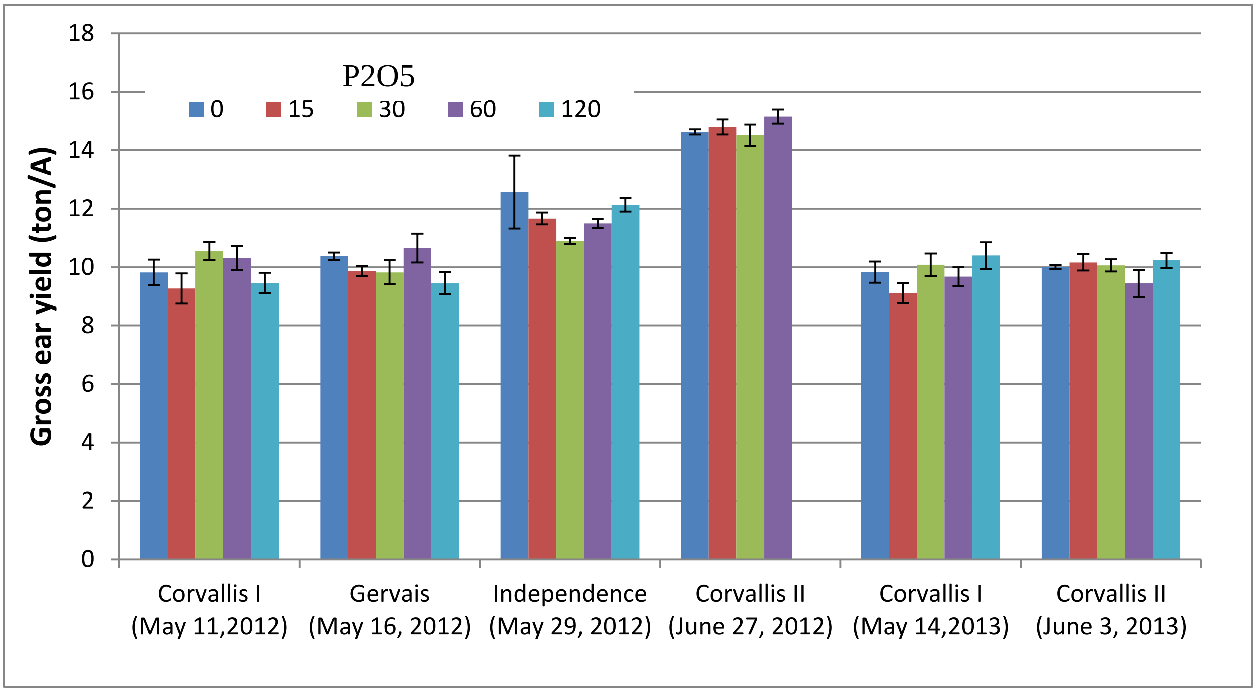

Figure 5-11. Sweet corn gross ear yield response to P2O5 rates applied at planting at 4 sites from 2012 and 2 sites from 2013 (+SE). Because there was no yield response to P fertilization at any site in both years, factors other than P were controlling yields (i.e. soil, location, variety, etc.). The 120 lb/A rate was omitted at Corvallis II in 2012.

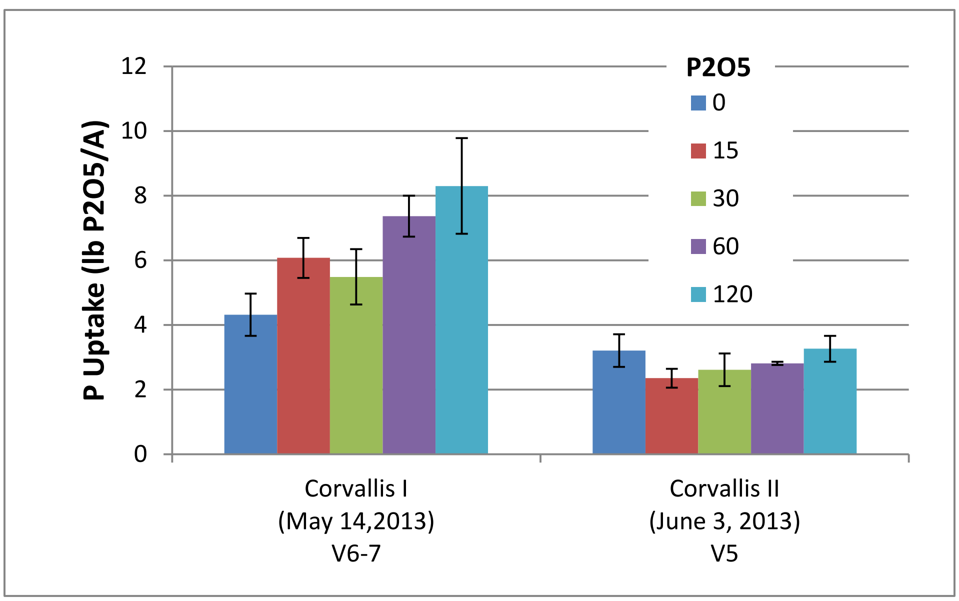

Figure 5-12. P uptake (+SE) for different rates of P2O5. Planting date and growth stage are given on the graph.

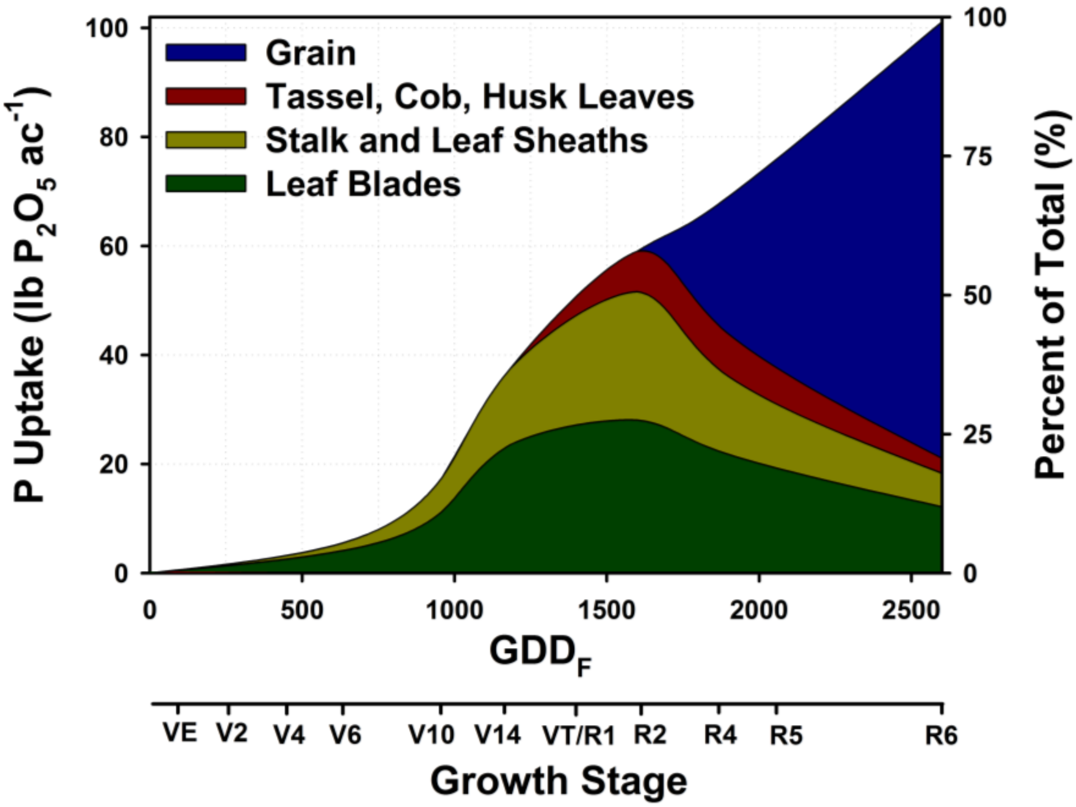

Figure 5-13. Example of total corn P uptake and partitioning for grain corn. Sweet corn in our trials were harvested at 1580 and 1745 GDD for Corvallis I and II, respectively. Graph from http://cropphysiology.cropsci.illinois.edu/research/nutrient_uptake.html.

For the Corvallis II site, these results validate OSU's P fertilizer recommendations for sweet corn. For the Corvallis II site which had a soil test P level >50 ppm, the guide recommends no P fertilizer additions. At this site (and the 4 sites from last year which had soil test P levels >50 ppm) soil test P was high enough so that the application of additional P fertilizer apparently did not provide a positive economic return. At the Corvallis II site, which had a soil test P level of 42 ppm, the guide recommends applying ~50 lbs P2O5/A (extrapolating from Table 7 in the guide). Although the 60 lb P2O5/A rate did result in a growth response early in the spring, the plants receiving no or less P were able to outgrow the effects of low P availability early on possibly due to warmer soils (i.e. higher P availability) and the aggressive root system of corn. The results from the Corvallis II site suggest that the OSU guidelines are conservative in their recommendations.

P supply to roots under actual field conditions using Plant-Root Simulator probes.

Soil temperature is a major factor affecting P supply to roots. The most critical period for P availability to corn is during seedling development, immediately after planting. The PRS measurements assessed P supply as affected by prevailing soil moisture, temperature, physical and biological conditions. Phosphorus supply (P flux to the PRS probe anion exchange membrane) varied among field sites (Table 5-12). No relationship between P flux onto the membrane and initial Bray 1P or soil temperature was observed. This highlights the fact that many other factors such as soil moisture, pH, mineralogy, and OM play an important role in P availability.

Table 5-12. Plant-Root Simulator Probes (PRS™) results. The probes were removed at 2wk intervals.

Site	Project	Est soil texture	Install date	Removal date	P absoption onto probe	Initial Bray 1 P	Avg soil temp @ 4"
					µg/10cm2/2wks		F
Corvallis	Corn P trial	sicl	14-May	28-May	4.7	42	60.5
Corvallis	Corn P trial	sicl	28-May	11-Jun	4.9	42	69.1
Corvallis	Corn P trial	sicl	11-Jun	25-Jun	3.5	42	69.4
Corvallis	Corn P trial	sicl	25-Jun	9-Jul	4.1	42	75.5
Corvallis	Corn P trial	sicl	9-Jul	23-Jul	3.8	42	71.3
N. Corvallis	Corn P trial	sicl	4-Jun	18-Jun	8.8	134	71.5
N. Corvallis	Corn P trial	sicl	18-Jun	2-Jul	25.5	134	71.1
N. Corvallis	Corn P trial	sicl	3-Jul	17-Jul	8.2	134	78.2
N. Corvallis	Corn P trial	sicl	17-Jul	31-Jul	14.8	134	73.2
Dever-Conner	Bean P trials	fsl	14-Jun	28-Jun	8.0	159	68.3
Dever-Conner	Bean P trials	fsl	28-Jun	12-Jul	6.7	159	76.7
Scio	Bean P trials	sicl	14-Jun	28-Jun	4.0	189	69.1
Scio	Bean P trials	sicl	28-Jun	12-Jul	11.9	189	75.8
Stayton	Nmin	sicl	7-Jun	21-Jun	2.8	132	66.8
Stayton	Nmin	sicl	21-Jun	5-Jul	2.7	132	74.5
Dever-Conner	Nmin	sil	4-Jun	18-Jun	9.2	141	70.8
Dever-Conner	Nmin	sil	18-Jun	2-Jul	6.5	141	74.5
Brooks	Nmin	sil	4-Jun	18-Jun	4.9	186	69.6
Brooks	Nmin	sil	18-Jun	2-Jul	3.3	186	71.8
N. Albany	Nmin	fsl	17-Jun	1-Jul	3.0	36	72.8
N. Albany	Nmin	fsl	1-Jul	15-Jul	1.8	36	81.4
N. Albany	Bean fumigation trial	l	7-Jun	21-Jun	5.6	44	69.5
N. Albany	Bean fumigation trial	l	21-Jun	5-Jul	3.6	44	74.0
N. Albany	Bean fumigation trial	l	5-Jul	19-Jul	5.7	44	72.8