OPVC FINAL PROJECT REPORT: 2015 **PROJECT YEAR**: 2 of 2

Project Title: Enhanced efficiency fertilizer technologies for improved production in sweet corn (2015)

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Total Project Request (all years): Year 1: $28,421 Year 2: $23,649

2. EXECUTIVE SUMMARY

Urea is a common nitrogen fertilizer for sweet corn production. This two year project evaluated commercially available urea additives for their potential to provide crop production and environmental benefits. Specifically, experiments were designed to evaluate the efficacy of urea fertilizer products containing a urease inhibitor (Agrotain Ultra), or nitrification inhibitors, or a polymer coated urea product (ESN). Products containing nitrification inhibitors (SuperU and Instinct) were evaluated only in 2014, and found to have efficacy similar to ESN in slowing conversion of urea to leachable nitrate-N. The control treatment in all studies was granular urea without additives.

Urease inhibitors can improve crop N use efficiency by inhibiting the soil enzyme (urease) that is responsible for converting urea to ammonium-N, the precursor to gaseous ammonia (NH_3) loss. Previous research in eastern Oregon demonstrated substantial gaseous ammonia loss (15 to 60% of N applied) during the first week after broadcast urea application. The Eastern Oregon trials were conducted with same measurement technique that we used in our Willamette Valley trials. Fields used for Eastern OR trials had light-textured soils with low cation exchange capacities (<10 meq/100g soil).

In three commercial Willamette Valley field trials (one trial in 2014; two trials in 2015), we used a modified passive flux method to quantify gaseous ammonia loss from urea alone vs. urea plus Agrotain (urease inhibitor). Measured ammonia loss from fertilizers to the atmosphere was close to zero. Agrotain did not alter measured ammonia loss (no benefit). Ammonia loss was measured during the first week after a broadcast fertilizer application to medium-textured (sandy loam, silt loam or loam) soils with cation exchange capacities of 25 to 30 meq/100g soil. Fields were irrigated with a big gun sprinkler the day before fertilizer application. Following application, urea prills remained on the soil surface where they dissolved following light precipitation or dew. Warm soil temperatures and low relative humidity created an environment conducive to ammonia loss. Our findings suggest that gaseous ammonia loss is not a major N loss pathway for our medium-textured Willamette Valley soils.

Polymer-coated urea products reduce the dissolution rate of urea. Research in other regions has demonstrated a benefit to crop N use efficiency when conditions favor N loss from the root zone by nitrate leaching. ESN, the polymer-coated product we evaluated, typically releases 20-25% of its N at application (due to imperfections in polymer coat) with the remainder of N released in 50 to 70 days at a soil temperature of 68 ^{o}F, according to the manufacturer.

Polymer-coated urea (ESN) did not increase corn ear yield vs. the urea control in 2014 or in 2015 field trials at the OSU Vegetable Research Farm. Corn yield increased with N fertilizer rate. Ear yield was equivalent for urea or ESN at equivalent preplant N fertilizer rates. A slower N release rate for ESN vs. urea was observed during the first 2 to 4 weeks after fertilizer application in laboratory incubations (2014). However, soil nitrate-N measured in the field at 6 weeks was similar for urea and ESN in 2014 & 2015, indicating no benefit to ESN. The field trials were managed to increase opportunity for nitrate leaching. Additional irrigation water was applied to simulate a very wet spring. In 2015, we observed evidence of N movement from the surface soil (0 to 10 inches) into the 10 to 20 inch soil depth. Soil samples (0-20 inches) at 6 weeks after planting recovered an average of 78% of applied N fertilizer, with similar soil N recoveries from ESN or from urea.

Overall, these trials showed little or no opportunity for increasing N fertilizer use efficiency in sweet corn production by using commercially-available urea additives. Local soils were not highly susceptible to gaseous ammonia loss or to early season nitrate leaching under the experimental conditions imposed.

3. FULL REPORT

3a. Background

Enhanced Efficiency Fertilizers (EEF) have the potential to improve the crop N use efficiency (NUE) as well as minimize negative environmental losses compared to conventional urea fertilizer (Guertal, 2009; Shoji et al., 2001). Depending on the product, they have the potential to reduce ammonia loss and/or nitrate leaching.

Nitrate Leaching

The goal of EEF products that are slow/controlled release or contain a nitrification inhibitor is to limit the amount of nitrate in the soil early in the season when N uptake is minimal and the leaching hazard is highest due to spring rains. Once fertilizer N has converted to nitrate, it is susceptible to leaching with irrigation or rainfall. By protecting the fertilizer N from leaching and keeping it in the root zone, there is the potential to reduce N applications thereby increasing the crop N use efficiency.

Many growers prefer to apply all N fertilizer at planting instead of splitting N into pre-plant and mid-season application. Although EEFs 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. Also, EEF fertilizers may directly benefit crop growth by allowing growers to maintain more uniform soil moisture. With EEF fertilizers, growers do not have to suspend irrigation in order to apply a sidedress N fertilizer application with a tractor-mounted spreader.

Despite the benefits of applying all 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, resulting in a high leaching hazard. Not only does this nitrate leached from the crop root zone potentially increase groundwater nitrate concentrations, but less N is available for crop growth, which could result in a deficiency and lower ear yields. The timing of N release from controlled release fertilizers vs. crop needs is the major issue. Ideally, the EEF delays N release until just prior to rapid growth of corn. The period between seeding and the beginning of stem elongation (jointing) is when potential for N loss is greatest. But, if N release from EEF is too slow, the crop will not have sufficient N for peak growth rate during stem elongation growth phase. Conversely, if EEFs do nothing to alter the timing of N fertilizer conversion to nitrate-N, then it provides no benefit over untreated urea fertilizer, and it is a wasted expense.

Although some EEF products have been marketed for many years, 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. But, in other experiments, EEF products have been found to have no benefit regardless of weather conditions (Hart et al., 2010).

Ammonia Loss

When urea is broadcast, some of the applied fertilizer N may be lost as ammonia. Although this loss can be minimized by applying irrigation water as close to the application as possible (within 24 h), in many cases several days up to a week may elapse before irrigation is applied. When applied to soil, the urease enzyme converts urea to ammonium-N, accompanied by a zone of elevated pH around the fertilizer granule. As a result, the balance between ammonium and ammonia is temporarily shifted towards ammonia, which is volatile. Given the right environmental conditions (soil moisture, pH, texture, temperature, wind speed, humidity, etc.), surface-applied urea can result in significant gaseous ammonia loss. In eastern Oregon, ammonia loss has been measured to be as high as 50% of applied urea-N when the urea was left on the soil surface for one week (Holcomb et al., 2011). But, soil and climate are different east of the Cascades and N loss rates need to be validated for western Oregon. For example, soils in western Oregon tend to have a lower pH and a higher OM and clay content, which can buffer the soil against an increase in pH due to urea hydrolysis and thus reduce ammonia loss.

Studies have shown that by using a product with a urease inhibitor such as NBPT (the active ingredient in Agrotain and SuperU), ammonia loss from broadcast urea can be significantly reduced (Rawluk, 2000). It works by keeping the urea from converting to ammonia/ammonium. Because NAPT degrades in 10-14 days, the soil should be irrigated as soon as possible after application to minimize ammonia loss even when this product is used. The goal of this part of the project is to determine how much N is lost when urea remains on the soil surface for an extended period following application, and whether adding a urease inhibitor is beneficial in limiting ammonia loss.

3b. Objectives

Nitrate leaching:

1. Quantify the amount of applied fertilizer N that can be protected from leaching by polymer-coated urea (ESN).
2. Determine if and by how much ESN can increase ear yield and quality when conditions favorable to nitrate leaching from the root zone occur 2 to 5 weeks after seeding.

Ammonia volatilization:

1. Quantify ammonia volatilization losses under a worst-case scenario (urea broadcast on moist soil, followed by 5 to 7 days without irrigation).
2. Determine if and how much a product containing a urease inhibitor (Agrotain Ultra) can reduce ammonia volatilization, and if the savings are enough to justify the higher cost of the product.

3c. Significant findings

Nitrate leaching:

ESN has the potential to prevent nitrate leaching under the right conditions (i.e., very sandy soils with high spring rainfall occurring 2 to 4 weeks after fertilizer application). In laboratory soil incubation in 2014, ESN was effective for 6+ weeks, but under field conditions studies in 2013 and 2014 showed that they are only effective for ~4 weeks. In 2015, there was 29% less nitrate in the soil at 3 weeks for the ESN treatments compared to urea. Despite a high leaching potential in this study (excess irrigations applied to a sandy loam/loam soil), we measured no yield benefit to using ESN. By week 6, we found more ammonium in the ESN treatments, however, it was only 11 lb N/acre and it did not have any influence on yield.

The following summarizes results from 2014 and 2015 for ESN

- In a laboratory soil incubation in 2014, recovery of N from the polymer coated urea was significantly less than conventional urea over the entire study period (6 weeks), demonstrating that the product was effective at slowly releasing urea. From Week 2 to 6, ESN was protecting 25-35% of added N from leaching.
- By week 6 in the 2014 lab incubation, ESN prills had released 83% of added urea-N. Although 60% of the prills were fully “intact” at week 6 (plump with no dimpling), they were full of liquid and much of the urea-N had diffused out of the prill.
- Under field conditions in 2014 ESN was measured to be effective up to the Week 4 sampling period, protecting between 43 and 37% of applied N from leaching at Week 2 and 4, respectively. In 2015, the ESN was only protecting 16% of applied N at Week 3. By Week 6 in both field trials, the ESN was no longer effective at protecting N from leaching.
- Some agronomic service companies recommend applying conventional urea with ESN to prevent an early season crop N deficiency, based on the idea that ESN might reduce nitrate-N too slowly to meet crop needs. Based on the data, this practice is not warranted. Nitrogen uptake by sweet corn is minimal in the first month after planting and ESN releases enough N to meet early season crop N needs even when soils are cool.

Ammonia loss

- Despite favorable conditions for ammonia loss (moist, warm soils with residues) measured ammonia loss for urea alone was small (< 1% of urea-N applied) at both field-sites.
- Agrotain Ultra showed variable performance at reducing ammonia loss, which may have been the result of non-uniform soil moisture conditions across treatments and replicates. However, when

ammonia volatilization is so low, there is no benefit to applying a urease inhibitor even if the product is highly effective.

- This research suggests that ammonia loss would be minimal for most well buffered (high clay and CEC) Willamette Valley loamy, acidic soils.

3d. Methods

Description of EEF fertilizers

- **ESN® (Environmentally Smart Nitrogen)** manufactured by Agrium Advanced Technologies, Inc. This product is a polymer coated urea and contains 44%N. The coating allows water 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. At current urea market prices, using ESN costs an additional ~$0.15/lb N.
- **Agrotain Ultra®** manufactured by Agrotain International (a subsidiary of Koch Agronomic Services). This product is a liquid product containing the urease inhibitor (NBPT) that was sprayed onto urea, coating the surface of the urea prills. The urease inhibitor has the potential to reduce ammonia volatilization losses from surface applied urea by slowing the conversion of urea to ammonium, which allows the soil to buffer pH changes and reduces ammonia losses. For our field trials, urea treated with Agrotain Ultra (3 quarts product per ton of urea) was obtained from a local fertilizer dealer.

Ear yield response and efficacy in protecting N from leaching for ESN

This trial was located at OSU's Vegetable Research Farm in Corvallis. The soil (0-12 inches) had the following properties: pH 6.7, 2.0% OM (LOI), estimated CEC of 16.6 meq/100g, soil test phosphorus (Bray P1 method) of 34 ppm, and soil test potassium (ammonium acetate extraction) of 187 ppm. Using the hydrometer method for measuring soil particle size distribution, the soil texture from 0-12 inches in blocks 1 and 3 was a sandy loam (13% clay and 56% sand) with the other blocks being a loam (15% clay and 47% sand).

On May 1, fertilizer was broadcast by hand to field plots (10 x 35 ft). See Table 1 for treatments and rates. Following application, the fertilizer was incorporated with a power harrow to a depth of ~5 inches. Treatment 6 also received a midseason topdress application at a rate 150 lb N per acre. A soil temperature probe (Hobo pendant) was installed at a depth of 3 inches. The treatments were arranged in a randomized complete block design with 5 replications. On the same day as the fertilizer application and incorporation the sweet corn var. 'Captain' was seeded and ~4 weeks after application doubles and plants spaced closer than 4 inches were removed. Although we were aiming for a plant population of 26-28,000 plants/acre, the final stand was 19,000 plants/acre; the result of poor germination. At planting 55 lb P2O5 per acre (from TSP) and 32 lb K2O per acre (from KCl and K-Mag) was banded. Soil was sampled at 3 wk. (0-12") and 6 wk. (0-10" and 10-20") after fertilizer application. Samples were extracted with 2M KCl and analyzed for ammonium and nitrate. The bulk density of the soil (0-10 inch depth) was measured using metal 3 inch diameter cores. The average bulk density was 1.35 g/cm3. This was used to calculate the quantity of ammonium and nitrate in the soil in lb N/acre.

To increase the potential for nitrate leaching, we applied 4.5 inches of irrigation water (as measured by placing 6 buckets randomly in the field) over the first 6 weeks after planting. The total amount of water on the field from rain and irrigation was 7.2 inches.

At harvest on August 13 (104 days after planting), ears from 30 feet of row (15 ft. from the middle two rows in each plot) were hand harvested. Gross ear weight, dry matter, and other parameters (tip fill, length, width, unhusked wt.) were measured.

Table 1. Fertilizers and N rates used in EEF field trial.

Trt	Fert	Timing	N rate lb/acre
1	None		0
2	Urea	PPI[1]	50
3	Urea	PPI	75
4	Urea	PPI	100
5	Urea	PPI	125
6	Urea	PPI+topdress	200[2]
7	ESN	PPI	50
8	ESN	PPI	75
9	ESN	PPI	100
10	ESN	PPI	125

1- preplant incorporated; 2- 50 lb PPI + 150 lb topdress

Ammonia volatilization trial (on-farm):
Ammonia volatilized from surface applied urea was measured using the modified passive flux method (Wood et al., 2000; Vaio et al., 2008) on two commercial farms in 2015. This consisted of a rotating mast placed at the center of each circular plot that was modified with a tripod to stabilize the mast during high wind events. Each mast was equipped with passive flux samplers at five heights (0.45, 0.75, 1.50, 2.25, and 3.00 m; Leuning et al., 1985). Each passive flux sampler consisted of a glass tube (0.7-cm i.d. by 20 cm long) with the inside surface coated with 3% (w/v) oxalic acid in acetone to scrub the NH3 in the air flowing through the tube. Each tube had an attached nozzle with a 1-mm hole to restrict incoming air flow to prevent NH3 saturation of the oxalic acid. Flux samplers were sealed in a Ziploc bag after being coated to ensure an NH3–free environment and were only removed when being placed on the masts.

Each circular plot received one of the following treatments; no fertilizer (Control), 150 lb urea-N/acre (Urea), and 150 lb Agrotain Ultra/acre (Agrotain). The fertilizer was evenly applied by hand in these plots. Normally farmers fertilize their corn around V6 when N uptake begins to increase rapidly. It was necessary for us to apply the fertilizer as early as preemergence to be able to work around the farmer's field management schedule. Treatments were arranged in a randomized complete block design with three replications. Each circular plot was separated by at least 330 ft. (100 m) to avoid contamination of NH3 between treatments (Vaio et al., 2008). The ground was visibly moist when the fertilizer was applied. The field was irrigated with a big gun prior to urea fertilizer application. The fertilizer was applied shortly after an irrigation when soil moisture was visible at the surface. This was done to create a worst case scenario. Because a big gun can only irrigate a section of the field at a time, each replicate (Control, Urea, and Agrotain) was typically applied several days apart. Both field had received preplant broadcast and incorporated ESN applications of approximately 150 lb/acre, and ESN prills were visible at the soil surface during the experiment.

Ammonia flux samplers were replaced every other day after the application of fertilizer and the collection continued until the plots were irrigated. Immediately after collection of the flux samplers from the masts, they were capped at both ends, placed in a sealed Ziploc bag, and stored in a refrigerator. The samples were extracted within 3 weeks of being collected. Flux samplers were extracted by adding 2 mL of deionized water and shaking for 10 min. The extracts were analyzed colorimetrically for ammonium-N (see appendix A for validation test methods to insure that our methods were correct).

The horizontal and vertical NH3 flux (Fx, μg N m^{-2} s^{-1}) for each flux sampler was calculated using the equations given by Schjoerring et al. (1992), Wood et al. (2000), and Vaio et al. (2008). A weather station (Onset Computer Corp model Hobo U30-NRC) was installed to measure wind speed, air and soil temperature (at 1-inch depth), and relative humidity every 15 minutes. Although wind speed was measured every minute, the data logger provided a 15 minute average. In Trial 1, the wind speed device was inoperable for most of the collection period.

Due to the large separation differences between towers and the potential for difference in soil properties, soil samples (0-1 inches) were taken in the circular plots receiving fertilizer. No soil samples were taken from the control plots.

Trial 1: Talbot

Trial 1 was conducted on a commercial farm located at the confluence of the South Santiam and Willamette River. The soil mapping units in the field were Newberg silt loam and Cloquato silt loam. Soil characteristics for each experimental plot are given in Table 2. Prior to sweet corn planting, the field had been in fescue for 8 years. As a result, there was significant residue of grass crowns. The start date for replicates 1, 2, and 3 was June 23, June 25, and July 1, respectively. The duration of the experiment was dictated by the irrigation interval. For replicates 1, 2, and 3 the duration was 8, 6, and 5 days, respectively. The short irrigation interval for rep 3 was due to very hot weather. Over the entire collection period, the soil temperature at 1” routinely topped out >100^{o}F (Fig. 1).

Table 2. Ammonia trial 1 (Talbot) soil properties (0-1 inch depth) in each circular experimental plot. Samples were collected prior to the addition of fertilizers.

Tower	Rep	Treatment	%clay[1]	% sand	Texture	pH (1:2)	CEC (meq/100g)[2]
1	1	Agrotain	22	20	sil	6.1	34.4
2	1	Urea	16	32	sil	6.3	27.0
4	2	Urea	29	10	sicl	6.4	30.7
6	2	Agrotain	19	18	sil	6.9	28.4
8	3	Agrotain	20	22	sil	5.9	31.3
9	3	Urea	25	12	sil	6.1	30.4

1- hydrometer method; 2- as measured by saturation/displacement method, using NH4 as the saturating cation.

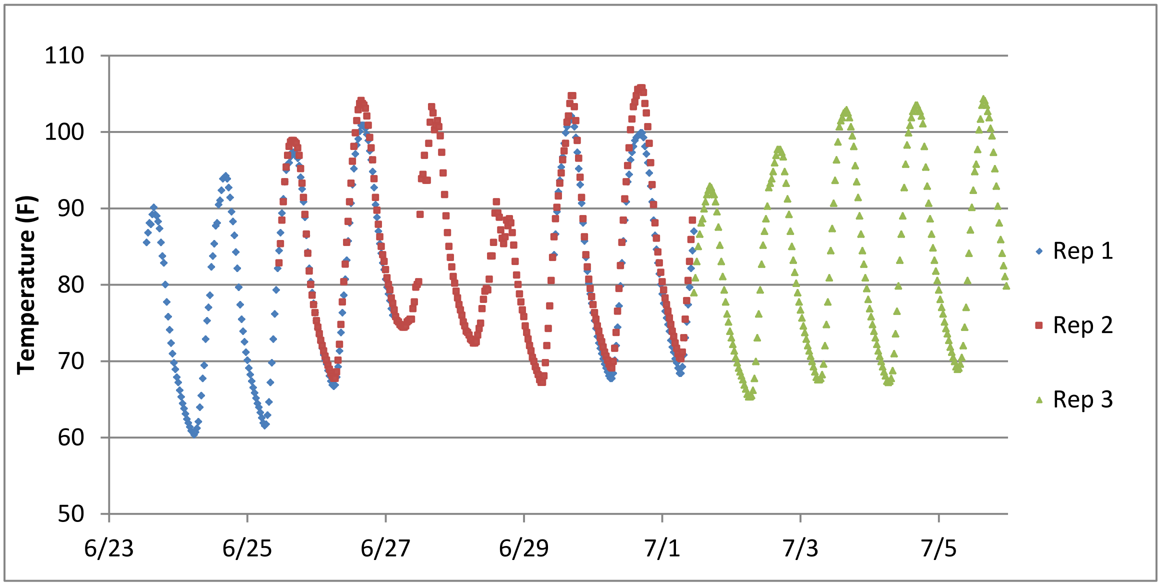

Figure 1. Soil temperature (^{o}F) at 1” in ammonia trial 1 (Talbot).

Trial 2: Monroe

Trial 2 was conducted on a commercial farm located east of Monroe. The soil mapping units in the field were Newberg loam and Cloquato silt loam with inclusions of Camas gravelly sandy loam. Soil characteristics for each experimental plot are given in Table 3. The first set of towers was compromised due to irrigation overlap and irrigation wind drift. Due to time and site constraints this site only had 2 replicates. The start date for both replicates 1 and 2 was July 23 and the experiment was terminated on July 29 (6 days and 3 collections). Soil temperatures at 1” were similar to those in trial 1 (Fig. 2). The field received 0.04” of rain between 7/25 and 7/26, which was enough to dissolve most of the prills.

Table 3. Ammonia trial 2 (Monroe) soil properties (0-1 inch depth) in each circular experimental plot. Samples were collected prior to the addition of fertilizers.

Tower	Rep	Treatment	%clay[1]	% sand	Texture	pH (1:2)	CEC (meq/100g)[2]
1	1	Agrotain	20	36	l	5.7	22
2	1	Urea	24	18	sil	5.5	26
3	2	Urea	22	28	sil/l	5.7	24
5	2	Agrotain	20	29	sil	5.8	23

1- hydrometer method; 2- as measured by saturation/displacement method, using NH4 as the saturating cation.

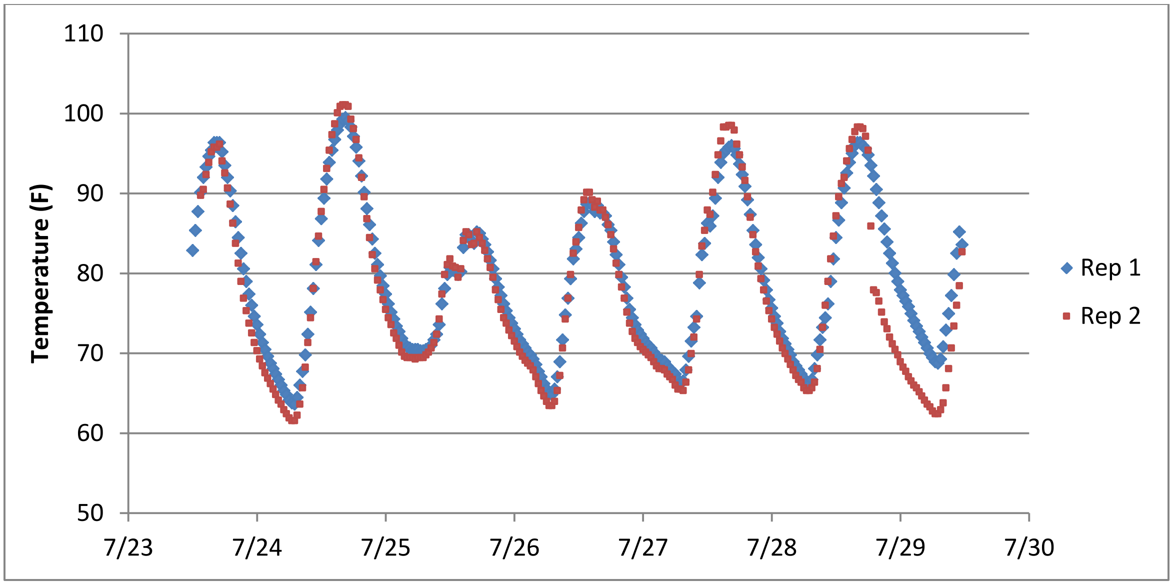

Figure 2. Soil temperature (^{o}F) at 1” in ammonia trial 2 (Monroe).

3e. Results & Discussion

Ear yield response and efficacy in protecting N from leaching for ESN

Rainfall and irrigation data are given in Fig. 3A. We had a dry spring in 2015. Over the first 6 weeks of the trial, the field only received 2.7” of rainfall, 1.7” of which fell in May. For comparison, the 30 yr. average rainfall in Corvallis for May is 2.3”. To increase the leaching potential and create a “worst case scenario”, we applied 6 irrigations and a total of 4.5” of water over the first 6 weeks of the project. We tried to time the irrigations shortly before or after rainfall, or even during rainfall, to minimize evaporation and maximize leaching. The average soil temperature over the first 3 weeks was 63F and was 71F from 3 to 6 weeks. Using reference evapotranspiration (ETr) from the Hyslop Agronomy Farm weather station and estimated crop ET coefficients for corn, we estimate that the evapotranspiration over the first 6 weeks was approximately 2.6 inches. If ET estimates are correct, the field received 4.6” of water beyond crop need, which should have been sufficient to cause movement of nitrate into deeper into the soil profile.

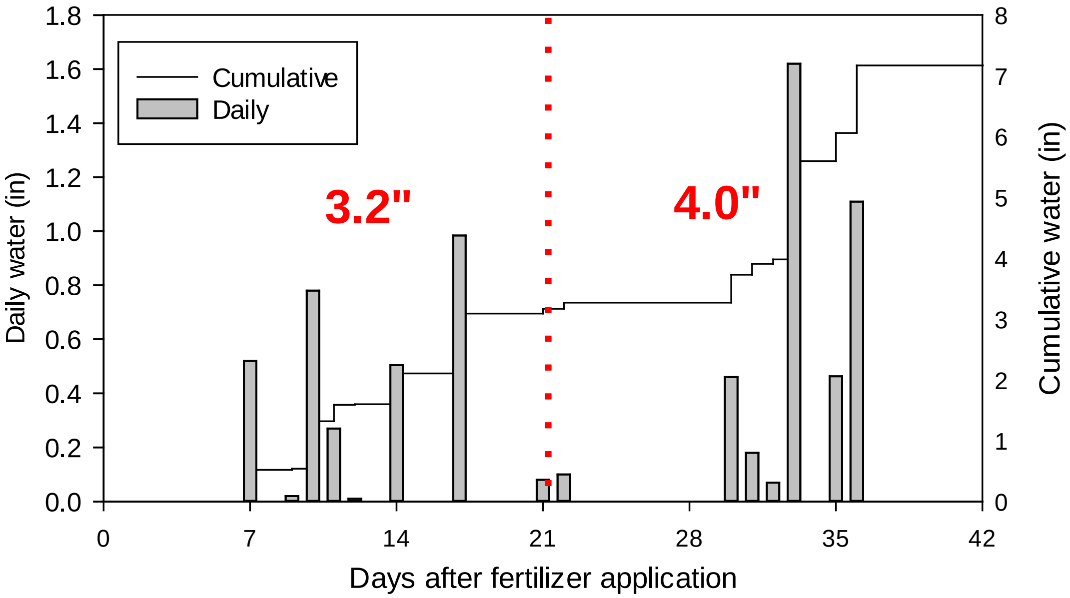

Figure 3A. Cumulative and daily water applied during the first 6 weeks after fertilizer application (May 1 to June 12). OSU Vegetable Research Farm, Corvallis. The total rainfall for each 3 week soil sampling interval is given between the dashed lines. For comparison, the 30 yr. average of rainfall in Corvallis for May and June is 2.3 and 1.5 inches, respectively.

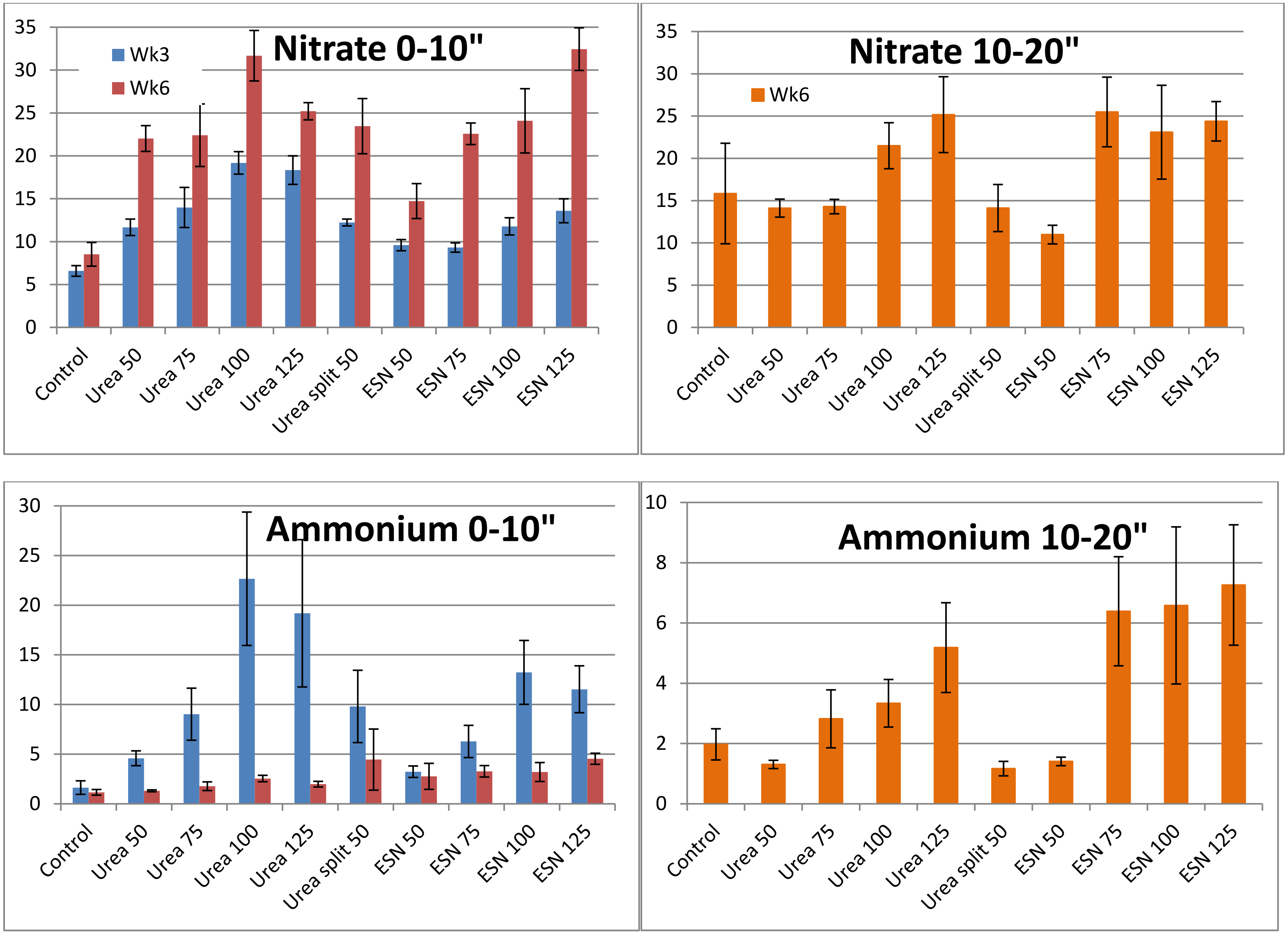

Figure 4. Soil mineral N (NO3-N and NH4-N) concentrations (mg N/kg soil = ppm). Error bars represent the SEM (n=5). OSU Vegetable Research Farm, Corvallis.

Table 3B. Soil mineral N at 3 and 6 weeks. Values are the average of 5 replicates. OSU Vegetable Research Farm, Corvallis.

	NO3-N (mg/kg)			NH4-N (mg/kg)			NO3-N + NH4-N (mg/kg)		
	0-10"		10-20"	0-10"		10-20"	0-10"		10-20"
Trt	Wk3	Wk6	Wk6	Wk3	Wk6	Wk6	Wk3	Wk6	Wk6
Control	6.6	8.5	15.8	1.6	1.2	2.0	8.2	9.7	17.8
Urea 50	11.7	22.0	14.1	4.6	1.3	1.3	16.2	23.3	15.4
Urea split 50	12.2	23.5	14.1	9.8	4.5	1.2	22.0	27.9	15.3
ESN 50	9.6	14.7	11.0	3.2	2.8	1.4	12.8	17.5	12.4
Urea 75	14.0	22.4	14.3	9.0	1.8	2.8	23.0	24.2	17.1
ESN 75	9.3	22.6	25.5	6.3	3.3	6.4	15.6	25.8	31.9
Urea 100	19.2	31.7	21.5	22.7	2.5	3.3	41.8	34.2	24.8
ESN 100	11.8	24.1	23.1	13.2	3.2	6.6	25.0	27.3	29.7
Urea 125	18.3	25.2	25.2	19.2	2.0	5.2	37.5	27.2	30.3
ESN 125	13.6	32.4	24.4	11.5	4.5	7.3	25.1	37.0	31.6
ANOVA P<0.05	**<0.001**	**<0.001**	**0.020**	**0.002**	0.308	**0.003**	**<0.001**	**<0.001**	**0.006**
LSD	**3.4**	**7.5**	**9.8**	**10.1**	NS	**3.7**	**12.5**	**9.1**	**12.4**
Contrast Urea vs. ESN	**<0.001**	0.321	0.366	**0.035**	**0.050**	**0.018**	**0.002**	0.878	0.153

Soil mineral N concentrations are given in Fig. 4 and Table 3B. At wk. 3, nitrate concentrations for the ESN treatments were an average 29% lower (18-39% depending on treatment) than the urea treatments. This is likely due to urea in the ESN prills that had not been released to soil yet. In 2014, a lab incubation showed that only half of the added ESN-N was released at 3 weeks, though under field conditions this release rate is faster. Ammonium levels at 3 weeks were also lower, supporting the hypothesis that not all the ESN urea had been released. Overall, at 3 weeks, approximately 16% of applied N was protected against leaching (range 13-23%).

Although the field received 4” of water from 3 to 6 weeks, nitrate levels in the top 20” of soil were not consistently different for paired N rates (Urea 50 vs. ESN 50) at Week 6. There was a trend of higher ammonium concentrations for the ESN treatments, however the absolute difference was small (average of 11 lb N/acre from 0-10"; range 3-16 lb N/acre). These results are similar to last year (2014) in that we did not see significant differences between straight urea and enhanced efficiency fertilizer products at 6 weeks despite the addition of irrigations to increase leaching. These results suggest that for moderately textured soils (sandy loam to loam), the ESN product performs no better than untreated urea even when precipitation + irrigation is increased during the first six weeks after planting.

Ear Yield and

No differences were measured in gross ear yield (Fig. 5 and Table 4) or ear characteristics (data not shown) between urea and EEF products for a given N rate. For the urea and ESN treatments where all fertilizer was applied preplant, ear yield increased with N rate up to 75-100 lb N/acre. The split urea application treatment (50 lb N/acre preplant + 150 lb N/acre at V6), had ear yield that was statistically not different from preplant urea or ESN applied at 100 lb N per acre (Table 4).

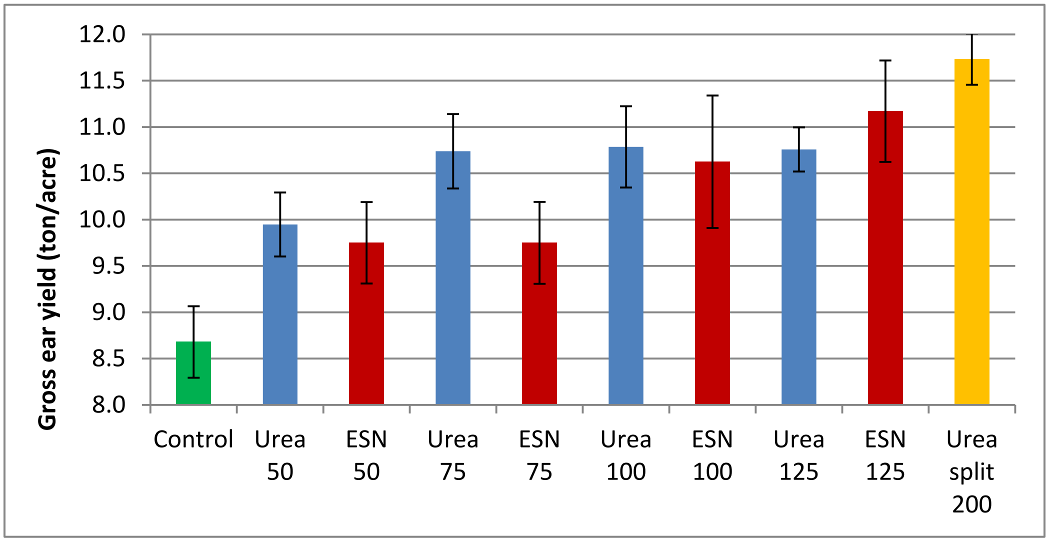

Figure 5. Gross ear yield from urea vs. ESN for different N rates. Error bars represent SE of the mean (n=5).

Table 4. Gross ear yield. Different letter indicate a statistical difference (LSD p=0.05). OSU Vegetable Research Farm, Corvallis.

Fert	Yield ton/acre	
Control	8.68	d
Urea 50	9.95	bcd
ESN 50	9.75	dc
Urea 75	10.74	abc
ESN 75	9.75	cd
Urea 100	10.79	abc
ESN 100	10.62	abc
Urea 125	10.76	abc
ESN 125	11.17	ab
Urea split 200	11.73	a

Ammonia volatilization:

Trial 1 (Talbot)

Environmental conditions should have been favorable for ammonia loss (Fig. 6). Because there was significant plant residue in the field as the field had just come out of 8 years in grass seed, soil urease enzyme activity was likely high, especially given the high soil temperatures at the surface (Fig. 1). Also, all plots had some visible moisture in the surface, which promotes dissolution of the urea prills. However, relative humidity was low enough that little dew was forming in the morning and in some plots the prills never dissolved.

The field site was surrounded by other crops (snap beans and wheat) as well as bordered by a riparian buffer adjacent to the Willamette River. Only the beans received a banded application of fertilizer, otherwise no fertilizers were broadcast to any of these adjacent areas during the trial.

Overall, cumulative ammonia volatilization only amounted to ≤2 lb N/acre (Fig 7), which amounts to less than 1% of applied fertilizer N. The differences between urea and Agrotain are likely due to differences in starting soil moisture, which resulted in differential dissolution of the applied prills. Working with big guns are challenging because they result in non-uniform soil moisture conditions across a field (i.e., a big gun may take 6-8 hrs. to get across a section of field, at one end the soil is drier and at the other wetter). But despite differences in soil moisture and dissolution of the prills, ammonia loss was insignificant across all reps. Figure 8 shows a worst case scenario where prills have started to dissolve into a small area, which concentrates the urea and raises the pH locally, increasing the potential for ammonia loss. However, ammonia loss for this treatment (urea- tower 4, rep 2) was insignificant (Fig. 7).

Agrotain did show some phytotoxicity on corn plants (Fig. 9) when applied at V3-4.

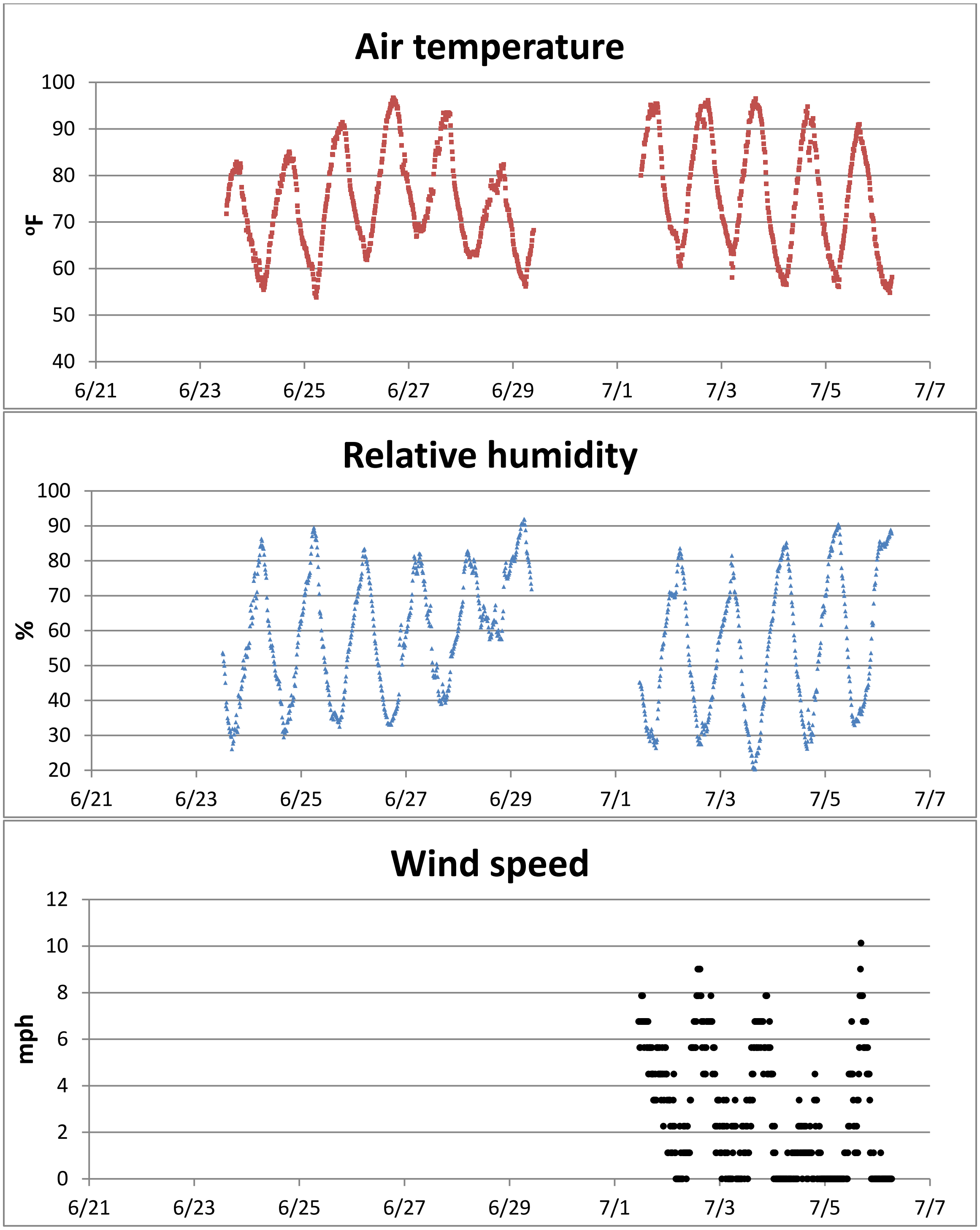

Figure 6. . Environmental conditions at trial 1 (Talbot). The wind speed gauge was inoperable for the first half of the trial.

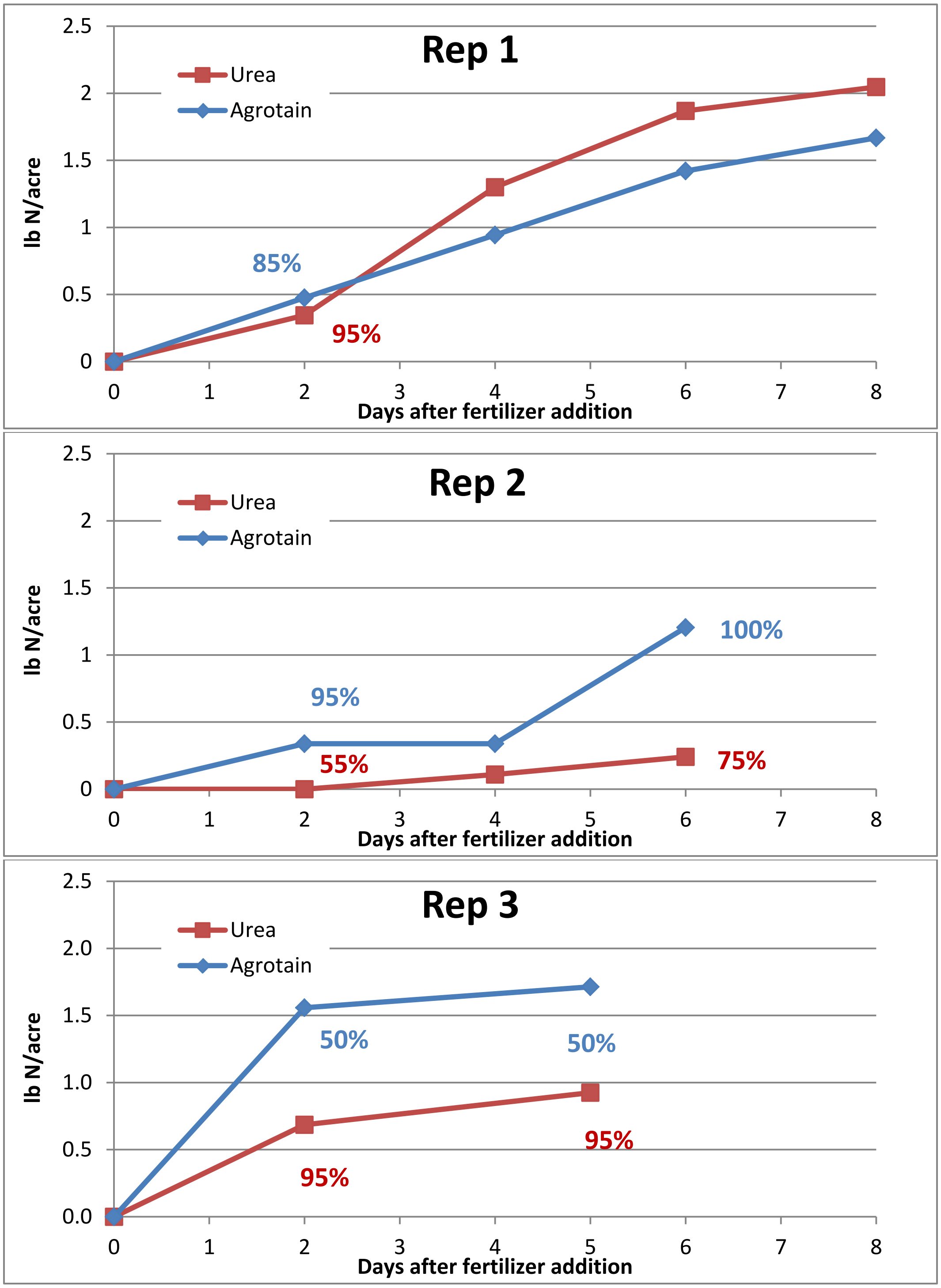

Figure 7. Cumulative ammonia loss following fertilizer addition from trial 1 (Talbot). The control has been subtracted from each treatment. The numbers on the graph represent the estimated percentage of applied fertilizer that had dissolved at the corresponding collection interval.

Figure 8. Partially dissolved urea prills (urea treatment Rep 2 Tower 4). This is a worst case scenario where the concentration of urea is localized. As the urea converts to ammonium, the pH increases, resulting in a shift in the ammonium/ammonia equilibrium to ammonia, resulting in ammonia loss.

Figure 9. Phytotoxicity of Agrotain Ultra on corn at V3-V4.

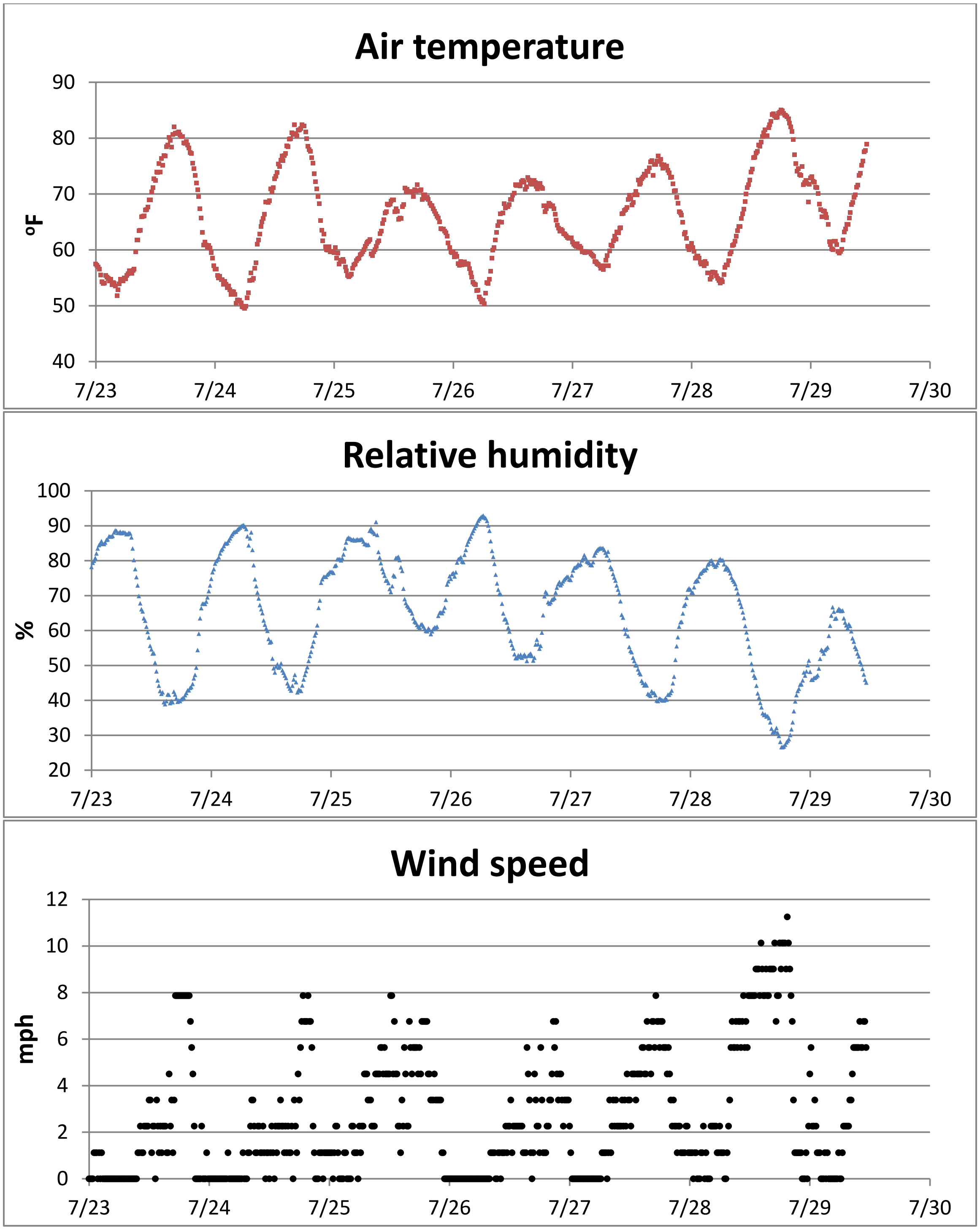

Figure 10. Environmental conditions at trial 2 (Monroe). Fertilizer was applied on 7/23. The field received 0.04” rain from 7/25 to 7/26.

Trial 2 (Monroe)

Environmental conditions for trial 2 are given in (Fig. 10). The field received 0.04” of rain between the second and fourth collection interval (7/25 and 7/27), which was enough to dissolve almost all of the fertilizer prills. All plots had some visible moisture in the surface, which promotes dissolution of the urea prills. The field site was surrounded by other crops (peppermint, grass seed, and squash). No fertilizers were broadcast onto any of these adjacent areas during the trial. The soil had a lower CEC and pH compared to the site in Talbot (trial 1).

Overall, cumulative ammonia volatilization only amounted to ≤1 lb N/acre (Fig 11), which amounts to <1% of applied fertilizer N. Unfortunately soil moisture was not completely uniform even in a plot, resulting in some areas with almost complete dissolution of prills and some with only partial. Rain occurring between the 2nd and 4th sampling intervals almost completely dissolved the fertilizer prills. But despite differences in soil moisture and dissolution of the prills, ammonia loss was insignificant across all reps.

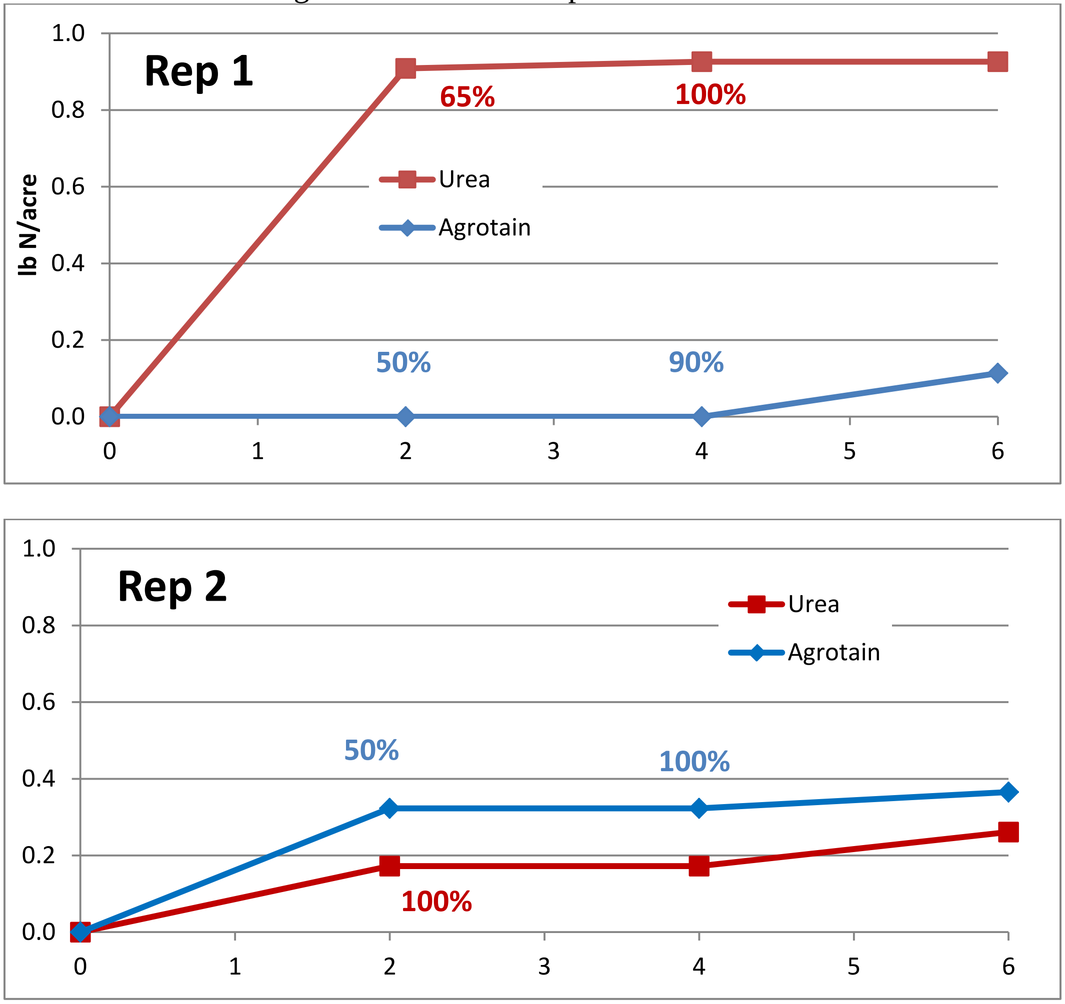

Figure 11. Cumulative ammonia loss following fertilizer addition from trial 2 (Monroe). The control has been subtracted from each treatment. The numbers on the graph represent the estimated percentage of applied fertilizer that had dissolved at the corresponding collection interval. The field received 0.04” of rain between day 2 and 3, which was enough to dissolve most prills.

Research conducted in the Lower Umatilla Basin (near Hermiston, OR) showed significant ammonia loss from surface-applied urea (50% in the week after application; Holcomb et al., 2011). Despite having favorable conditions for ammonia loss in our field trials (moist, warm soil and wind), ammonia loss was insignificant at our field sites in both 2014 and 2015. The difference in soil characteristics between the Hermiston area and the Willamette Valley may explain why. Table 5 shows the relevant soil characteristics for our field site and the field site used by Holcomb et al. (2011) near Hermiston. As urea hydrolyzes, it raises the pH around the prill. The maximum pH reached around the prill depends on the capacity of the soil to "dampen" or buffer a rise in pH (as indicated by CEC). Apparently, our soil had sufficient buffering capacity to prevent pH rise above the threshold for ammonia loss (pH 7.5). Our soil was well buffered compared to the soil from Holcomb's field site, with a CEC that was 3-4 times greater and a clay percentage that was ~4X greater. Our field research results suggest that ammonia loss may be minimal when urea is applied to medium-textured (loamy) acidic soils commonly found in the Willamette Valley.

Table . Soil characteristics from the Holcomb et al. (2011) study vs. those from our field sites.

	Holcomb [1]	Trial 1 (Talbot)	Trial 2 (Monroe)
pH	6.5	6.3	5.7
CEC (meq/100g)	8.0	30	24
OM (%)	<1	NA	NA
clay (%)	6	22	22
sand (%)	60	19	28
USDA texture	sandy loam	silt loam	silt loam/loam

1-only soil pH was reported in their study. Other soil characteristics listed here are based on NRCS soil map data.

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4. BUDGET DETAILS

Category	2014 Budget Items	2014 (Year 1)	2015 (Year 2)
Salary & Benefits	Sullivan, Dan	NA	1864
	OPE, Sullivan (48%)	NA	895
Salary & Benefits	Salary, Heinrich	10000	8200
	OPE, Heinrich (67%)	6700	5084
Wages & Benefits	Wages (Summer labor)	2200	1760
	Benefits, summer labor, 8%	176	141
Equipment	Equipment	0	400
Supplies	Supplies (field and lab)	1000	400
Travel	Travel	600	500
Plot Fees	Plot Fees (land rental)	1385	1385
Other	Other (nutrient analyses, ammonia trapping, plant, soil)	6360	3020
Total	Total	28,421	23,649

Appendix A: Validation of ammonia quantification test methods

To verify that out test methods were accurately measuring the extracted ammonium/oxalic acid solution and that there were no interferences, we performed the following experiment. We had two concerns about the method; 1) the reference standards were in a matrix of KCl not oxalic acid/water, and 2) the pH of the extract is 1.9 and we were concerned that this low pH would interfere with the colorimetric reaction, which needs a basic pH.

Methods

Coated tubes containing oxalic acid were extracted using the methods previously described in this report. The extract was “spiked” with varying amounts of a 10 ppm commercial ammonium standard. The estimated concentration based on the spike was then compared to the measured value.

Results and discussion

The estimated concentration vs. actual measured concentration is given in Table A1. The oxalic acid solution did not interfere with NH4-N recovery. Standards prepared with a matrix solution of KCl were appropriate for measuring NH4-N in the oxalic acid extracts.

Table A1. Estimated concentration of ammonium spiked oxalic acid solution and measured ammonium concentration using a standard curve generated by reference samples in a KCl matrix.

Estimated	Measured
NH4-N (mg/l)	
0.50	0.50
0.90	0.93
1.70	1.74
2.30	2.36
2.90	2.91