Final Report for FREP 14-0508SA

A. Project Information.

1. Reporting Period: January 2015 to September 2018.

2. Project Title: Field Evaluation and Demonstration of Controlled Release N Fertilizers in the Western United States

3. FREP Grant number: 14-0508SA

4. Project Leaders: Charles A. Sanchez, Professor, University of Arizona, Maricopa Agricultural Center, 37860 W Smith Enke Rd, Maricopa, AZ 85138, phone 928-941-2090, e-mail sanchez@ag.arizona.edu

Richard Smith, Farm Advisor, Cooperative Extension Monterey County, 1432 Abbott Street, Salinas, CA 93901, phone 831-759-7357, e-mail

B. Objectives

The objective of this project is to conduct experiment-demonstrations with CRN technologies in vegetable producing areas in California and Arizona with a wide range of CRN technologies available. Experiment demonstrations will all occur with grower-cooperators and CRN management will be compared to their standard practices. Success will be discerned by data collected, grower interest, and grower implementation. We will compile data on grower participation, interest, and adaptation.

C. Abstract.

Nitrogen is the nutrient most limiting to crop production in the western United States. Because of the rigid produce quality standards enforced by the market, vegetable crops receive appreciable amounts of N fertilizer for optimal yield and quality. Amounts of N applied range from 200 to 400 kg/ha and crop recoveries are generally less than 50%.

There are numerous possible fates of fertilizer applied N, in addition to the desired outcome of crop uptake. The urea and ammonium components of the N fertilizer might be lost through ammonia volatilization. The nitrate-N might be lost to leaching with irrigation water below the crop root zone possibly impairing surface and ground water. Nitrate might also be lost as N_2 and N_2O gasses via denitrification processes affecting air quality and climate. The global warming potential of N_2O is 300 times that of CO_2 and N fertilizer is estimated to account for one-third the total greenhouse gas production in agriculture. Furthermore, all forms of N might be immobilized into the organic soil fraction by the soil microbial population where availability to the crop is delayed.

Both California and Arizona have mandated Best Management Practices (BMP’s) to varying degrees. These practices generally involve timing, amounts, and placement of N, and irrigation water application. The use of controlled release N (CRN) fertilizer sources is another promising

option. Controlled-release N sources have shown positive results for vegetable production. Early work in Arizona has shown CRN sources to be highly effective for lettuce under some conditions. Recent work in the low desert of the southwestern United States evaluated the response of lettuce, broccoli, cauliflower, celery, and spinach to controlled release N fertilizer. The use of CRN was compared to soluble N fertilizers applied pre-plant and soluble N fertilizers applied in split-side-dress applications. Under several production scenarios, the use of CRN strategies was economically favorable. There was also variation in the efficacy of the various CRN technologies. There is risk of damage to using a CRN 90 product in warm fall plantings. Solutions include using CRN120 and band placement. Experiment-demonstrations show CRN technologies are an economical viable strategy for N management for cool season vegetables. Data from the central coast and the desert show nitrification inhibitors sometimes provide benefit and sometimes they do not. CRN based programs showed less benefits in drip irrigated warm season vegetables in the desert where N can be metered through the system in anticipation of crop needs, since nearly 100% of the water required is supplied by irrigation opportunities for N leaching are minimal.

D. Introduction

Intensive vegetable production in the southwestern U.S. receives large annual applications of nitrogen (N) fertilizers. Amounts of N applied range from 200 to 400 kg/ha and crop recoveries are generally less than 50% (Mosier et al., 2004). There are numerous possible fates of fertilizer applied N in addition to the desired outcome of crop uptake (Sanchez and Dorege, 1996; Havlin et al., 2005). The urea and ammonium components of the N fertilizer might be lost through ammonia volatilization. The nitrate-N might be lost to leaching with irrigation water below the crop root zone possibly impairing surface and ground water (Sanchez, 2000). Nitrate might also be lost as N_2 and N_2O gasses via de-nitrification processes affecting air quality and climate. Furthermore, all forms of N might be immobilized into the organic soil fraction by the soil microbial population where availability to the crop is delayed. The global warming potential of N_2O is 300 times that of CO_2 and N fertilizer is estimated to account for one-third the total greenhouse gas production in agriculture (Strange et al., 2008). One study reported that N fertilization (inorganic or organic) accounted for 75% of the greenhouse gas emissions from agriculture production (including production, application, and nitrous oxide emissions) and after N is accounted for there are no significant differences between conventional, organic, or integrated farming practices (Hiller et al., 2009).

N management in the western United States remains a continuing challenge. Both California and Arizona have mandated Best Management Practices (BMP's) to varying degrees. These practices generally involve timing, amounts, and placement of N, and irrigation water application. The use of controlled release N (CRN) fertilizer sources is another promising option. The successful implementation of CRN management where appropriate will reduce adverse environmental impacts of fertilizer N and improve profitability in California and the western United States in general.

E. Work Description

Task 1. Release rates for a range of products from a number of manufactures will be determined using the models and methods we developed.

During the first period we determined release rates and we modelled release for a number of products in our possession. This included ESN, and various Duration, Polyon, and GalXe release products. We used data collected on release rates to guide product selections for each crop planting window.

Task 2. A few experiment-demonstrations were implemented in Yuma, Imperial, and Riverside Counties in 2015. Planting in Salinas (Monterey County) were conducted in spring, summer and fall.

Desert Celery 2015

The field was an Indio silty clay loam (mixed, superactive, calcareous, hyperthermic Typic Torrifluvent) with a grower cooperator in the Yuma Valley. The treatments included two CRN products ESN (CRN 90) and Gal-Xe (CRN 120) applied to provide 132 and 176 lbs N/A pre-plant. The fertilizer was spread over listed beds using a specially calibrated applicator. The applied fertilizer was roto-mulched into the beds. The grower standard practices was a total of 386 lbs/A N by side-dress and water-run. The low rate of CRN (132 kg N/ha) received two side-dress N applications of 25 gal/A UAN 32 per acre. The high rate only received one application of UAN 32. The second side-dress was applied to the CRN treatments by mistake.

The entire area was fertilized with P as 11-52-0 (MAP) at 550 lbs/A applied pre-plant and disked. Celery was transplanted two rows per bed on 42 inch centers. All irrigations, pest control and fertilizer management other than N were standard practices. Yields were collected February 20, 2015 and marketable yields were calculated after grading.

Desert Romaine Heart 2015

This field was mapped as a Carsitas loamy sand (mixed, hyperthermic Typic Torripsamment) and was in cooperation with a grower in the Coachella Valley (Riverside County). Pre-plant P as 3-35-0 was applied by band in the beds at 50 gal/A. The pre-plant N treatments included ESN (CRN 90) and Gal-Xe (CRN 120) applied at 125 and 200 lbs N/A. The fertilizer was applied to 80 inch beds using a calibrated applicator and power-mulched into the beds. Romaine (cv. Fresh Heart) was seeded by planting 5 rows on 80 inch beds. The grower standard practice was one side-dress of 50 gal AN20 to the acre and a second side-dress of 60 gal AN20 to the acre (total 210 lbs N/A). The 125 lbs N/A CRN rates received the first side-dress but not the second (230 lbs N/A total). The high rate of CRN received no side-dress N fertilizer. Yields were collected January 29, 2015 and marketable yields were calculated after grading.

Desert Spinach 2015a

The field was mapped as a Holtville sandy loam (calcareous, hyperthermic Typic Torrifluvents) and was with a grower-cooperator located in Bard (Imperial County). Pre-plant P was 11-52-0 (MAP) applied at 400 lbs/A broadcast and disked. The pre-plant controlled release N products were Duration 45 (CRN 45) and Gal-Xe 90 (CRN 90) applied at 175 and 200 lbs N/A. The dry fertilizers were applied with a calibrated fertilizer applicator and power-mulched into the beds. The GSP received three applications of UAN32 at 30 gal/A (approximately 315 lbs N total per acre) spaced throughout the season. The low and high rates of CRN received one application of 30 gal UAN 32 late in the season (approximately 280 and 305 lbs N/A total, respectively). Spinach (cv. Banjo) was planted on 84 inch beds. The experiment was harvested December 29.

Desert Broccoli 2015a

The field used for this study was mapped as a Carsitas loamy sand (mixed, hyperthermic Typic Torripsamment) and was with a grower cooperator in the Coachella Valley. Pre-plant P was 70 gal/A 3-35-0 applied by band at seeding. The pre-plant CRN treatments were 125 and 200 kg N/ha as ESN (CRN 90#1) and Gal-Xe (CRN 90#2). The fertilizer was applied using a calibrated commercial applicator by layering it into listed beds. Broccoli (cv. Ironman) was seeded in double row beds on 40 inch centers. The GSP was two side-dress applications of 50 gallons AN 20 to the acre. The low rate of CRN received the first but not the second side-dress. The high rate of CRN received no side-dress fertilizer. Broccoli was harvested March 12, 2015 and after grading, marketable yields were calculated.

Desert Spinach 2015b

This site was a Holtville silty clay loam (calcareous, hyperthermic Typic Torrifluvents) located in Bard. This experiment-demonstration was harvested March 26, 2015. The treatments compared grower standard practice to programs that included reduced rates of N as CRN. We used one CRN 45 and one CRN 90 at two rates (75 and 150 lbs N/A) applied pre-plant and power-mulched into the beds. The GSP received three applications of UAN32 of 30 gal/A (approximately 315 lbs N total per acre) spaced throughout the season. The low and high rates of CRN received one application of 30 gal UAN 32 late in the season (approximately 180 and 255 lbs N/A total, respectively).

Central Coast Iceberg and Romaine Lettuce 2015a

These trials were conducted in cooperation with a grower and Wilbur Ellis, Inc. west of Soledad. The soil type at the site was Metz fine sandy loam. Half the field was preplanted with 400 lbs of 3.5-12-14 (14 lbs N/A). Replications 1 & 2 were on the preplanted area and replications 3 & 4 did not receive preplant. The quantity of nitrogen in the preplant was quite low and we did not feel that it would confound the evaluation. All treatments received an application of anti-crustant of 30 gallons/A of 5-20-0 (15 lbs N/A). Half of the experimental area was planted with romaine and the other half head lettuce on April 21, 2015. The crop was thinned on May 16. Each plot was one 80-inch wide bed by 540 feet long. Two sidedress applications of 20-0-0-5 were made with commercial equipment; the quantity of 20-0-0-5 was adjusted to make the standard, the moderate nitrogen and the moderate nitrogen plus nitrapyrin treatments. Nitrapyrin was applied at 0.5 and 1.0 lbs a.i./A to two treatments. Two 50-foot long strips of Duration and Novatec were included in the trial as observational treatments. These are both dry materials and were applied by hand. See table 1 for rates of materials and timing. The crops were grown with standard production practices. Soil samples were collected every 10 days during the growing. Harvest evaluations were conducted by sampling 60 heads from each plot and weighing and subsampling them for total N content. The harvest for romaine took place on June 26 and head lettuce on July 1. Data was converted to tons/A from stand count data conducted earlier in the season.

Central Coast Romaine Lettuce 2015b

This trial was conducted at the USDA Spence Research Station south of Salinas on Chualar loam soil. The field was listed with 300 pounds/A of potassium sulfate (130 lbs K) one month prior to planting. The trial was seeded with the variety 'Sun Belt' on June 17. Anticrustant at the rate of 25 gallons/A of 6-16-0 (15.5 lbs N/A) was applied on June 18 and the first water was applied on June 19. The field was thinned on July 8. The fertilizer treatments were applied in two ways: a post thinning application was made on July 12 by shanking the fertilizer between the seedlines using a Fairbanks small-plot dry fertilizer applicator; the remainder of all fertilizer treatments were applied through the drip system. The crop was sprinkler irrigated until after thinning when the drip tape was applied on July 12. The first drip irrigation and fertigation to the drip treatments was applied on July 13 and the second on July 29. See table 5 for treatments and rates. Each plot was 2 40-inch beds wide by 150 feet long and replicated 4 times in a RCBD. The field was sprinkler irrigated until thinning and then was irrigated with drip for the rest of the growth cycle. The drip system applications of liquid fertilizer were injected into the drip irrigation system by use of a multi-port manifold with backflow prevention valves which fed two inch layflat that provided water and fertilizer for each treatment. Injector ports in each layflat were used to inject the appropriate rate of UAN 32 liquid fertilizer. Battery powered pumps were used to inject fertilizer/nitrification inhibitors mixtures into the layflat and injections were made during the middle third of irrigation events. Irrigation levels were managed at 140% of ET. Treatments were evaluated for soil nitrate three times during the growth cycle, and total nitrogen content at harvest. Nitrate leaching was conducted in each plot by sampling down to three feet at the beginning of the cropping season to establish the baseline levels and at the end of the cropping season to evaluate nitrate movement to deeper soil depths.

<u>Central Coast Romaine Lettuce 2015c</u>

This spinach trial was conducted in a commercial production field with a cooperating grower near Gonzales. The soil at the site was Mocho silty clay loam. This was the first crop of the season on this block. Each plot was three 80-inch beds wide by the length of the field. Duration ST and NovaTec were applied at the equivalent of 120 lbs N/A applied prior to planting. The materials were applied by a commercial application rig on April 14. The material was power mulched into the beds on the same day and planted April 22 (Irrigated on April 23). The grower standard had a total of 180 lbs N/A applied (60 lbs N/A at planting and two 60 lbs N/A fertigations on May 6 and 14, respectively). Soil ammonium and nitrate were evaluated by collecting 10 soil cores from each plot down to 12". Initial soil levels at the start of trial (April 14) were 40.1 ppm nitrate. Yield evaluations were conducted on May 22 (29 days after wet date DAWD).

<u>Central Coast Spinach 2015a</u>

This spinach trial was conducted in a commercial production field with a cooperating grower near Gonzales. The soil at the site was Mocho silty clay loam. This was the first crop of the season on this block. Each plot was three 80-inch beds wide by the length of the field. Duration ST and NovaTec were applied at the equivalent of 120 lbs N/A applied prior to planting. The materials were applied by a commercial application rig on April 14. The material was power mulched into the beds on the same day and planted April 22 (Irrigated on April 23). The grower standard had a total of 180 lbs N/A applied (60 lbs N/A at planting and two 60 lbs N/A fertigations on May 6 and 14, respectively). Soil ammonium and nitrate were evaluated by collecting 10 soil cores from each plot down to 12". Initial soil levels at the start of trial (April

14) were 40.1 ppm nitrate. Yield evaluations were conducted on May 22 (29 days after wet date DAWD).

Central Coast Spinach 2015b

This spinach trial was conducted in a commercial production field with a cooperating grower near Castroville. The soil at the site was Pacheco clay. This was the first crop of the season on this block. Each plot was one 80-inch bed wide by 15 feet long with four replications and laid out in a randomized complete block design. All fertilizer treatments were applied at planting (including the grower standard) except for the ammonium sulfate followed by a topdress of 70 lbs N/A on May 17. All pre-plant treatments were applied on April 17 and mulched into the soil with a power mulcher. The wet date was April 20. Soil ammonium and nitrate were evaluated by collecting 10 soil cores from each plot down to 12". Initial soil levels at the start of trial (April 14) were 50.9 ppm nitrate. Yield evaluation was conducted on May 27 (37 DAWD).

Central Coast Mizuna 2015a

This mizuna trial was conducted on a commercial production field near Gonzales. The soil at the site was Mocho silt loam. Each plot was three 80-inch beds wide by the length of the field. Duration and NovaTec were applied at 120 lbs N/A with a commercial application rig on September 23. The material was mulched into the beds on the same day and planted; first water was on September 25. The grower standard had a total of 180 lbs N/A applied (60 lbs N/A at planting followed by 60 lbs N/A fertigations on October 2 and October 13). Soil ammonium and nitrate were evaluated by collecting 10 soil cores from each plot down to 12". Initial soil level at the start of trial (April 14) was 31.0 ppm nitrate. Yield evaluation was conducted on October 19 (24 DAWD).

Task 2a and 2b.

Continued studies in fall-winter-spring 2015-2016. We made the decision to continue to focus on cool season crops since results in 2015 were variable. Warm season were postponed until 2017-2018.

Iceberg Lettuce, Yuma County, AZ.

A field experiment-demonstration was established late fall in the Yuma Valley on a silty clay loam. The experiment demonstration included two CRN products (D90 and D120) and two rates of pre-plant application (75 and 150 lbs N/A). The fertilizer was applied to 42 inch beds using a calibrated applicator and power-mulched into the beds. These were compared to a grower practice consisting of sidedress and water runs totaling approximately 250 lbs N/A. The 75lb rates of CRN received one side-dress application of UAN 32 of 142 lbs N/A. Whole plant and soil samples were collected December 18, January 8, January 28, and February 24. Midribs were collected January 28 and February 24. The experiment was harvested March 2, 2016.

Broccoli, Imperial County, CA

This field experiment-demonstration was established in the late fall in the Bard valley, California on a clay loam. The experiment demonstration included two CRN products (D90 and D120) and two rates of pre-plant application (75 and 150 lbs N/A). The fertilizer was applied to 42 inch beds using a calibrated applicator and power-mulched into the beds. These were compared to a grower practice consisting of a sidedress and water runs totaling approximately 250 lbs N/A.

The 75lb rates of CRN received one side-dress application of UAN 32 of 125 lbs N/A. Whole plant and soil samples were collected December 18, January 8, January 28, and February 24. Petioles were collected January 28 and February 24. The experiment was harvested March 3, 2016.

Spinach, Imperial County, CA

This field experiment was established in the winter in the Bard valley, California on a clay loam. We applied two rates of CRN45 (100 and 200 lbs N/A). The fertilizer was applied to 84 inch beds using a calibrated applicator and power-mulched into the beds. The grower practice received 240 lbs N/A as AN20 through the sprinklers. The area with the CRN plots was projected to receive 40% less. This was allegedly accomplished by turning off the sprinkler lines surrounding the CRN plots during fertigation. The authors are skeptical that this was done well. Soil and plant samples were collected February 12, and March 4. This experiment was harvested March 4.

Spinach, Riverside County, CA

This experiment-demonstration was established in the late fall on a loamy sand in the Coachella valley. We applied two rates of CRN45 (100 and 200 lbs N/A). The fertilizer was applied to 80 inch beds using a calibrated applicator and power-mulched into the beds. The grower practice received three top dress applications of ammonium sulfate of 300 lbs/A. The plots receiving the low rate of CRN received two top dress applications and the plots receiving the high rate of CRN received one top dress application of ammonium sulfate. Plant and soil samples were collected December 17, January 14, and January 29. This experiment was harvested January 29

Romaine Hearts, Riverside County, CA

This experiment-demonstration was established in the late fall on a loamy sand in the Coachella valley. We applied two rates of CRN45 (125 and 200 lbs N/A). The fertilizer was applied to 80 inch beds using a calibrated applicator and power-mulched into the beds. The grower standard practice was one side-dress of 50 gal AN20 to the acre and a second side-dress of 60 gal AN20 to the acre (total 210 lbs N/A). The low rate of CRN received the 1st sidedress but not the 2nd. The high rate of CRN received no sidedress. Plant and soil samples were collected January 14, January 28, and February 24. This experiment was harvested March 16, 2016.

Iceberg Lettuce, Yuma County, AZ

This experiment was conducted in the North Gila Valley on a loam soil in the winter of 2015. In this experiment-demonstration a 40 acre field was divided into two. One half received 200 lbs N/A as CRN 90. This was broadcast and disked into the field prior to bedding. The other half received water run and sidedress N totaling about 240 lbs N/A. Samples were collected January 8, January 28, February 26, and March 15. This experiment-demonstration was harvested March 20, 2016.

Spinach, Pinal County, AZ

This experiment was established on a Casa Grande loam. The controlled release fertilizer was applied pre-plant at rates of 150 and 300 lbs N/A and power-mulched. Spinach was planted 6 rows per 40 inch bed on January 22, 2016. This experiment included several N sources including urea, ammonium sulfate, FUSN, Polyon 45 (CRN), and super urea. The N applications, except the CRN treatments, were made by two top dress applications on February 11 and February 26. For this spinach experiment we also measured nitrous oxide emission from selected plots 5 days after N application using a chamber method. The spinach was harvested March 20, 2016.

Central Coast 2016

This trial was conducted at the USDA Spence Research Station. The soil at the site was Chualar loamy sand: pH 6.98; CEC 17.9; OM (LOI) 1.76%; Sand, Silt Clay 60, 24, 16%, respectively. The variety 'Sun Valley' was seeded on June 21 and the first sprinkler germination water was applied on June 22. No nitrogen was applied at or prior to planting. The crop was sprinkler irrigated until thinning (10 inch spacing) on July 15. Fertilizer was applied in two ways: 1) dry fertilizers applied in the first application (July 19) followed by liquid fertilizer injected into the drip system for the second application (August 5); and 2) liquid fertilizer injected into the drip system for both the first (July 22) and second fertilizer (August 5) applications. Dry fertilizer materials were applied with a Fairbanks small-plot dry fertilizer applicator on July 19. The dry materials were applied with two shanks applied to the inside of the seedlines 2-3 inches deep. The surface drip irrigation was installed on July 20 and 21 and was used to irrigate and fertigate the crop for the remainder of the crop cycle. Treatments fertigated on the first application date were applied on July 22, and all treatments that received a second fertilizer application, were fertigated on August 5 (see Table 1). Fertilizer used for all fertigations was urea ammonium nitrate (UAN 32). A 12 mainline manifold was used to apply the fertilizers to each treatment and to keep the treatments separate. Battery powered pumps were used to inject fertilizer/nitrification inhibitors mixtures into the layflat and injections were made during the middle third of irrigation events. Nitrapyrin at 0.5 and 1.0 lbs a.i./A was applied in three methods: 1) total quantity of nitrapyrin was applied to ammonium sulfate crystals and applied as a dry material, 2) total quantity of nitrapyrin was applied in the first fertigation, and 3) the total quantity of nitrapyrin was divided in half and split between the first and second fertigation (see Table 1). Each plot was two 40-inch beds wide by 100 feet long and all treatments were arranged in a randomized complete block design with four replications. All experimental fertilizer treatments were applied at a moderate fertilizer amount (80 lbs N/A) and were compared with an unamended treatment also applied at 80 lbs N/A and a standard treatment applied at 150 lbs N/A. Nitrapyrin rates (0.5 and 1.0 lbs a.i./A) were applied based on the area treated. The field was irrigated with 130% ET which supplied excess irrigation water to test which materials maintain a greater percentage of mineral N as ammonium which is less likely to leach. Soil samples were collected four times during the crop cycle. Lettuce was harvested on August 23 by cutting thirty six heads from each plot, weighing them and subsampling them for dry weigh and total N content.

Task 2c. Additional experiment-demonstration in the desert with cool season crops.

Romaine Hearts in Coachella Valley (Riverside County, CA).
The crop was established 5 plant rows per 80 inched beds. About at the four leaf stage the crop was thinned to 12 inches between plants. The crop was sprinkler irrigated the entire growth period. This experimental area received 88 and 176 lbs N/A as CRN 90 compared to grower standard practice which was two applications of UAN 32 at 50 gal/A (350 lbs N/). The 88 lb/A treatment received one application of UAN32 (174 lbs N/A) and the 176 lbs N/A CRN treatment

received no sidedress N. Whole plant samples and soil samples were collected November 10, November 29, December 27, and January 17. The experiment was harvested January 17, 2016.

Iceberg Lettuce (Imperial County)
This experiment-demonstration was established near Bard California. The CRN 90 was applied at 90 and 180 lbs N/A. The grower standard practice was sidedress N at 50 gal UAN 32 to the acre (175 lbs N/A). Tissue and soil samples were collected December 21, January 8, January 27, and February 20

Spinach in Coachella Valley (Riverside County, CA)
This crop was planted on 80 inch beds near Indio. The crop was sprinkler irrigated the entire growth period. The experimental area received 90 and 180 lbs N/A as CRN 45. The grower standard practices received three top dress applications of ammonium sulfate 300 lbs/A (189 lbs N/A). The 90 lbs N/A CRN rate received one top dress applications (an additional 63 lbs N/A). Whole plant samples and soil samples were collected November 10, November 29, and December 27. The experiment was harvested December 27.

Spinach (Imperial County)
This experiment-demonstration was established near Bard California. The CRN 45 was applied at 90 and 180 lbs N/A. The grower standard practice UAN 32 applied through the sprinkler for a total seasonal rate of 200 lbs N/A. The low rate of CRN received an additional 80 lbs N/A through the sprinkler. Tissue and soil samples were collected December 27, January 9 and January 19. The experiment was harvested January 19.

Spinach experiment demonstrations, Pinal County, AZ
These experiment-demonstrations had the same treatment design but were repeated across three planting windows. These were all established on a Casa Grande loam. This experiment included several N sources including urea, super urea, ammonium sulfate, ammonium sulfate with nitrification inhibitor, FUSN, and Polyon 45 (CRN45). The controlled release fertilizer was applied pre-plant at rates of 100 and 200 lbs N/A and power-mulched. Spinach was planted 6 rows per 40 inch beds. The N applications, except the CRN treatments, were made by two top dress applications. The first experiment was planted December 15, 2016 and harvested February 13, 2017. The second experiment was planted February 2, 2017 and harvested March 22, 2017. The third experiment was planted March 8, 2017 and harvested April 19, 2017.

Task 2d. Experiment demonstrations with warm-season vegetables.

Desert Potato
This study was conducted on a Casa Grande loam in Pinal County Arizona. The treatments included no nitrogen (control), and 100 and 200 lbs N/A as CRN90 and 120. These were compared to sidedress UAN 32 (GSP) at 200 lbs N/A. The experiment was planted February 27, 2017 and harvested June 8, 2017.

Desert Pepper
A field experiment-demonstration was conducted with chile pepper (*Capsicum annuum*) to compare CRN management to grower standard practice on a loamy sand. The CRN products

were applied pre-plant and the drip applied UAN 32 was applied during the season. The pepper was a New Mexico Chile type “Sandia Hot”. The plot area received 75 kg P/ha as MAP applied pre-plant and disked into the soils. This crop was transplanted into the field on March 17, 2017 and established by sprinkler irrigation. Thereafter, all irrigations were by subsurface drip. The peppers were transplanted in single rows on beds having 3.5 ft centers with an in-row spacing of 18 inches. Plant samples were collected for dry weight determinations April 13, April 20, April 27, and July 10. We did not take root samples during the growing season because we did not want to damage the buried drip irrigation system. Root samples were collected after the final harvest on July 10. Leaf samples were collected midseason. Tissue samples were ground, weighed, and digested in sulfuric acid and peroxide. N and P in digests was determined colorimetrically. The harvest dates for peppers were May 26, June 6, and June 30.

Desert Tomato

N experiment-demonstration was conducted with tomato (cv. Mountain Fresh) to evaluate CRN (Gal-Xe) and SymTRX20S as an N source. SymTRX20 is an organic slow release N source. The plot area received 75 kg P/ha as MAP applied pre-plant and disked into the soils. The N treatments were 100, and 200 kg N/ha as a controlled release fertilizer (Gal-Xe), and SymTRX20S. These were compared to a negative control receiving no N fertilizer and a positive control receiving 200 kg N/ha as UAN 32 applied through the drip system during the season (standard practice). The tomato were transplanted into the field on March 17, 2017 and established by sprinkler irrigation. Thereafter, all irrigations were by subsurface drip. Whole plant samples were collected from all plots to estimate plant growth to treatment. Plant samples were collected April 13, April 20, April 27, and July 10. We did not take root samples during the growing season because we did not want to damage the buried drip irrigation system. Root samples were collected after the final harvest on July 10. Leaf samples were collected midseason. Tissue samples were ground, weighed, and digested in sulfuric acid and peroxide. N in digests was determined colorimetrically. Yield data were collected by harvesting fruit as it matured over the month of May, June, and July.

Desert Watermelon

An experiment demonstration was were conducted with watermelon (*Citrullus lanatus*) to compare CRN management to grower standard practice. The CRN products were applied pre-plant and the drip applied UAN 32 was applied during the season. The watermelon cultivar was Apollo. The plot area received 75 kg P/ha as MAP applied pre-plant and disked into the soils. This crop was transplanted into the field on March 17, 2017 and established by sprinkler irrigation. Thereafter, all irrigations were by subsurface drip. . The watermelons were transplanted in single rows on beds with 7 ft centers with an in-row spacing of 36 inches. This spacing does not include the male pollinator that was planting every 5 plants, in between two seedless spaced at 36 inches. Plant samples were collected for dry weight determinations April 13, April 20, and April 27. We could not take watermelon plants after April 27 because the vines became interwoven and individual plants could not be distinguished. We did not take root samples during the growing season because we did not want to damage the buried drip irrigation system. Root samples were collected after the final harvest on July 10. Leaf samples were collected midseason. Tissue samples were ground, weighed, and digested in sulfuric acid and peroxide. N and P in digests was determined colorimetrically. The harvest dates were May 26, June 1, June 7, and June 15.

Task 2e. Additional experiment in the central coast and desert (cool and warm season crops 2017-2018). Task e to address data gaps.

<u>Central Coast Lettuce 2017</u>

This trial was conducted at the USDA Spence Research Station. The soil at the site was Chualar sandy loam: pH 7.22; OM (LOI) 1.45%; Sand, Silt Clay 67, 18, 15%, respectively. The variety 'Sun Valley' was seeded on June 15 and the first germination water was applied with sprinklers on June 16. No nitrogen (N) was applied at or prior to planting. The crop was sprinkler irrigated until the plants were thinned (10 inch spacing) on July 6. On July 7 drip tape was installed (one medium flow tape applied to the middle of the bed). All fertilizer was applied through the drip system in two applications on July 11 and July 28 (see Table 1 for rates and types of materials tested). The standard fertilizer used was urea ammonium nitrate (UAN 32) except for treatments that provided all of their own N. A drip application system that had 12 separate manifolds was used to apply the each treatment (one treatment per manifold see photo 1). Battery powered pumps were used to inject fertilizer and fertilizer additive mixtures into each manifold. All injections were made during the middle third of irrigation events. Each plot was two 40-inch beds wide by 100 feet long; all treatments were arranged in a randomized complete block design with four replications. All experimental fertilizer treatments were applied at a moderate fertilizer rate (80 lbs N/A) in order to detect any increase in yield from the treatments over the unamended moderate N treatment. All amended treatments were compared with an unamended treatment (80 lbs N/A), a standard treatment (150 lbs N/A) and the untreated control (0 lbs N/A). The field was irrigated with 130% ET which supplied excess irrigation water to test which materials to provide an improvement in yield under an excessive irrigation regime. Soil samples were collected six times during the crop cycle. Lettuce was harvested on August 17 by cutting fifty four untrimmed heads from the two inside seedlines of each plot and weighing them to provide a measure of total crop biomass. Six heads from each plot were subsampled, dried and analyzed for total N content to provide a measure of N uptake (biomass N).

<u>Desert Lettuce Fall-Winter 2017-2018</u>

Lettuce (cv. Husky) was seeded on raised beds (two plant rows per bed) on 1m centers on October 12, 2017. The crop was established by sprinkler irrigation. Thereafter the crop was irrigated by furrow irrigation. The P source was 40 Rock at 100 kg P/ha and was applied to the entire plot area. The N treatments included combinations CRN 90, organic based slow release (SymTRX20S), and other combinations of conventional N sources. All P and the pre-plant N treatments (CRN 90 and SymTRX20S) were roto-mulched into beds. In season N was applied by side dress applications. Lettuce leaf tissue and soil samples were collected mid-season. Soil samples were extracted with 2 M KCl. Tissue samples were ground, weighed, and digested in sulfuric acid and peroxide. Ammonium-N and nitrate-N in the extracts and total N in the digests was determined colorimetrically. All experiment-demonstrations were randomized complete block designs with 4 replications. Lettuce was harvested January 19, 2018. All data were subjected to analysis of variance using an appropriate statistical model.

<u>Desert Broccoli Fall-Winter 2017-2018</u>

Broccoli (cv. Osprey) was seeded in double row beds on 1 m centers and sprinkler irrigated on October 12, 2017. The P source was 40 Rock at 100 kg P/ha and was applied to the entire plot area. The treatments included combinations of UAN32 side-dress and CRN 90 and CRN 120. All pre-plant fertilizers were roto-mulched into the beds. The crop was established by sprinkler irrigation. Thereafter the crop was irrigated by furrow irrigation. The broccoli was harvested at on February 4 and February 12 by removing mature head on each harvest date.

<u>Desert Cauliflower Fall-Winter 2017-2018</u>
Cauliflower (cv. Minuteman) transplants grown in a commercial greenhouse were transplanted into the field Oct. 13, 2017 with a transplanting machine into single row beds on 1 m centers. The P source was 40 Rock at 100 kg P/ha and was applied to the entire plot area. The treatments included combinations of UAN32 side-dress and pre-plant CRN90 and CRN 120. All pre-plant fertilizers were roto-mulched into the beds. The crop was established by sprinkler irrigation. Thereafter the crop was irrigated by furrow irrigation. The cauliflower was harvested January 12 and January 17, 2018 by removing mature heads on each date.

<u>Desert Cabbage Fall-Winter-2017- 2018</u>
Cabbage (cv. Supreme Vantage) transplants grown in a commercial greenhouse were transplanted into the field Oct. 13, 2017. The P source was 40 Rock at 100 kg P/ha and was applied to the entire plot area. The treatments included combinations of UAN32 side-dress and pre-plant CRN 90 and CRN 120. All pre-plant fertilizers were roto-mulched into the beds. The seedlings were planted with a transplanting machine into double row 1 m beds. The crop was established by sprinkler irrigation. Thereafter the crop was irrigated by furrow irrigation. Mature cabbage heads were harvested January 16 and 24, 2018.

<u>Desert Celery fall-Winter-Spring 2017-2018</u>
Celery (cv. Command) transplants grown in a commercial greenhouse were transplanted into the field Oct. 13, 2017. The P source was 40 Rock at 100 kg P/ha and was applied to the entire plot area. The treatments included combinations of UAN32 side-dress and pre-plant CRN 90 and CRN 120. All pre-plant fertilizers were roto-mulched into the beds. The plants were planted with a transplanting machine into double row 1 m beds. The crop was established by sprinkler irrigation. Thereafter the crop was irrigated by furrow irrigation. The celery was harvested March 27, 2018.

<u>Desert Onions fall-Winter-Spring 2017-2018</u>
Onions (cv.RB 4020) were seeded on raised beds (two plant rows per bed) on 1m centers on October 12, 2017. The crop was established by sprinkler irrigation. Thereafter the crop was irrigated by furrow irrigation. The P source was 40 Rock at 100 kg P/ha and was applied to the entire plot area. The N treatments included combinations of CRN 120 and an organic based slow release (SymTRX20S), and other combinations of conventional N sources. All P and the pre-plant N treatments (SymTRX20S and CRN 120) were roto-mulched into beds. In season N was applied by side dress applications. Onion leaf tissue and soil samples were collected mid-season. Soil samples were extracted with 2 M KCl. Tissue samples were ground, weighed, and digested in sulfuric acid and peroxide. Ammonium-N and nitrate-N in the extracts and total N in the digests was determined colorimetrically. All experiments were randomized complete block

designs with 4 replications. Onions were harvested May 23, 2018. All data were subjected to analysis of variance using an appropriate statistical model.

Desert Carrot Fall-Winter Spring 2017-018

Carrot (cv. Bolero) were seeded in six plant row 1 m beds on October 10, 2017. All experiments were randomized complete block designs with 4 replications. The P source was 40 Rock at 100 kg P/ha and was applied to the entire plot area. WE did not have space for five treatments in this demonstration so we focused on comparing mixed to full CRN programs. The treatments included combinations of UAN32 side-dress and pre-plant CRN90 and CRN 120. All pre-plant fertilizers were roto-mulched into the beds. The crop was established by sprinkler irrigation. Thereafter the crop was irrigated by furrow irrigation. Carrots were harvested March 4, 2018. All data were subjected to analysis of variance using an appropriate statistical model.

Desert Artichokes Fall-Winter-Spring 2017-2018

Artichokes (cv. Imperial Star) were seeded one row on 2 m beds on October 10, 2017. All experiments were randomized complete block designs with 4 replications. The P source was 40 Rock at 100 kg P/ha and was applied to the entire plot area. The treatments included combinations of UAN32 side-dress and pre-plant CRN 90 and CRN 120. All pre-plant fertilizers were roto-mulched into the beds. The crop was established by sprinkler irrigation. Thereafter the crop was irrigated by furrow irrigation. Artichokes were harvested when mature from April 18 to May 16, 2008. All data were subjected to analysis of variance using an appropriate statistical model.

Desert Spinach Spring 2018

Spinach (cv. Meerkat RZ) was seeded 9 rows per 40 inch beds. Individual plots were $35m^2$. The wet date was March 2, 2018. The N treatments included CRN 45, the slow release organic products SymTRX20S and 17113-2, as well as other conventional fertilizers including UAN 32, ammonium sulfate (AMS). The spinach was irrigated using solid set sprinklers season-long. Leaf and soil samples were collected at maturity. Soil samples were extracted with 2 M KCl. Tissue samples were ground, weighed, and digested in sulfuric acid and peroxide. Ammonium-N and nitrate-N in the extracts and total N in the digests was determined colorimetrically. Spinach plots were harvested with a yard hedger to simulate the mechanical mowing practices in commercial harvests. All data were subjected to analysis of variance using an appropriate statistical model.

Sweetcorn N Experiment

Sweet corn (cv. Cabo Sweet) was seeded March 5 in single row beds on 1 m centers. The crop was established by furrow irrigation. Thereafter, the entire plot area was irrigated by subsurface drip. Individual plots were four rows 40 ft long. The P source was 40 Rock at 75 kg P/ha and was applied to the entire plot area. The N treatments included ESN (CRN 90), organic based slow release sources (SymTRX20S) and other combinations of conventional N sources (UAN 32, ammonium sulfate, and ESN). All P and the pre-plant N treatments (SymTRX20S and CRN 90) were roto-mulched into beds. In season N was applied by side dress applications. The leaf opposite and below the ear was collected May 15, 2018, oven-dried, ground, and total N in the leaf was measured. We did not collect soil samples in this experiment out of concern for damaging the buried dip system. Yields were collected June 12 by harvesting all ears in 20 ft of one row. All data were subjected to analysis of variance using an appropriate statistical model.

<u>Chile Pepper Spring 2018</u>
An experiment-demonstration with chile pepper (*Capsicum annuum*) was conducted to evaluate efficacy of N management practices under furrow and drip irrigation. This evaluation was conducted on a soil mapped as a superstition loamy sand (Sandy, mixed, hyperthermic Typic Haplocalcids). The plots received 75 kg P/ha as MAP applied pre-plant and disked into the soil. The pre-plant N treatments (CRN 120) were applied by hand roto-mulched into beds. In season N (UAN 32) was applied by side-dress applications or through the buried drip systems. The pepper transplants (cv. Sandia Hot) were planted March 29, 2018. Yield data were collected by harvesting fruit as it matured over the month of June and July. Data were subjected to an analysis of variance.

<u>Tomato Spring 2018</u>
An experiment-demonstration with tomato (*Solanum lycopersicum*) was conducted to evaluate efficacy of N management practices under furrow and drip irrigation. This evaluation was conducted on a soil mapped as a superstition loamy sand (Sandy, mixed, hyperthermic Typic Haplocalcids). The plots received 75 kg P/ha as MAP applied pre-plant and disked into the soil. The pre-plant N treatments (CRN 120) were applied by hand roto-mulched into beds. In season N (UAN 32) was applied by side-dress applications or through the buried drip systems. The tomato transplants (cv. Mountain Fresh) were planted March 21, 2018. Yield data were collected by harvesting fruit as it matured over the month of June and July. Data were subjected to an analysis of variance.

<u>Watermelon</u>
An experiment-demonstration with watermelon (*Citrullus lanatus*) was conducted to evaluate efficacy of N management practices under furrow and drip irrigation. This evaluation was conducted on a soil mapped as a superstition loamy sand (Sandy, mixed, hyperthermic Typic Haplocalcids). The plots received 75 kg P/ha as MAP applied pre-plant and disked into the soil. The pre-plant N treatments (CRN 120) were applied by hand roto-mulched into beds. In season N (UAN 32) was applied by side-dress applications or through the buried drip systems. The pepper transplants (cv. Sandia Hot) were planted March 21, 2018. Yield data were collected by harvesting fruit as it matured over the month of June and July. Data were subjected to an analysis of variance.

F. Data/Results

Task 1. Release rates for a range of products from a number of manufactures will be determined using the models and methods we developed.
We have used the data collected in Task 1 to select products evaluated in all other tasks.

Task 2

<u>Desert Celery 2015</u>

The CRN products produced better growth and higher above-ground N accumulation in the early season compared to GSP (Tables 1 and 2). Higher petiole nitrate-N levels early in the season for CRN treatments also reflect the better N nutritional status (Table 3). The CRN treatments also show more available soil NO3-N early in the season (Table 4). However, the higher soil nitrate late in the season to GSP and low rate of CRN reflect the side-dress applications of UAN32 later in the season. By the end of the season the celery for the GSP treatment caught up producing similar yields to CRN management (Table 5). Nevertheless, these yields were obtained at higher N rates than CRN management. This grower is interested in evaluating CRN further.

<u>Desert Romaine Hearts 2015</u>
Whole plant samples show more above-ground dry matter and N accumulation to CRN early in the season (Tables 6 and 7)). The CRN treatments resulted in more soil available NO3-N early in the season and higher midrib nitrate-N levels at the second sampling. (Table 8 and 9). However, higher nitrate late in the season to GSP and low rate of CRN reflect the side-dress applications of AN20. It seems the CRN 90 provided more available N than CRN 120. We had not yet received the CRN 90 product from the 2nd supplier when this experiment was initiated. The GSP caught up late in the season resulting in similar total marketable yield (Table 10). We had conducted a demonstration with romaine in 2013-2014 and obtained increased yield. This grower has requested additional demonstrations.

<u>Desert Spinach 2015a</u>
There were few meaningful differences in early growth, N accumulation, and leaf N (Tables 11, 12, and 13). Soil test nitrate-N levels generally reflect the effects of the slower and faster release products (Table 14). In contrast to previous experiments, some of the CRN treatments yielded statistically less than the GSP but the CRN treatments did use much less N fertilizer (Table 15). Part of the challenge with this particular experiment was that some of the CRN products tested did not release N sufficiently fast to meet N demand by spinach. This is our fifth spinach in-field grower experiment- demonstration and the previous four resulted in CRN management out-yielding GSP. This was our first demonstration with this particular grower and although we did not improve yields, his harvest manager was impressed with the uniformity. This grower is also interested in the fact that with CRN management, water run timing is less critical. This grower has incorporated CRN into his spinach program.

<u>Desert Broccoli 2015</u>
It seemed the CRN 90#1 damaged the broccoli slightly due to a fertilizer placement issue (Table 16 and 17). The quick release is reflected in the higher soil N levels (Table 19). For this particular study, final yields were similar for the GSP and CRN management (Table 20). Although there were no differences in yield, the CRN program would have saved the grower two side-dress fertilizer applications. The grower has requested additional experiment-demonstrations.

<u>Desert Spinach 2015b</u>
Overall, both the high and low rates of CRN 90 produced yields similar to the grower practice at considerably lower N rates (Table 21). Overall, these results are similar to others we collected in previous years. We wish to note that the CRN 90 outperformed the CRN 45 in this particular spinach experiment demonstration. However, for spinach experiments conducted during the

cooler part of the season we have found in previous work that CRN 45 usually outperformed CRN 90. This grower has worked with us in 2014 and 2015 and has implemented CRN products into their spinach N management programs.

Central Coast Iceberg and Romaine Lettuce 2015a

The standard treatment had the highest levels of mineral nitrogen on the June 18 and July 2 evaluation dates (Table 22). On June 18 both nitrapyrin treatments had higher soil nitrate-N than the moderate or untreated treatments. There were no statistical differences in the fresh weight of romaine at harvest (Table 23). However, there is a trend that indicates that higher dry weight in the nitrapyrin treatments than the moderate nitrogen treatments and greater nitrogen uptake in the nitrapyrin treatments than the moderate treatment. There were few differences in soil mineral nitrogen among the moderate nitrogen treatments (Table 24). There were no statistical differences in the yield of head lettuce among the moderate nitrogen treatments, but there were trends indicating higher yield with the nitrapyrin treatments (Table 25). The same trends were evident in the combined data of both the romaine and head lettuce trials.

Central Coast Romaine Lettuce 2015b

The main statistical differences were between the untreated and other treatments (Table 26). As was seen in trials 1 & 2, there are trends that indicate higher yield in the fertilizer technology treatments over the moderate nitrogen treatment. The exception was the nitrapyrin at 1.0 lb a.i./A which may have had some phytotoxicity. The nitrogen technology treatments did not have higher percent nitrogen in the tissue, but higher nitrogen uptake than the moderate nitrogen treatment was attributable to greater biomass. The same trends were evident in the tractor and drip applied nitrogen treatments. Yield increases in the nitrogen technology treatments over the moderate nitrogen treatments were typically around 2.0 tons/A. There was greater nitrate at the 2nd foot in the soil at harvest in the standard treatment (Table 27); all other treatments had less nitrate at the 2nd foot.

Central Coast Romaine Lettuce 2015c

NovaTec maintained higher soil ammonium levels than any other treatment in all sampling dates (Table 28). All treatments maintained elevated levels of nitrate in the soil until the May 21 sampling date. ESN had the highest soil nitrate-N levels until harvest. None of the treatments gave statistically improved yield over the grower's standard treatment (Table 29). However, there is a trend showing Everest and NovaTec had improved yield over the grower's standard.

Central Coast Spinach 2015a

The background levels of residual soil nitrate-N at the trial site were 40.1 ppm at the beginning of the trial. In spite of high residual soil nitrate, all treatments had higher yield than the untreated control (Table 30). The grower standard treatment had higher yield than NovaTec and Duration ST in this trial. However, it was necessary to turn the sprinklers off of the area where the NovaTec and Duration ST treatments were during fertigations of the grower standard treatment (this occurred twice) and this may partially account for the lower yield in these treatments. NovaTec had higher levels of ammonium in the soil than all other treatments over the course of the crop cycle.

Central Coast Spinach 2015b

The residual soil nitrate in the soil at the beginning of the trial was 50.9 ppm nitrate-N. In spite of this high amount of residual soil nitrate, all treatments had significantly greater yield than the untreated control (Table 31). There was basically no yield response between the moderate amount of nitrogen (ammonium sulfate 90 lbs N/A) and the grower standard and the ammonium sulfate with 70 lbs top-dressed. Some of the nitrogen technology treatments such as ammonium sulfate treated with nitrapyrin, NovaTec and Duration ST that had lower yields than the moderate nitrogen treatment. It is unclear why this occurred in this trial. Ammonium sulfate treated with nitrapyrin and NovaTec maintained higher ammonium levels than the other treatments except for the ammonium sulfate treatment that was top-dressed on May 17 (Table 32).

<u>Central Coast Mizuna 2015a</u>
The residual soil nitrate-N levels at the beginning of this trial were 31.0 ppm. NovaTec and Duration ST treatments were applied at 33% less than the grower standard, but there was no statistical difference in the yield among these treatments (Tables 33 and 34).

Task 2a and 2b. Fall-winter-spring 2015-2016

<u>Iceberg Lettuce, Yuma County, AZ</u>.
Above ground N accumulations were generally not different across treatments (Table 35) Midrib nitrate-N concentrations was generally higher in the treatments receiving CRN compared to grower standard practice (Table 36). Inorganic N concentration changed by sampling date and was influenced by N release from the CRN products and the time of grower side-dress or water run (Table 37). Yields across treatments were generally similar except for the low rate of CRN 120 which significantly lower than some treatments (Table 38).

<u>Broccoli, Imperial County, CA</u>
During the latter sample times the CRN treatments had higher above-ground N accumulation than the GSP (Table 39). There were no significant differences in midrib nitrate-N levels across the season (Table 40). Inorganic N concentrations were generally higher for the controlled release treatments compared to GSP (Table 41). Broccoli yields were generally higher for all CRN treatments compared to GSP (Table 42). Some of these CRN management strategies were economically viable management strategies.

<u>Spinach, Imperial County, CA</u>
Leaf N concentrations were higher in the CRN treatments relative to the control the first sample time but not the second (Table 43). Inorganic-N was generally high for all treatments on both sample dates (Table 44). The CRN treatments resulted in higher yields compared to GSP (Table 45). However, as noted in the method section, we are not confident that our grower cooperator adequately controlled N applied through the sprinkler in the CRN treatments.

<u>Spinach, Riverside County, CA</u>
There were few meaningful differences in total above ground N accumulation of spinach (Table 46) Leaf N concentrations and soil inorganic N changed across sampling date due to differing CRN release rates and grower top dress application (Tables 47 and 48). Yields were slightly higher for the CRN treatments (Table 49) but as it worked out, for this experiment, the CRN treatments got more total N fertilizer applied.

Romaine Hearts, Riverside County, CA

In this experiment warm soil temperatures and poor CRN placement resulted in stunted early growth for the CRN treatments and resulted in generally lower N accumulation (Table 50). Midrib nitrate-N levels were higher for the CRN treatments only later in the season (Table 51). Inorganic N concentration changed by sampling date and was influenced by N release from the CRN products and the time of grower side-dress or water run (Table 52). In this experiment, the low rate of CRN resulted in lower yields compared to the GSP and high rate of CRN (Table 53).

Iceberg Lettuce, Yuma County, AZ

Total above-ground N accumulations were similar for the GSP and CRN treatment (Table 54). Although not statistically significant, midrib nitrate-N levels were consistently higher for the CRN treatment compared to the GSP (Table 55). Soil nitrate-N was generally higher for the CRN treatment later in the season (Table 56). The CRN management resulted in significantly higher yields compared to GSP (Table 57).

Spinach, Pinal County, AZ

There were no statistically significant differences in soil inorganic N near harvest (Table 58). There were differences in spinach leaf N concentrations to N rate and sometimes source. Leaf N concentration was lower for the low rate of CRN and both low and high rates of urea. The N fertilizer was top dressed as is typically done for spinach and we noticed some foliage damage with conventional urea but not the super urea which has both a urease and nitrification inhibitor. Yields significantly increased by N rate and sometimes N source. In this experiment, the highest yields were obtained with the 45 day Polyon CRN product, followed by FUSN. The lower yields were achieved with conventional urea. There are reports in the literature that CRN products can reduce nitrous oxide emissions. We did not observe that in this study (Figure 1). The CRN, FUSN, and urea results in similar nitrous oxide losses. However, the losses were notably lower for super urea.

Central Coast 2016

All treatments had significantly higher yield parameters than the untreated control indicating a good yield response to applied N in the trial. The following table shows the preliminary soil mineral nitrogen levels at planting on June 21 and prior to the first fertilizer application on July 22. Residual soil nitrate levels were low at the trial site at the beginning of the trial through thinning.

	Depth	NH_4-N	NO_3-N	Total
June 21	1st foot	2.23	9.64	11.87
	2nd foot	2.16	4.71	6.86
July 22	1st foot	2.90	9.27	12.17
	2nd foot	2.26	6.53	8.79

Dry fertilizer applied by tractor followed by fertigation of liquid fertilizer treatments. There was no difference in yield between the standard treatment (150 lbs N/A) and the unamended moderate treatment (80 lbs N/A). Even though yield did not differ, there was a significantly less N uptake in the moderate N treatment. The nitrapyrin treatment had more ammonium and less nitrate on July 28 and less nitrate on August 5 and 18 than the unamended moderate treatment

(Tables 59 and 60). There was a trend indicating lower yield in the nitrapyrin treatments than the unamended moderate treatment and it appears that some difference in the N nutrition of the nitrapyrin treatment when applied to ammonium sulfate may have negatively affected the yield of lettuce. All feather meal was all applied on the first fertilizer application and it released N slower than other treatments. It had low ammonium and nitrate levels on July 28 which was 7 days after activation of the material by irrigation water and indicates that there may have resulted in low N available to the lettuce crop at this stage of the crop cycle. On August 5 there were high nitrate and ammonium levels in the soil, but they returned to low levels by August 18. It had the lowest yield, N uptake and N concentration in crop tissue of all fertilizer treatments. *Fertigation of liquid fertilizer for both fertilizations**:*** There was significantly lower yield in the unamended moderate N treatment than the standard treatment in the drip application followed by drip application treatments. There was no difference in yield between the unamended moderate N rate and nitrapyrin treatments applied only in the first fertigation application. However, there was a trend of higher yield in the nitrapyrin treatments split between the first and second fertigations over the unamended moderate N treatment. All nitrapyrin treatments had lower nitrate in the soil on the August 5 and August 18 soil sampling dates. This data may give evidence that nitrapyrin applications spread over a large part of the crop cycle may have a more beneficial effect on yield than nitrapyrin applications made at one point in the crop cycle. This result may give some indication that the longevity of nitrapyrin in the soil may be limited due to warm summer soil temperatures which ranged from 70 to 75 °F during the course of the trial.

Desert Romaine Hearts, Coachella Valley

Fall temperatures were above average and the high rate of CRN90 caused crop damage (Tables 61, 62, and 63). We selected CRN90 as the product most appropriate for this window based on historical weather records. However, CRN120 would have been a safer choice. Plant growth and above-ground N accumulation was sometimes higher for GSP compared to CRN management. The high rate of CRN90 resulted in reduced yields compared the lower rate of CRN90 and GSP. The differences between the low rate of CRN90 and GSP were not statistically significant, but the low rate of CRN received less fertilizer than GSP.

Desert Lettuce, Imperial County, CA

The high rate of CRN resulted in less growth and N accumulation compared to the lower rate and GSP (Tables 64 and 65). In this experiment the GSP resulted in higher final yields (Table 66). Interestingly, the high rate of CRN had higher residual N at harvest suggesting a delayed release (Table 67).

Desert Spinach, Coachella valley

There were no significant differences in leaf N concentrations (Table 68). However, as we have observed in previous studies, CRN management provided better yields compared GSP on these coarse textured soils in the Coachella Valley (Table 69)

Desert Spinach, Coachella Valley

There were no significant differences in leaf tissue N concentrations to N management practice (Table 70). There were no significant differences to CRN management compared to GSP in this experiment (Table 71). There were no meaningful differences in residual inorganic N (Table 72).

Desert Spinach, Pinal AZ Early Winter 2016-2017

In fall-winter 2016-2017, there was a large yield response to the first increment (100 lbs N/A) of N fertilizer (Table 73). The significant quadratic trend suggest that for most sources the second increment of N fertilizer generally did not improve yields further. There were also differences among sources. Interestingly, the N conserving products (CRN, AS+NI, and SU) seemed to produce lower yields compared to the treatments that provided nitrate-N early in the season. Leaf tissue N increase to N rate and varied by source. The ammonium sulfate treatments with and without nitrification inhibitors had higher residual ammonium and nitrate N at harvest indicating delayed nitrate production. We did not observe this for the super urea and CRN sources where we suspect much of N remained in the polymer or in the soil as urea. We did not analyze for total N or urea.

Desert Spinach, Pinal AZ Winter 2017

As with the early -winter experiment there was a large response to the first increment of N for all sources and often no further response to the second increment (Table 74). As with the first experiment, FUSN performed well. In this experiment, the CRN treatments performed better than in the fall. As in the fall experiment residual inorganic soil N increased with N rate. There were also differences in residual N at harvest among sources.

Desert Spinach, Pinal AZ Winter-Spring 2017

There were significant yield increases by N rate (Table 75). As in the early winter and winter experiments, response were largely associated with the first increment of N fertilizer. In fact, for some source (AS+NI, Urea, SU) the second increment reduced yield. The CRN sources were the best treatments in this experiment. As in the fall and winter, residual N increased with N rate. Interestingly, the ammonium sulfate with the inhibitor had much higher levels of ammonium N than the ammonium sulfate without the inhibitor.

Task 2d. Experiment demonstrations with warm-season vegetables.

Desert Potato

Overall, yields of potatoes were low this cropping season and there was no yield response to N. The only significant difference was the high rate of CRN90 reduced yields compared to the control, GSP, and other CRN treatments. Leaf tissue concentrations were within an acceptable range for potato. The only significant difference was the high rate of CRN120 was a little higher than the untreated control (Table 76).

Desert Peppers
The leaf N concentrations for all fertilizer treatments were significantly greater than the control (Tables 77). The CRN products seemed to promote early growth (Table 78) but the advantage diminished with time and the drip applied UAN 32 growth surpassed CRN by the end of the season. Yields were generally higher for the drip applied UAN 32 treatment (GSP) compared to CRN Management (Tables 79 and 80).

Desert Tomato
Early plant growth seems to be greater for the plots receiving CRN management (Gal-Xe) compared to other N sources (Table 81). However, by the end of the season differences in plant growth to N rate or source were not statistically significant. Leaf tissue N concentrations increased to N fertilization and were highest for the drip applied UAN 32 (Table 82). As with early growth, early yields were higher with CRN compared to the untreated control and other N sources (Tables 83 and 84). However, by the third, fourth, and fifth harvests, the positive control (drip applied UAN 32) produced much higher yields resulting in higher seasonal total yield. The high rate of SymTRX20 produced yields similar to the CRN management but less than drip applied UAN32.

Desert Watermelon
Leaf N concentrations across all treatments were not significantly different (Table 85). Plant growth was generally higher for drip applied UAN 32 compared to CRN treatments but the differences were no statistically significant (Table 86). Watermelon yields were generally higher to drip applied UAN32 compared to CRN management (Tables 87 and 88). These results were surprising because in past experiments we got large responses to CRN in watermelon productions. It should be noted that most of these previous studies used furrow irrigation instead of drip. We will design demonstrations in spring 2018 in an attempt to explain these anomalies.

Task 2e. Additional experiment in the central coast and desert (cool and warm season crops 2017-2018).

Central Coast Summer 2017

There was a strong response to applied N in this trial. The untreated control had lower yield and N uptake than all other treatments (Table 89). The standard treatment had higher yield and higher N uptake than all other treatments. The unamended moderate N treatment yield was intermediate to the untreated control and standard treatments; this provided a good opportunity to be able to determine if the experimental treatments, also applied at the moderate N level, gave any yield improvement. None of the experimental treatments increased the fresh or dry biomass yield over the unamended moderate N treatment (Table 90). 7-0-1-7-7 had greater N uptake and higher percent N in the tissue than the unamended moderate treatment. There were no significant differences in soil mineral N levels until after the second fertigation on August 1 (Table 90); on this date, soil ammonium levels were higher in the 7-0-1-7-7 treatments than in the unamended moderate N treatment. Following that date, none of the treatments had higher levels of mineral nitrogen than the unamended moderate N treatment.

Desert Lettuce Experiment-Demonstration Fall-Winter 2017-2018

All N treatments produced higher lettuce yield compared to the untreated control but there were no statistical differences among the various N treatments (Table 91). Similarly, leaf N concentration were only significantly lower for the untreated control. The highest levels of residual soil N were associated with treatments receiving 100% UAN32 and 70% UAN32 or ammonium sulfate. Interestingly, the 175 kg N rate of all the blended N sources seems to produce slightly higher yields than 200 kg N/ha UAN32 alone but the differences were not statistically significant.

Desert Broccoli Experiment Demonstration Fall-Winter 2017-2018

The blend of CRN 120 and UAN 32 produced significantly higher yields the first harvest which has important economic implications (Table 92). However other treatments compensated the second harvest. The treatments receiving the 100% CRN pre-plant programs resulted in significantly less total yield than the treatments receiving all or partial side dress UAN 32.

Cauliflower Experiment Demonstration Fall-Winter 2017-2018

Early yield of cauliflower was higher for all treatments that included a full or partial CRN treatment (Table 93). As with broccoli there was a compensation the second harvest but final total yields were statistically higher (not statically in every case) for full or partial CRN treatments.

Cabbage Experiment-demonstration Fall-Winter 2017-2018

Cabbage yields were higher for treatments that received full or partial UAN 32 side-dress N (Table 94). The yields for the partial CRN programs were higher compared to 100% side-dress UAN 32.

Onion N Experiment-Demonstration Fall-Winter-Spring 2017-2018

Yield of top grade onions and leaf tissue N increased to N fertilization. However, there were no statistically significant differences among source combinations (Table 95). Onions has a much longer growing period than lettuce and residual soil N was lower. Most observed differences in residual soil N were between the control and selected fertilizer treatments. As with lettuce, most of the N source and source combinations produced slightly higher yields at 175 kg N/ha than the 200 kg N/ha UAN 32 treatment but the differences were not statistically significant.

Carrot Experiment Demonstration Fall-Winter-Spring 2017-2018

Carrot yields were similar for the 100% CRN treatments and the mixed CRN and side-dress UAN 32 treatments (Table 96). Residual soil nitrate-N was higher for the 100% CRN treatments.

Celery Experiment-Demonstration Fall-Winter-Spring 2017-2018

Celery yields with the mixed CRN-side-dress programs were higher compared to either 100% CRN or side-dress N management (Table 97).

Artichokes Experiment-Demonstration Fall-Winter-Spring 2017-2018

There were no significant differences in artichoke yields among the fertilizer treatments evaluated (Table 98).

Spinach N Experiment-Demonstration Spring 2018

UAN 32 is often applied through the sprinklers. However, because we could not apply water applied UAN 32 in a randomized design in this particular evaluation, we tried to simulate it with very dilute sprays. Unfortunately, we failed and burned the plants. Burning sometimes occurs in commercial sprinkler applied applications but not to the extent we observed. In these studies the 100% UAN32 resulted in no yield and treatments receiving partial UAN32 resulted in yields less than the control (Table 99). The best treatments were combinations of CRN 45 and SYMTRX20S or 171113-2, with the former slightly better. There were differences in residual soil N between the control and fertilizer treatments.

Sweet corn Experiment Spring-Summer 2018

Yields for 100% UAN32, the 70% UAN32 with either 30% SymTRX20S and 171113-2 were not different from the control (Table 100). It seems the irrigation hydrology under the drip scenario did not transport the side dress fertilizer into the root zone. Perhaps we should have applied the UAN32 through the drip system or conducted the experiment under a furrow irrigation scenario. Yield for the 60% ESN with either UAN32, SymTRX20S, or 171113-3 were not significantly different from each other. There were no meaningful differences among tissue leaf concentration.

Pepper Experiments Demonstration Spring-Summer 2018

There was a significant interaction between N management and irrigation method (Table 101 and 102). Furrow irrigation seemed to produce superior yields when furrow irrigation was used with the high rate of CRN 120 but similar or lower yields with control, the lower CRN 120 treatment, and the UAN 32 treatment.

Tomato Experiment Demonstration Spring Summer 2018

Cumulative tomato yields were generally higher for drip irrigation compared to furrow irrigation (Table 103 and 104). The CRN treatments seemed to outperform the UAN 32 treatment and the 100 kg N/ha fertilizer rate of CRN 120 was sufficient for maximum yields.

Watermelon Experiment Demonstration

For watermelons yields under drip irrigation were superior to furrow irrigation. (Tables 105 and 106). There was not a large response to N. Only the 0 kg N/ha N rate under furrow irrigation resulted in significantly less yield compared to other treatments. This same N rate under drip irrigation resulted in yields statistically similar to other N treatments. Perhaps under drip irrigation there was less leaching of the residual N in the soil prior to planting,

G. Discussion

Overall, the data show that CRN management has a promise as a tool for efficient N management in cool season vegetable cropping systems in the western United States. In some instances is showed increased growth and yield compared to GSP. In many cases is maximized production at lower N rates. There are risks of damage when CRN 90 is used in warm falls. The solution would be using CRN120 or band placement. CRN based program showed less benefits in drip irrigated warm season vegetables in the desert where N can be metered through the system in anticipation of crop needs since nearly 100% of the water required is supplied by irrigation opportunities for N leaching are minimal.

H. Impacts

This project has demonstrated that CRN and other N enhancing technologies are tools for efficient N management. We have developed tools for matching product release rate with crop season. We have demonstrated this technology across a number of cropping scenarios in the desert and the central coast. A couple of large growers have implemented these technologies into their fertilizer management programs and other are trying it on a limited scale. We anticipate impacts will increase as we share this data base in more outreach venues.

I. Outreach

The Yuma cooperative Extension office did not have a director or Crop Advisor during 2016 and 2017 and scheduling of formal events was infrequent and limited. Thus we compensated by scheduling small gathering in grower fields which we found have more impact. Attached are a list of most events.

Presentation and viewing of plots in Coachella at Desert Mist farm in romaine heart field. January 29, 2015. This occurred day of harvest for this experiment-demonstration. There was less than 7 growers and PCA's, all associated with Ocean Mist, Prime Time, and Ag Services.

Presentation in celery field on February 19, 2015 in Duda field in south Yuma Valley, the day before harvest. Perhaps there were 10 growers present.

Presentation of CRN and other N enhancing products at Maricopa Agricultural Center Family Farm Day on November 21, 2015. There was poster area with a CRN poster and individuals were transported to plots in tractor drawn trailers. Attendance was several 100 including families since there were all types of activities. I estimate growers and crop advisors whom got exposure to our CRN presentations were less than 30.

Presentation in lettuce field at JV Farms February 24, 2016, the day of harvest. About seven growers present, all associated with JV Farms but JV grows for Dole, T&A, Fresh Express, and Taylor.

Presentation in broccoli field at Top Flavor in Bard on March 2, 2016, the day before harvest. About 9 growers and fertilizer dealers. Most T&A growers and CPS PCA's.

Presentation of CRN and other N enhancing products at Maricopa Agricultural Center Family Farm Day on November 19, 2016. There was poster area with a CRN poster and individuals were transported to plots in tractor drawn trailers. Attendance was several 100 including families since there were all types of activities. I estimate growers and crop advisors whom got exposure to our CRN presentations were less than 30.

Presentation and viewing of plots in Coachella at Desert Mist farm in spinach field. December 25, 2017. This occurred day of harvest for this experiment-demonstration. There was less than 4 growers and crop advisors all associated with Ocean Mist and Ag Services

Presented results to growers and crop advisors at the Desert Ag Conference in Chandler, AZ on April 27, 2017. There were about 25 growers and PCAs in the audience.

Presentation of CRN and other N enhancing products at Maricopa Agricultural Center Family Farm Day on November 18, 2017. There was poster area with a CRN poster and individuals were transported to plots in tractor drawn trailers. Attendance was several 100 people including families since there were all types of activities. I estimate growers and crop advisors whom got exposure to our CRN presentations was less than 30.

Showed pepper, tomato, and watermelon plots at Yuma Mesa Agricultural Center on May 10, 2018 to small group (about 11).

Outreach activities are on-going. For example we will show plots at Maricopa Agricultural Center Family Farm day November 17, 2018. We are scheduled to speak on CRN at California ASA February 6, 2019 and the Southwestern Ag Summit February 20, 2019.

Two very large growers that have implemented CRN technologies into their fertilizers programs. Three others are continuing to evaluate.

J. Factsheet Database Template

1. Project Title:	Field Evaluation and Demonstration of Controlled Release N Fertilizers in the Western United States
2. FREP Grant Number:	FREP Grant number: 14-0508SA
3. Project Leaders:	Charles A. Sanchez, Professor, University of Arizona, Maricopa Agricultural Center, 37860 W Smith Enke Rd, Maricopa, AZ 85138, phone 928-941-2090, e-mail sanchez@ag.arizona.edu Richard Smith, Farm Advisor, Cooperative Extension Monterey County, 1432 Abbott Street, Salinas, CA 93901, phone 831-759-7357, e-mail
4. Start/end date	January 2015 through September 2018
5. Project Location	Low Desert Region of Southwestern US

6. Counties — Imperial and Riverside Counties, CA, Yuma and Pinal Counties AZ

7. Highlights — Controlled release fertilizer technologies are an economically sound and environmentally friendly N management practice for many desert vegetable production systems.

8. Introduction

Intensive vegetable production in the southwestern U.S. receives large annual applications of nitrogen (N) fertilizers. Amounts of N applied range from 200 to 400 kg/ha and crop recoveries are generally less than 50%. There are numerous possible fates of fertilizer applied N in addition to the desired outcome of crop uptake. The urea and ammonium components of the N fertilizer might be lost through ammonia volatilization. The nitrate-N might be lost to leaching with irrigation water below the crop root zone possibly impairing surface and ground water. Nitrate might also be lost as N_2 and N_2O gasses via de-nitrification processes affecting air quality and climate. Furthermore, all forms of N might be immobilized into the organic soil fraction by the soil microbial population where availability to the crop is delayed. The global warming potential of N_2O is 300 times that of CO_2 and N fertilizer is estimated to account for one-third the total greenhouse gas production in agriculture. One study reported that N fertilization (inorganic or organic) accounted for 75% of the greenhouse gas emissions from agriculture production (including production, application, and nitrous oxide emissions) and after N is accounted for there are no significant differences between conventional, organic, or integrated farming practices.

N management in the western United States remains a continuing challenge. Both California and Arizona have mandated Best Management Practices (BMP's) to varying degrees. These practices generally involve timing, amounts, and placement of N, and irrigation water application. The use of controlled release N (CRN) fertilizer sources is another promising option. The successful implementation of CRN management where appropriate will reduce adverse environmental impacts of fertilizer N and improve profitability in California and the western United States in general.

9. Methods/Management

From 2015 through 2018 experiment-demonstrations were conducted with grower-cooperators and at University Research Centers to evaluate N management programs that included controlled release fertilizers and other technologies aimed to enhance fertilizer N efficiency. Studies included vegetable production sites in the desert region including Riverside and Imperial Counties, California, and Yuma and Pinal Counties, Arizona. Studies were also conducted in the central coast (Monterey County). These experiment demonstrations compared grower standard practices which were largely conventional programs with traditional soluble N sources, programs with controlled release or other enhanced technology programs, and mixed programs (traditional and enhanced efficiency programs mixed). Crop evaluated included iceberg and romaine lettuce, spinach, broccoli, cauliflower cabbage, carrot, onion, artichokes, potato, sweet corn, peppers, tomato, and watermelons.

10. Findings

We worked across a wide variation in crop production scenarios. Variations included crops, soil texture, irrigation management, and grower practices. The results show that controlled release fertilizers can result in improved N fertilizer use efficiency in many of these crop production scenarios. Paramount to success is matching the product release rate with anticipated crop demand for crop and season. A product with too slow a release, will deprive crops of required N during key growth stages and compromise yield. Crop with too fast a release can result in crop damage due to osmotic stress. We have developed the tools to match products with crop demand. The actual benefits to CRN and other enhanced N technologies varied by site. The probability of benefit increases with less efficient irrigation methods and coarser textured soils. Because response varies by site and growing practices, we cannot make a universal recommendation. The use of CRN has to be customized for each production scenario. However, this body of work demonstrates CRN technologies represent an economically viable and environmentally sound N management practice for many vegetable production scenarios. Some of our grower cooperators have successfully integrated the use of CRN technologies into their fertilizer program. An existing obstacle to more adaptation of these technologies is technical support from the suppliers.

K. Product/Results

As of the writing of this report we have no products to report. We have a draft of one refereed publication resulting from this work that we hope to submit before the end of October. We plan to complete and extension Fact Sheet shortly after the first of the year. Other publication will follow. We will send updates to CDFA FREP and these outputs are completed.

Literature Cited

Havlin, J., S., L. Tisdale, J. D. Beaton, and W.L. Nelson. 2005. – Soil Fertility and Fertilizers, 7th Edition. Pearson Prentice Hall, NJ.

Hiller, J., C. Hawes, G. R. Squire, A. Hilton, S. Wale, and P. Smith. 2009. The carbon foot prints of food production. International. J. Agric. Sustain. 7:107-118.

Mosier, A. R, Syers, J. K., and Freney, J. R. 2004. Nitrogen fertilizer: An essential component of increased food, feed, and fiber production. Pages 3-18 in: SCOPE 65: Agriculture and the Nitrogen Cycle: Assessing the Impacts of Fertilizer Use on Food Production and the Environment, A. R. Mosier, J. K. Syers, and J. R. Freney, eds. Island Press, Washington, DC.

Sanchez, CA. 2000. Response of lettuce to water and N on sand and the potential for leaching of nitrate-N. HortScience 35:73-77.

Sanchez, C. A., and T. A. Doerge. 1999. Using nutrient uptake patterns to develop efficient nitrogen management strategies for vegetables. HortTechnology 9:601-606.

Strange, A., J. Park, R. Bennett, and R. Phipps. 2008. The use of life cycle assessment to evaluate the environmental impacts of growing genetically modified nitrogen use efficient canola. Plant Biotechnology J. 6:337-345

Table 1. Dry matter accumulation of celery to N management in fall-winter 2014-2015.

Treatment	Date			
	11/6	12/3	12/23	2/13
	Plant Dry weight (g/plant)			
GSP	0.8	5.4	21.0	56.6
CRN 90 (132 lbs N/A)	2.0	9.5	22.6	55.6
CRN 120 (132 lbs N/A)	1.8	10.2	20.5	64.6
CRN 90 (176 lbs N/A)	1.6	9.4	18.7	59.8
CRN 120 (176 lbs N/A)	1.1	7.5	18.9	68.9
LSD	0.6	2.1	4.1	9.8

LSD=Least significant difference at P=0.05. NS=not significant.

Table 2. Above ground N accumulation by celery as affected by N management in fall-winter 2014-2015.

Treatment	Date			
	11/6	12/3	12/23	2/13
	Above-ground N accumulation (mg/plant)			
GSP	16.9	175.1	501.0	1453.0
CRN 90 (132 lbs N/A)	65.6	315.6	550.8	1421.5
CRN 120 (132 lbs N/A)	56.7	349.5	508.3	1855.7
CRN 90 (176 lbs N/A)	50.5	303.0	424.7	1552.4
CRN 120 (176 lbs N/A)	33.4	264.3	456.1	2037.2
LSD	16.4	58.4	106.2	430.1

LSD=Least significant difference at P=0.05. NS=not significant.

Table 3. Petiole nitrate-N by celery as affected by N management in fall-winter 2014-2015.

Treatment	Date			
	11/6	12/3	12/23	2/13
	Petiole nitrate-N (mg/kg)			
GSP	9226	8129	14946	5982
CRN 90 (132 lbs N/A)	17836	10657	12486	8975
CRN 120 (132 lbs N/A)	16768	9988	14989	5231
CRN 90 (176 lbs N/A)	17317	12468	14960	9469
CRN 120 (176 lbs N/A)	14718	11344	19945	5730
LSD	4836	4962	6879	2689

LSD=Least significant difference at P=0.05. NS=not significant.

Table 4. Inorganic soil N in celery rooting zone as affected by N management in Fall-winter 2014-2015.

Treatment	Date							
	11/6		12/3		12/23		2/13	
	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N (mg/kg)							
GSP	5.8	19.8	13.5	56.9	3.1	28.1	10.7	108.1
CRN 90 (132 lbs N/A)	6	62.5	9.1	42.7	18.8	88.5	17.6	143.3
CRN 120 (132 lbs N/A)	17.8	52.0	9.2	58.4	22.7	59.3	20.5	162.9
CRN 90 (176 lbs N/A)	5.6	22.6	11.9	47.1	10.2	43.8	6.2	71.7
CRN 120 (176 lbs N/A)	5.4	16.9	24.8	36.3	4.5	53.3	8.5	66.9
LSD	1.1	2.3	9.1	2.5	8.1	3.3	6.5	8.1

LSD=Least significant difference at P=0.05. NS=not significant.

Table 5. Yield response of celery to N management in fall-winter 2014-2015.

Treatment	Yield (MT/ha)
GSP	118.4
CRN 90 (132 lbs N/A)	107.0
CRN 120 (132 lbs N/A)	116.6
CRN 90 (176 lbs N/A)	115.8
CRN 120 (176 lbs N/A)	107.6
LSD	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 6. Plant dry weights of romaine lettuce to N management in fall-winter 2014-2015.

Treatment	Date		
	12/1	12/17	1/3
	Plant dry weight (g/plant)		
GSP	0.33	5.42	7.63
CRN 90 125 lbs N/A	0.58	4.59	8.23
CRN 120 125 lbs N/A	0.48	4.72	9.27
CRN 90 200 lbs N/A	0.60	5.16	7.37
CRN 120 200 lbs N/A	0.70	5.52	7.46
LSD	0.13	0.8	1.1

LSD=Least significant difference at P=0.05. NS=not significant.

Table 7. Above ground N accumulation by romaine lettuce to N management in fall-winter 2014-2015.

Treatment	Date		
	12/1	12/17	1/3
	Above ground N accumulation (mg/plant		
GSP	12.8	118.9	207.6
CRN 90 125 lbs N/A	21.6	160.3	228.9
CRN 120 125 lbs N/A	17.3	116.6	231.1
CRN 90 200 lbs N/A	22.0	116.6	209.2
CRN 120 200 lbs N/A	23.9	125.1	209.5
LSD	5.3	NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 8. Midrib nitrate-N of romaine lettuce to N management in fall-winter 2014-2015.

Treatment	Date		
	12/1	12/17	1/3
	Midrib nitrate-N (mg/kg)		
GSP	23531	11082	8930
CRN 90 125 lbs N/A	12893	57576	9231
CRN 120 125 lbs N/A	21179	82193	9983
CRN 90 200 lbs N/A	11532	21564	8475
CRN 120 200 lbs N/A	14072	13435	12459
LSD	7759	6364	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 9. Inorganic soil N in romaine lettuce rooting zone as affected by N management in fall-winter 2014-2015.

Treatment	Date					
	12/1		12/17		1/3	
	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N (mg/kg)					
GSP	5.1	9.7	3.4	10.1	3.1	29.9
CRN 90 125 lbs N/A	4.5	18.1	4.1	16.5	18.8	50.2
CRN 120 125 lbs N/A	3.6	23.4	4.3	12.4	22.7	131.9
CRN 90 200 lbs N/A	4.2	23.2	3.1	11.5	10.3	14.2
CRN 120 200 lbs N/A	4.9	25.5	3.8	16.0	4.5	13.5
LSD	NS	1.3	NS	1.2	7.6	4.7

LSD=Least significant difference at P=0.05. NS=not significant.

Table 10. Yield response of romaine lettuce to N management in fall-winter 2014-2015.

Treatment	Yield (MT/ha)
GSP	45.8
CRN 90 125 lbs N/A	49.9
CRN 120 125 lbs N/A	48.2
CRN 90 200 lbs N/A	49.4
CRN 120 200 lbs N/A	45.2
LSD	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 11. Plant dry weights of spinach to N management in fall-winter 2014-2015.

Treatment	Date		
	12/3	12/10	12/23
	Plant Dry weight (g/plant)		
GSP	0.04	0.10	0.35
CRN 90 (175 lbs N/ha)	0.04	0.10	0.34
CRN 45 (175 lbs N/A)	0.03	0.08	0.34
CRN 90 (200 lbs N/A)	0.03	0.08	0.28
CRN 45 (200 lbs N/A)	0.04	0.08	0.40
LSD	NS	0.02	0.10

LSD=Least significant difference at P=0.05. NS=not significant.

Table 12. Above ground N accumulation by spinach to N management in fall-winter 2014-2015.

Treatment	Date		
	12/3	12/10	12/23
	Above-ground N accumulation (mg/plant)		
GSP	1.4	4.3	14.5
CRN 90 (175 lbs N/ha)	1.2	4.0	14.5
CRN 45 (175 lbs N/A)	1.2	3.4	15.0
CRN 90 (200 lbs N/A)	1.1	2.9	11.8
CRN 45 (200 lbs N/A)	1.3	3.4	16.8
LSD	NS	0.9	4.5

Table 13. Spinach leaf N concentration to N management in fall-winter 2014-2015.

Treatment	Date		
	12/3	12/10	12/23
	Leaf N (%)		
GSP	3.92	4.21	3.63
CRN 90 (175 lbs N/ha)	4.03	4.03	3.89
CRN 45 (175 lbs N/A)	3.89	3.99	4.01
CRN 90 (200 lbs N/A)	3.91	3.78	3.98
CRN 45 (200 lbs N/A)	3.69	4.02	3.85
LSD	NS	0.18	0.18

Table 14. Inorganic soil N in spinach rooting zone as affected by N management in fall-winter 2014-2015.

Treatment	Date					
	12/3		12/10		12/23	
	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N (mg/kg)					
GSP	5.1	39.9	6.7	11.0	14.2	11.3
CRN 90 (175 lbs N/ha)	30.2	35.5	138.6	21.6	16.2	33.8
CRN 45 (175 lbs N/A)	4.9	21.6	19.0	10.7	13.1	26.9
CRN 90 (200 lbs N/A)	5.3	17.7	130.6	3.1	18.0	43.0
CRN 45 (200 lbs N/A)	8.4	22.4	48.1	1.1	13.7	15.9
LSD	19	2.6	41.5	3.0	1.2	7.8

LSD=Least significant difference at P=0.05. NS=not significant.

Table 15. Yield response of spinach to N management in fall-winter 2014-2-15.

Treatment	Yield (MT/ha)
GSP	24.8
CRN 90 (175 lbs N/ha)	19.2
CRN 45 (175 lbs N/A)	18.4
CRN 90 (200 lbs N/A)	13.8
CRN 45 (200 lbs N/A)	16.7
LSD	2.9

LSD=Least significant difference at P=0.05. NS=not significant.

Table 16. Dry weights of broccoli to N management in winter 2014-2015.

Treatment	Date			
	12/17	1/3	1/12	2/18
	Dry weight (g/plant)			
GSP	0.009	0.138	0.368	22.15
CRN 90#1 (125 lbs N/A)	0.008	0.123	0.394	27.55
CRN 90#2 (125 lbs N/A)	0.008	0.114	0.362	29.69
CRN 90#1 (200 lbs N/A)	0.008	0.103	0.361	28.04
CRN 90#2 (200 lbs N/A)	0.009	0.124	0.331	22.94
LSD	0.0008	0.015	0.057	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 17. Above ground N accumulation of broccoli to N management in winter 2014-2015.

Treatment	Date			
	12/17	1/3	1/12	2/18
	Above-ground N accumulation (mg/plant)			
GSP	0.38	6.86	18.56	834.1
CRN 90#1 (125 lbs N/A)	0.42	5.28	20.21	1111.5
CRN 90#2 (125 lbs N/A)	0.30	5.08	18.89	1212.1
CRN 90#1 (200 lbs N/A)	0.36	4.69	19.23	1039.2
CRN 90#2 (200 lbs N/A)	0.36	5.82	17.90	797.2
LSD	0.04	0.88	NS	326.1

LSD=Least significant difference at P=0.05. NS=not significant.

Table 18. Petiole nitrate-N of broccoli to N management in winter of 2014-2015.

Treatment	Midrib nitrate-N
GSP	8468
CRN 90#1 (125 lbs N/A)	14974
CRN 90#2 (125 lbs N/A)	22454
CRN 90#1 (200 lbs N/A)	17451
CRN90#2 (200 lbs N/A)	6728
LSD	9236

LSD=Least significant difference at P=0.05. NS=not significant.

Table 19. Inorganic soil N in broccoli rooting zone as affected by N management in Fall Winter 2014-2015.

Treatment	Date							
	12/17		1/3		1/12		2/18	
	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N mg/kg)							
GSP	4.0	0.8	3.3	0.7	4.0	19.8	6.4	17..9
CRN 90#1 (125 lbs N/A)	4.2	8.8	13.5	13.5	20.9	50.8	7.1	21.1
CRN 90#2 (125 lbs N/A)	3.0	3.0	11.8	11.9	4.2	11.0	8.6	14.9
CRN 90#1 (200 lbs N/A)	15.8	24.0	11.2	43.0	6.0	41.2	6.1	25.2
CRN#2 (200 lbs N/A)	4.6	2.1	6.5	7.6	6.4	18.5	8.5	15.1
LSD	9.1	1.4	4.7	2.1	1.0	2.2	NS	3.9

LSD=Least significant difference at P=0.05. NS=not significant.

Table 20. Response of broccoli to N management in winter of 2014-2015.

Treatment	Yield MT/ha
GSP	10.3
CRN 90#1 (125 lbs N/A)	9.4
CRN 90#2 (125 lbs N/A)	9.8
CRN 90#1 (200 lbs N/A)	8.7
CRN#2 (200 lbs N/A)	8.4
LSD	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 21. Yield response of spinach to N management in winter-spring 2015.

Treatment	Yield (MT/ha)
GSP (315 lbs N/A as UAN 32)	34.5
CRN-45 (75 lbs N/A) plus 105 lbs N as UAN 32	29.7
CRN-90 (75 lbs N/A) plus 105 lbs N as UAN 32	33.4
CRN 45 (150 lbs N/A)) plus 105 lbs N as UAN 32	29.6
CRN 90 (150 lbs N/A)) plus 105 lbs N as UAN 32	34.1
LSD	4.2

LSD=Least significant difference at P=0.05. NS=not significant.

Table 22. Romaine lettuce, nitrate and ammonium levels on five evaluations

Treatment	Sidedress No. 1 May 16 lbs N/A	Sidedress No. 2 May 29 lbs N/A	Total N/A[1]	May 28		June 3		June 11		June 18		July 2	
				NO_3-N ppm	NH_4-N ppm	NO_3-N ppm	NH_4-N ppm	NO_3-N ppm	NH_4-N ppm	NO_3-N ppm	NH_4-N ppm	NO_3-N ppm	NH_4-N ppm
Standard	60	80	140	13.2	12.8	10.6	18.1	18.1	8.0	8.7^{A}	3.8	9.6^{A}	4.8^{A}
Moderate + Nitrapyrin 0.5 lbs a.i./A	60	40	100	6.6	1.7	5.2	4.2	4.6	1.0	2.7^{AB}	0.9	0.7^{B}	0.7^{BC}
Moderate + Nitrapyrin 1.0 lbs a.i./A	60	40	100	4.0	1.0	6.7	5.3	2.9	1.0	2.7^{AB}	2.6	0.9^{B}	0.6^{BC}
Moderate	60	40	100	2.6	0.5	6.5	6.7	3.3	0.7	1.8^{B}	0.4	2.6^{B}	0.8^{AB}
Untreated	0	0	0	2.4	0.6	2.6	0.5	1.8	0.5	1.0^{B}	0.5	0.4^{B}	0.6^{C}
Pr>F treat				0.2433	0.3093	0.1309	0.1481	0.0546	0.3848	0.037	0.2212	0.0159	0.0091
LSD $_{0.05}$				NS	NS	NS	NS	NS	NS	-	NS	-	-
Observational													
Duration	60	40	100	3.8	1.2	3.7	2.5	2.9	4.1	1.5	0.5	0.6	0.7
Novatec	60	40	100	3.2	0.7	4.5	1.1	2.8	2.7	1.3	0.4	0.9	0.9

In addition, all treatments received 15 lbs N/A with the anti-crustant, replications 1&2 14 lbs N/A preplant, reps 3&4 no preplant.

Table 23. Romaine lettuce, leaf N on June 11 and yield evaluations and nitrogen uptake on June 26

Treatment	Sidedress No. 1 May 16 lbs N/A	Sidedress No. 2 May 29 lbs N/A	Total N/A[1]	Leaf %N June 11	Mean head wt lbs	Fresh lbs/A	Fresh tons/A	Dry lbs/A	%N	lbs N/A
Standard	60	80	140	3.69	1.76	73,405.9	36.70	4669.4	3.16^{A}	147.3
Moderate + Nitrapyrin 0.5 lbs a.i./A	60	40	100	3.57	1.68	70,252.2	35.13	4409.6	2.85^{BC}	126.3
Moderate + Nitrapyrin 1.0 lbs a.i./A	60	40	100	3.57	1.65	67,468.5	33.73	4363.1	2.86^{BC}	124.5
Moderate	60	40	100	3.62	1.50	66,030.9	33.02	4015.4	2.93^{AB}	116.9
Untreated	0	0	0	2.39	1.32	57,331.2	28.67	3453.3	2.32^{C}	81.9
Pr>F treat				<0.0001	0.1187	0.2141	0.2138	0.0618	0.0211	0.0158
$LSD_{0.05}$				0.0032	NS	NS	NS	NS	-	33.674
Observational										
Duration	60	40	100	3.12	1.62	71,727.4	35.86	4592.3	2.77	127.2
Novatec	60	40	100	2.71	1.52	66,348.9	33.17	4208.3	2.62	110.2

1 – In addition, all treatments received 15 lbs N/A with the anti-crustant, replications 1&2 14 lbs N/A preplant, reps 3&4 no preplant.

Table 24. Head lettuce, nitrate and ammonium levels on five evaluations

Treatment	Sidedress No. 1 May 16 lbs N/A	Sidedress No. 2 May 29 lbs N/A	Total N/A[1]	May 28		June 3		June 11		June 18		July 2	
				NO_3-N ppm	NH_4-N ppm	NO_3-N Ppm	NH_4-N ppm	NO_3-N ppm	NH_4-N ppm	NO_3-N ppm	NH_4-N ppm	NO_3-N ppm	NH_4-N ppm
Standard	60	80	140	5.7	0.7	7.8	5.2	14.6[A]	0.5	10.2	3.9	9.0	0.7
Moderate + Nitrapyrin 0.5 lbs a.i./A	60	40	100	4.2	0.6	4.9	1.0	4.3[B]	0.7	3.1	0.5	3.7	1.4
Moderate + Nitrapyrin 1.0 lbs a.i./A	60	40	100	4.6	0.7	9.6	0.7	5.1[B]	3.4	3.1	3.4	3.2	0.9
Moderate	60	40	100	5.0	0.8	8.7	1.7	3.3[BC]	0.5	3.1	0.5	5.8	0.8
Untreated	0	0	0	4.3	0.8	3.9	0.4	1.5[C]	0.5	0.9	0.6	1.2	0.6
Pr>F treat				0.7360	0.6937	0.0625	0.7544	0.0018	0.8572	0.0023	0.3036	0.0483	0.4513
$LSD_{0.05}$				NS	NS	NS	NS	-	NS	3.9011	NS	5.0449	NS

1 – In addition, all treatments received 15 lbs N/A with the anti-crustant, replications 1&2 14 lbs N/A preplant, reps 3&4 no preplant.

Table 25. Trial No. 2. Head lettuce, leaf N on June 11 and yield evaluations on July 2

Treatment	Sidedress No. 1 May 16 lbs N/A	Sidedress No. 2 May 29 lbs N/A	Total N/A[1]	Leaf %N June 11	Fresh lbs/A	Fresh tons/A	Dry lbs/A	%N	lbs N/A	Combined Head and Romaine		
										Fresh tons/A	Dry lbs/A	lbs N/A
Standard	60	80	140	4.56	78,395.0	39.20	3209.0	3.56	114.0	37.95	3,939.2	130.7
Moderate + Nitrapyrin 0.5 lbs a.i./A	60	40	100	4.43	73,126.9	36.56	3344.1	3.09	102.7	35.84	3,876.8	114.5
Moderate + Nitrapyrin 1.0 lbs a.i./A	60	40	100	4.45	73,669.8	36.83	3474.0	3.18	110.4	35.28	3,918.5	117.4
Moderate	60	40	100	4.28	68,997.4	34.50	3232.8	3.10	100.1	33.75	3,624.1	108.4
Untreated	0	0	0	2.70	47,183.2	23.59	2664.6	1.77	48.0	26.12	3,059.0	64.9
Pr>F treat				<0.0001	0.0006	0.0006	0.0610	<0.0001	<0.0001	<0.0001	0.0022	<0.0001
$LSD_{0.05}$				0.3335	11520	5.76	NS	0.2871	15.087	4.38	460.7	16.8

1 – In addition, all treatments received 15 lbs N/A with the anti-crustant, replications 1&2 14 lbs N/A preplant, reps 3&4 no preplant.

Table 26. Romaine Trial Spence. Application timing, dates and rates (lbs N/A)

Material[1]	App. Method[2]	1st app. N/A	2nd app. N/A	Total N/A	Mean head wt lbs	Fresh yield lbs/A	Fresh yield tons/A	Dry yield lbs/A	Biomass %N	Biomass lbs N/A
Untreated	---	0	0	15	1.76	55,063.0	27.53	2,844.9[E]	2.67	76.2
Standard	tractor	65	65	145	2.19	68,700.9	34.35	3,244.4[ABCD]	3.69	119.5
Moderate	tractor	40	20	75	2.02	63,248.6	31.62	2,994.1[DE]	3.11	93.0
Nitrapyrin 0.50 lb ai	tractor	40	20	75	2.17	68,121.7	34.06	3,183.3[ABCDE]	3.06	97.5
Nitrapyrin 1.0 lb ai	tractor	40	20	75	2.01	63,150.7	31.58	3,061.5[BCDE]	2.94	89.7
Duration ST	tractor	40	20	75	2.15	67,509.3	33.75	3,324.5[AB]	3.07	102.1
Novatec	drip	40	20	75	2.12	66,431.5	33.22	3,163.6[ABCD]	3.20	101.6
NSure/UN 32 (25:75)	drip	40	20	75	2.20	68,935.8	34.47	3,281.6[ABC]	3.11	102.1
NSure/UN 32 (25:75) NBPT	drip	40	20	75	2.15	67,383.9	33.69	3,149.0[ABCD]	3.04	95.5
NSure/24-0-0-10S (25:75)	drip	40	20	75	2.15	67,415.6	33.71	3,104.3[CDE]	3.27	101.2
Standard	drip	65	65	145	2.26	70,865.1	35.43	3,347.9[A]	3.36	112.6
Moderate	drip	40	20	75	2.00	62,789.0	31.39	3,054.0[DE]	2.92	89.4
Pr>F treat					0.0007	0.0007	0.0007	0.0215	<.0001	<.0001
$LSD_{0.05}$					0.19	5,924.7	2.96	**	0.28	11.4

1 all treatments received 15 lbs N/A as an anticrustant; 2 – all 2nd applications were applied with the drip system

Table 27 Trial No. 3. Romaine Trial Spence. Nitrate-N at three depths in the soil on four sampling dates during the crop cycle

Treatment	depth (ft)	6/10/15*	7/9/15*	7/31/15	8/17/15
Untreated	0-1	22.6	10.4	2.0^{BC}	2.1
	1-2	14.9	10.1	-	1.3^{C}
	2-3	12.3	6.9	-	-
155 (Standard) tractor	0-1	22.6	10.4	11.6^{AB}	4.7
	1-2	14.9	10.1	-	7.1^{A}
	2-3	12.3	6.9	-	-
105 (Moderate) tractor	0-1	22.6	10.4	5.6^{BC}	2.2
	1-2	14.9	10.1	-	2.7^{BC}
	2-3	12.3	6.9	-	-
105 Nitrapyrin 0.50 lb ai tractor	0-1	22.6	10.4	2.9^{C}	2.2
	1-2	14.9	10.1	-	2.0^{BC}
	2-3	12.3	6.9	-	-
105 Nitrapyrin 1.0 lb ai tractor	0-1	22.6	10.4	3.8^{C}	1.6
	1-2	14.9	10.1	-	1.6^{C}
	2-3	12.3	6.9	-	-
105 Duration ST tractor	0-1	22.6	10.4	4.8^{C}	3.4
	1-2	14.9	10.1	-	1.8^{C}
	2-3	12.3	6.9	-	-
105 Novatec drip	0-1	22.6	10.4	2.2^{C}	1.8
	1-2	14.9	10.1	-	1.6^{C}
	2-3	12.3	6.9	-	-
105 NSure/UN 32 (25:75) 31.1 drip	0-1	22.6	10.4	5.7^{BC}	3.6
	1-2	14.9	10.1	-	1.9^{BC}
	2-3	12.3	6.9	-	-
105 NSure/UN 32 (25:75) 31.5 NBPT drip	0-1	22.6	10.4	3.4^{C}	3.4
	1-2	14.9	10.1	-	2.8^{BC}
	2-3	12.3	6.9	-	-
105 NSure/24-0-0-10S 25.2 (25:75) drip	0-1	22.6	10.4	5.2^{C}	2.0
	1-2	14.9	10.1	-	2.4^{BC}
	2-3	12.3	6.9	-	-
155 (Standard) drip	0-1	22.6	10.4	16.5^{A}	2.1
	1-2	14.9	10.1	-	3.4^{B}
	2-3	12.3	6.9	-	-
105 (Moderate) drip	0-1	22.6	10.4	6.4^{BC}	2.4
	1-2	14.9	10.1	-	2.2^{BC}
	2-3	12.3	6.9	-	-

* samples collected on a per rep basis.

Table 28. Romaine Trial. Soil nitrate and ammonium levels on seven evaluation dates during the crop cycle

Treatment	Soil ammonium-N ppm							Soil nitrate-N ppm						
	5/1/15	5/7/15	5/12/15	5/21/15	6/4/15	6/8/15	6/18/15	5/1/15	5/7/15	5/12/15	5/21/15	6/4/15	6/8/15	6/18/15
Everest	2.7	1.5	4.4	2.3	1.6	1.0	0.9	30.1	34.5	38.1	29.7	11.3	4.9	1.9
NovaTec	42.7	22.3	41.0	9.9	9.0	3.4	3.0	20.4	18.7	17.5	18.6	6.1	3.0	1.7
ESN	3.2	0.6	3.2	2.1	0.5	1.1	1.0	36.8	42.6	39.0	33.8	15.1	12.8	7.4
Galaxy	4.0	1.1	4.3	2.3	0.9	1.3	0.8	51.8	49.0	67.0	55.2	13.1	9.4	0.6
Grower's Std	na	na	na	0.5	0.3	0.6	0.4	na	na	na	14.5	3.6	1.8	0.4
Pr>F treat	0.0014	<0.0001	<0.0001	<0.0001	<0.0001	0.0083	0.0014	<0.0001	0.0036	<0.0001	<0.0001	0.0308	0.0039	0.0009
$LSD_{0.05}$	17.0	1.9	10.2	1.2	2.3	1.3	1.0	7.6	13.0	11.8	7.2	7.4	5.2	2.6

Table 29. Romaine Trial. Harvest and nitrogen uptake evaluations on June 22.

Treatment	head wt (lbs)	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A
Everest	1.82	86,479.3	43.24	4,996.6	3.05	152.4
NovaTec	1.84	87,187.1	43.59	4,780.7	3.19	152.5
ESN	1.71	77,113.6	38.56	4,436.1	2.91	129.1
Galaxy	1.66	75,506.9	37.75	4,285.2	2.79	119.6
Grower's Std	1.74	81,038.2	40.52	4,549.0	2.88	131.0
Pr>F treat	0.2089	0.0162	0.0162	0.0276	NA	<.0001
$LSD_{0.05}$	NS	7991.4	3.9962	454.41	NA	13.425

30. Yield evaluation nitrogen uptake on May 22 and soil mineral nitrogen evaluations over the crop cycle on four dates.

Treatment	Total N lbs/A	Fresh lbs/A	Fresh tons/A	Dry lbs/A	%N	lbs N/A	Soil ammonium-N ppm				Soil nitrate-N ppm			
							Apr 30	May 6	May 13	May 18	Apr 30	May 6	May 13	May 18
NovaTec	120	16,574.7	8.3	1,399.6	5.8	81.2	80.6	9.6	40.2	22.1	31.2	35.8	37.3	22.9
Duration ST	120	16,151.4	8.1	1,433.0	5.5	78.3	4.0	4.2	1.3	1.6	30.8	39.8	36.0	21.6
Grower's Standard	180	20,979.0	10.5	1,644.6	5.8	95.7	na	na	0.5	2.1	na	na	30.2	24.0
Untreated	0	13,411.2	6.7	1,306.1	4.9	63.5	0.6	0.4	0.4	0.7	27.5	31.5	25.4	12.9
Pr>F treat		0.0007	0.0007	0.0027	0.0019	0.0022	0.0023	0.0403	0.0056	0.0163	0.5006	0.0025	0.0153	0.0175
LSD $_{0.05}$		2,072	1.03	122.0	0.36	10.89	28.04	6.38	17.95	12.80	NS	2.66	6.82	5.91

4/15 soil nitrate = 40.0 ppm

Table 31. Trial No. 6. Spinach Trial. Yield evaluation nitrogen uptake on May 27

Treatment	Total N lbs/A at planting	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A
Ammonium sulfate	90	35,737.6	17.9	2,069.0	5.55	114.8
Ammonium sulfate + nitrapyrin 1.0 lb a.i./A	90	30,601.2	15.3	1,825.6	5.51	100.9
NovaTec	90	28,643.6	14.3	1,702.2	5.42	92.2
Duration ST	90	31,889.4	15.9	1,876.3	5.59	105.0
SuperU	90	35,653.9	17.8	2,019.6	5.65	114.4
Ammonium sulfate (+ topdress 70 lbs N/A)	90	35,804.5	17.9	2,027.8	5.97	121.1
Grower Standard (Urea + ammonium sulfate)	160	37,143.0	18.6	2,131.8	5.72	122.0
Untreated	0	19,441.5	9.7	1,324.9	4.98	66.1
Pr>F treat		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
$LSD_{0.05}$		3198.5	1.6	157.0	0.25	11.2

Table 32. Continued. Soil mineral nitrogen evaluations over the crop cycle on four dates.

Treatment	Total N lbs/A at planting	Soil ammonium-N ppm					Soil nitrate-N ppm				
		Apr 30	May 5	May 11	May 19	May 26	Apr 30	May 5	May 11	May 19	May 26
Ammonium sulfate	90	25.7	3.8^{CDE}	1.3^{AB}	4.2^{C}	4.8^{BC}	18.8	19.4^{B}	12.7^{B}	8.0^{B}	4.1^{A}
Ammonium sulfate + nitrapyrin 1.0 lb a.i./A	90	25.1	8.7^{AB}	3.3^{AB}	11.8^{B}	14.0^{AB}	10.8	12.5^{D}	7.6^{C}	4.4^{C}	2.0^{CD}
NovaTec	90	25.6	17.1^{A}	2.5^{A}	17.5^{AB}	16.1^{A}	10.6	14.5^{D}	6.5^{C}	3.7^{C}	2.4^{CD}
Duration ST	90	7.1	1.7^{DE}	0.8^{CD}	12.9^{B}	3.7^{C}	13.1	12.4^{D}	6.9^{C}	5.4^{C}	2.9^{BC}
SuperU	90	19.9	2.9^{CDE}	1.4^{CD}	3.2^{C}	2.5^{C}	15.7	24.0^{BC}	17.8^{AB}	5.2^{C}	3.5^{AB}
Ammonium sulfate (+ topdress 70 lbs N/A)	90	30.0	3.8^{CD}	1.1^{ABC}	30.7^{A}	13.1^{AB}	16.1	16.7^{C}	11.6^{B}	11.4^{A}	7.7^{A}
Grower Standard (Urea + ammonium sulfate)	160	31.1	4.1^{BC}	1.1^{BC}	3.2^{C}	5.3^{BC}	22.3	37.9^{A}	29.2^{A}	10.6^{AB}	7.8^{A}
Untreated	0	4.4	0.8^{E}	0.6^{D}	3.8^{C}	3.3^{C}	5.7	6.9^{E}	3.1^{D}	4.2^{C}	1.4^{D}
Pr>F treat		0.0005	<0.0001	0.0025	<0.0001	0.0034	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
LSD $_{0.05}$		11.9	***	***	**	**	5.5	***	***	**	***

Table 33. Trial No. 7. Mizuna yield evaluation and nitrogen uptake on October 19.

Treatment	Total N lbs/A	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A
NovaTec	120	25,460.8	12.73	1,793.3	7.34	123.9
Duration ST	120	27,955.0	13.98	1,922.4	7.54	135.5
Grower's standard	180	27,775.1	13.88	1,808.6	7.00	117.5
Pr>F treat		0.3294	0.3287	0.4183	0.1483	0.2962
$LSD_{0.05}$		NS	NS	NS	NS	NS

Table 34. Trial No. 7. Soil mineral nitrogen evaluations over the crop cycle of mizuna.

Treatment	Total N lbs/A	Soil Ammonium-N ppm				Soil Nitrate-N ppm				Total Mineral-N ppm			
		Sept 23	Oct 5	Oct 12	Oct 19	Sept 23	Oct 5	Oct 12	Oct 19	Sept 23	Oct 5	Oct 12	Oct 19
NovaTec	120	0.2	113.5	63.3	15.9	28.5	45.7	39.2	18.5	28.7	159.2	102.5	34.5
Duration ST	120	0.2	7.6	13.0	1.3	28.5	61.3	44.7	20.4	28.7	68.9	57.8	21.7
Grower's standard	180	0.2	1.0	0.9	0.6	28.5	25.1	8.1	3.3	28.7	26.1	9.0	3.8
Pr>F treat		NA	NA	NA	0.0007	NA	NA	NA	0.0028	NA	NA	NA	0.0019
$LSD_{0.05}$		NS	NS	NS	4.0	NS	NS	NS	6.2	NS	NS	NS	9.1

Table 35. Above ground N accumulation by lettuce as affected by N management in fall-winter 2015-2016.

Treatment	Date			
	12/18	1/8	1/28	2/24
	Above-ground N accumulation (mg/plant)			
GSP	6.4	63.9	272.5	553.8
CRN 90 (75 lbs N/A)	3.9	57.7	256.6	593.9
CRN 120 (75 lbs N/A)	6.9	61.9	278.2	575.7
CRN 90 (150 lbs N/A)	3.8	59.3	278.5	669.8
CRN 120 (150 lbs N/A)	5.6	46.1	307.4	599.0
LSD	1.0	NS	NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 36. Midrib nitrate-N by lettuce as affected by N management in fall-winter 2015-2016.

Treatment			
	1/8	1/28	2/24
	Midrib NO3-N (mg/kg)		
GSP	6200	9109	3316
CRN 90 (75 lbs N/A)	8264	12085	3339
CRN 120 (75 lbs N/A)	8827	9058	3916
CRN 90 (150 lbs N/A)	9039	13280	4075
CRN 120 (150 lbs N/A)	10388	10370	3688
LSD	2120	2909	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 37. Inorganic soil N in lettuce rooting zone as affected by N management in Fall-winter 2015-2016.

Treatment	Date							
	12/18		1/8		11/28		2/24	
	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N (mg/kg)							
GSP	2.2	24.9	8.0	16.6	12.4	12.0	13.1	62.0
CRN 90 (75 lbs N/A)	1.7	18.9	5.7	41.0	10.2	6.9	8.6	83.3
CRN 120 (75 lbs N/A)	4.5	27.3	5.7	25.2	10.5	7.9	12.5	66.5
CRN 90 (150 lbs N/A)	2.5	22.6	3.4	51.7	9.2	25.1	8.8	63.7
CRN 120 (150 lbs N/A)	2.7	24.1	9.8	41.7	11.6	18.6	10.0	96.2
LSD	1.0	5.2	NS	8.5	1.9	4.0	2.6	12.7

LSD=Least significant difference at P=0.05. NS=not significant.

Table 38. Yield response of iceberg lettuce to N management in fall-winter 2015-2016.

Treatment	Yield (MT/ha)
GSP	53.1
CRN 90 (75 lbs N/A)	50.3
CRN 120 (75 lbs N/A)	54.7
CRN 90 (150 lbs N/A)	49.0
CRN 120 (150 lbs N/A)	51.5
LSD	3.1

LSD=Least significant difference at P=0.05. NS=not significant.

Table 39. Above ground N accumulation by broccoli as affected by N management in fall-winter 2015-2016.

Treatment	Date			
	12/18	1/8	1/28	2/19
	Above-ground N accumulation (mg/plant)			
GSP	6.9	62.3	431	840
CRN 90 (75 lbs N/A)	5.8	83.5	522	1079
CRN 120 (75 lbs N/A)	6.0	60.6	381	955
CRN 90 (150 lbs N/A)	4.2	62.5	534	984
CRN 120 (150 lbs N/A)	6.6	66.9	450	1626
LSD	2.4	16.5	1NS	356

LSD=Least significant difference at P=0.05. NS=not significant.

Table 40. Petiole nitrate-N for broccoli as affected by N management in fall-winter-spring 2015-2016.

Treatment		
	1/28	2/19
	Midrib NO3-N (mg/kg)	
GSP	3195	3262
CRN 90 (75 lbs N/A)	3827	3932
CRN 120 (75 lbs N/A)	3827	3672
CRN 90 (150 lbs N/A)	3009	2103
CRN 120 (150 lbs N/A)	3806	3366
LSD	796	670

LSD=Least significant difference at P=0.05. NS=not significant.

Table 41. Inorganic soil N in broccoli rooting zone as affected by N management in Fall-winter-spring 2015-2016.

Treatment	Date							
	12/18		1/8		1/28		2/24	
	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N (mg/kg)							
GSP	3.9	11.3	3.9	15.2	4.6	13.1	38.4	48.8
CRN 90 (75 lbs N/A)	11.3	26.1	11.3	19.8	8.3	16.8	12.8	56.8
CRN 120 (75 lbs N/A)	11.2	17.6	11.3	25.4	10.9	29.5	12.3	69.0
CRN 90 (150 lbs N/A)	9.8	30.5	9.8	28.8	7.8	22.4	16.8	32.2
CRN 120 (150 lbs N/A)	10.9	26.8	10.9	21.2	5.9	26.0	19.7	45.2
LSD	7.2	9.1	2.7	3.2	1.9	7.0	3.9	12.4

LSD=Least significant difference at P=0.05. NS=not significant.

Table 42. Yield response of broccoli N management in fall-winter 2015-2016.

Treatment	Yield (MT/ha)
GSP	11.6
CRN 90 (75 lbs N/A)	16.2
CRN 120 (75 lbs N/A)	12.4
CRN 90 (150 lbs N/A)	13.9
CRN 120 (150 lbs N/A)	17.7
LSD	1.9

LSD=Least significant difference at P=0.05. NS=not significant.

Table 43. Leaf N in spinach as affected by N management in winter 2016.

Treatment	Date	
	2/19	3/4
	N Content (%)	
GSP	4.69	6.12
CRN 45 (100 lbs N/A)	6.69	6.07
CRN 45 (200 lbs N/A)	6.83	6.54
LSD	NS	0.23

LSD=Least significant difference at P=0.05. NS=not significant.

Table 44. Inorganic soil N in rooting zone of spinach crop as affected by N management in winter 2016.

Treatment	Date			
	2/19		3/4	
	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N (mg/kg)			
GSP	64.7	65.5	9.0	58.6
CRN 45 (100 lbs N/A)	111.3	79.1	9.5	73.4
CRN 45 (200 lbs N/A)	94.7	65.1	21.2	67.2
LSD	9.1	7.0	2.9	4.0

LSD=Least significant difference at P=0.05. NS=not significant.

Table 45. Yield response of spinach to N management in winter 2016.

Treatment	Yield (MT/ha)
GSP	13.7
CRN 45 (100 lbs N/A)	15.7
CRN 45 (200 lbs N/A)	21.1
LSD	2.7

LSD=Least significant difference at P=0.05. NS=not significant.

Table 46. Above ground N in spinach as affected by N management in winter 2015-2016.

Treatment	Date		
	12/27	1/14	1/28
	Above-ground N accumulation (mg/plant)		
GSP	0.19	14.1	24.5
CRN 45 (100 lbs N/A)	0.24	10.3	22.1
CRN 45 (200 lbs N/A)	0.30	9.0	22.5
LSD	0.06	2.5	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 47. Inorganic soil N in rooting zone of spinach crop as affected by N management in winter 2015-2016.

Treatment	Date					
	12/27		1/14		1/28	
	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N (mg/kg)					
GSP	1.6	5.5	5.0	24.0	8.9	16.2
CRN 45 (100 lbs N/A)	4.2	15.8	6.9	9.9	8.2	8.6
CRN 45 (200 lbs N/A)	2.6	8.8	4.0	5.0	8.7	7.5
LSD	0.1	0.6	1.1	1.5	NS	7.5

LSD=Least significant difference at P=0.05. NS=not significant.

Table 48. Leaf N in spinach as affected by N management in winter 2015-2016.

Treatment	Date		
	12/27	1/14	1/28
	N Content (%)		
GSP	4.43	5.14	4.21
CRN 45 (100 lbs N/A)	5.30	4.39	3.88
CRN 45 (200 lbs N/A)	4.98	4.28	3.87
LSD	0.65	NS	0.34

LSD=Least significant difference at P=0.05. NS=not significant.

Table 49. Yield response of romaine to N management in winter 2015-2016.

Treatment	Yield (MT/ha)
GSP	18.4
CRN 45 (100 lbs N/A)	22.3
CRN 45 (200 lbs N/A)	20.2
LSD	1.5

LSD=Least significant difference at P=0.05. NS=not significant.

Table 50. Above ground N in romaine hearts crop as affected by N management in winter-spring2015-2016.

Treatment	Date		
	1/14	1/29	2/28
	Above-ground N accumulation (mg/plant)		
GSP	1.6	29.1	435.4
CRN 90 (125 lbs N/A)	1.3	23.4	460.1
CRN 90 (200 lbs N/A)	1.3	23.3	364.3
LSD	NS	NS	88.6

LSD=Least significant difference at P=0.05. NS=not significant.

Table 51. Midrib nitrate-N by romaine hearts as affected by N management in winter-spring 2015-2016.

Treatment		
	1/29	2/28
	Midrib NO3-N (mg/kg)	
GSP	4508	8652
CRN 90 (125 lbs N/A)	4800	13286
CRN 90 (200 lbs N/A)	4601	10987
LSD	NS	3789

LSD=Least significant difference at P=0.05. NS=not significant.

Table 52. Inorganic soil N in rooting zone of romaine heart crop as affected by N management in winter-spring 2015-2016.

Treatment	Date					
	1/14		1/29		2/x	
	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N (mg/kg)					
GSP	5.5	6.3	12.0	7.1	3.4	17.5
CRN 90 (125 lbs N/A)	9.4	12.2	9.3	24.5	3.7	26.1
CRN 90 (200 lbs N/A)	5.2	15.5	10.0	25.0	4.6	20.1
LSD	0.9	1.4	2.5	5.1	0.8	3.1

LSD=Least significant difference at P=0.05. NS=not significant.

Table 53. Yield response of romaine to N management in winter-spring 2015-2016.

Treatment	Yield (MT/ha)
GSP	61.5
CRN 90 (125 lbs N/A)	48.2
CRN 90 (200 lbs N/A)	62.6
LSD	13.4

LSD=Least significant difference at P=0.05. NS=not significant.

Table 54. Above ground N accumulation for iceberg lettuce as affected by N management in winter-spring 2016.

Treatment	Date			
	1/8	1/28	2/14	310
	Above-ground N accumulation (mg/plant)			
GSP	0.34	8.2	65.5	350.0
CRN 90	0.38	7.7	69.2	405.9
LSD	NS	NS	NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 55. Inorganic soil N in lettuce rooting zone as affected by N management in winter-spring 2016.

Treatment	Date							
	1/8		1/28		2/14		3/10	
	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N
	Soil N (mg/kg)							
GSP	1.5	14.5	9.2	18.2	7.6	14.2	3.1	16.7
CRN	1.6	13.6	11.0	31.0	12.6	19.2	3.3	17.8
LSD	NS	NS	NS	5.5	3.5	2.9	NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 56. Midrib nitrate-N for iceberg lettuce as affected by N management in winter-spring 2016.

Treatment	Date	
	2/14	3/10
	(mg/kg)	
GSP	8859	10743
CRN	10523	11827
LSD	NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 57. Marketable yield of iceberg lettuce as affected by N management in winter-spring 2016.

Treatment	Yield MT/ha
GSP	61.8
CRN	65.0
Stat.	*

Table 58. Response of spinach to N rate and N source.

N Rate	N Source	Yield (MT/ha)	Soil NH4-N (mg/kg)	Soil Nitrate-N (mg/kg)	Leaf N (%)	N Uptake (kg/ha)
0	---	2.2	3.4	3.6	3.29	5.11
150	CRN	9.5	2.8	7.1	2.84	27.2
300	CRN	12.8	8.2	27.2	4.28	38.7
150	AS	9.5	1.2	7.5	4.25	27.8
300	AS	8.7	2.3	30.0	4.76	28.5
150	FUSN	9.3	4.2	4.4	4.19	27.1
300	FUSN	9.9	2.1	13.9	4.33	28.7
150	Urea	9.6	2.3	7.2	4.12	27.7
300	Urea	8.8	1.6	8.9	4.10	25.2
150	SU	8.0	2.9	5.4	4.50	24.7
300	SU	9.9	5.1	5.8	4.60	31.9
Stat. N Rate		L** Q**	NS	L**	L*Q*	L**Q**
N Source		1.8	3.2	9.8	0.40	NS

Table 59. Application protocol of fertilizer treatments and yield components of lettuce on August 23

Material	Nitrapyrin application timing	1st Application		2nd Application		Total	Fresh Biomass tons/A	Head wt lbs	% solids	Dry Biomass lbs/A	N uptake lbs/A	Tissue %N
		Method	lbs N/A	Method	lbs N/A	N/A						
Untreated	---	---	0	---	0	0	17.897	1.14	5.72	2,042.3	52.2	2.56
Standard	---	dry tractor	75	liq. drip	75	150	27.706	1.77	5.30	2,938.1	107.6	3.66
Moderate	---	dry tractor	40	liq. drip	40	80	27.359	1.74	5.08	2,776.6	94.8	3.43
Nitrapyrin 0.50 lb ai[1]	1st app.	dry tractor	40	liq. drip	40	80	24.697	1.57	5.29	2,603.3	88.6	3.41
Nitrapyrin 1.0 lb ai[1]	1st app.	dry tractor	40	liq. drip	40	80	25.961	1.66	5.18	2,681.5	89.5	3.35
Feather meal 12-0-0[2]	---	dry tractor	80	liq. drip	0	80	23.014	1.47	5.36	2,469.7	73.0	2.97
Standard	---	liq. drip	75	liq. drip	75	150	28.313	1.81	5.00	2,814.9	102.4	3.64
Moderate	---	liq. drip	40	liq. drip	40	80	23.566	1.50	5.21	2,458.1	80.6	3.29
Nitrapyrin 0.50 lb ai[3]	1st app.	liq. drip	40	liq. drip	40	80	23.832	1.52	5.40	2,573.9	82.0	3.19
Nitrapyrin 1.0 lb ai[3]	1st app.	liq. drip	40	liq. drip	40	80	24.619	1.57	5.12	2,519.7	80.6	3.21
Nitrapyrin 0.50 lb ai[4]	1st & 2nd app.	liq. drip	40	liq. drip	40	80	25.363	1.62	5.13	2,592.4	83.3	3.21
Nitrapyrin 1.0 lb ai[4]	1st & 2nd app.	liq. drip	40	liq. drip	40	80	25.727	1.64	5.36	2,758.9	86.3	3.14
Pr>F treat							<0.0001	<0.0001	0.1179	<0.0001	<0.0001	<0.0001
$LSD_{0.05}$							2.980	0.19	ns	283.5	9.2	0.31

1 - total quantity of nitrapyrin applied in the 1st application on ammonium sulfate; 2 – all feather meal applied in the first application with the tractor; 3 - total quantity of nitrapyrin applied in the first application in UN32; 4 – total quantity of nitrapyrin split between 1st and 2nd applications in UN32

Table 60. Mineral nitrogen levels in the top foot of soil on three evaluation dates during the crop cycle

Treatment	Application Methods	Total N applied	July 28			August 5			August 18		
			NH_4-N	NO_3-N	total	NH_4-N	NO_3-N	total	NH_4-N	NO_3-N	total
Untreated	---	0	2.43^{D}	2.90	5.33	2.34^{D}	6.41	8.75	2.26^{F}	1.94^{E}	4.21^{E}
Standard	tractor/drip	150	22.21^{A}	5.40	27.61	8.99^{A}	23.01	32.00	7.42^{AB}	11.39^{A}	18.80^{A}
Moderate	tractor/drip	80	4.31^{ABC}	7.31	11.61	6.38^{BC}	20.74	27.12	2.55^{BCD}	7.29^{AB}	9.84^{ABC}
Nitrapyrin 0.50 lb ai[1]	tractor/drip	80	7.70^{A}	2.59	10.29	4.72^{AB}	16.10	20.82	8.90^{ABC}	2.77^{CD}	11.67^{ABCD}
Nitrapyrin 1.0 lb ai[1]	tractor/drip	80	7.26^{AB}	2.21	9.47	9.19^{AB}	6.60	15.79	5.77^{A}	2.29^{DE}	8.06^{AB}
Feather meal 12-0-0[2]	tractor/drip	80	2.50^{CD}	3.12	5.62	2.06^{D}	11.73	13.79	2.66^{CDE}	4.25^{BCD}	6.91^{BCD}
Standard	drip/drip	150	5.82^{A}	12.19	18.01	2.96^{ABC}	22.60	25.56	2.35^{DEF}	8.15^{A}	10.50^{A}
Moderate	drip/drip	80	3.22^{ABCD}	7.28	10.50	2.98^{BC}	20.87	23.86	2.15^{F}	4.87^{ABC}	7.02^{BCD}
Nitrapyrin 0.50 lb ai[3]	drip/drip	80	3.48^{ABCD}	7.94	11.41	2.89^{CD}	12.53	15.42	2.57^{DE}	2.74^{DE}	5.31^{DE}
Nitrapyrin 1.0 lb ai[3]	drip/drip	80	3.46^{ABC}	5.62	9.07	3.43^{ABC}	7.59	11.01	2.40^{DEF}	2.78^{DE}	5.18^{DE}
Nitrapyrin 0.50 lb ai[4]	drip/drip	80	2.78^{BCD}	7.08	9.85	2.60^{CD}	11.34	13.94	2.39^{EF}	3.84^{BCD}	6.22^{BCD}
Nitrapyrin 1.0 lb ai[4]	drip/drip	80	3.80^{AB}	3.79	7.58	2.93^{CD}	12.36	15.29	2.45^{DEF}	3.00^{CD}	5.45^{CDE}
Pr>F treat			0.0310	0.0681	0.1634	0.0010	0.1971	0.2452	<.0001	<.0001	0.0004

1 - total quantity of nitrapyrin applied in the 1st application on ammonium sulfate; 2 – all feather meal applied in the first application with the tractor; 3 - total quantity of nitrapyrin applied in the first application in UN32; 4 – total quantity of nitrapyrin split between 1st and 2nd applications in UN32

Table 61. Plant growth of romaine lettuce CV to N management in fall-winter 2016-2017.

Treatment	Practice	Plant dry weight (g/plant)			
		Date			
		11/10	11/29	12/27	1/17
1	176 lbs N/A CRN90	0.06	2.1	12.1	18.2
2	88 lbs N/A CRN90 +174 lbs N/A UAN32	0.05	2.6	8.4	14.6
3	GSP 350 lbs N/A UAN32	0.07	3.0	7.7	18.5
LSD		NS	0.7	3.1	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 62. Above ground N accumulation to N management in fall-winter 2016-2017.

Treatment	Practice	N accumulation (mg/plant)			
		Date			
		11/10	11/29	12/27	1/17
1	176 lbs N/A CRN90	1.6	59.0	316.4	421.4
2	88 lbs N/A CRN90 +174 lbs N/A UAN32	1.3	66.9	212.9	283.5
3	GSP 350 lbs N/A UAN32	1.9	83.7	200.8	378.3
LSD		NS	17.0	91.2	138.0

LSD=Least significant difference at P=0.05. NS=not significant.

Table 63. Yield response of romaine hearts to N management in fall-winter 2016-2017.

Treatment	Practice	Marketable Yield (MT/ha)
1	176 lbs N/A CRN90	62.6
2	88 lbs N/A CRN90 +174 lbs N/A UAN32	71.1
3	GSP 350 lbs N/A UAN32	79.2
LSD		16.6

LSD=Least significant difference at P=0.05. NS=not significant.

Table 64. Growth of iceberg lettuce to N management in winter-spring 2016-2017.

Treatment	Practice	Dry weight (g/plant			
		Date			
		12/21	1/8	1/27	2/20
1	CRN1	0.06	0.93	12.1	33.6
2	CRN2	0.07	1.00	8.4	50.7
3	GSP	0.09	1.41	7.7	51.4
LSD		0.02	0.28	3.1	8.0

LSD=Least significant difference at P=0.05. NS=not significant.

Table 65. Above-ground N accumulation of iceberg lettuce to N management winter-spring 2016-2017.

Treatment	Practice				
1	180 lbs N/A CRN90	2.4	34.5	338.9	673.5
2	90 lbs N/A CRN 90	2.8	40.3	235.4	1083.5
3	GSP 175 lbs N/A UAN32	3.1	56.0	211.1	1130.2
LSD		0.4	11.7	73.6	154.0

LSD=Least significant difference at P=0.05. NS=not significant.

Table 66. Response of Iceberg Lettuce to N management in winter-spring 2016-2017.

Treatment	Practice	Yield (MT/ha)
1	180 lbs N/A CRN90	48.2
2	90 lbs N/A CRN 90	59.2
3	GSP 175 lbs N/A UAN32	65.8
LSD		5.3

LSD=Least significant difference at P=0.05. NS=not significant.

Table 67. Residual inorganic soil N following lettuce harvest to N management winter-spring 2016-2017.

Treatment	Practice	NH4-N	NO3-N
		(mg/kg)	(mg/kg)
1	180 lbs N/A CRN90	13.0	162.9
2	90 lbs N/A CRN 90	10.8	97.4
3	GSP 175 lbs N/A UAN32	11.1	65.5
LSD		NS	20.7

LSD=Least significant difference at P=0.05. NS=not significant.

Table 68.Leaf N concentration of spinach to N management in Coachella Valley

Treatment	Practice	Leaf N (%)		
		Date		
		11/10	11/29	12/23
1	180 lbs N/A CRN45	3.13	3.27	2.91
2	90 lbs N/A CRN 45 + 63 lbs N/A ammonium sulfate	2.97	3.30	2.99
3	189 lbs N/A ammonium sulfate	3.15	3.08	2.49
LSD		NS	NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 69. Spinach yield in Coachella Valley to N management.

Treatment	Practice	Yield (MT/ha)
1	180 lbs N/A CRN45	14.9
2	90 lbs N/A CRN 45 + 63 lbs N/A ammonium sulfate	11.9
3	189 lbs N/A ammonium sulfate	10.7
LSD		1.1

LSD=Least significant difference at P=0.05. NS=not significant.

Table 70. Spinach leaf N content to N management in Bard.

Treatment	Practice	Leaf N (%)		
		Date		
		12/27	1/9	1/9
1	180 lbs N/A CRN45	2.54	3.22	3.24
2	90 lbs N/A CRN 45 + 75 lbs N/A UAN32	2.73	3.47	3.28
3	200 lbs N/A UAN 32	2.79	3.75	3.39
LSD		NS	0.44	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 71. Spinach yield in Bard Valley to N management.

Treatment	Practice	Yield MT/ha
1	180 lbs N/A CRN45	17.3
2	90 lbs N/A CRN 45 + 75 lbs N/A UAN32	16.5
3	200 lbs N/A UAN 32	16.6
LSD		NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 72. Residual inorganic soil N following spinach harvest to N management in Bard.

Treatment	Practice	NH4-N	NO3-N
		(mg/kg)	(mg/kg)
1	180 lbs N/A CRN45	0	45.9
2	90 lbs N/A CRN 45 + 75 lbs N/A UAN32	0	39.6
3	200 lbs N/A UAN 32	1.7	40.3
LSD		1.4	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 73. Response of spinach to N rate and N source fall-winter 2016-2017.

N Rate	N Source	Yield (MT/ha)	Soil NH4-N (mg/kg)	Soil Nitrate-N (mg/kg)	Leaf N (%)	N Uptake (kg/ha)
0	---	3.3	25.1	30.6	1.77	3.0
100	CRN 45	4.6	10.9	28.9	2.19	5.1
200	CRN 45	7.3	11.4	29.8	2.58	9.7
100	AS	6.9	84.7	42.1	3.03	10.5
200	AS	7.8	149.7	105.5	3.29	12.7
100	AS+NI	6.8	140.9	31.9	2.95	9.97
200	AS+NI	5.0	332.4	29.4	3.22	8.05
100	FUSN	7.6	12.4	38.5	3.06	11.6
200	FUSN	6.8	16.6	55.3	3.32	11.4
100	Urea	6.8	23.9	38.5	3.17	10.8
200	Urea	6.5	35.4	52.9	3.11	10.3
100	SU	5.8	34.9	42.5	3.37	9.6
200	SU	4.9	28.5	37.1	3.49	8.6
Stat.						
N Rate		L**Q**	L*	L**	L**Q**	L**Q**
N Source (LSD)		1.5	90.9	17.6	0.33	2.6

*, ** Significant linear (L) and quadratic trend to N rate. LSD=Least significant difference at P=0.05 to source. NS=not significant.

Table 74. Response of spinach to N rate and N source winter 2017.

N Rate	N Source	Yield (MT/ha)	Soil NH4-N (mg/kg)	Soil Nitrate-N (mg/kg)	Leaf N (%)	N Uptake (kg/ha)
0	---	4.0	25.4	33.1	1.96	4.21
100	CRN	11.1	23.1	26.8	2.47	14.4
200	CRN	13.1	28.7	31.4	2.95	19.2
100	AS	12.2	53.5	69.0	3.00	18.4
200	AS	14.0	79.8	143.4	3.18	22.3
100	AS+NI	12.3	69.3	58.6	3.02	18.6
200	AS+NI	10.8	366.7	44.5	3.01	16.3
100	FUSN	14.7	22.6	41.2	3.21	23.5
200	FUSN	10.0	123.1	145.3	3.24	15.9
100	Urea	13.0	35.2	52.0	3.01	19.6
200	Urea	11.2	34.6	76.5	3.10	17.2
100	SU	11.7	42.8	47.7	3.31	19.4
200	SU	10.4	58.0	60.0	3.50	17.9
Stat.						
N Rate		L**Q**	L**	L**	L**Q**	L**Q**
N Source (LSD)		2.4	151	37.8	0.31	NS

*, ** Significant linear (L) and quadratic trend to N rate. LSD=Least significant difference at P=0.05 to source. NS=not significant.

Table 75. Response of spinach to N rate and N source winter spring 2017...

N Rate	N Source	Yield (MT/ha)	Soil NH4-N (mg/kg)	Soil Nitrate-N (mg/kg)	Leaf N (%)	N Uptake (kg/ha)
0	---	4.5	35.3	14.3	1.97	4.6
100	CRN	10.4	29.3	17.4	2.34	12.1
200	CRN	10.6	35.1	18.7	2.53	13.6
100	AS	8.8	60.0	78.6	2.49	10.8
200	AS	8.4	104.8	170.2	2.65	11.1
100	AS+NI	9.2	123.2	22.4	2.75	12.7
200	AS+NI	7.3	165.5	44.9	2.59	9.3
100	FUSN	8.3	18.6	35.5	2.53	10.4
200	FUSN	7.6	45.1	29.8	2.58	9.9
100	Urea	9.1	26.9	57.1	2.64	12.1
200	Urea	7.5	66.6	184.0	2.68	10.2
100	SU	9.2	79.8	50.4	2.85	13.2
200	SU	6.0	85.7	59.4	3.31	9.9
Stat.						
N Rate		L**Q**	L*	L**	L**Q*	L**Q**
N Source (LSD)		1.6	70.0	38.0	0.48	2.7

*, ** Significant linear (L) and quadratic trend to N rate. LSD=Least significant difference at P=0.05 to source. NS=not significant.

Table 76. Response of potato to N management in spring 2017.

N Rate (kg/ha)	N Source	Yield US1	Yield US2	Total Yield	Leaf N
		MT/ha			(%)
0	--	9.6	4.3	13.9	1.9
100	CRN 90	8.0	4.3	12.4	2.1
100	CRN 120	9.4	4.7	14.1	2.3
200	CRN 90	6.0	1.7	7.7	2.1
200	CRN 120	7.1	3.8	10.9	2.1
200	UAN 32 Sidedress	8.9	3.0	11.9	2.1
LSD		NS	1.7	4.6	0.3

LSD=Least significant difference at P=0.05. NS=not significant.

Table 77. Leaf tissue N and P concentration of pepper to N management.

N Rate (kg/ha)	N Source	Leaf N (%)	Leaf P (%)
Control	--	0.58	0.38
100	CRN	1.23	0.28
200	CRN	1.08	0.24
200	UAN32 Drip	1.30	0.24
LSD		0.21	0.14

LSD=Least significant difference at P=0.05. NS=not significant.

Table 78. Above-ground growth and final root mass of peppers to N management.

N Rate (kg/ha)	N Source	Sample Date				
		4/13	4/20	4/27	7/10	7/10
		g/plant				g/root
Control	-	0.59	1.42	1.65	36.5	4.3
100	CRN	1.00	2.57	5.41	43.6	4.8
200	CRN	1.00	2.12	6.85	50.2	6.9
200	UAN32 Drip	0.33	1.25	2.65	54.47	6.8
LSD		NS	NS	4.2	10.8	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 79. Pepper yields by harvest date to N management.

N Rate (kg/ha)	N Source	Harvest Date		
		5/26	6/6	6/30
		MT/ha		
Control	--	0.14	0.14	1.48
100	CRN	1.10	1.48	3.73
200	CRN	1.44	1.38	3.82
200	UAN32 Drip	1.49	4.86	10.7
LSD		0.99	1.24	6.8

LSD=Least significant difference at P=0.05. NS=not significant.

Table 80. Cumulative pepper yields across harvest dates to N management.

N Rate (kg/ha)	N Source	Harvest Date		
		5/26	6/6	6/30
		MT/ha		
Control	--	0.14	0.27	1.75
100	CRN	1.10	2.69	6.35
200	CRN	1.44	2.82	6.64
200	UAN32 Drip	1.49	6.35	17.02
LSD		0.99	2.3	4.6

LSD=Least significant difference at P=0.05. NS=not significant.

Table 81. Plant weight of tomato across sample dates and root weights immediately after final harvest as affected by N rate and Source.

Treatment	N Rate (kg/ha)	N Source	Sample Date				
			4/13	4/20	4/27	7/10	7/10
			g/plant				g/root
1	0	-	1.11	3.80	20.1	136.2	39.6
2	100	CRN	3.00	14.3	39.9	152.3	36.5
3	200	CRN	4.42	12.9	56.0	180.6	44.7
4	100	SymTRX20S	1.09	6.8	19.0	123.0	41.2
5	200	SymTRX20S	2.92	4.0	29.5	128.6	25.7
6	200	UAN 32	1.48	8.9	28.9	184.6	27.8
LSD			2.67	6.5	12.9	NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 82. Leaf tissue N content for tomato to N rate and source.

Treatment	N Rate (kg/ha)	N Source	Leaf N (%)
1	0	-	2.93
2	100	CRN	3.50
3	200	CRN	3.13
4	100	SymTRX20S	3.26
5	200	SymTRX20S	3.12
6	200	UAN 32	3.69
LSD			0.39

LSD=Least significant difference at P=0.05. NS=not significant.

Table 83. Tomato yields on individual harvest dates to N rate and source.

Treatment	N Rate (kg/ha)	N Source	Harvest Date				
			6/7	6/15	6/23	6/30	7/7
			MT/ha				
1	0	-	0.37	1.6	6.7	0.7	8.9
2	100	CRN	1.82	4.3	8.6	2.2	17.6
3	200	CRN	1.46	2.8	6.9	2.6	18.3
4	100	SymTRX20S	0.38	1.4	4.7	1.2	12.7
5	200	SymTRX20S	0.57	1.7	4.8	1.4	20.5
6	200	UAN 32	1.39	3.3	11.6	4.5	33.2
LSD			1.38	2.3	3.7	1.2	11.6

LSD=Least significant difference at P=0.05. NS=not significant.

Table 84. Cumulative tomato yields across harvest dates to N rate and source.

Treatment	N Rate (kg/ha)	N Source	Harvest Date				
			6/7	6/15	6/23	6/30	7/7
1	0	-	0.37	2.0	8.6	9.3	18.2
2	100	CRN	1.82	6.1	14.7	16.9	34.5
3	200	CRN	1.46	4.2	11.2	13.8	32.1
4	100	SymTRX20S	0.38	1.7	6.5	7.7	20.4
5	200	SymTRX20S	0.57	2.2	7.0	8.4	28.8
6	200	UAN 32	1.39	4.6	16.3	20.7	53.9
LSD			1.38	3.3	5.8	5.8	12.9

LSD=Least significant difference at P=0.05. NS=not significant.

Table 85. Leaf tissue N and P concentration of watermelon to N management.

N Rate (kg/ha)	N Source	Leaf N (%)	Leaf P (%)
Control	--	2.42	0.30
100	CRN	2.12	0.27
200	CRN	2.32	0.29
200	UAN32 Drip	2.34	0.32
LSD		NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 86. Above-ground growth and final root mass of watermelons to N management.

N Rate (kg/ha)	N Source	Sample dates			
		4/13	4/20	4/27	7/10
		g/plant			g/root
Control	--	5.45	35.4	45.2	72.8
100	CRN	6.56	28.6	41.6	88.4
200	CRN	5.54	17.7	28.9	60.0
200	UAN32 Drip	8.11	27.7	67.8	43.0
		NS	NS	NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 87. Watermelon yields by harvest date to N management.

N Rate (kg/ha)	N Source	Harvest dates			
		5/26	6/1	6/7	6/15
		MT/ha			
Control	--	11.8	7.9	0	5.9
100	CRN	7.3	9.8	5.2	5.7
200	CRN	3.87	2.3	7.8	9.9
200	UAN32 Drip	6.8	19.6	6.7	2.8
LSD		7.9	17.2	NS	NS

LSD=Least significant difference at P=0.05. NS=not significant.

Table 88. Cumulative watermelon yields across harvest dates to N management.

N Rate (kg/ha)	N Source	Harvest dates			
		5/26	6/1	6/7	6/15
		MT/ha			
Control	--	11.8	19.7	19.7	25.6
100	CRN	7.3	17.1	22.2	27.9
200	CRN	33.9	6.1	14	23.9
200	UAN32 Drip	6.8	26.4	33.0	35.9

LSD=Least significant difference at P=0.05. NS=not significant.

Table 89. Application protocol of fertilizer treatments and yield components of lettuce on August 23

Material	Additive Rate	Total Fertilizer N/A	Fresh Biomass tons/A	Mean head lbs	% solids	Dry Biomass lbs/A	N uptake lbs/A	Tissue %N
Untreated	---	0	19.65 a	1.3	6.9	2,680.1	47.4 a	1.8
Standard (UN32)	---	150	37.92 c	2.4	5.9	4,507.0	127.4 e	2.8
Moderate (UN32)	---	80	33.17 b	2.1	6.0	3,961.2	93.8 bc	2.4
AR-034	2 gallons/ 100 lbs N fert	80	32.20 b	2.1	5.8	3,714.6	95.6 bcd	2.6
Nutrasphere	9.0 fl oz/A	116	34.30 b	2.2	5.6	3,851.0	106.2 cd	2.8
Nutrasphere	9.0 fl oz/A	80	32.14 b	2.0	5.5	3,526.8	91.3 b	2.6
7-0-1-7-7	---	80	33.06 b	2.1	5.6	3,717.8	107.0 d	2.9
7-0-1-7-8	---	80	32.19 b	2.1	5.9	3,777.4	95.6 bcd	2.5
BioWish Crop Liquid	0.4% wt/wt fert	80	32.74 b	2.1	6.0	3,908.4	99.1 bcd	2.5
BioWish Crop 16-40-0	1.0 lb/A	80	32.27 b	2.1	6.0	3,844.6	101.4 bcd	2.6
Pr>F treat			0.0001	0.0001	0.0047	0.0001	0.0001	0.0001
$LSD_{0.05}$			3.14	0.2	0.6	369.1	12.8	0.2

Table 90. Mineral nitrogen levels in the top foot of soil on six evaluation dates during the crop cycle

Material	Additive Rate	Fertilizer total N/A	June 20		July 11		July 25		Aug 1		Aug 7		Aug 18	
			NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N
Untreated	---	0	1.0	12.1	0.6	10.0	0.5	1.9	0.5	4.3	0.4	5.7	0.5	9.0
Standard	---	150	1.0	12.1	0.5	10.6	1.0	4.9	1.7	19.2	1.1	13.8	1.4	21.5
Moderate	---	80	1.0	12.1	0.5	14.6	0.7	3.8	0.9	9.6	1.3	14.2	0.8	10.7
AR-034	2 gallons/ 100 lbs N fert	80	1.0	12.1	0.4	14.0	1.1	6.8	0.9	13.4	0.5	6.7	0.6	7.0
Nutrasphere	9.0 fl oz/A	116	1.0	12.1	0.6	13.4	0.8	3.1	1.2	13.2	0.8	12.1	0.9	14.2
Nutrasphere	9.0 fl oz/A	80	1.0	12.1	0.6	13.1	0.6	2.8	1.2	14.1	1.1	15.2	0.7	10.0
7-0-1-7-7	---	80	1.0	12.1	0.4	13.3	0.6	3.3	1.7	15.5	1.0	11.0	1.0	14.5
7-0-1-7-8	---	80	1.0	12.1	0.5	10.7	0.7	3.6	1.1	7.7	0.5	8.1	0.7	11.5
BioWish Crop Liquid	0.4% wt/ wt fert	80	1.0	12.1	0.6	11.4	0.8	4.7	1.4	12.3	0.9	15.2	0.8	8.1
BioWish Crop 16-40-0	1.0 lb/A	80	1.0	12.1	0.5	9.9	0.9	4.3	0.8	9.1	0.7	10.5	0.6	7.9
Pr>F treat			---	---	0.9181	0.5177	0.2454	0.2986	0.0024	0.005	0.0136	0.315	0.067	0.0049
$LSD_{0.05}$			---	---	NS	NS	NS	NS	0.6	6.6	0.5	NS	0.5	6.7

Table 91. Response of lettuce to N management.

Treatments	Yield	Leaf N	Soil NH4-N	Soil NO3-N
	MT/ha	%	mg/kg	mg/kg
Control	22.3	1.66	4.8	8.3
200 kg N/ha UAN32	31.2	2.32	6.5	230
175 kg N/ha (30% SYMTRX20S PP and 70% UAN32 SD)	39.8	2.54	6.2	182
175 kg N/ha (60% CRN 120 PP and 40% UAN32 SD)	35.3	2.17	5.8	53.1
175 kg N/ha (60% CRN120 PP and 40% SYMTRX20S PP)	35.3	2.18	5.2	16.5
175 kg N/ha (30% AMS PP and 70% UAN32 SD)	35.0	2.53	3.6	144
LSD	9.0	0.39	2.4	74.7

LSD is least significant difference at P<0.05. NS is not significant P>0.05. SD=side dress; PP=pre-plant; AMS=ammonium sulfate.

Table 92. Response of broccoli to N management.

Treatment	Date		
	2/4	2/12	Total
	Yield (MT/ha)		
200 kg N/ha UAN 32	9.3	16.4	25.6
175 kg N/ha CRN 120	7.9	8.6	16.5
175 kg N/ha CRN 90	7.6	7.6	15.2
75 kg N/ha CRN 120 plus 100 kg N/ha UAN 32	9.8	10.7	20.5
75 kg N/ha CRN 90 plus 100 kg N/ha UAN 32	11.9	5.5	17.4
	1.9	4.9	4.8

LSD is least significant difference at P<0.05. NS is not significant P>0.05.

Table 93. Response of cauliflower to N management

Treatment	Date		
	1/12	1/17	Total
	Yield MT/ha		
200 kg N/ha UAN 32	3.7	26.6	30.3
175 kg N/ha CRN 90	37.9	5.2	43.1
175 kg N/ha CRN 120	34.6	8.2	42.8
75 kg N/ha CRN 120 plus 100 kg N/ha UAN 32	15.0	27.5	42.5
75 kg N/ha CRN 90 plus 100 kg N/ha UAN 32	31.2	18.2	49.4
LSD	13.2	10.9	15.4

LSD is least significant difference at P<0.05. NS is not significant P>0.05.

Table 94. Response of cabbage to N management.

Treatment	Date		
	1/16	1/24	Total
	MT/ha		
200 kg N/ha UAN 32	85.4	10.4	95.8
175 kg N/ha CRN 120	68.5	9.4	77.9
175 kg N/ha CRN 90	78.7	10.7	89.4
75 kg N/ha CRN 120 plus 100 kg N/ha UAN 32	91.3	11.1	102.4
75 kg N/ha CRN 90 plus 100 kg N/ha UAN 32	110.0	6.8	116.6
LSD	22.8	NS	18.7

LSD is least significant difference at P<0.05. NS is not significant P>0.05.

Table 95. Yield of onion to N management.

Treatments	Yield	Leaf N	Soil NH4-N	Soil NO3-N
	MT/ha	%	mg/kg	mg/kg
Control	22.3	1.66	4.8	8.3
200 kg N/ha UAN32	31.2	2.32	6.5	230
175 kg N/ha (30% SYMTRX20S PP and 70% UAN32 SD)	39.8	2.54	6.2	182
175 kg N/ha (60% CRN 120 PP and 40% UAN32 SD)	35.3	2.17	5.8	53.1
175 kg N/ha (60% CRN120 PP and 40% SYMTRX20S PP)	35.3	2.18	5.2	16.5
175 kg N/ha (30% AMS PP and 70% UAN32 SD)	35.0	2.53	3.6	144
LSD	9.0	0.39	2.4	74.7

.LSD is least significant difference at P<0.05. NS is not significant P>0.05. SD=side dress; PP=pre-plant; AMS=ammonium sulfate

Table 96. Response of carrot to N management.

	Yield MT/ha		Soil NH4-N	Soil NO3-N	Leaf N
	US1	US2	mg/kg	mg/kg	%
175 kg N/ha CRN 120	46.3	21.1	5.8	161	1.4
175 kg N/ha CRN 90	44.9	21.8	5.4	106	1.8
75 kg N/ha CRN 120 plus 100 kg N/ha UAN 32	45.2	19.4	5.0	14.1	1.3
75 kg N/ha CRN 90 plus 100 kg N/ha UAN 32	46.1	21.6	5.7	38.5	1.8
LSD	NS	NS	NS	99.9	NS

LSD is least significant difference at P<0.05. NS is not significant P>0.05.

Table 97. Response of celery to N management.

Treatment	Yield (MT/ha)
200 kg N/ha UAN 32	52.4
175 kg N/ha CRN 120	51.4
175 kg N/ha CRN 90	45.8
75 kg N/ha CRN 120 plus 100 kg N/ha UAN 32	77.3
75 kg N/ha CRN 90 plus 100 kg N/ha UAN 32	75.1
LSD	

LSD is least significant difference at P<0.05. NS is not significant P>0.05.

Table 98. Response of artichokes to N management.

Treatment	Date			
	4/18	5/1	5/16	Total
	Yield (MT/ha)			
200 kg N/ha UAN 32	3.1	4.1	7.7	14.9
175 kg N/ha CRN 120	3.0	5.7	8.3	17.1
175 kg N/ha CRN 90	2.7	3.8	8.9	15.4
75 kg N/ha CRN 120 plus 100 kg N/ha UAN 32	4.9	5.9	9.3	20.1
75 kg N/ha CRN 90 plus 100 kg N/ha UAN 32	4.8	5.4	8.8	18.9
	NS	NS	NS	NS

LSD is least significant difference at P<0.05. NS is not significant P>0.05.

Table 99. Response of spinach to N management.

Treatment	Yield	Leaf N	Soil NH4-N	Soil NO3-N
	MT/ha	%	mg/kg	mg/kg
Control	4.4	2.7	6.5	
UAN32	0	--	4.3	
30% SYNTRX20S PP and 70% UAN32 WR	1.1	2.6	6.0	
30% 17113-2 PP and 70% UAN32 WR	2.3	2.8	7.7	
30% AMS and 70% UAN32 WR	1.3	2.6	10.0	
60% ESN PP and 40% UAN32 WR	3.0	3.1	7.8	
60% ESN PP and 40% SYTRX20S PP	6.9	2.9	10.9	
60% ESN PP and 40% 17113-2 PP	5.4	2.9	19.5	
LSD	2.9	0.4	9.8	

LSD is least significant difference at $P<0.05$. NS is not significant $P>0.05$.

Table 100. Response of sweetcorn to N management.

Treatment	Yield	Leaf N
	kg/ha	%
Control	3758	1.32
UAN32	3481	1.15
30% SYNTRX20S PP and 70% UAN32 SD	3696	1.22
30% 17113-2 PP and 70% UAN32 SD	4854	1.29
30% AMS and 70% UAN32 SD	5254	1.21
60% ESN PP and 40% UAN32 SD	6031	1.28
60% ESN PP and 40% SYTRX20S PP	5054	1.23
60% ESN PP and 40% 17113-2 PP	5665	1.35
LSD	2176	NS

LSD is least significant difference at $P<0.05$. NS is not significant $P>0.05$ LSD is least significant difference at $P<0.05$. NS is not significant $P>0.05$ LSD is least significant difference at $P<0.05$. NS is not significant $P>0.05$.

Table 101. Yield of chile pepper to N management and irrigation method by harvest date.

N Rate	N Source	Irrigation	Date		
			6/5	6/18	7/5
			Yield MT/ha		
0	--	Furrow	0.5	1.03	2.75
0	--	Drip	1.4	1.84	3.23
100	CRN 120	Furrow	4.4	3.19	4.21
100	CRN 120	Drip	1.7	1.98	1.77
200	CRN 120	Furrow	5.2	5.10	5.33
200	CRN 120	Drip	2.2	2.66	5.32
200	UAN 32	Furrow	2.5	5.75	6.85
200	UAN 32	Drip	0.8	1.62	2.60
Irrigation			**	**	**
Treatment (LSD)			1.81	1.21	1.32
Irrigation by Treatment			*	**	**

*,** main effects significant at the 5 and 1% levels, respectively. LSD at P<0.05. NS=not significant.

Table 102. Cumulative yield of chile pepper to N management and irrigation method across harvest dates.

N Rate	N Source	Irrigation	Date		
			6/5	6/18	7/5
			MT/ha		
0	--	Furrow	0.54	1.57	4.31
0	--	Drip	1.43	3.27	6.51
100	CRN 120	Furrow	4.35	7.54	11.75
100	CRN 120	Drip	1.70	3.69	5.47
200	CRN 120	Furrow	5.16	10.27	15.6
200	CRN 120	Drip	2.21	4.88	10.2
200	UAN 32	Furrow	2.51	8.25	15.1
200	UAN 32	Drip	0.80	2.43	5.02
Irrigation			**	**	**
Treatment (LSD)			1.8	2.2	2.8
Irrigation by Treatment			*	**	**

*,** main effects significant at the 5 and 1% levels, respectively. LSD at P<0.05. NS=not significant.

Table 103. Yield of tomato N management and irrigation method by harvest date.

N Rate	N Source	Irrigation	Date				
			6/6	6/13	6/19	6/25	7/3
			Yield MT/ha				
0	--	Furrow	0.2	1.5	5.8	12.0	32.4
0	--	Drip	1.0	4.1	15.9	31.1	14.3
100	CRN 120	Furrow	0.6	7.6	21.9	21.7	19.2
100	CRN 120	Drip	0.8	5.5	23.7	49.5	14.0
200	CRN 120	Furrow	2.5	8.0	23.6	20.7	26.4
200	CRN 120	Drip	0.7	4.2	20.0	38.8	18.1
200	UAN 32	Furrow	1.2	3.0	9.8	22.9	27.7
200	UAN 32	Drip	3.5	7.4	13.2	36.9	12.9
Irrigation			NS	NS	NS	**	**
Treatment (LSD)			2.0	3.1	9.7	14.0	NS
Irrigation by Treatment			NS	NS	NS	NS	NS

*,** main effects significant at the 5 and 1% levels, respectively. LSD at P<0.05. NS=not significant

Table 104. Cumulative yield of tomato to N management and irrigation method across harvest dates.

N Rate	N Source	Irrigation	Date				
			6/6	6/13	6/19	6/25	7/3
			MT/ha				
0	--	Furrow	0.2	1.6	7.4	19.4	51.9
0	--	Drip	1.0	5.1	21.0	52.0	66.4
100	CRN 120	Furrow	0.6	8.2	30.1	51.8	71.7
100	CRN 120	Drip	0.8	6.3	30.0	79.5	93.5
200	CRN 120	Furrow	2.5	10.5	34.1	54.8	81.2
200	CRN 120	Drip	0.7	4.9	24.8	63.7	81.8
200	UAN 32	Furrow	1.2	4.2	14.1	36.9	64.6
200	UAN 32	Drip	3.5	10.9	24.1	61.1	74.0
Irrigation			NS	NS	NS	**	**
Treatment (LSD)			NS	3.8	8.6	17.2	22.3
Irrigation by Treatment			NS	**	*	NS	NS

*,** main effects significant at the 5 and 1% levels, respectively. LSD at P<0.05. NS=not significant

Table 105. Yield of watermelon to N management and irrigation method by harvest date.

N Rate	N Source	Irrigation	Date			
			6/14	6/20	6/28	7/3
			MT/ha			
0	--	Furrow	0	2.3	1.1	8.0
0	--	Drip	0	2.9	11.9	12.0
100	CRN 120	Furrow	1.6	10.7	6.8	4.7
100	CRN 120	Drip	4.2	5.9	10.0	5.9
200	CRN 120	Furrow	0	4.0	11.1	6.9
200	CRN 120	Drip	2.3	10.2	14.9	4.6
200	UAN 32	Furrow	6.5	3.4	7.6	3.6
200	UAN 32	Drip	0	13.2	7.6	5.8
Irrigation			NS	NS	*	NS
Treatment (LSD)			2.8	5.1	7.6	NS
Irrigation by Treatment			*	*	NS	NS

*,** main effects significant at the 5 and 1% levels, respectively. LSD at P<0.05. NS=not significant

Table 106. Cumulative yield of watermelon to N management and irrigation method across harvest dates.

N Rate	N Source	Irrigation	Date			
			6/1	6/20	6/28	7/3
			MT/ha			
0	--	Furrow	0	2.3	3.4	11.4
0	--	Drip	0	2.9	14.8	26.8
100	CRN 120	Furrow	1.6	12.3	19.0	23.7
100	CRN 120	Drip	4.2	10.7	20.0	25.9
200	CRN 120	Furrow	0	4.0	15.1	22.0
200	CRN 120	Drip	2.3	12.5	27.4	32.0
200	UAN 32	Furrow	6.5	10.0	17.5	21.1
200	UAN 32	Drip	0	13.2	20.8	26.6
Irrigation			NS	NS	**	**
Treatment (LSD)			2.8	6.5	10.8	10.0
Irrigation by Treatment			*	NS	NS	NS

*,** main effects significant at the 5 and 1% levels, respectively. LSD at P<0.05. NS=not significant

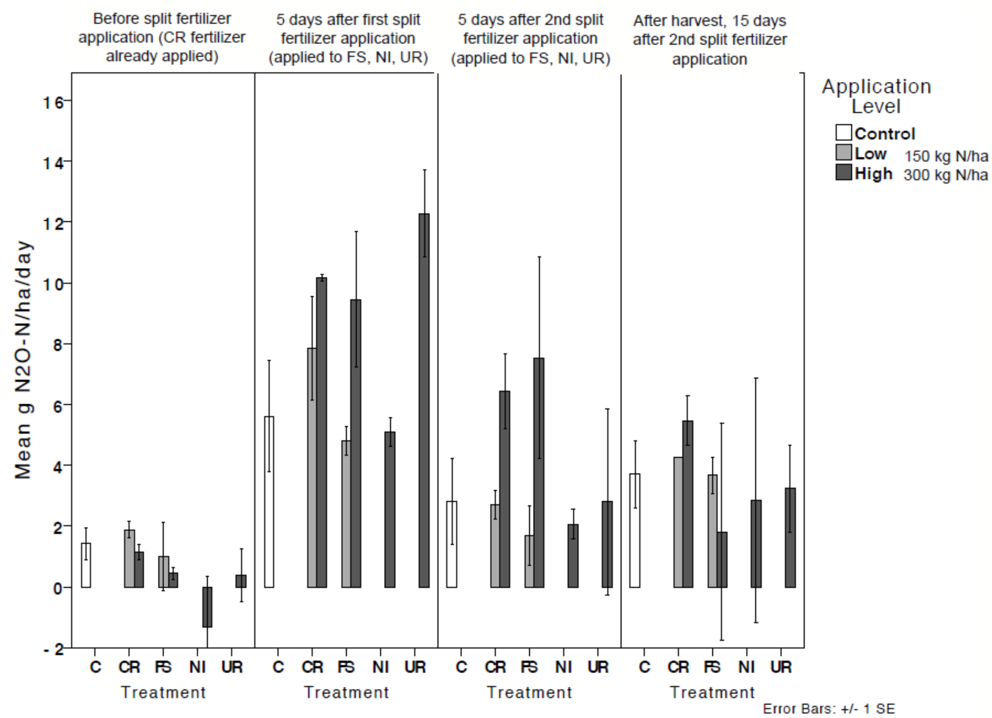

Figure 1. Nitrous oxide emissions from selected N management practices.