Title: Verification and Development of Best Management Practices for Conventionally and Organically Grown Carrots in the Sandy Soils of the Suwannee Valley

Funding Source: FDACS, Office of Ag Water Policy, Grant Award ID: 023490

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Co-PIs: Robert Hochmuth and Danielle Treadwell, UF/IFAS

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Summary and Recommendations of Conventional Nitrogen Research

Conventional N Study (2 Years)

This two-year research project evaluated various nitrogen rates using conventional nitrogen sources when growing four carrot cultivars. Response to nitrogen rate was similar regardless of cultivar in this trial. The current University of Florida recommendation for nitrogen rate in carrot is 175 lbs per acre. This trial showed significant increase in carrot yield up to at least 150 lbs per acre, then levelling off at rates above 200 lbs per acre. The statistical model identifies 184 lbs per acre as the optimum rate based on the quadratic plateau model having the best fit of the data. The results of this trial were similar in terms of the yield across nitrogen rates and cultivars in both years. The specific cultural practices and nitrogen application methods used in this trial are very important. The key application methods included: all nitrogen was applied with a drop spreader (modified banded pattern) to the entire bed top and none was applied to the area between the beds (tire track area), nitrogen applications were split several times over the season (highest rates included applications near weekly most of the season), and soil moisture sensors were used to manage irrigation events to help assure there were adequate moisture levels and minimize leaching nitrogen from the carrot root system. Without implementing the specific best management practices used in this trial, it is unlikely that the same result of 184 lbs per acre would be the optimum rate for carrot yield. Inefficiencies of using broadcast applications of nitrogen fertilizer, especially early in the carrot season, would likely result in higher nitrogen rates being needed to attain the same yield. Future nitrogen recommendations should include a discussion of best management practices as well as rate. Consideration of changing the recommended nitrogen rate slightly above 175 lbs per acre seems to be justified if these best management practices are part of that discussion.

Controlled Release Nitrogen Study (1 Year)

This one-year research trial of controlled release forms of nitrogen fertilizer in carrot production showed the potential of this technology as a best management practice. Many of the controlled release nitrogen treatments produced similar yield and quality to conventional nitrogen sources using other irrigation and fertilizer BMPs. A second year of research is needed to confirm the results in the first year. Future fertilizer and irrigation BMP research should include controlled release sources of nitrogen.

Conventional Nitrogen Rate and Cultivar Two-Year Research Trial Summary

MANUSCRIPT DRAFT

To be submitted to HortScience, Journal of the American Society for Horticultural Science

Yield and Quality of Four Carrot Cultivars and Eight Nitrogen Rates Using Best Management Practices in North Florida Sandy Soils

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Additional index words. plant nutrition, 4-Rs Principles, nitrogen use efficiency, plant tissue nitrogen, *Daucus carota*

Abstract. **Carrot [*Daucus carota* L. var. *sativus* Hoffm.] production acreage has increased significantly in North Florida and South Georgia in the past five years. Deep sandy soils, moderate winter climate, availability of irrigation water, and proximity to eastern markets are favorable for carrot production in the region. Nitrogen (N) is required for successful carrot production and the current recommended N rate in Florida is 175 lb per acre. The objective of this study was to evaluate/verify the recommended N rate for the sandy soils of North Florida using the industry standard cultivars. Carrot cultivars for the cello market, 'Choctaw' and 'Maverick', and cultivars for the cut and peel market, 'Triton' and 'Uppercut 25', were direct seeded on 40-inch pressed bed tops on October 29, 2016 and November 2, 2017 in Live Oak, Florida. Eight N rates (50, 100, 150, 200, 250, 300, 350, and 400 lb per acre) were used and regression analyses were used to determine the optimum N rate for carrot in North Florida. The results from a quadratic plateau regression for both seasons combined indicated 184 lb per acre of N as the optimum rate for producing carrots, regardless of cultivar. In conclusion, all four cultivars seem suitable for North Florida production except for 'Uppercut 25' when a severe winter is forecasted. This study resulted in valuable information on best management**

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practices for carrot production in Florida, especially nutrient stewardship as these results show the importance of the practices of right placement, timing and rate to increase N use efficiency.

For the past decade, the United States has been a net importer of fresh or chilled carrots (USDA-ERS, 2019). The average annual fresh market carrot production in the United States between 2008 and 2018 was 1.32 million tons (USDA-NASS, 2019). Florida carrot production is destined primarily to the fresh market and acreage has more than doubled between 2007 and 2017, totaling 4,256 acres (USDA-NASS, 2019). Florida carrots have historically been grown primarily on high organic matter soils (muck soils) in Central and South Florida. Muck soils require very low nitrogen inputs, whereas carrot production on sandy soils requires high nitrogen inputs. Most of the carrot production on muck soils was stopped in 1998 when the state purchased much of the environmentally sensitive lands in the Zellwood, FL area around Lake Apopka where much of the carrot acreage was located. After the Zellwood area carrot production stopped, some acreage of carrots was initiated in the North Florida area but remained relatively small until about 2015. During that time, as a result of California water shortages in carrot production areas, two large carrot producers from California began purchasing land and carrot processing infrastructure in North Florida and South Georgia to initiate increased production in the southeastern United States. In addition, smaller ventures of carrot production were initiated by existing growers in this same region resulting in those carrots being shipped long distances to processing and packing facilities in the northern United States and Canada. The North Florida and South Georgia region has several characteristics favorable for this significant increase in carrot acreage. The region has a moderate winter climate favorable for carrot production, adequate availability of large tracts of agricultural land with deep sandy soils, a currently abundant supply of high-quality ground water for irrigation, proximity to a large agricultural allied industry with input suppliers, and ready access to large consumer markets on the east coast.

North Florida's deep sandy soils are excellent for production of carrots, but are also vulnerable to leaching nutrients, especially nitrogen. The recent 2018 proposal and pending adoption of a Basin Management Action Plan (BMAP) (FDEP, 2018) for much of the Suwannee River Basin of North Florida has led the University of Florida research and extension faculty to evaluate nitrogen management strategies for conventional carrot production in sandy soils including, but not limited to, nitrogen rates. The impairment to the water bodies in this BMAP area has been identified as nitrogen and therefore guiding the focus of this research. There is also a need for more research on the adoption of best management practices (BMPs) such as the efficient cultural practices advocated in the 4-Rs Principles (Right: rate, source, placement, and timing), as well as adoption of efficient irrigation management practices. The adoption of a BMAP in a region makes it mandatory for farmers to follow BMPs and to reach the recommended nitrogen rate. Since carrot is a relatively high N requiring crop and very little research had been conducted on carrots in North Florida in sandy soils, it became a high priority crop for Florida agencies such as Florida Department of Agriculture and Consumers Services, Florida

Department of Environmental Protection and the Suwannee River Water Management District to determine the current best management practices for nitrogen use in carrot production.

Nitrogen is often the most limiting nutrient in sandy soils and the current recommended N rate for carrots in Florida is 175 lbs per acre (Liu et. al, 2019). This recommendation for carrots is based on one research study completed in the 1990s in Alachua County (Hochmuth et. al, 1999) as well as other research on carrots grown in similar soils, but in areas outside Florida. Current production practices are somewhat different from those used in past research trials. Since carrot is a relatively new crop to North Florida and the current UF/IFAS recommendation could prove to be obsolete, in part for not reflecting the needs of new cultivars and desired plant populations, bed and row configurations, irrigation management, and fertigation technologies that may all differ in sandy soils; nitrogen research studies needed to be initiated in this region.

The objectives of this study were to determine the optimum nitrogen rate in carrot grown in sandy soils of North Florida using best management practices, to demonstrate the existing nitrogen best management practices for conventionally grown carrots in the region as growers expand production, and to evaluate common commercial cultivars for both cello and cut-and-peel carrot markets.

Materials and Methods

Field trials were conducted at the University of Florida, North Florida Research and Education Center - Suwannee Valley in Live Oak, Florida. The soil series was characterized as Hurricane - Sandy, siliceous, thermic Oxyaquic Alorthods (Weatherspoon, 2006), a typical soil type used for carrot production in North Florida. The soil was prepared and fumigated prior to planting. The soil fumigant Telone II (1,3-dichloropropene, Corteva, Wilmington, DE) was applied at 18 gal/A on 9 Sept. 2016 (2017 Season) and on 13 Oct. 2017 (2018 Season) at 12-14 inches below the soil surface. After fumigation, the soil was irrigated to improve fumigant efficacy. Rye windbreaks were seeded in the spray alleys to reduce damage from wind-blown sand. Dolomitic lime was applied, at a rate of 2000 lb per acre both seasons. Boron was applied at 1 lb per acre on 19 Oct. 2016 and on 27 Oct. 2017, and Sul-Po-Mag (0N-0P_2O_5-22K_2O) was applied at a rate of 400 lb per acre on 20 Oct. 2016 and on 27 Oct. 2017. These fertilizer applications were broadcast applied to the entire field to supply lime and pre-plant nutrients, based on soil test results. An application of preplant fertilizer 13N-4P_2O_5-13K_2O (2017 season) and 14N-4P_2O_5-14K_2O (2018 season) were banded in a 40-inch wide band to the soil surface at 192 lb of N per acre (2017 season) and 180 lbs per acre (2018 season) and rototilled into the top six inches. The soil was then pressed into beds that were 40 inches wide and 4 inches high using a bed press implement. Beds were spaced 72-inches to prevent contamination of nitrogen treatments between beds. The trials were arranged in a split-plot design with randomized complete blocks and four replications.

Main plot. The main plot factor was N application rate. The N application rate range was established to include the University of Florida Institute of Food and Agricultural Sciences guideline of 175 lb N/A (Liu et al., 2019) with rates above and below 175 lb N/A.

In both 2017 and 2018 seasons, eight nitrogen rates were tested in increments of 50 lb N per acre, resulting in rates of 50, 100, 150, 200, 250, 300, 350, 400 lb per acre. The schedule for each nitrogen fertilizer application was chosen to provide the best distribution of nitrogen during the season based on plant growth stage (Table 1). For the 300, 350 and 400 lb N rates weekly applications were made beginning 27 December 2017 and 28 December 2018 to avoid crop damage from excess fertilizer. All plots received 25 lb N per acre before seeding to start all plants in all plots with the same nitrogen rate. The starter fertilizer supplied in 2017 was 13N-$4P_2O_5$-$13K_2O$ and 14N-$4P_2O_5$-$14K_2O$ was used in 2018. In-season N rate treatment applications were made using ammonium nitrate (32N-$0P_2O_5$-$0K_2O$) applied to the 40-inch bed top with a single hopper fertilizer drop spreader, designed for two rows, with four directional spouts modified to apply an even distribution of fertilizer to the single 40-inch bed top (First Products, Tifton, GA). Fertilizer rates were calculated using the linear bed foot method (Hochmuth and Hanlon, 2018) for a bed spacing of 52 inches which is more typical on commercial farms. All nitrogen fertilizer, preplant and top-dress applications, were made to the 40-inch bed area only.

Two broadcast applications of Sul-Po-Mag (0N-$0P_2O_5$-$22K_2O$-22S-11Mg) at rate of 230 pounds per acre were made both seasons on 19 Jan. and 2 Feb. 2017, and on 22 Jan. and 16 Feb. 2018 resulting in 50 lb per acre of potash in each application. Thus, the total potash applied including all preplant and in-season applications was 188 lb/acre and 202 lb/acre for the 2017 and 2018 seasons, respectively. In addition, 46 lb of phosphate per acre was applied on 22 Jan. 2018 to match grower practices in the area.

Sub plot. The subplot factor was carrot cultivar. The four carrot cultivars grown in this study were 'Choctaw' (Nunhems USA, Inc., Parma, ID), 'Maverick' (Nunhems USA, Inc., Parma, ID), 'Triton' (Sakata Seed America, Inc., Morgan Hill, CA) and 'Uppercut 25' (Nunhems USA, Inc., Parma, ID). These cultivars were selected for this trial in consultation with local growers. 'Choctaw' was also selected since previous Florida research was conducted on the cultivar. 'Choctaw' and 'Maverick' are larger carrots used for fresh pack whole carrot (cello type), and 'Triton' and 'Uppercut 25' are smaller diameter carrots used for "cut and peel" or "snack" products.

The cultivars were direct seeded on 29 Oct. 2016 and on 2 Nov. 2017. Carrots were mechanically seeded using a Seed Spider planter (Sutton Agricultural Enterprises, Inc., Salinas, CA). The seeder planted the seed in four rows spaced 1.875 inches apart and ¼ inch deep, then pressed the soil on the bed top firmly with a roller. The final carrot row configuration was two sets of four rows with 12 inches between sets, on a 40-inch pressed bed top. Sub plots were 50 ft long and consisted of four beds, one per cultivar, in each nitrogen rate main plot. Each block contained all eight N rate main plots and was replicated and randomized four times.

Plant stand counts were taken in the 2017 season 45 days after plant emergence to better estimate final plant populations. Final plant populations, in plants per acre, were 402,095 for ‘Choctaw’, 343,979 for ‘Maverick’, 667,553 for ‘Triton’, and 1,010,930 for ‘Uppercut 25’ in 2017 season. Final plant populations in 2018 were estimated at 470,000 for ‘Choctaw’, 460,000 for ‘Maverick’, 850,000 for ‘Triton’, and 850,000 for ‘Uppercut 25’. Target plant populations were provided by local growers using these cultivars and final plant stands were similar to the target populations.

Growing conditions. Cultural practices along with pest and disease management strategies consistent with grower practices were implemented both seasons. The primary disease of concern was *Alternaria* leaf blight which is caused by the fungal agent *Alternaria dauci* (Farrar et. al, 2004). *Alternaria* can directly impact yield by reducing the photosynthetic leaf area and can limit mechanical harvesting as this fungus can cause 50% leaf loss (Paret, 2019). This disease was managed by weekly fungicide applications during weather conditions conducive to disease development using recommended rotations of chemical classes. The primary weed species were cutleaf evening primrose (*Oenothera laciniate*) and wild mustard (*Sinapis arvensis*). Two post emergence applications of linuron based herbicide Lorox DF (NovaSource, Phoenix, AZ), one week apart, were made beginning at the 4-leaf stage of the carrots resulting in excellent weed control.

Irrigation was applied using a low pressure overhead linear move system (Valmont Industries Inc., Valley, NE). Soil moisture was monitored using two soil moisture sensors (EnviroSCAN; Sentek, Stepney, AU) that read soil moisture at 4, 8, 12, 16, and 20-inch depths. Interpretation of moisture movement through the soil profile enabled accurate scheduling and delivery of irrigation during the growing seasons. The irrigation schedule followed standard best management practices for North Florida. Air temperature, growing degree days, rainfall, and solar radiation were collected from a Florida Automated Weather Network (www.fawn.ifas.ufl.edu) weather station located within 100 m of the experiment site.

Plant performance parameters. Cold injury was quantified by ratings using the Horsfall-Barratt semi-quantitative scale and visual assessment as described by Francis (2013). Horsfall and Barratt (1945) proposed a grading system for measuring plant disease severity that is based on 50 percent as a mid-point and the grades differ by a factor of two in either direction. This scale ranges from 1 to 12, one being the lowest rating (no infection) and 12 being 100 percent infection. Using the Horsfall-Barratt method can minimize human error in interpreting the percentage of foliage damaged. Observations were triggered if observed air temperatures were 30 degrees F or below and cold injury ratings were taken if injuries were apparent.

Samples of most recently matured leaves were submitted for leaf tissue N analysis on two occasions in each season, on 10 Feb. and 14 Mar. 2017 and on 7 Feb. and 15 Mar. 2018. Each sample consisted of at least 25 complete leaves, blade and petiole. Samples were submitted to the Waters Agricultural Labs (Camilla, GA) where the plant tissue was processed and analyzed

for total Kjeldahl nitrogen (reported as percent N). Average plant height (inches) was taken in each plot one week prior to harvest by measuring the plant foliage height among the most representative plants within the plot.

Yield and carrot quality characteristics. Carrots were harvested based on predicted harvest date from local growers, primarily, in conjunction with target size ranges for 'Choctaw' and 'Maverick'. When the target date was approaching, a few carrots per treatment were sampled for a general assessment of the percentage of carrots that reached marketable length and width to verify the selected harvest date was correct. Harvests were carried out on 10 and 11 Apr. 2017, and 19 and 20 Apr. 2018. Carrots were loosened from the soil by undercutting the beds with a metal undercutter blade on a 3-point hitch. The undercutter was lowered approximately 15 inches below the top of the bed. A 20-ft sub plot in the center of each 50-ft plot was used for yield data collection. The carrots were hand-pulled from the 20-ft sub plot, tops were removed by hand and carrots were bagged in the field. Total harvested weight (lb) per sub plot was measured and recorded. Individual carrot weights, diameter at the top of the carrot, length of carrot and a total weight of 15 randomly selected carrots from each plot each year were recorded on the same day as harvest. From this data, the grade of each carrot was determined using the U. S Department of Agriculture grades and standards for topped carrots (USDA, 1965).

Statistical analysis. Data were analyzed using the Generalized Linear Mixed Model, Regression, and Nonlinear Regression Procedures of SAS (SAS Version 9.4; SAS Inst. Inc., Cary, NC). A two-way analysis of variance was performed for yield and carrot quality data to determine significance of main effects and presence of interaction among N rate and cultivar. Means separation was used to examine differences between nitrogen rates within each cultivar treatment. Regression analysis was used to determine if a linear or quadratic relationship existed for nitrogen rate treatments. Both seasons were treated as separate experiments for data analysis except for the overall regression of nitrogen application rate and marketable yield.

Results

Growing season weather. Weather was generally favorable for carrot production in both seasons largely due to relatively dry weather conditions. Figure 1 shows the growing season trends of maximum and minimum air temperatures with cumulative growing degree days and daily rainfall with daily, weekly, and cumulative solar radiation for both 2017 and 2018 growing seasons. Rainfall trends were similar during both seasons with the exception of one rain event on 28 January 2018 that may have caused nutrient leaching.

Cold injury ratings. Significant differences in cold injury ratings were seen between N rates (Table 2) and between carrot cultivars (Table 3) but the interaction between N rate and cultivar was not significant in either year. During the 2017 season, the lowest recorded temperature was 25.3˚ F (Fig. 1) on 8 January 2017 (71 DAP). Cold injury was observed throughout the trial but the injury to the crop was considered minor because only the extreme tips of the foliage

showed signs of injury (Table 2). Although there were significant differences between the N treatments, the differences were biologically insignificant. Minor cold injury to the carrot foliage was also observed and recorded on 16 March 2017 (138 DAP) when temperatures reached a minimum of 28.22˚ F (data not shown). During the 2018 season, the lowest recorded temperature was 21.7˚ F on 18 January 2018 (77 DAP) among six nights with temperatures reaching less than 28.0˚F and very minor cold injury was reported (data not shown). Cold injury to the carrot foliage was observed and recorded after a late cold event on 15 March 2018 (133 DAP) when temperatures reached a min of 28.1˚ F.

Significantly higher cold injury ratings of 4.5 to 5.8 (12 to 25% foliage damage) were recorded in plants that were treated with 150, 300, 350, and 400 lb/acre of N in comparison to plants fertilized with 50 and 100 lb/acre of N that were rated at 4.0 and 4.2, respectively (6 to 12% foliage damage) in 2017. In 2018, plants treated with 400 lb/acre of N showed 12 to 25% foliage damage (5.1 rating), statistically higher than plants treated with any other N rate. According to the Horsfall-Barratt scale ratings, no foliage damage was observed in plants treated with 50 lb/acre of N in 2018. A general trend was seen both years with increased injury at higher N rates as compared to lower N rates.

Cold injury ratings were significantly different between carrot cultivars (Table 3). The cultivar Choctaw had statistically lower injury ratings when compared to all other varieties in both seasons and in 2018 'Choctaw' showed virtually no foliage damage from cold injury. The cultivar Uppercut 25 showed statistically higher foliage damage when compared to all other cultivars in 2017 and had the highest injury rating of all cultivars, 6.9 rating, at 25 to 50% foliage damage.

Leaf N concentration. A trend in leaf N concentration was observed in both seasons in that leaf N concentrations increased as N rates increased (Table 2). Despite the statistical differences found among N rate treatments, measured leaf N concentrations were above the current recommendation for Florida grown carrots of 1.8-2.5 % N 60 days after seeding and 1.5-2.5 % N during harvest (Hochmuth et al., 2018). There were some significant differences in leaf N concentration between carrot cultivars, but the differences were not consistent across sampling dates and between years. There was no interaction between N rate and cultivar for leaf N concentrations.

Plant height. Plants fertilized with 50 lb N/A were significantly shorter than plants fertilized with any other N rate (Table 2). There were significant differences in plant heights among the cultivars (Table 3). The cultivars Triton and Uppercut 25 plant heights were taller than 'Choctaw' or 'Maverick' in both seasons. Although there were significant differences in plant heights, carrots from all N treatments and from all cultivars were tall enough to allow for mechanical harvest with a carrot top lifter harvester type, which requires at least 6 to 8 inches of foliage. There was no interaction between N rate and cultivar for carrot height.

Yield. Total yield was considered equivalent to marketable yield because in both seasons >95% of the yield was marketable according to the USDA grades and standards (data not shown). There were no significant differences in the interaction between nitrogen rate and cultivar for

total yield in 2017 and 2018, thus the main effect of nitrogen application rate and carrot cultivar were examined.

In both seasons, N rate had a significant effect on marketable yield such that, plants fertilized with 50 lb N /acre resulted in the lowest yield, followed by plants fertilized with 100 lb N /acre (Table 2). It was also seen in both years that carrots fertilized with 150 lb N /acre or more yielded 29.7 to 33.2 tons per acre and there were no significant differences in yield. The interaction between nitrogen rate and cultivar was not significant.

There were significant differences in marketable yield between cultivars in 2018 however, there were no differences in yield between cultivars in 2017 (Table 3). The cut and peel cultivar Triton yielded the highest, followed by ‘Uppercut 25’ and ‘Maverick’. The cello cultivar Choctaw yielded the lowest at 26.6 tons/acre (mean across all N rates), yet, the yield was within the North Florida industry expected yield of 25 to 30 tons per acre.

Carrot marketable yield data from both years were combined for an overall regression analysis with all N applications rates and carrot cultivars. There was a significant quadratic response of marketable yield to the increase of N rate application (Figure 2). According to the first derivative of the function, the optimum N fertilizer application rate was 184 lb per acre with a respective marketable yield of 31.8 tons per acre.

Carrot quality characteristics. Carrot diameter, root length, and individual weight showed a significant interaction between cultivar and N application rate however, with the exception of the 50 lb N /acre treatment, all cultivars and all N rates produced carrots of acceptable length, diameter and individual weight (data not shown). Considering USDA and industry parameters, carrot diameter, length and individual weight for the cultivars used in this study, do not seem to be sensitive to the N application rates that were tested.

Table 4 and Table 5 show the interaction of N rate and carrot cultivar on carrot diameter and carrot length, respectively. The United States Department of Agriculture (USDA) established quality grades and standards for topped carrots. Each carrot sold under U.S. Extra No. 1 and U.S. No.1, the higher quality categories, have diameter of not less than ¾ inch or more than 1-1/2 inches, and the length is not less than 5 inches (USDA, 1965). Both cello cultivars Choctaw and Maverick achieved the marketable diameter across all N rates in 2017 and 2018 (USDA, 1965). The cultivars Triton and Uppercut 25 did not achieve 0.75 inches of diameter when fertilized with 50, 100, and 400 lb N /acre in 2017 and the same was true for ‘Uppercut 25’ when fertilized with 50 lb N /acre in 2018.

All cultivars across all N rate treatments were longer than the 5 inches for desirable market. ‘Choctaw’, ‘Triton’, and ‘Uppercut 25’ were significantly shorter when fertilized with 50 lb per acre of N.

Table 6 shows the interaction effects of the N rate and carrot cultivar on individual carrot weight.

Discussion

Maintaining a healthy strong carrot top for top lifter types of harvesters is very important. Maintaining a healthy top (foliage) means maintaining adequate disease control and providing sufficient plant nutrition, including nitrogen. In the two years of this study, even the low N rates were able to maintain carrot tops tall enough to be harvested, but without adequate disease control, the lowest N rate of 50 lbs per acre would have been at greater risk of not having sufficient height or adequately healthy tops.

Leaf N concentrations were consistently above the reported recommended adequate ranges (Hochmuth et al., 2018). Westerveld et al. (2003) analyzed how reliable leaf tissue nitrogen concentrations are for predicting the need for additional N applications in carrot. Leaf N concentrations from those trials “corresponded to published critical N concentrations in some cases, however, the use of published critical N concentration could have resulted in either over or under-application of N applications to the crops. Cultivar, soil type, and climate were shown to affect tissue N concentration. Based on these results, it was concluded that local research and field verification is required before leaf tissue N critical nutrient concentrations become useful for determining fertilizer needs of carrots grown in Ontario, Canada”.

Carrots were harvested based on predicted harvest date from local growers, primarily, in conjunction with target size ranges for ‘Choctaw’ and ‘Maverick’. ‘Triton’ and ‘Uppercut 25’ were much smaller than expected for optimum harvest. Carrot population was reduced on the second season since first season data showed carrots were a bit small, but also they could be smaller because cut and peel were harvested a bit earlier. In future years, ‘Choctaw’ and ‘Maverick ‘should be separated from ‘Triton’ and ‘Uppercut 25’ into two separate harvests/experiments. Although the cut and peel cultivars did not meet the 0.75-in diameter at the lowest N rate, cut and peel cultivars may not be held to the same fresh market standards as the cello cultivars.

The yield results of the nitrogen rate trials over both seasons showed the nitrogen rates of 50 and 100 lbs per acre resulted in lower yields than all other rates. All plots received 25 lbs per acre before seeding so to get all plants established uniformly before the implementation of the various N regimes for the different rates. The yields found in nitrogen rates of 150 lbs per acre and above resulted in yields that were not significantly different. When the yield data was plotted and analyzed for the “best fit” line, it was found that a linear plateau model line was the best fit. In both years, the yield data was very similar, and the linear plateau model was the best fit in both years. The computer model using a linear plateau shows 184 lbs per acre to be the point where the optimum yield is found. The data indicates yields level off after 184 lbs per acre. This would indicate the current rate guideline in Florida of 175 lbs per acre is slightly lower than this two-year study would suggest. This slight increase above the current N rate (175 lbs/A) could also be due to higher plant populations and improved modern cultivars used today.

Warncke (1996) also showed that carrot yields often do not respond to increasing N application rate.

The research study reported here used very specific best management practices to evaluate the various nitrogen rates and all nitrogen applications, preplant and during the season, were made to the bed tops only, using a drop spreader. The bed top was 40 inches and the spacing between bed centers was 52 inches. Therefore, there would be a 12-inch tire track area between each bed which represents about 23% of the land mass in the field. In situations where nitrogen would be broadcast applied with a ground applicator, or applied via fertigation through an overhead irrigation system, the efficiency of those N applications would be much less that the bed top only placement used in this study. The N that is applied between the beds, especially early in the season when the carrot root system is not well developed, is much more vulnerable to being leached after high irrigation or high rainfall events. Growers in the region use a variety of bed configurations and spacings, but most result in tire track areas of at least 15%, some up to 23%. Future BMPs for carrots should include a N rate but must also include specific cultural practices. The other important cultural practices to consider include: bed spacings and configurations, N placement, timing of N applications, and irrigation management. Likewise, in this research, nitrogen was applied in several small split applications, often only one week apart. This frequent application timing plan over the entire season until a couple weeks from harvest supports Westerveld et al. (2006) findings that describes nitrogen uptake of carrots throughout the growing season. This reinforces the benefit of right timing (multiple applications) of N applications. It is likely growers would only be able to attain the 184 lbs per acre rate by utilizing the BMPs associated with the 4-Rs Principles (right: rate, place, source and timing). The correct placement on the bed top only will be essential.

Irrigation during the season was managed by viewing soil moisture sensor data from sensors placed at 4, 8, 12, 16, and 20 inches. Early in the season the moisture is maintained in the top 8-12 inches and as the roots grow to their maximum depth of 12-16 inches, the irrigation is managed to maintain adequate moisture to a depth of 16 inches, but care is taken to prevent irrigation from moving past the 20-inch depth. Westerveld et al. (2006b) indicated that carrot roots can efficiently uptake N 30 cm below the soil surface (11.8 inches). The observations of soil moisture sensor data in this trial suggest maturing carrots (75-90 days after seeding) are able to uptake water and nutrient to 16 inches, but very little at 20 inches.

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Table 1. Nitrogen application schedule per nitrogen rate treatment for both 2017 and 2018 growing seasons. Top dressing applications are show by application date and days after transplanting.

Treatment																
2017 Season	28-Nov	13-Dec	20-Dec	27-Dec	3-Jan	10-Jan	17-Jan	24-Jan	31-Jan	7-Feb	14-Feb	20-Feb	28-Feb	7-Mar	14-Mar	21-Mar
	30	45	52	59	66	73	80	87	94	101	108	114	122	129	136	143
Total N rate[z]	Nitrogen rates for top dressing applications (lb/acre)															
50	10.6											14.4				
100	10.6		10.6					10.1		10.1		10.1		10.1		14.4
150	15.6		15.6			15.6		15.6		15.6		15.6		15.6		15.6
200	21.9		21.9			21.9		21.9		21.9		21.9		21.9		21.9
250	28.1		28.1			28.1		28.1		28.1		28.1		28.1		28.1
300	18.3	18.3		18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
350	21.7	21.7		21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7
400	25.0	25.0		25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
2018 Season	4-Dec	18-Dec	21-Dec	28-Dec	4-Jan	11-Jan	16-Jan	25-Jan	1-Feb	8-Feb	13-Feb	22-Feb	1-Mar	8-Mar	13-Mar	22-Mar
	32	46	49	56	63	70	75	84	91	98	103	112	119	126	131	140
Total N rate[z]	Nitrogen rates for top dressing applications (lb/acre)															
50		8.3						8.3						8.3		
100	10.7		10.7			10.7			10.7			10.7		10.7		10.7
150	15.6		15.6			15.6		15.6		15.6		15.6		15.6		15.6
200	21.9		21.9			21.9		21.9		21.9		21.9		21.9		21.9
250	28.1		28.1			28.1		28.1		28.1		28.1		28.1		28.1
300	18.3	18.3		18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
350	21.7	21.7		21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7
400	25.0	25.0		25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0

[z]The total nitrogen rate for the season (pounds per acre) includes a pre plant application of 25 pounds per acre of N for all treatments.

Table 2. Effect of nitrogen fertilization rate on cold injury foliage ratings, leaf nitrogen concentration, plant height, and total marketable yield for both 2017 and 2018 growing seasons.

Treatment	Cold injury rating[z,y]		Leaf nitrogen[z] (%N) First sampling[x]		Leaf nitrogen[z] (%N) Second sampling[w]		Plant height[z] (inches)		Marketable yield[z] (tons per acre)	
Season 2017										
Nitrogen rate (lb/acre)										
50	4.0	c	2.8	d	3.0	cd	7.9	c	13.8	c
100	4.2	bc	3.2	c	2.8	d	11.4	b	24.6	b
150	5.8	a	3.8	b	3.1	bcd	13.4	a	31.1	a
200	4.5	abc	3.9	b	3.1	abc	13.6	a	32.0	a
250	5.4	abc	3.9	b	3.2	abc	13.2	a	31.3	a
300	5.8	a	4.1	ab	3.4	a	13.3	a	32.1	a
350	5.8	a	4.2	a	3.4	ab	12.9	a	32.6	a
400	5.6	a	4.1	ab	3.4	ab	12.9	a	31.2	a
Significance										
L[v]	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
Q	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
Season 2018										
Nitrogen rate (lb/acre)										
50	1.7	c	3.5	c	2.7	b	11.0	d	21.1	d
100	2.1	c	4.0	bc	2.7	b	13.4	c	26.6	c
150	2.7	bc	4.2	ab	2.8	b	15.4	a	31.9	ab
200	2.3	bc	4.3	ab	3.0	ab	15.1	ab	32.4	ab
250	2.0	c	4.3	ab	3.2	a	15.6	a	33.2	a
300	2.4	bc	4.4	a	3.3	a	15.2	ab	32.4	a
350	3.4	b	4.6	a	3.3	a	15.1	ab	30.6	ab
400	5.1	a	4.5	a	3.3	a	14.1	bc	29.7	b
Significance										
L[v]	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
Q	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	

[z]Values followed by the same letter within a column indicate means are not significantly different ($P \leq 0.05$) with means separation by Tukey-Kramer test.

[y]Ratings are based on the Horsfall-Barratt scale, 1 representing virtually no damage and 12 representing 100% of damage.

[x]First sample for leaf nitrogen concentration was at 104 and at 97 DAP for the 2017 and 2018 season, respectively.

[w]Second sample for leaf nitrogen concentration was at 136 and at 133 DAP for the 2017 and 2018 season, respectively.

[v]L = linear; Q = quadratic response.

Table 3. Effect of carrot cultivar on cold injury foliage ratings, leaf nitrogen concentration, plant height, and total marketable yield for both 2017 and 2018 growing seasons.

Treatment	Cold injury rating[z,y]		Leaf nitrogen[z] (%N) First sampling[x]		Leaf nitrogen[z] (%N) Second sampling[w]		Plant height[z] (inches)		Marketable yield[z] (tons per acre)	
Season 2017										
Cultivar										
Choctaw	3.6	c	3.7	ab	3.3	a	12.0	b	28.4	NS
Maverick	5.0	b	3.9	a	3.3	a	11.3	c	28.4	NS
Triton	5.0	b	3.7	ab	3.1	ab	12.8	a	28.4	NS
Uppercut 25	6.9	a	3.7	b	3.0	b	13.2	a	29.2	NS
Season 2018										
Cultivar										
Choctaw	1.3	b	4.1	NS	3.1	NS	13.9	b	26.6	c
Maverick	2.9	a	4.3	NS	3.1	NS	13.3	b	29.3	b
Triton	3.2	a	4.2	NS	2.9	NS	14.8	a	33.4	a
Uppercut 25	3.4	a	4.2	NS	3.0	NS	15.4	a	29.6	b

[z]Values followed by the same letter within a column indicate means are not significantly different ($P \leq 0.05$) with means separation by Tukey-Kramer test. Values followed by notation NS indicate no significant difference between means.

[y]Ratings are based on the Horsfall-Barratt scale, 1 representing virtually no damage and 12 representing 100% of damage.

[x]First sample for leaf nitrogen concentration was at 104 and at 97 DAP for the 2017 and 2018 season, respectively.

[w]Second sample for leaf nitrogen concentration was at 136 and at 133 DAP for the 2017 and 2018 season, respectively.

Table 4. Interaction effects of nitrogen fertilization rate and carrot cultivar, sliced by cultivar, on postharvest quality attribute, carrot diameter.

Treatment	Carrot diameter (inches)[z]			
	Cello cultivars		Cut and peel cultivars	
	Choctaw	Maverick	Triton	Uppercut 25
Season 2017				
Nitrogen rate (lb/acre)				
50	0.94 d	0.88 b	0.71 b	0.62 b
100	1.25 ab	1.08 a	0.85 a	0.72 ab
150	1.30 a	1.16 a	0.85 a	0.82 a
200	1.29 ab	1.09 a	0.84 a	0.78 a
250	1.09 c	1.15 a	0.89 a	0.79 a
300	1.19 abc	1.13 a	0.86 a	0.80 a
350	1.18 abc	1.18 a	0.90 a	0.75 a
400	1.17 bc	1.14 a	0.82 ab	0.74 ab
Significance				
L[y]	0.122	0.001	0.001	0.002
Q	0.0001	0.0001	0.0001	0.002
Season 2018				
Nitrogen rate (lb/acre)				
50	0.93 c	0.99 c	0.85 ab	0.69 c
100	1.05 b	1.07 abc	0.88 ab	0.78 abc
150	1.27 a	1.14 a	0.91 a	0.82 ab
200	1.13 b	1.10 ab	0.84 ab	0.80 ab
250	1.12 b	1.15 a	0.86 ab	0.85 ab
300	1.07 b	1.04 abc	0.87 ab	0.81 ab
350	1.11 b	1.11 ab	0.85 ab	0.87 a
400	1.04 b	1.02 bc	0.80 b	0.75 bc
Significance				
L[y]	0.420	0.710	0.070	0.004
Q	0.0001	0.0001	0.060	0.0001

[z]Values followed by the same letter within a column indicate means are not significantly different ($P \leq 0.05$) with means separation by Tukey-Kramer test.

[y]L = linear; Q = quadratic response.

Table 5. Interaction effects of nitrogen fertilization rate and carrot cultivar, sliced by cultivar, on postharvest quality attribute, carrot length.

Treatment	Carrot length (inches)[z]							
	Cello cultivars				Cut and peel cultivars			
	Choctaw		Maverick		Triton		Uppercut 25	
Season 2017								
Nitrogen rate (lb/acre)								
50	7.53	b	8.00	a	7.17	b	6.84	c
100	8.60	a	8.01	a	7.98	a	7.81	b
150	8.10	ab	8.24	a	7.97	a	8.69	a
200	8.55	a	7.97	a	8.27	a	8.10	ab
250	8.16	ab	8.12	a	8.42	a	7.97	ab
300	8.35	a	8.43	a	8.02	a	7.79	b
350	8.50	a	8.58	a	8.50	a	8.19	ab
400	7.93	ab	8.43	a	8.32	a	7.75	b
Significance								
L[y]	0.530		0.100		0.032		0.100	
Q	0.400		0.200		0.070		0.120	
Season 2018								
Nitrogen rate (lb/acre)								
50	7.10	c	7.96	b	7.57	c	7.96	b
100	8.08	b	8.47	ab	7.97	abc	8.30	b
150	9.08	a	8.53	ab	7.67	bc	8.64	ab
200	8.56	ab	8.51	ab	7.98	abc	8.70	ab
250	8.40	ab	8.68	ab	8.22	abc	9.18	a
300	8.14	b	8.02	b	8.32	ab	9.14	a
350	8.11	b	8.94	a	8.43	a	9.26	a
400	8.59	ab	8.18	b	8.13	abc	8.19	b
Significance								
L[y]	0.002		0.330		0.0001		0.090	
Q	0.0001		0.040		0.001		0.001	

[z]Values followed by the same letter within a column indicate means are not significantly different ($P \leq 0.05$) with means separation by Tukey-Kramer test.

[y]L = linear; Q = quadratic response.

Table 6. Interaction effects of nitrogen fertilization rate and carrot cultivar, sliced by cultivar, on postharvest quality attribute, carrot individual weight.

Treatment	Carrot individual weight (ounces)[z]							
	Cello cultivars				Cut and peel cultivars			
	Choctaw		Maverick		Triton		Uppercut 25	
Season 2017								
Nitrogen rate (lb/acre)								
50	0.10	b	0.10	c	0.07	c	0.04	b
100	0.20	a	0.15	b	0.11	b	0.06	ab
150	0.22	a	0.17	b	0.11	b	0.10	a
200	0.22	a	0.16	b	0.12	b	0.09	a
250	0.19	a	0.18	b	0.13	ab	0.09	a
300	0.21	a	0.18	ab	0.12	ab	0.10	a
350	0.19	a	0.22	a	0.16	a	0.09	a
400	0.19	a	0.19	a	0.13	a	0.08	ab
Significance								
L[y]	0.040		0.0001		0.001		0.001	
Q	0.0001		0.0001		0.001		0.0001	
Season 2018								
Nitrogen rate (lb/acre)								
50	0.10	d	0.14	c	0.11	a	0.07	d
100	0.14	cd	0.16	bc	0.11	a	0.09	cd
150	0.24	a	0.19	ab	0.12	a	0.11	abc
200	0.19	b	0.19	ab	0.13	a	0.11	abc
250	0.17	bc	0.21	ab	0.13	a	0.13	ab
300	0.17	bc	0.17	abc	0.14	a	0.12	abc
350	0.18	bc	0.21	a	0.13	a	0.14	a
400	0.17	c	0.16	bc	0.11	a	0.10	bcd
Significance								
L[y]	0.050		0.022		0.600		0.001	
Q	0.0001		0.0001		0.850		0.0001	

[z]Values followed by the same letter within a column indicate means are not significantly different ($P \leq 0.05$) with means separation by Tukey-Kramer test.

[y]L = linear; Q = quadratic response.

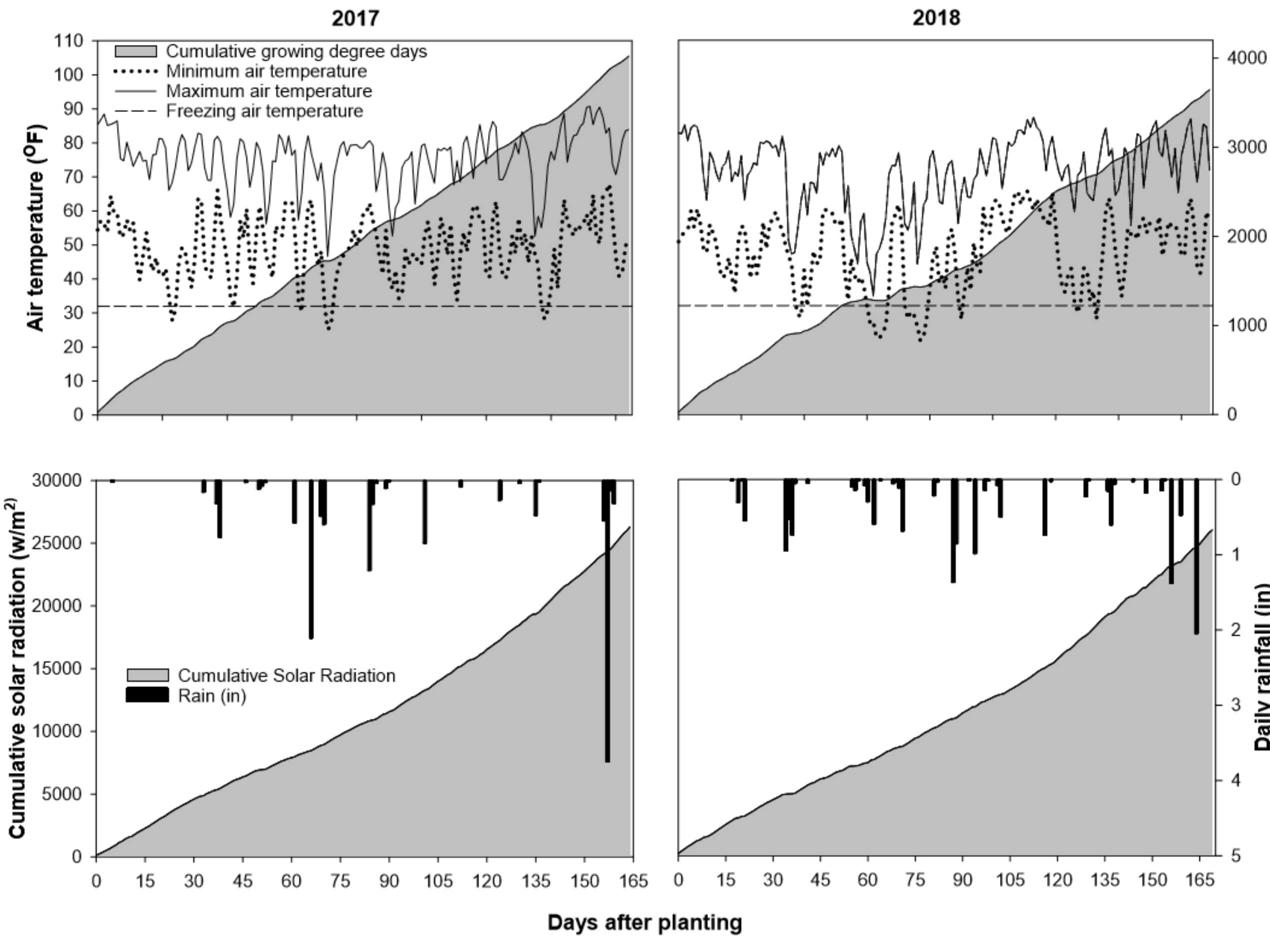

Figure 1. Maximum and minimum air temperatures with cumulative growing degree days (base temperature 38°F) and daily rainfall with daily, weekly, and cumulative solar radiation for 2017 and 2018 growing seasons in Live Oak, FL. Data source: Florida Automated Weather Network (< http://fawn.ifas.ufl.edu >).

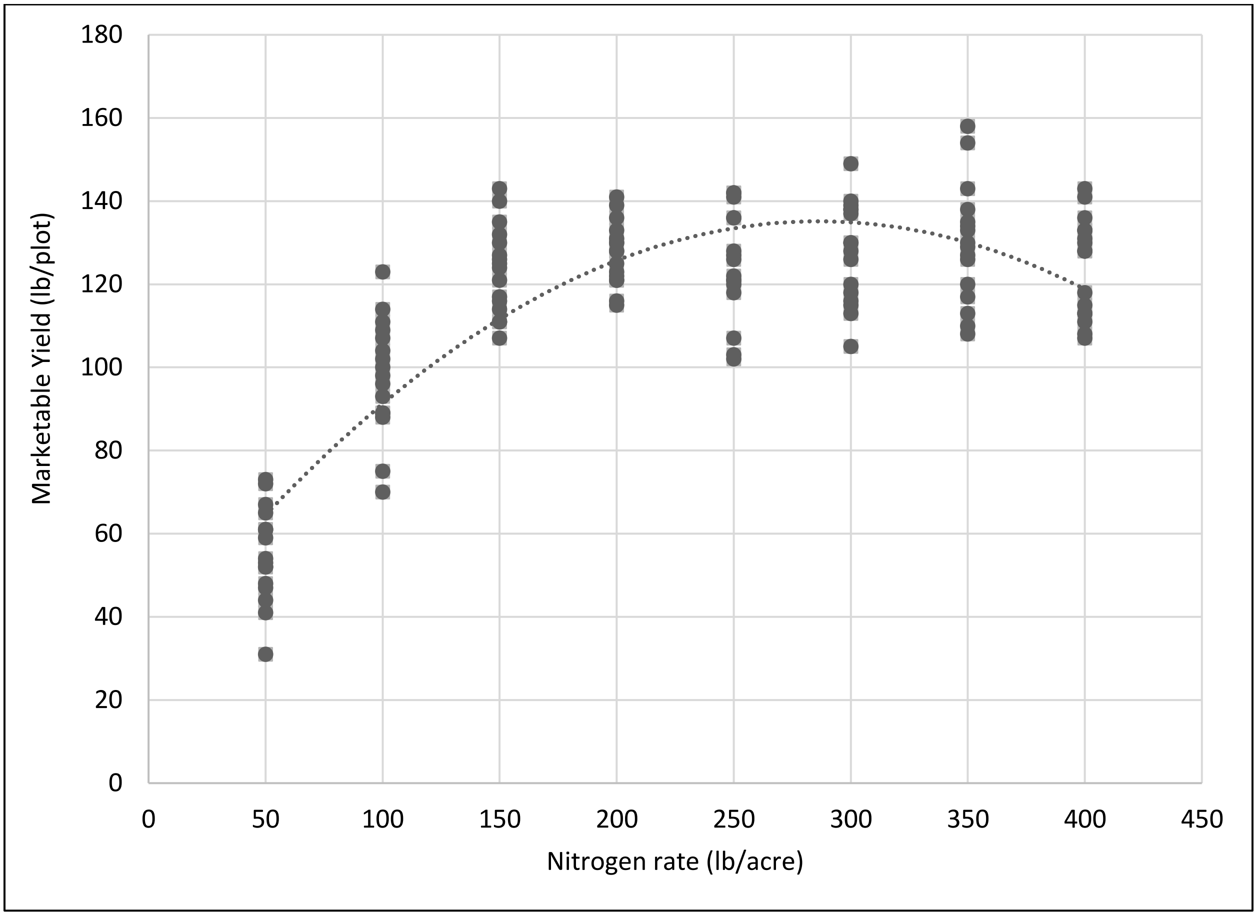

Figure 2. Response of carrot marketable yield (lb/plot) and nitrogen rate applied (lb/acre) for eight nitrogen application rates tested during the 2017 and 2018 growing seasons combined, and all cultivars combined.

Photographs of Conventional Nitrogen and Cultivar Study

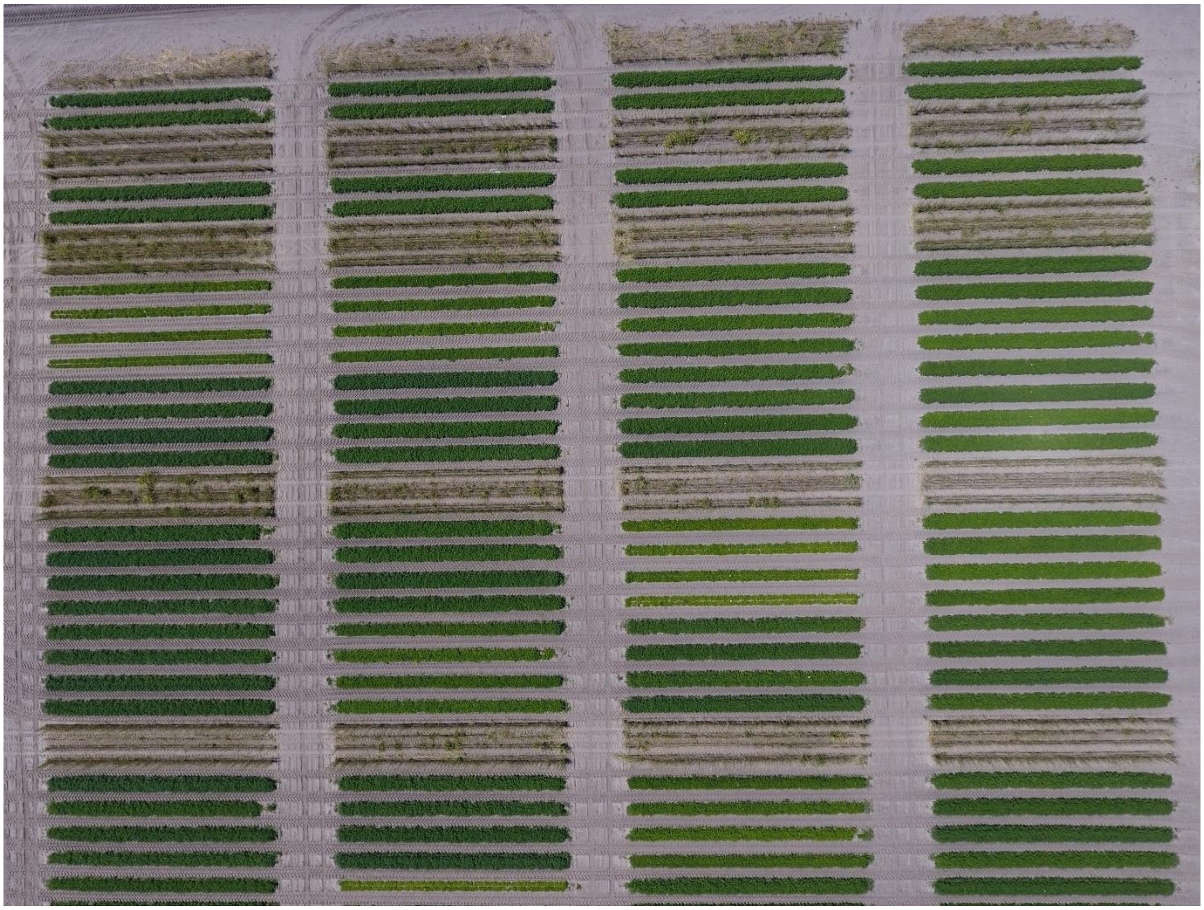

Figure 1. Drone photo of 2018 conventional carrot trial during April of 2018

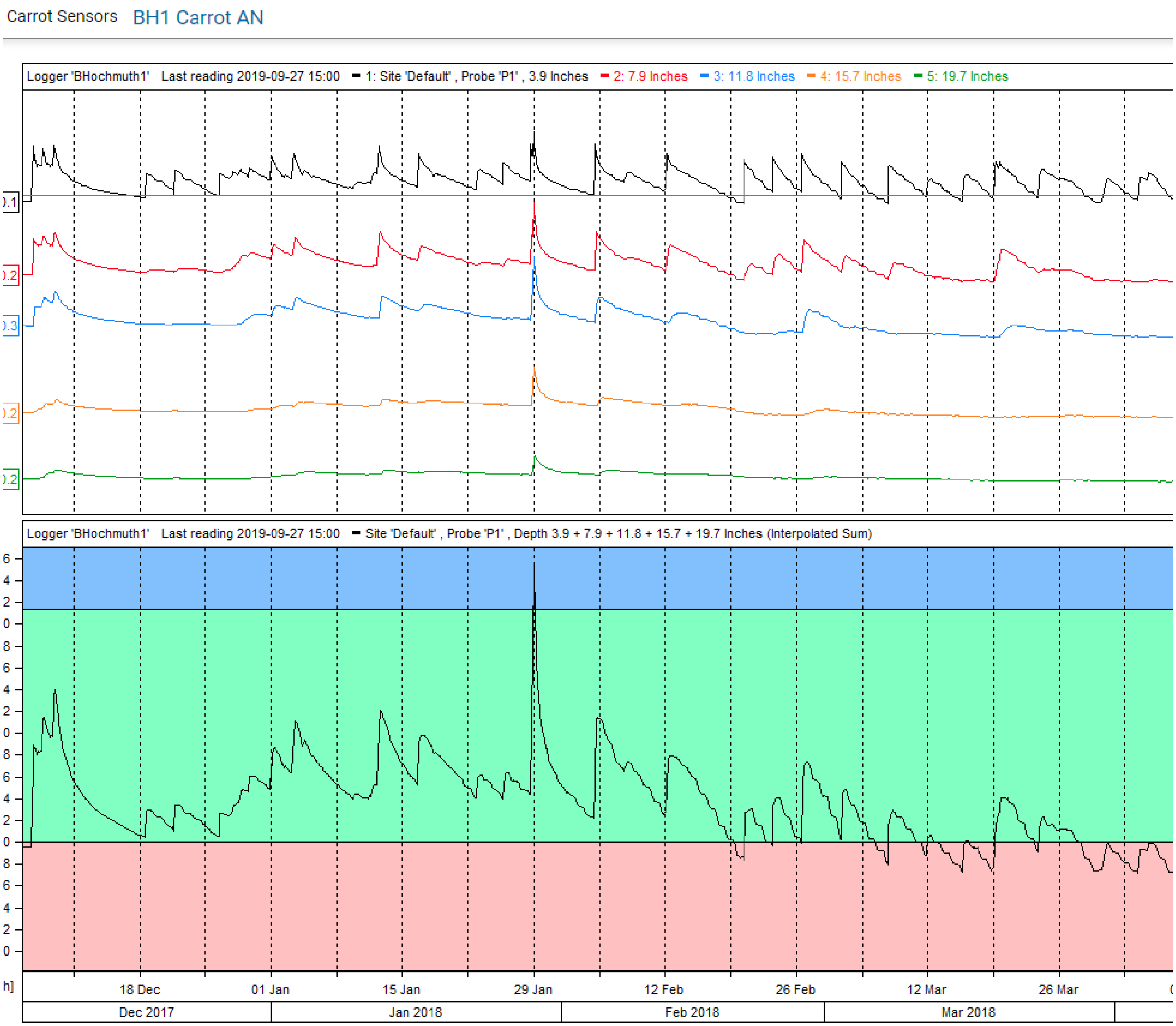

Figure 2. Soil moisture sensor data showing the only potential slight leaching rainfall event during the 2017-18 season on January 28, 2018

Figure 3. Measuring plant height and taking cold injury ratings in April, 2018.

Figure 4. Undercutting carrot plots in preparation for hand-harvest in 2018.

Figure 5. Labor crew preparing for harvesting plots of carrots.

Figure 6. Carrot harvests into mesh bags for transport to barn for data collection.

Figure 7. A typical subset of 15 carrots taken from each of the 128 plots for length, diameter and weight data collection.

Controlled Release Nitrogen One-Year Trial Summary

Yield and Quality of Maverick Carrots Grown Using Conventional and Controlled Release Nitrogen Fertilizers in North Florida

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Jay Skillman, Harrell's (Lakeland, FL), Jason Woulfin, Pursell Agri-Tech (Sylacauga, AL) partners in planning this trial, providing fertilizer materials and partial funding support.

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We also would like to thank Waters Agricultural Labs (Camilla, GA) for their partnership and support with the leaf tissue analyses and Nunhems/Bayer for donating the carrot seed. Our team would also like to acknowledge the guidance provided by local carrot producers, Clif Townsend, Townsend Brothers Farm (Live Oak, FL) and Russ Hamlin, Generation Farms (Lake Park, GA).

This study was conducted at the North Florida Research and Education Center- Suwannee Valley to compare different sources and rates of nitrogen (N) fertilizer in carrot production in North Florida. Conventional granular nitrogen fertilizer (ammonium nitrate) and controlled release fertilizer (CRF) from two companies, Harrell's and Pursell Agri-Tech, were evaluated with different N formulations and rates.

Materials and Methods

The field trial was conducted at the University of Florida, North Florida Research and Education Center - Suwannee Valley in Live Oak, Florida.

Land Preparation

Dolomitic lime was applied, based on soil samples, at a rate of 2000 lbs per acre and incorporated with a harrow. Potassium (K_2O) was applied for an in-season total of 250 lbs per acre, with the majority of the treatments receiving 65.5lbs per acre preplant, see Table 1 for additional information on preplant K_2O. In addition, 46 lbs of phosphate per acre was applied to match grower practices in the area.

Fertilizer Treatment Application Methods

The soil was pressed into beds 40 inches wide by 6 inches high. Beds were spaced at 72 inches on center. Preplant fertilizer was banded in a 40-inch wide band on the soil surface where the beds will be formed

and rototilled into the top 6 inches. See Table 1 for fertilizer analysis and pounds of nitrogen per acre for each treatment.

Nitrogen fertilizer rates were calculated using the linear bed foot method (Hochmuth and Hanlon, 2018) using a bed spacing of 52 inches which is more typical on commercial farms. The wider bed spacing used in this trial was used to avoid potential cross contamination of nitrogen from one bed to the next side to side and to fit the tire spacing of the equipment available to conduct this trial. All nitrogen fertilizer, preplant and top-dress, applications, were made to the 40-inch bed area only.

The N application rate range was established to include the University of Florida Institute of Food and Agricultural Sciences recommendation of 175 lbs/A (Liu et al., 2019) and rates higher and lower than the recommended rate.

Conventional nitrogen applications were made using ammonium nitrate (32 N-0 P_2O_5-0 K_2O) applied to the 40-inch bed top. Controlled release fertilizer applications were made according to treatments listed in Table 1. All treatments were applied using a fertilizer drop spreader with four directional spouts modified to apply an even distribution of fertilizer to the bed top.

Three soil moisture sensors were established in the trial to monitor soil moisture and were strategically placed in plots that represented a conventional nitrogen plot and one Harrell's and one Pursell controlled release N plot.

Bed Planting and Crop Care

The carrot cultivar 'Maverick' was used in this trial and because it is a high yielding cultivar, is popular among local growers, and has been used in previous trials here at NFREC-SV. Carrots were mechanically seeded using a Seed Spider Planter (Sutton Agricultural Enterprises, Inc., Salinas, CA) on November 29, 2018.The seeder placed the seed in four rows spaced 1.875 inches apart and ¼ inch deep, then pressed the soil firmly with a roller. The final carrot row configuration was two sets of four rows with 12 inches between sets, on a 40-inch wide pressed bed top. Plots were 50 ft long. The plots were arranged in a randomized complete block design with four replications.

Cultural practices and pest management strategies consistent with grower practices were implemented. This included an application of the soil fumigant Telone II well in advance of seeding. Special attention during the season was given to managing *Alternaria spp.* leaf spot by applying preventive fungicide applications every 1 to 2 weeks.

Data Collection

Samples of most recently matured leaves were taken for leaf tissue N analysis on three occasions Jan 25, Feb 26, and March 26, 2019. Samples were submitted to Waters Agricultural Labs, Camilla, GA. Average plant height (inches) was taken in each plot the morning prior to harvest by measuring the plant foliage height in the most representative spot within the plot.

Harvest

Carrots were harvested based on the predicted harvest date provided by local growers and by assessing carrot size (width and length). All plots were harvested on April 22, 2019. Carrots were harvested with a chain-style carrot harvester with an oscillating undercutter bar cutting approximately 14 inches below the top of the bed.

Total harvested weight (lbs) per plot was measured and recorded. Twenty carrots from each plot were randomly selected and individual carrot weights, diameter at the widest section of the top of the carrot, and length of carrot were recorded on the same day as harvest.

Data Analysis
Data were analyzed using the Generalized Linear Mixed Model, Regression, and Nonlinear Regression Procedures of SAS (SAS Version 9.4; SAS Inst. Inc.). A two-way analysis of variance was performed for yield and carrot quality data to determine the significance of the main effects. Means separation was used to examine differences between nitrogen treatments.

Results & Discussion

The overall carrot yields in this trial were in the range of 19.54 to 29.83 tons per acre (Table 2). 'Maverick' is a high performing cultivar and in this trial, performed well across many nitrogen treatments. Yields above 25 tons per acre were similar to yields found in previous trials at this research farm and are comparable to commercial yields in this region. The top numerical yield was found with Pursell's 19-0-19 at 200 lbs per acre (treatment 14), but it was not significantly different from eleven of the sixteen nitrogen fertilizer treatments in this trial. When grouped by the type of nitrogen fertilizer treatment, all three rates of ammonium nitrate, all Harrell's fertilizer treatments except the lowest rate of CRF 30-0-0 (treatment 4), and two of the Pursell's fertilizers (treatments 14 and 16) were all in the top eleven yield group (Figure 1). The lowest total yield was found with Pursell 44-0-0 at 175 lbs per acre (treatment 12) but was not significantly different from eleven other treatments, including all Harrell's treatments and all but one of Pursell treatments. This lack of significant differences between many of the treatments indicates that many of the fertilizer treatments performed well in this trial. The standard, multiple-application ammonium nitrate treatments at 150, 200 and 250 lbs per acre (treatments 1, 2, and 3) were all in the top yielding group and there was no difference in yield across the three ammonium nitrate rates. This is consistent with the results found in previous research at this center (data not shown). Harrell's rates of CRF 30-0-0 from 125 to 225 lbs of N per acre (treatments 5 to 9) and Harrell's CRF 20-0-25 (treatment 10) all performed among the top yield treatments. Only the 100 lbs per acre rate of 30-0-0 (treatment 4) was not in that top yield group. Two of the Pursell treatments were in the top yield group, including CRF 19-0-19 and 11-0-44 plus 44-0-0 (treatments 14 and 16, respectively).

There were several high rainfall periods over multiple days of continuous rainfall during the early part of the growing season (Figure 2, Table 3). During this period, we observed poor carrot growth and poor foliage color on all treatments. There was sufficient rainfall to leach the soluble nitrogen from the upper soil profile where the young carrot roots were located. The soluble nitrogen in the ammonium nitrate plots was, of course all soluble, and whatever nitrogen had released from all controlled release fertilizers during that period would have been vulnerable to leaching as well. The one treatment that seemed to grow the best during the first 60 days and had the darkest green color foliage, even better than the multiple application ammonium nitrate treatments, was Pursell's 19-0-19 (treatment 14). A higher early nitrogen release rate in this treatment may have been the cause for the difference seen between this treatment and the others. The trial protocol restricted the investigators from making any additional nitrogen applications during this leaching rain event period, but it is believed an additional application of soluble nitrogen would have been beneficial to essentially all treatments. Even the ammonium nitrate treatments would have likely benefitted because the timing between nitrogen applications was approximately two weeks and this may have been too long between applications when leaching rain events were occurring. This early rainy period may have negatively impacted total yields across all treatments because it is during this period when the crop is setting the tap root that will become the carrot. A nitrogen deficient plant may not set a long, straight, healthy tap root and thus, yield can be reduced during this time frame. Although the early part of the season was characterized as having wetter

than normal weather, we did not observe foliage damage due to freezing temperatures, which is supported by the mild winter temperatures recorded (Table 4).

Carrot quality is determined by carrot diameter and length. In this trial, most carrots were approximately 1-inch in diameter and 7 to 8.5 inches in length (Table 5). Essentially all harvested carrots fell within the USDA standards of at least 0.75 inches in diameter and over 5 inches in length (USDA, 1965). Carrot diameter was greatest in Pursell's 19-0-19 treatment (treatment 14) and ammonium nitrate treatment at 250 lbs per acre (treatment 3), but these were not significantly different from eight other fertilizer treatments (Table 5). Carrot length was greatest in Harrell's 20-0-25 treatment (treatment 10) and was not significantly different from the length found in ten other treatments. The shortest carrots were found in Harrell's 30-0-0 at 175 lbs per acre (treatment 7) but it was not significantly different from the length found in nine other fertilizer treatments. In general, carrot diameter and length were stable across the wide range of fertilizer treatments.

Leaf tissue sample results show the nitrogen level in the leaf tissue was consistently higher in this trial (Table 6) than reported adequate nitrogen ranges at various stages of growth (Table 7). On the first sampling date, 13 of the 16 treatments had similar nitrogen levels, all above 4.31 % N. Results of the second sampling date showed many treatments had slightly lower N levels than the first sampling date, however, most of the Pursell treatments had much lower N levels on the second sampling date. Leaf N levels on the third sampling date ranged from 3.09% to 4.42%, but there was no significant difference found among all nitrogen fertilizer treatments. These data may help fertilizer suppliers, Harrell's and Pursell, to adjust the coatings to better meet the crop N needs over the entire season. Leaf tissue data for all other important plant nutrients was reviewed (not reported here) and showed adequate levels of all other nutrients were maintained during the season for this trial using the data in Table 7 as the standard adequate ranges.

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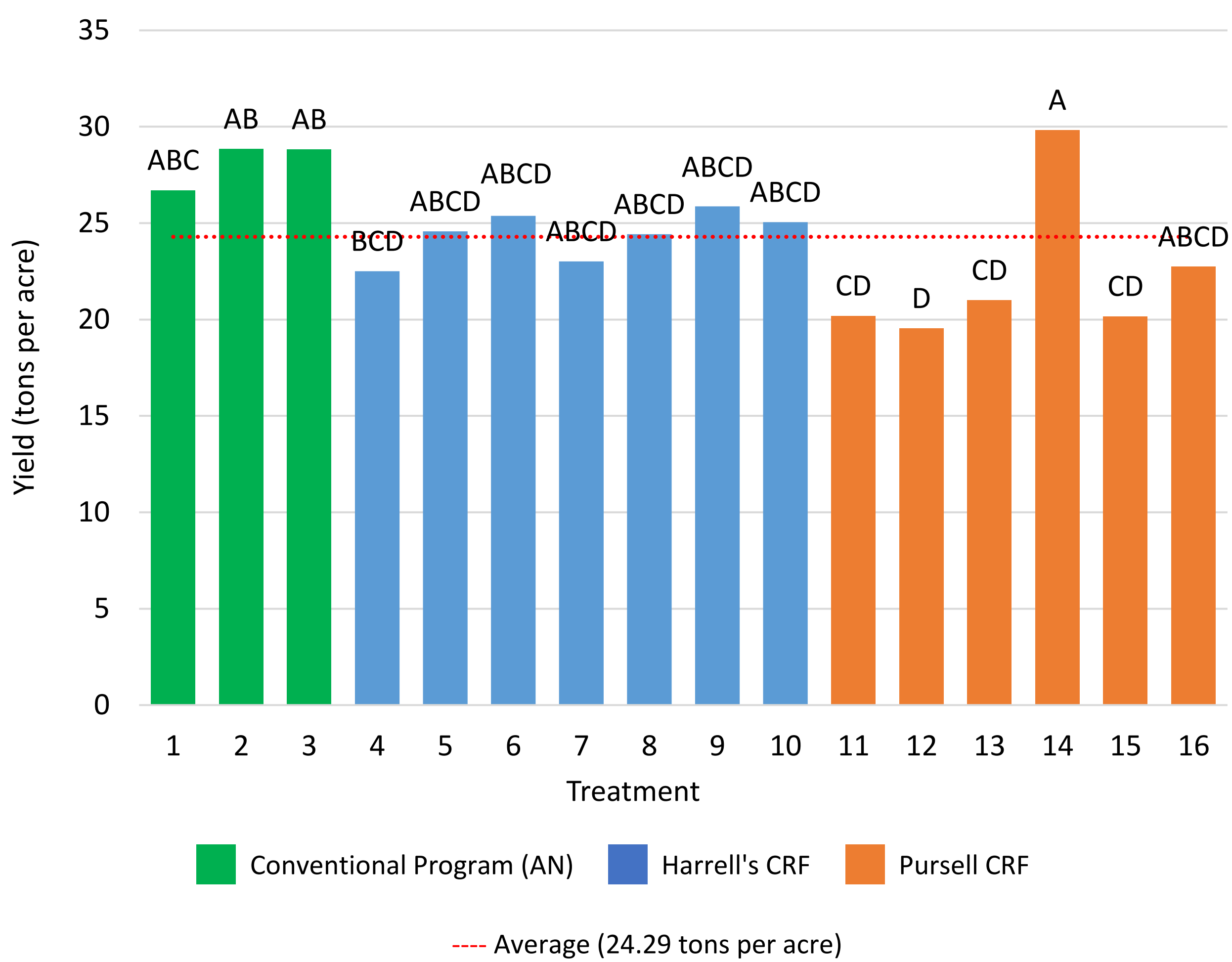
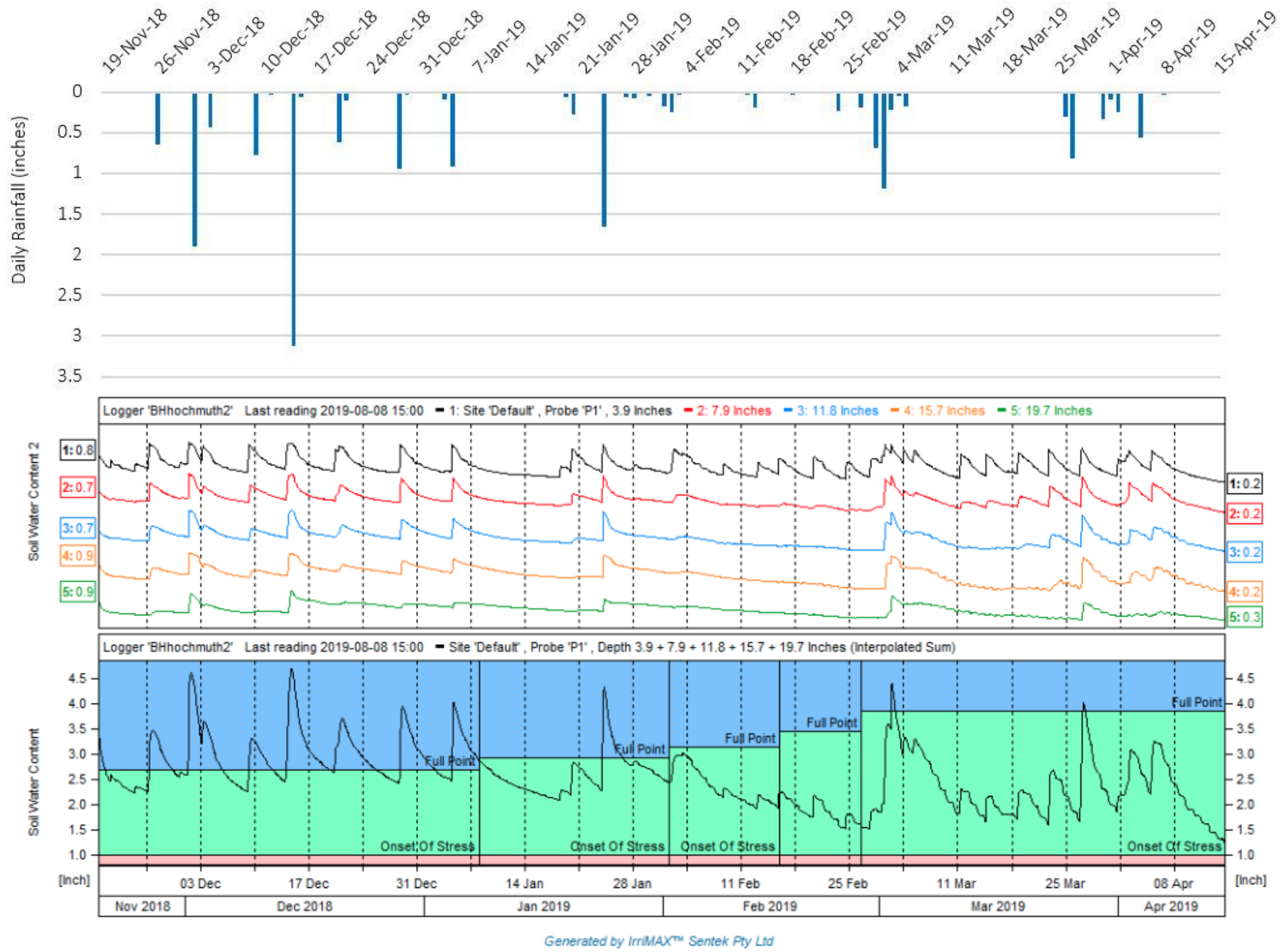
Figures and Tables

Figure 1. Total marketable yield (tons per acre) per treatment.



[a]Total marketable yield means (bars) with the same letter are not significantly different. Mean separation by Tukey-Kramer test at 5% level (Alpha=0.05).

Figure 2. Daily rainfall and soil moisture content during the growing season, Nov. 29, 2018 to Apr. 22, 2019.[2]



[2] The top graph shows rainfall in inches (FAWN). The graph in the center shows soil moisture content readings for each soil moisture sensor placed at different depths beneath the soil surface: 4" (black line), 8" (red line), 12" (blue line), 16" (orange line), and 20" (green line). The bottom graph shows soil moisture content as the sum of all sensors and it is shown within a blue zone indicating soil moisture saturation, a green zone indicating optimum soil moisture, and a red zone indicating low soil moisture and potential crop stress.

Table 1. Summary of nitrogen treatments studied in this trial.

Fertilizer	Treatment	Fertilizer Analysis	Target N Season Rate (pounds per acre)	Preplant N Rate (pounds per acre)	Top dress N total (pounds per acre)	Target K_2O Season Rate (pounds per acre)	Preplant K_2O Rate (pounds per acre)	Top dress K_2O total (pounds per acre)
Conventional Nitrogen Program (AN)	1	32-0-0	150	25	125[a]	250	62.5	187.5[b]
	2	32-0-0	200	25	175[a]	250	62.5	187.5[b]
	3	32-0-0	250	25	225[a]	250	62.5	187.5[b]
Harrell's Controlled Release Fertilizer (CRF)	4	30-0-0	100	100	0	250	62.5	187.5[b]
	5	30-0-0	125	125	0	250	62.5	187.5[b]
	6	30-0-0	150	150	0	250	62.5	187.5[b]
	7	30-0-0	175	175	0	250	62.5	187.5[b]
	8	30-0-0	200	200	0	250	62.5	187.5[b]
	9	30-0-0	225	225	0	250	62.5	187.5[b]
	10	20-0-25	200	200	0	250	250	0
Pursell Agri-Tech Controlled Release Fertilizer (CRF)	11	44-0-0	150	150	0	250	62.5	187.5[b]
	12	44-0-0	175	175	0	250	62.5	187.5[b]
	13	44-0-0	200	200	0	250	62.5	187.5[b]
	14	19-0-19	200	200	0	250	200	50[c]
	15	11-0-44 44.5-0-0	200	200	0	250	250	0
	16	11-0-44 44-0-0	200	200	0	250	250	0

[a]The total N top dressed was evenly divided into eight applications.
[b]The total K_2O top dressed was applied in three applications of 62.5 pounds of K_2O per acre.
[c]For treatment 14, 50 pounds per acre of K_2O were applied on January 31, 2019 (64 days after planting).

Table 2. Summary of yield, height, and weight results from conventional and controlled release nitrogen treatments in carrots.

Fertilizer	Treatment	Fertilizer Analysis	Target N Season Rate (pounds per acre)	Preplant N Rate (pounds per acre)	Yield (tons per acre)[a]		Plant Height (inches)[a]		Individual Weight (ounces)[a]
Conventional Nitrogen Program (AN)	1	32-0-0	150	25	26.71	ABC	13.25	AB	2.41
	2	32-0-0	200	25	28.85	AB	13.88	A	2.59
	3	32-0-0	250	25	28.82	AB	13.63	A	2.76
Harrell's Controlled Release Fertilizer (CRF)	4	30-0-0	100	100	22.51	BCD	11.88	ABC	2.34
	5	30-0-0	125	125	24.57	ABCD	13.00	ABC	2.49
	6	30-0-0	150	150	25.38	ABCD	12.75	ABC	2.48
	7	30-0-0	175	175	23.01	ABCD	13.13	AB	2.45
	8	30-0-0	200	200	24.42	ABCD	13.38	AB	2.29
	9	30-0-0	225	225	25.88	ABCD	12.88	ABC	2.74
	10	20-0-25	200	200	25.05	ABCD	13.50	AB	2.45
Pursell Agri-Tech Controlled Release Fertilizer (CRF)	11	44-0-0	150	150	20.20	CD	12.00	ABC	2.28
	12	44-0-0	175	175	19.54	D	11.25	BC	2.20
	13	44-0-0	200	200	21.00	CD	12.13	ABC	2.17
	14	19-0-19	200	200	29.83	A	13.50	AB	2.67
	15	11-0-44 44.5-0-0	200	200	20.17	CD	10.75	C	2.39
	16	11-0-44 44-0-0	200	200	22.74	ABCD	12.38	ABC	2.25

[a]Means followed by the same letter in a column are not significantly different. Mean separation by Tukey-Kramer test at 5% level (Alpha=0.05). If no letters are shown, no significant differences were found within the data on that column.

Table 3. Summary of growing conditions (temperature and rainfall) during the growing season.

	Growing Season (month and year)					
	Nov.18	Dec.18	Jan.19	Feb.19	Mar.19	Apr.19
Temperature at 7' (F)						
Min.	30.80	30.25	30.29	34.19	32.02	42.66
Max.	87.01	80.28	81.19	86.94	84.60	88.72
Total Accumulated Rainfall (inches)	4.03	8.07	3.22	1.14	3.82	1.99

Source: Florida Automated Weather Network (FAWN), Report Generator for Live Oak, Florida.

Table 4. Freeze events (days during which temperature was below 32 degrees F) during growing season of Nov. 29, 2018 to Apr. 22, 2019.

Date	Duration (hours)
28-Nov-18	3
12-Dec-18	3
11-Jan-19	4
17-Jan-19	1
21-Jan-19	2
30-Jan-19	2
31-Jan-19	6
6-Mar-19	1
7-Mar-19	2

Table 5. Summary of quality parameters results from conventional and controlled release nitrogen treatments in carrots.

Fertilizer	Treatment	Fertilizer Analysis	Target N Season Rate (pounds per acre)	Preplant N Rate (pounds per acre)	Quality Parameters	
					Individual Diameter (inches)[a]	Individual Length (inches)[a]
Conventional Nitrogen Program (AN)	1	32-0-0	150	25	0.94 BC	7.21 DE
	2	32-0-0	200	25	1.03 AB	7.46 CDE
	3	32-0-0	250	25	1.07 A	7.80 ABCDE
Harrell's Controlled Release Fertilizer (CRF)	4	30-0-0	100	100	1.01 ABC	7.58 BCDE
	5	30-0-0	125	125	1.01 ABC	8.05 ABCD
	6	30-0-0	150	150	1.01 ABC	8.16 ABC
	7	30-0-0	175	175	1.03 ABC	7.09 E
	8	30-0-0	200	200	0.93 BC	7.82 ABCDE
	9	30-0-0	225	225	0.91 BC	7.84 ABCDE
	10	20-0-25	200	200	1.01 ABC	8.62 A
Pursell Agri-Tech Controlled Release Fertilizer (CRF)	11	44-0-0	150	150	0.91 C	8.41 AB
	12	44-0-0	175	175	1.01 ABC	7.49 BCDE
	13	44-0-0	200	200	0.94 BC	8.33 ABC
	14	19-0-19	200	200	1.08 A	7.77 ABCDE
	15	11-0-44 44.5-0-0	200	200	0.94 BC	8.24 ABC
	16	11-0-44 44-0-0	200	200	0.98 ABC	7.76 ABCDE

[a]Means followed by the same letter in a column are not significantly different. Mean separation by Tukey-Kramer test at 5% level (Alpha=0.05). If no letters are shown, no significant differences were found within the data on that column.

Table 6. Summary of nitrogen leaf tissue analysis lab results from Waters Agricultural Laboratories for the three sampling dates at 58, 93, and 124 days after planting.

Fertilizer	Treatment	Fertilizer Analysis	Target N Season Rate (pounds per acre)	Leaf Tissue Nitrogen Concentration (%)[a]				
				1st Sampling Date (1/25/2019)		2nd Sampling Date (3/1/2019)		3rd Sampling Date (4/1/2019)
Conventional Nitrogen Program (AN)	1	32-0-0	150	4.56	ABCD	4.61	AB	4.19
	2	32-0-0	200	4.69	ABC	4.72	A	4.14
	3	32-0-0	250	4.66	ABC	4.49	ABC	3.88
Harrell's Controlled Release Fertilizer (CRF)	4	30-0-0	100	4.50	ABCD	4.11	ABCD	4.42
	5	30-0-0	125	4.72	ABC	4.11	ABCD	3.34
	6	30-0-0	150	4.59	ABC	3.91	CD	3.76
	7	30-0-0	175	4.84	AB	3.95	BCD	3.48
	8	30-0-0	200	4.87	A	4.13	ABCD	3.63
	9	30-0-0	225	4.83	AB	4.19	ABCD	3.09
	10	20-0-25	200	4.73	ABC	4.42	ABC	3.62
Pursell Agri-Tech Controlled Release Fertilizer (CRF)	11	44-0-0	150	4.60	ABC	3.66	D	3.63
	12	44-0-0	175	4.25	CD	3.65	D	3.65
	13	44-0-0	200	4.60	ABC	3.82	CD	3.88
	14	19-0-19	200	4.69	ABC	3.71	D	3.75
	15	11-0-44 44.5-0-0	200	4.06	D	3.54	D	3.79
	16	11-0-44 44-0-0	200	4.31	BCD	3.53	D	3.49

[a]Means followed by the same letter in a column are not significantly different. Mean separation by Tukey-Kramer test at 5% level (Alpha=0.05). If no letters are shown, no significant differences were found within the data shown on a given column.

Table 7. UF/IFAS adequate ranges for macronutrients and micronutrients in leaf tissue for Florida grown carrots.

Stage of Growth	Leaf Tissue Nutrients										
	N	P	K	Mg	Ca	S	B	Zn	Mn	Fe	Cu
	%						ppm				
60 Days After Seeding	1.8-2.5	0.2-0.4	2.0-4.0	0.2-0.5	2.0-3.5	-	20-40	20-60	30-60	30-60	4-10
During Harvest Period	1.5-2.5	0.2-0.4	1.4-4.0	0.4-0.5	1.0-1.5	-	20-40	20-60	30-60	20-30	4-10

Source: Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida. G. Hochmuth, D. Maynard, C. Vavrina, E. Hanlon, and E. Simonne

Photographs of Controlled Release Nitrogen Study

Figure 8. Taking height measurements prior to harvest

Figure 9. Preparing plots for harvest with mechanical topper to remove vegetative tops to facilitate harvest

Figure 10. Mechanical harvester digging individual carrot plots

Figure 11. Carrots coming off the end of the mechanical harvester and chain conveyer system

Figure 12. One plot of harvested carrots loaded into a pallet “sock” readied for transport to the weighing and grading shelter location

Figure 13. Plot weights for total plot recorded

Figure 14. Measurements for individual carrots being recorded

Figure 15. Caliper being used to take carrot diameter measurements

Figure 16. Twenty carrot sub-sample for individual quality measurements

Summary and Recommendations of Nitrogen Management in Organic Carrot Production

This study was the beginning of the development of a nitrogen recommendation for organic carrot. As in most organic systems, the estimation of the timing and availability of nitrogen is not straightforward. Rates of biological activity are governed by soil temperature, moisture, and the species and density of organisms present in the soil. Carrots are a cool season crop, planted at the end of hurricane season and harvested during a time when late freezes can damage shoots and reduce the crops' capacity for optimum root growth and expansion. During the 100-day production season, soil temperature and moisture are generally highly variable and influence the mineralization rate of nitrogen. Even when the same N fertility source is used, changes in the operational environment from year to year demand consideration of a range of N rates, rather than a single value. While we are unable to make a statistically valid comparison, the yield in organic carrot was lower than conventional carrot each year. Based on the data analysis to date, yield of organic carrot increased with increasing rates of nitrogen, far more than the 175-200 lb a^{-1} reported in the conventional N rate study. Shoot and root nitrogen concentration (based on dry weight) were one third to one half lower than conventional carrot as stated in laboratory reports, indicating the capacity for more nitrogen uptake if more fertilizer N was provided. Residual soil N at harvest was also low in all treatments. It is possible that additional nitrogen would have increased yield without posing an environmental risk, and that the N recommendation for organic carrot may be greater than the recommended rate for conventional carrot. Organic carrot producers need better tools to manage crop nutrition. In-field quick tests, perhaps shoot N concentration could provide the necessary documentation to validate if and when additional N is needed. Nitrogen is consistently one of the most expensive inputs in organic systems. The more the N is processed, the more expensive the product. Multiple sources of nitrogen with different availability rates would be ideal and would allow producers to respond accordingly to changing crop conditions. For example, a well-timed N solution that could be delivered through fertigation may be worth the cost if there is a yield gain. Future work should include developing these tools, fine tuning the N sources, and expanding nitrogen management evaluation to other organic specialty crops, particularly those with high N demand. To date, the initial data analysis is complete. Additional analysis will include a closer look at the N partitioning at harvest, and a more thorough discussion of the variable responses to increasing N rates. The paper will be published in HortTechnology or HortScience, whichever seems more appropriate following review and revision of the manuscript.

Organic Nitrogen Rate Research Trial Report

Title: Organic Carrot Response to Five Nitrogen Rates in a Florida Sandy Soil

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Additional Index Words. Best management practices, plant nutrition, nitrogen use efficiency, root to shoot ratio, *Daucus carota*

Abstract. (250 words) 261
Consistently ranked in the top five most popular vegetables in the U.S., carrot [*Daucus carota* L. var. *sativus* (Hoffm.) Arcang] acreage has increased near the Florida-Georgia border in both organic and conventional systems due in part to market infrastructure, mild winters, and deep sandy soils. Land grant university nitrogen (N) recommendations for conventional vegetable systems are regularly re-evaluated to optimize N use on farm and minimize risk of N leaching. The University of Florida's current recommendation for conventional carrots is 196 kg ha^{-1} N, but there is no recommendation for organic carrot or any other organic specialty crop in Florida. The objective of this study was to begin to develop a university recommendation for N in carrot to support this region's certified organic producers. A cello type carrot was evaluated during a two year study on certified organic land near Live Oak, Florida. Five N treatments ranging from 168 kg ha^{-1} N to 393 kg ha^{-1} N in 56 kg ha^{-1} increments were randomized and replicated four times. A commercially-available poultry litter fertilizer (3-2-3) provided N and potassium (K). Boron (B) at 2.24 kg ha^{-1} was added per pre-plant soil test recommendation. All B and 50% of the N was pre-plant incorporated. Remaining N was applied in two equal applications at 5 and 7 weeks after planting (WAP) by banding between rows and lightly incorporating to a depth of 4 cm. Carrot was seeded November 14, 2016, November 15, 2017 and November 29, 2018 on 18.3 m pressed beds (four 16.5 cm row spacing) by mechanical seeder to 459,200 and seed ha^{-1}, respectively.

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Suwannee Valley for executing the trial. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the University of Florida.

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Introduction

Organic agriculture continues to grow with sales of organic food and non-food products in the United States, totaling $39.1 billion, in 2014, up 11.3 percent from the previous year, according to the latest survey on the organic industry from the Organic Trade Association (OTA). The percent of consumers who buy organic products has risen in the south from 68 to 80% over the last year alone, representing a higher rate of growth than in other regions of the US (OTA, 2015). The proposed project holds great potential for expanding organic vegetable production in the southern states as they rank 3rd (FL), 5th (NC), 11th (GA), and 16th (VA) in total organic acres of vegetable production nationally (ERS, 2011). Organic carrots comprise 14% of the domestic carrot market and retail prices for bagged organic carrots were on average 30% greater than conventional carrots for the past 7 years (Jaenicke and Carlson, 2015).

Consistently ranked in the top five most popular vegetables in the U.S., carrot [*Daucus carota* L. var. *sativus* (Hoffm.) Arcang] acreage has increased in the north Florida and south Georgia region in both organic and conventional systems due in part to market infrastructure, mild winters, and deep sandy soils. There is a high risk of nitrogen leaching in sandy soil, and the poor predictability of nutrient release from pre-plant organic fertilizer often results in a shortage of nitrogen and/or potassium mid- to late-season, reducing crop yield and quality.

There is increasing interest in expanding carrot production in North Florida due to favorable climatic conditions and market demand. Farmers in the area produced an estimated 200 acres of organic carrot in spring 2017. Fertilizer nitrogen (N) rate is an important factor to determine yields but over-fertilization can lead to negative impacts on water quality. To date there are no reliable data to guide the use and management of nitrogen fertilizer in organic carrot production systems in FL. The goal of this project was to develop evidenced-based recommendations for nutrient management in organic carrots to support the success of North Florida vegetable producers while conserving our state’s natural resources. The purpose of this study was to evaluate the effect of five nitrogen rates on the yield and quality of cello-type carrot grown on USDA-certified organic land at NFREC- Suwannee Valley and identify the nitrogen rate that supports the greatest yield while minimizing risks to water quality.

Materials and Methods

Site Description and Experimental Design. Trials were conducted in a different location each year on certified organic land (Quality Certification Services, Gainesville, FL) at the UF/IFAS North Florida Research and Education Center – Suwannee Valley near Live Oak on a Chipley-Foxworth-Albany soil series complex (Thermic, coated Aquic or Typic Quartzipsamments and Loamy, siliceous, subactive, thermic Aquic Arenic Paleudults). All inputs and methods were compliant with the USDA National Organic Standards, were included in our farming system plan, and were approved by our certification agency prior to use. Prior to crop establishment, soil samples were collected and submitted to the UF/IFAS Extension Soil Testing Laboratory for analysis of macro and micronutrient content. No analysis was conducted to determine pre-plant soil N. Per pre-plant soil test recommendation, both sites received 2242 kg ha^{-1} (2,000 lb a^{-1}) of dolomitic lime each fall. Boron (B) was incorporated with fertilizer in 2018 before seeding at 2.24 kg ha^{-1} (2 lb a^{-1}). Five N treatments ranging from 168 kg ha^{-1} N to 393 kg ha^{-1} N in 56 kg ha^{-1} increments were randomized and replicated four times (50 lb a^{-1} increments from 150 to 350 lb a^{-1}). These rates were selected based on previous Florida research for best management practices in conventional carrot (Hochmuth et al., 1999). Each plot measured 18 m long (60 ft), 1.3 m wide (4.2 ft).

Fertilizer Application. In year one of the experiment, the fertilizer employed in the trial was a blended fertilizer approved for use in USDA certified organic systems, made exclusively of poultry litter (Microstart 60, 3-2-3, manufactured by Perdue AgriRecycle, LLC, Seaford, DE) with an analysis of 3% N, 2% P_2O_5 and 3% K_2O (3% N – 0.87% P – 2.5% K). At the end of the first year of the study, the company dissolved, and thus a different N source with a similar analysis was obtained. The fertilizer employed in years two and three was made exclusively of poultry litter and locally sourced with an analysis of 2.9% N, 3.25% P_2O_5 and 3.7% K_2O (2.9% N – 1.42% P – 3.08% K). All B and 50% of the N was pre-plant incorporated. Remaining N was applied in two equal applications at 5 and 7 weeks after planting (WAP) by banding between rows and lightly incorporating to a depth of 4 cm (Table 1). The amount of applied N for each treatment was calculated starting from the recommended fertilizer amount for a 52-inch bed top, adjusted for the N concentration of the fertilizer (3%) and the actual length of the production plots. Fertilizer was applied on each plot by hand and was distributed as evenly as possible on the bed top, avoiding the shoulder of the bed. Fertilizer was lightly incorporated with a basket weeder prior to final bed shaping.

Sowing Carrots. The production beds were 18 m. long, 1.30 m wide, and approximately 20 cm high. Beds were shaped and pressed prior to seeding. In 2017, ‘Choctaw’ was selected for the trial as it is a variety widely used in organic farming and an adopted cultivar in this area. ‘Choctaw’ is a larger carrot typically used for fresh pack whole carrot. In 2018, compliant ‘Choctaw’ seed was unavailable so ‘Maverick’, a genetically similar and improved cultivar of ‘Choctaw’ was used. Seed both years was sourced from Nunhems USA (Parma, ID). Beds were mechanically cultivated

with a rototiller and reshaped with a bed shaper. Carrots were sown on November 15, 2017 and November 20, 2018 using a Spider (Sutton Agricultural Enterprises, Salinas, CA) vegetable seed planter. This seeder is used widely among farmers in our area. This seeder has an internal high density sponge that attracts small seeds by electrostatic charge, then releases that charge and drops seed in place in rows in the soil approximately 0.63 cm deep and then presses the soil firmly with a roller. Seeds were coated with an organic compliant zeolite to reduce accumulation of static charge in the planter. Carrot were seeded on a 101.6 cm bed top in two strips of seed with four lines of seed in each strip. Carrots were planted at a depth of 0.63 cm in 4 rows per bed. The rows were spaced equidistant from one another 17.8 cm apart to facilitate mechanical weeding. Stand establishment was less than expected each year. Therefore, the seed density increased annually. The population targets were set at 31 live plants per bed foot, or 410,000 plants a^{-1} in 2016, 470,000 plants a^{-1} in 2017, and 500,000 plants a^{-1} in 2018.

Pest Management. A cover crop of cereal rye (‘Wrens Abruzzi’) was seeded between replications annually after carrot seeding to protect young plants from the wind and serve as a barrier to wind-born pathogens. Carrots were scouted weekly for insects, diseases and weeds. Weeds were removed by hand in year one on a weekly basis early in the season, then every 14 days thereafter. In years two and three, new cultivation equipment including a propane flame weeder, a basket weeder and a spring tine weeder were used between carrot rows on the bed tops. Weeds emerging from the carrot canopy later in the season were rouged by hand weekly. Row middles were mechanically cultivated regularly all three years. No insect pests were observed. Special attention was given to Alternaria leaf spot management by applying preventative fungicide applications weekly beginning February 17 through March 27 at first occurrence of Alternaria on the research station. Products were compliant formulations and included Actinovate AG (Streptomyces) and Nordox (copper). All products were rotated to prevent over exposure of any singular active ingredient. Melocon was applied according to the label the season for nematode control.

Pre-harvest soil collection. Soil samples were collected from each plot two to three days prior to harvest by bulking six soil cores (2 cores each between each of the three middle rows on the bed to a depth of 6 inches), mixing, and submitting to ESTL for inorganic N (with KCl extraction) and total Kjeldahl nitrogen (TKN) analysis (inorganic plus organic N). Organic N will be determined by subtraction, and all three variables will be analyzed.

Harvest. Harvest occurred on April 18, 2017, April 20, 2018, and April 17, 2019. Plots were marked to 10 ft sample sections in plot areas that were at least 3 ft from plot ends and excluded buried lysimeters. Carrots were harvested by undercutting the beds with a metal undercutter blade. The undercutter was lowered approximately 15 inches below the top of the bed. A sub plot 10-ft of bed in the center of the plot was used for yield data collection. The carrots were hand pulled from the 10-ft sub plot and tops were removed by hand in the field. Carrots were bagged

in the field and taken to a grading area for data collection. Total harvested weight (lbs) per sub plot was measured and recorded. An additional subsample of carrots was removed from a one quarter meter sample frame to record quality parameters and those methods are summarized below.

Plant fresh and dry weight, length, and crown diameter. At harvest, plants sampled from the frame were numbered so the top weight and its corresponding root weight could be summed for a total plant weight during data management. Tops were removed at the suture with clippers, the crown diameter measured with an electronic caliper, and tops and roots were weighed then measured for length individually and recorded in the field. Each top was placed in a labelled paper bag. Correspondingly, each carrot root was placed in separate labelled bag. After field sampling, the carrots were transported to the laboratory on UF campus and placed in a forced-air oven at 65 °C for 75 h, at which time they were determined to be dry (at constant weight). Dry weight of shoots and roots were recorded by individually per plant, and the samples were submitted to A&L laboratory for determination of total N concentration.

Weather and Irrigation. Weather was generally favorable for carrot production during all years. Center pivot irrigation was scheduled to meet evapotranspiration losses calculated by a 183 cm Sentec probe (Waterford MI) installed in the center of the trial in years one and three. These sensors monitored soil moisture at 10, 20, 30, 40, and 50 cm depths. No probe was installed in year two; instead, soil moisture scheduling was informed by a probe installed on a plot with similar soil 60 m away. The data provided by these sensors guided the irrigation events during the season. Irrigation was supplied as needed using overhead irrigation provided by a center pivot. Cold injury was observed throughout the unit but was minor, only extreme tips of foliage showed signs of browning.

Statistical Analysis. Data were analyzed using the PROC GLIMMIX procedure for each measured variable within SAS Version 9.4 (SAS Institute, Cary, NC). Nitrogen rate was treated as a fixed effect and replication was treated as a random effect. Data were analyzed with years combined and significant interactions occurred between variables, analysis of variance was conducted for each site-year. When only main effects were significant, data are presented for the main effect means of nitrogen rate only. Means separation was used to examine differences between nitrogen rates within each cultivar treatment. Regression analysis was used to determine if a linear or quadratic relationship described the effect of nitrogen rate treatments on carrot yield. A summary of the analysis of variance is presented in Table 2.

Results and Discussion

Carrot Quality. In years two and three, root fresh weight increased with N rates greater than or equal to 280 kg ha^{-1}, and shoot fresh weight responded similarly (Table 3). As root fresh weight increased, so did the crown diameter, which followed similar statistical trends. Interestingly, root length did not respond to increasing N and ranged between 17 and 25 cm throughout the study. Root dry weight is an important quality characteristic to producers because it reduces the proportion of weight loss due to evaporation in transport. Root dry weight (Table 4) was similar among N rates in year one, but increased slightly with increasing N in years two and three; likely not enough to justify the additional costs of N. The percentage of N in both shoots and roots was very low at harvest (Table 4). Shoot N is expected to fall within the 3%-3.5% range. However, nitrogen concentrations in roots and shoots was not influenced by N rate in two of three years, and over the course of the study, the greatest concentration of N recorded was 2.68% in shoots and 1.56% in roots, both in the first year.

Yield. Carrots responded similarly to N rate treatments all three years (Table 5). The fertility source used in the first year resulted in greater yields than the second and third year (data not shown). In contrast to conventional carrot, organic carrot appears to respond more readily to additional N beyond the current IFAS recommendation. Carrot yields in the 168 kg ha^{-1} and 224 kg ha^{-1} treatments would likely fall below economic thresholds based on input received from area growers.

Soil Nitrogen. Only main effects of year ($P=0.0024$) and treatment ($P=0.0223$) were significant for TKN from soil samples collected immediately prior to harvest. Inorganic N was significant only for year ($P<0.0001$). In this study, the residual soil TKN at harvest indicates some N was in organic form and was not available to the crop (Figure 1). Soil inorganic N (NH_4-N + NO_3-N) was approximately 1% of TKN in samples collected at harvest in 2019 (Figure 2). The low amount of mineralized N throughout the profile indicates a very low risk of leaching with this system over the range of N rates. Given the potential remaining for additional mineralization it is imperative that organic producers follow a harvested crop with a deep-rooted cover crop or cash crop in the shortest window of time possible to minimize risk of leaching loss. Nitrogen accumulation at depths below 30 inches could be utilized by deep rooted cereal crops, including cover crops, thus increasing the overall nitrogen use efficiency of the system.

Conclusion

Nitrogen management in organic systems is complex and requires an integrated approach involving crop rotation, pest management, tillage, and other cultural practices. Coordinating the timing of availability of mineralized nitrogen with crop demand will result in the lowest cost to the producer, the lowest risk to water quality, and the greatest crop productivity. In this study,

carrot yield was similar between 336 and 392 kg ha^{-1}, indicating that additional nitrogen contributions beyond 336 kg ha^{-1} with the fertility sources in this study would not result in a crop response.

Literature Cited

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Table 1. Nitrogen application date and rates used in the organic carrot study 2016-2019

	N fertilizer application (kg ha^{-1})		
Treatment (kg ha^{-1} N)	At planting (50% N)	5 WAP (25%)	7 WAP (25%)
168	84	42	42
224	112	56	56
280	140	70	70
336	168	84	84
392	196	98	98

WAP = Weeks after planting

Table 2. ANOVA summary of variables tested in the organic nitrogen rate study during the three production seasons from 2016-2019 in Live Oak, FL

VARIABLE	YEAR	TRT	YEAR*TRT	STE
Fresh Root wt g/plant	<.0001	0.0006	0.5008	8.5748
Fresh Shoot wt g/plant	<.0001	<0.001	0.7589	2.6455
Root Length cm	<.0001	0.4826	0.6513	0.7529
Shoot Length cm	<.0001	<.0001	0.0054	0.9170
Crown Diameter mm	<.0001	0.0002	0.2139	1.2568
Root Dry wt g/plant	<.0001	0.0019	0.6921	0.8483
Shoot Dry wt g/plant	<.0001	0.0009	0.8054	0.3889
Plant Dry wt g/plant	<.0001	<.0001	0.1484	6.5156
Root:Shoot Dry wt	<.0001	0.3064	0.1123	0.1019
Root N%	<.0001	0.1385	0.0411	0.0592
Shoot N%	<.0001	0.2765	0.0382	0.0758
Yield kg ha^{-1}	<.0001	<.0001	0.0543	0.7584

Table 3. Summary of Organic Carrot Quality Characteristics in Response to Five Rates of Nitrogen (N) in 2017-2019 at NFREC-SV, Live Oak, FL

Treatment kg ha^{-1} N	Root Fresh Weight		Shoot Fresh Weight		Root Length	Shoot Length		Crown Diameter	
	g per root		g per shoot		cm	cm		mm	
2016-2017									
168	121.96		35.72		24.32	48.18		36.92	
224	112.96		32.76		23.58	46.40		35.11	
280	121.94		39.64		23.31	49.54		36.39	
336	135.16		40.41		23.90	49.12		38.53	
392	134.70		46.87		24.32	49.48		38.15	
	P=0.4030		P=0.0709		P=0.7359	P=0.0880		P=0.5216	
2017-2018									
168	54.50	C	11.34	B	19.92	34.83	B	22.96	C
224	59.87	BC	12.41	B	19.58	36.43	B	24.84	BC
280	81.06	AB	17.26	AB	21.73	41.22	A	28.16	BC
336	69.66	ABC	14.84	B	20.30	42.72	A	26.50	AB
392	92.99	A	22.39	A	21.73	43.67	A	31.74	A
	P=0.0272		P = 0.0413		P=0.4285	P=0.0011		P=0.0236	
2018-2019									
168	57.99	C	12.24	C	17.25	33.19	C	24.83	C
224	81.59	BC	19.75	BC	18.79	36.21	BC	29.22	BC
280	94.86	AB	25.54	AB	19.69	39.74	B	30.09	AB
336	82.46	BC	23.62	AB	19.81	44.04	A	29.08	B
392	113.76	A	32.93	A	19.99	44.78	A	33.02	A
	P = 0.0201		P=0.0085		P=0.4043	P=0.0001		P=0.0063	

[a]Means followed by the same letter in a column are not significantly different. Mean separation by Fisher's LSD test at 5% level (Alpha=0.05). If no letters are shown, no significant differences were found within the data on that column.

Table 4. Summary of Organic Carrot Quality Characteristics in Response to Five Rates of Nitrogen (N) in 2017-2019 at NFREC-SV, Live Oak, FL

Treatment kg ha^{-1} N	Root Dry Weight g $root^{-1}$		Shoot Dry Weight g $shoot^{-1}$		Root:Shoot Dry		Root N %		Shoot N %	
2016-2017										
168	13.90		5.81		2.40		1.45		2.24	
224	12.92		5.45		2.38		1.51		2.40	
280	14.11		6.32		2.22		1.50		2.68	
336	15.44		6.42		2.40		1.44		2.43	
392	15.90		7.08		2.28		1.56		2.47	
	P=0.3465		P=0.1934		P=0.5077		P=0.4956		P=0.2420	
2017-2018										
168	5.88	C	2.09		2.85		1.31		1.77	
224	6.61	BC	2.21		3.12		1.37		1.90	
280	8.84	AB	2.75		3.23		1.30		1.65	
336	7.61	ABC	2.58		2.99		1.36		2.10	
392	9.40	A	3.27		3.01		1.24		1.56	
	P=0.0342		P=0.01954		P=0.8429		P=0.7177		P=0.0669	
2018-2019										
168	6.74	B	2.05	C	3.26	A	0.96	C	1.03	B
224	9.11	AB	3.15	BC	2.92	B	1.03	BC	1.40	B
280	10.48	A	3.95	AB	2.81	BC	1.18	AB	1.26	B
336	8.93	AB	3.51	ABC	2.75	BC	1.23	A	1.51	AB
392	11.65	A	4.80	A	2.49	C	1.34	A	1.70	A
	P=0.0368		P=0.0304		P=0.0035		P=0.0015		P=0.0374	

[a]Means followed by the same letter in a column are not significantly different. Mean separation by Fisher's LSD test at 5% level (Alpha=0.05). If no letters are shown, no significant differences were found within the data on that column.

Table 5. Organic Carrot Marketable Yield 2017-2019 at NFREC-SV, Live Oak, FL

Treatment kg ha^{-1} N	Yield kg ha^{-1}	
168	37619	C[a]
224	39795	C
280	46378	B
336	50019	AB
392	50815	A
	$P < 0.0001$	

[a]Means followed by the same letter in a column are not significantly different. Mean separation by Fisher's LSD test at 5% level (Alpha=0.05).

Figure 1. Total Kjeldahl nitrogen (TKN) in mg kg^{-1} at six soil depths at organic carrot harvest in 2019 at the UF/IFAS NFREC-SV near Live Oak, FL.

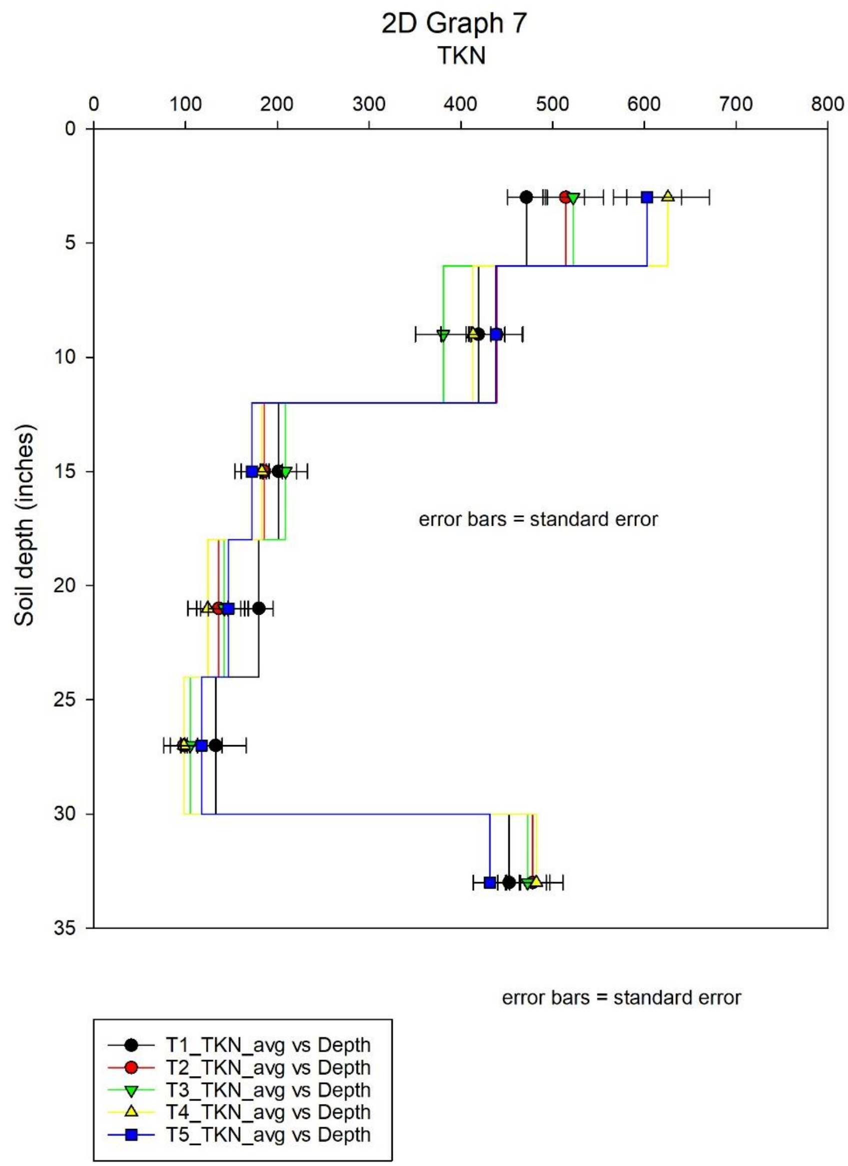
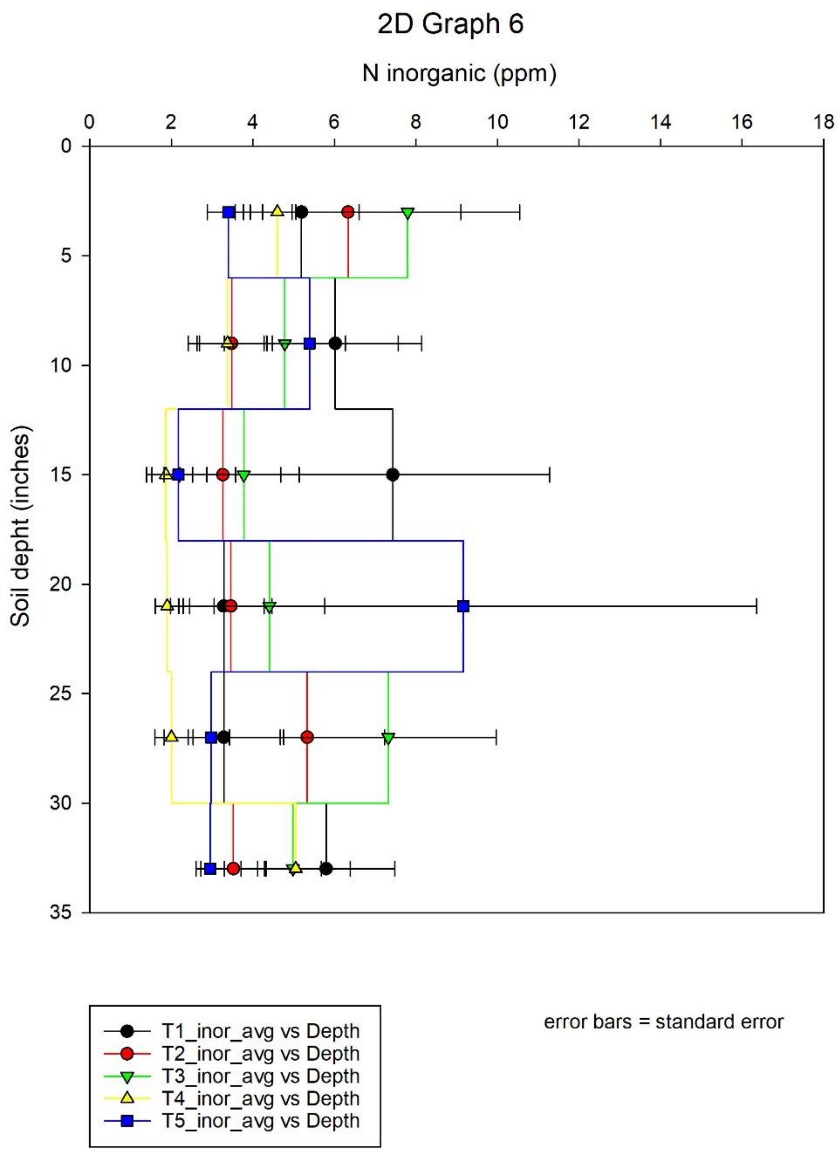


Figure 2. Inorganic nitrogen (NH_4-N + NO_3-N) at organic carrot harvest in 2019.



Photographs of Organic Study

Figure 17. Pelletized poultry litter fertilizer (3-2-3) used in the organic nitrogen study.

Figure 18. Propane flame weeder used on carrot beds after seeding and prior to carrot emergence.

Figure 19. Preharvest soil sampling to 36" in six-inch increments in the organic unit in 2019.

Figure 20. Preharvest sample frame of organic carrots.

Figure 21. Organic carrots from a one quarter meter sample frame before harvest in 2019.

Figure 22. This carrot is a keeper! Organic Unit 2019.

Extension Deliverables

1. Carrot Grower Field Days

The **2017 Twilight Carrot Field Day** was held at the UF/IFAS NFREC- Suwannee Valley on February 16, 2017 from 4:30 to 6:00 pm, followed by an industry-sponsored dinner. Dinner sponsors included: Farm Credit, Nunhems Seeds USA, Inc., and Bejo Seeds Inc. The objective of this meeting was to tour and showcase the carrot research projects being conducted at this UF Center. Research trial plot plans and treatments were provided at the field day. There were 30 attendees at this field day including farmers, researchers, Extension educators, agency representatives and allied industry representatives. The field trials discussed at the field day included the following:

1. Conventional carrot nitrogen rate study with four cultivars (Choctaw, Mavrick, Triton, and Uppercut 25). There are eight nitrogen rates in the study from 50 to 400 lbs/A at 50 lbs/A increments. (PI: Robert Hochmuth, with FDACS Office of Ag Water Policy funding). An aerial view of this trial is attached above.
2. Organic carrot nutrient management study with various rates of organic nitrogen fertilizer**.** (PI: Danielle Treadwell, with FDACS Office of Ag Water Policy funding)
3. Organic carrot nutrient management study with various timings and strategies of organic nitrogen applications**.** (PI: Danielle Treadwell, with FDACS Office of Ag Water Policy funding)
4. Conventional carrot herbicide study evaluating rates and number of applications of Lorox and Tricor. (PI: Peter Dittmar, with SVAEC funding support)
5. Conventional carrot sprayer study comparing a traditional field boom sprayer to an Agmatic Solutions sprayer for disease control. (PI: Nick Dufault, with funding from Agmatic Solutions)

The **2018 Twilight Carrot Field Day** was held at the UF/IFAS NFREC- Suwannee Valley on April 5, 2018 from 5:30 to 7:30 pm, followed by an industry-sponsored dinner. Dinner sponsors included: Farm Credit, Nunhems Seeds USA, Inc., Arysta Life Science, Bayer, Dow/Dupont, Harrell's Fertilizer, and Bejo Seeds Inc. The objective of this meeting was to tour and showcase the carrot research projects being conducted at this UF Center. Research trial plot plans and treatments were provided at the field day. There were 45 attendees at this field day including farmers, researchers, Extension educators, agency representatives and allied industry representatives. The field trials discussed at the field day included the following:

1. Conventional carrot nitrogen rate study with four cultivars (Choctaw, Maverick, Triton, and Uppercut 25). There are eight nitrogen rates in the study from 50 to 400 lbs/A at 50 lbs/A increments. (PI: Robert Hochmuth, with FDACS Office of Ag Water Policy funding)
2. Organic carrot nutrient management study with various rates of organic nitrogen fertilizer. (PI: Danielle Treadwell, with FDACS Office of Ag Water Policy funding)
3. Management of Alternaria leaf blight on carrot by fungicides and SAR inducers. (PI: Dr. Mathews Paret, with funding support from Arysta Life Science)
4. Controlled-release fertilizer use in carrots, a preliminary study. (PI: Robert Hochmuth, with funding support from Harrell's Fertilizer)

5. Evaluating root-knot nematode damage in carrot and efficacy of nematicides. (PI: Dr. Zane Grabau, with funding support from Bayer and Dupont)

The **2019 Twilight Carrot Field Day** was held at the UF/IFAS NFREC- Suwannee Valley on April 8, 2019 from 5:30 to 7:30 pm, followed by an industry-sponsored dinner. Dinner sponsors included: Farm Credit, Nunhems Seeds USA, Inc., Arysta Life Science, Bayer, Corteva, Harrell's Fertilizer, and Pursell Fertilizer. The objective of this meeting was to tour and showcase the carrot research projects being conducted at this UF Center. Research trial plot plans and treatments were provided at the field day. There were 58 attendees at this field day including farmers, researchers, Extension educators, agency representatives and allied industry representatives. The field trials discussed at the field day included the following:

1. Controlled release nitrogen fertilizer studies (2 trials) (PI: Robert Hochmuth, with FDACS Office of Ag Water Policy, Harrel's Fertilizer and Pursell Fertilizer funding).
2. Organic carrot nutrient management study with various rates of organic nitrogen fertilizer (PI: Danielle Treadwell, with FDACS Office of Ag Water Policy funding)
3. Conventional carrots with varied nitrogen and irrigation rate trial (PI: Dr. Michael Dukes with USDA NIFA grant funding, Jason Merrick, PhD student presenting)
4. Foliar disease management of carrot trial (PI: Dr. Mathews Paret with industry funding support)

Note: The well-attended 2019 Carrot field Day was conducted prior to carrot harvest. **Deliverable #11** requires feedback to growers after harvest. The project team plans to conduct a workshop after the September 30 project end date, but final results were still being compiled up to September 30. However, to complete this deliverable, PIs communicated the overall results with the management of key carrot farm (Grimmway Farms). A telephone conversation between R. Hochmuth (Co-PI) and Russ Hamlin, Agronomist for Grimmway Farms, on September 23 occurred to summarize the results of this project. Similar communications occurred between Danielle Treadwell (Co-PI) and Logan Petry, Organic Production Manager for Grimmway Farms, periodically through August and September.

2. Presentations at SE Regional Fruit and Vegetable Conference January 11-13, 2018 (3)

2.1. Poster Presentation

Carrot Nitrogen Management in North Florida Sandy Soils

Hochmuth, R.*, C. Barrett, B. Broughton, and M. Boyette
UF/IFAS North Florida Research and Education Center- Suwannee Valley, Live Oak, Fl.
Contact: Bob Hochmuth, 7580 CR 136 East, Live Oak, FL. 32060. Phone: 386-362-1725.
Email: bobhoch@ufl.edu
Abstract: North Florida's deep sandy soils are excellent for production of carrots, but are also vulnerable to leaching nutrients, especially nitrogen. The recent adoption of a Basin Management Action Plan for

much of the Suwannee River Basin has led University of Florida research and Extension faculty to evaluate nitrogen management strategies for conventional carrot production including, but not limited to, nitrogen rates. Following the 4-Rs Principles (Right: rate, source, placement, and timing), research was initiated in the 2016-17 season at the North Florida Research and Education Center- Suwannee Valley, near Live Oak, FL to evaluate eight seasonal nitrogen rates and four standard carrot cultivars ('Choctaw', 'Maverick', 'Triton', and 'Uppercut 25') for production and quality. Initial data for the 2016-17 season indicates total yield and quality for all four cultivars increased to 150 lbs of nitrogen per acre and leveled off after 200 lbs per acre when all post-planting nitrogen applications were made to the bed top only by using a drop fertilizer spreader, and all irrigation events were managed using multi-level soil moisture sensors to prevent nitrogen leaching.

2.2. Poster Presentation

Nitrogen Management in Organic Carrot Production in North Florida.

Perez, J.[1], D. Treadwell[1], R. Hochmuth[2], B. Broughton[2], M. Boyette[2], and D. N. Campbell[1]
[1]UF-IFAS Horticultural Sciences, Gainesville, FL.
[2]UF-IFAS North Florida Research and Education Center (NFREC)- Suwannee Valley, Live Oak, FL.
Contact: Jose Perez, PO Box 110690, Gainesville, FL, 32611. Phone 352-294-1692
Email: joseperezoro@ufl.edu
Farmers in North Florida produced an estimated 200 acres of organic carrot in spring 2017. Nitrogen (N) recommendations for organic carrots in Florida are needed to support optimum economic yields and also prevent negative impacts to the water quality in the region. This team evaluated the effect of five N rates on the yield and quality of 'Choctaw' carrots grown on USDA-certified organic land at NFREC-Suwannee Valley. These N rates were equal to, greater, and less than the existing University of Florida conventional carrot N recommendations. Shoot length and weight increased with increasing nitrogen plant content (P = 0.0517 and 0.0447), but no differences were observed in roots, root to shoot ratio or dry matter percentage. Yield ranged from 21.2 tons a^{-1} to 25.4 tons a^{-1} and was similar among N rates, indicating that not all the N applied at the higher rates were utilized by carrot, and that excess N may potentially pose a risk to water quality if not utilized by subsequent crops.

2.3. Oral Presentation (Invited)

11:00 – 11:30 Growing Organic Carrots – Dr. Danielle Treadwell, Horticulture University of Florida
Nutrient and water management recommendations in organic carrot production are needed to ensure increase organic carrot production, and to minimize the high costs associated with USDA-organic compliant fertilizer as well as risk to water quality. This presentation will discuss a preliminary recommended nitrogen management strategy for cello-type carrots.

3. Oral Presentation at the Crop Science Society of America's Annual Meeting, Tampa, FL 2017 (1)

Danielle D Treadwell[1]*, Robert C Hochmuth*[2]*, Ludovica Zampieri*[3] *and Jose Perez*[3]*, (1)P.O. Box 110690, University of Florida, Gainesville, FL*
(2)Suwannee Valley Agricultural Extension Center, University of Florida-IFAS Suwannee Valley Agricultural Extension Center, Live Oak, FL
(3)Horticultural Sciences, University of Florida - IFAS, Gainesville, FL

Abstract:
Industry leaders and farmers estimate that within the next three years, carrot acreage in the Suwannee Valley region in north central Florida will exceed 3,200 – 4,000 ha. The carrot industry is currently 1,214 ha, of which 405 ha are certified organic. Pursuant to the Florida Watershed Restoration Act, a two year study of organic carrot was initiated to develop N BMPs that would retain N in the root zone and minimize risk to water quality. The University of Florida's (UF/IFAS) N recommendation for conventional carrots is 196 kg ha^{-1} N. No N recommendations exist for organic systems, specifically. Five N treatments ranging from 168 kg ha^{-1} N to 393 kg ha^{-1} N in 56 kg ha^{-1} increments were randomized and replicated four times in the certified organic unit at the UF/IFAS Suwannee Valley Extension Center near Live Oak, FL. Prior to field preparation, barrel lysimeters were installed under each plot to a depth of 0.81 m to monitor nitrate leaching. A commercially available poultry litter fertilizer (3%N, 2%P_2O_5, and 3% K_2O) was used. Boron (B) at 2.24 kg ha^{-1} was added per pre-plant soil test recommendation. All B and 50% of the N were pre-plant incorporated. Remaining N was applied in two equal applications at 5 and 7 weeks after planting (WAP) by banding between rows and lightly incorporating to a depth of 3.8 cm. A cello-type carrot [*Daucus carota* L. var. *sativus* (Hoffm.) Arcang] 'Choctaw' was seeded November 14, 2016 on 18.3 m beds (four 16.5 cm row spacing) by mechanical seeder to 459,200 seed ha^{-1}. Center pivot irrigation was scheduled to meet evapotranspiration losses calculated by a 183 cm Sentec probe (Waterford MI) installed in the center of the trial area. One day prior to harvest, soil samples and aboveground weed biomass were collected from each plot, and lysimeters were pumped yielding samples from four plots. On April 13, 2017 (12 WAP) carrots were harvested within a 3 m section of each plot, graded, and weighed. Carrot root and shoot subsamples were analyzed for root:shoot weight and total N; and together with weed biomass, lysimeter and soil solution data, will be used to estimate the distribution of N within each N rate treatment. Carrot yield was similar among treatments and ranged from 47,636 kg ha^{-1} in TRT 2 (224 kg ha^{-1} N) to 56,872 kg ha^{-1} in TRT 5 (392 kg ha^{-1} N) and supported our visual observations of similarities among treatments prior to harvest. Yield in this experiment was similar to commercial growers in our area. While these results are preliminary, evidence suggests that the amount of N required in organic carrot systems is less than published recommendations for conventional carrot systems, and additional N may pose a risk to water quality.

4. Popular Press Article (1)

Vegetable and Specialty Crop News. July 6, 2017. Available at: http://vscnews.com/carrot-industry-emerging-florida/

"Research Support for the Emerging Organic Carrot Industry in Florida's Suwannee Valley"

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5. Agency and Allied Industry Presentations

PowerPoint Presentations were given by Robert Hochmuth to various groups over the course of this grant. These presentations included an overview of the carrot BMP research being conducted as a part of the overall presentations. Examples of the presentations included but not limited to:

1. Developing Nitrogen Recommendations for Vegetable Crops- Carrot Example. Presented at Fertilizer Industry 4-Rs Training Live Oak, FL. 2018
2. NFREC-Suwannee Valley Research and Extension Update for Water and Nutrient Management. Presented to Florida Farm Bureau State Committee for Water and Fertilizer Research 2018
3. NFREC-Suwannee Valley Research and Extension Update for Water and Nutrient Management. Presented to the Suwannee River Partnership Steering Committee. 2018.
4. UF/IFAS NFREC-Suwannee Valley- What We Do. Live Oak Rotary Club and Live Oak Lions Club. 2019

6. NFREC-Suwannee Valley Research Field Trolley Tours

During the three years of this project, at least ten tours each year (30 total) were conducted at the NFREC-Suwannee Valley that included a stop at the organic and conventional carrot BMP research plots. These tours provided the opportunity to increase the knowledge of at least 1,000 citizens about the carrot BMP research program. These particular trolley tours were generally focused on showcasing the water and nutrient management trials being conducted at this Center. Tour groups included several stakeholder groups including, but not limited to: local and state legislative groups, Farm Credit of Florida, Leadership Suwannee, NFREC-SV Advisory Committee, UF Division of Sponsored Programs-Office of Research, Florida Association of Conservation Districts (NE Region Counties), Florida Association of County Agricultural Agents Mid-Year Meeting, FDACS Office of Ag Water Policy (various administration and staff), Nuffield International Farm Scholars, Springs advocate groups, and various Florida FFA chapter teachers and members.

Photographs of Extension Programs

Figure 23. April 5, 2018 Carrot grower field day

Figure 24. April 5, 2018 carrot grower field day tour at conventional nitrogen rate study.

Figure 25. 2018 organic Plots at the carrot grower field day tour.

Figure 26. 2019 carrot field day discussion regarding controlled release fertilizers, April 8, 2019

Figure 27. 2019 Carrot field day indoor meeting topic discussions, irrigation BMPs.

Figure 28. 2019 carrot field day, organic research plot presentation

Figure 29. Organic carrot plots at carrot field day April 8, 2019

Figure 30. Weeding implements used in the organic research plots and displayed for discussion at 2019 carrot field day

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