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The Effect of Nitrogen on Population Dynamics of the Chilli Thrips, *Scirtothrips dorsalis* (Thysanoptera: Thripidae), on Hydroponically Grown Jalapeño Pepper (*Capsicum annuum*)

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Chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) is an economic pest of fruit, ornamental, and vegetable crops. The present study addresses the effects of nitrogen (N) fertilization on the population dynamics of chilli thrips on Jalapeño peppers (*Capsicum annuum*) that were grown in a hydroponic system with different concentrations of N. We experimented with five concentrations of hydroponic fertilizer (2%, 4%, 5.5%, 7%, and 8.5%) that were given to Jalapeno peppers by fertigation, with N being the independent variable while concentrations of potassium and phosphorus were held constant. A 4% N concentration was found to be the most favorable since it resulted in the fewest chilli thrips per leaf (0.86), produced the highest mean number of marketable fruit per plant (9.75), and produced the largest average fruit size per plant (85.76 g). Increasing concentrations of N did not increase fruit yields. For each N concentration, the lowest third of the pepper plant was found to have the highest mean number of chilli thrips per leaf. This study will help pepper growers manage populations of the chilli thrips, a major economic pest, by altering N fertilizer concentrations to optimum levels. This study will also help to determine the ideal on-plant level scouting area for growers to expeditiously find chilli thrips on pepper plants. This research study has significant potential in developing an integrated management program against chilli thrips in fruit, ornamental, and vegetable crops.

Chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) is a polyphagous plant pest with a host range of more than 200 plant species in over 40 families (Mac Leod and Collins, 2006. The geographic distribution of *S. dorsalis* includes parts of Asia and the United States (Ananthakrishnan, 1993; Chang, 1995; USDA–APHIS, 2007). It was first detected in Miami, on a shipment of peppers from St. Vincent and the Grenadines in 2003 (Seal et al., 2006). Since its establishment in 2005, chilli thrips has become a major pest in ornamental and landscape plants, but is also known to attack citrus, strawberry, grape, cotton, onion, rose, tomato, and other fruit and vegetable crops (Coolidge, 2005; Kumar et al., 2012; Silagyi and Dixon, 2006).

Chilli thrips directly and indirectly injure their host plant with the oviposition by females and feeding behavior. Chilli thrips injure plants by piercing and emptying plant cells using their stylet-like mouthparts (Ananthakrishnan, 1993). This causes a bronzing of leaves from injury to subdermal tissue and ultimately deforms the plant parts. Robust infestation can defoliate the plant (Seal and Klassen, 2009). Indirect injury is caused by transmission of viral diseases; chilli thrips are known to vector the *Peanut bud necrosis virus* (PBNV), the *Peanut chlorotic fan virus* (PCFV), the *Peanut yellow spot virus* (PYSV), the *Tomato spotted wilt virus* (TSWV), and several other plant diseases (Funderburk et al., 2011).

Pepper is an important vegetable crop in Florida, where it is grown on more than 17,500 acres and sold primarily as a fresh product during the winter (USDA–ERS, 2013). Yields range from less than 1,000 bushels/ acre to more than 1,333 bushels/acre. Production costs often exceed $12 per bushel or $12,100 per acre, hence a yield of at least 1,000 bushels per acre is needed to meet production costs (Li et al., 2006). Considering the importance of the pepper crop, the present study will focus on limitations to jalapeño pepper production.

Pepper production is affected by biotic and abiotic factors. Biotic factors include soilborne pathogens and insects that damage different parts of the pepper plants, resulting in economically important losses to the crop. As a biotic factor, chilli thrips is an important pest that causes considerable yield losses (Seal et al., 2006). The most important abiotic factors include irrigation and fertilization levels (Jovicich, 2001). High N-based fertilizers used in commercial production of pepper enhance plant growth, but if used improperly, may cause various pest problems (Kwon, 2006; Lu et al., 2007; Mattson, 1980; Petitt et al., 1994; Ponder et al., 2001; Villamayor, 1976; White, 1984).

Hydroponic crop production offers many advantages over traditional crop production in soil (Stajano, 2003). Hydroponics may involve the use of vertical growth systems, which can in-

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crease crop production per unit area of greenhouse (Tyson, 2011). Hydroponic crops grow faster and larger than crops grown in soil because the plants use less energy acquiring nutrients from the soil. All required nutrients are fed directly from irrigation water to the root systems of hydroponically grown plants. Water efficiency can be at least doubled in a hydroponic system because water is only introduced when it is lost to the plant (Burrage, 1998). Many soilborne pathogens and pests are avoided in hydroponic systems because there is no soil to provide a refuge or inoculating medium (Massachusetts Institute of Technology, 2012).

Mannion et al. (2012) evaluated the effects of three fertilization rates on population densities of chilli thrips on several rose cultivars. Plants given high fertilization were more attractive to chilli thrips than the control plants. However, no significant difference was observed for *S. dorsalis* densities among the different rates of fertilizer. Nitrogen levels can also affect the rate of insect feeding (Ponder et al., 2001). On cotton, Villamajor (1976) found that N-fertilized plants were more susceptible to attack by *Aphis gossypii* and *Helicoverpa armigera* than unfertilized plants, and higher N rates led to higher infestation rates, but also higher yields. When plants are heavily fertilized, more free amino acids are available in their tissues, allowing for more rapid growth of the plant and of insect populations that feed on them (Mattson, 1980). Thus, N is an important limiting factor in the life cycle of herbivores (Mattson, 1980). There have been no previous studies on the effects of different N fertilizer levels on chilli thrips under hydroponic conditions.

The goal of this study was to determine how N levels applied to jalapeño peppers affect the population dynamics of chilli thrips in hydroponic systems. The purpose of this research was to determine the fertilizer rate that best promotes plant growth without increasing *S. dorsalis* population density on jalapeño peppers. We also determined the level of plant damage caused by *S. dorsalis* to jalapeño peppers grown under five N concentrations.

Materials and Methods

Chilli thrips colony maintenance. Chilli thrips colonies were maintained in a greenhouse at the Tropical Research and Education Center in Homestead, FL where the thrips were raised on cotton (*Gossypium hirsutum*) and jalapeño pepper plants. The cotton and pepper plants were raised from seeds in a Fafard #2 soil mix (Premier Tech Horticulture, Quakertown, PA). Cotton was seeded directly into 2-L pots (3 seeds per pot) filled with the soil mix. The pots were watered once daily or as needed with 100 mL each time to maintain sufficient moisture in the soil. Fertilizer (20N–20P–20K) was applied at the rate of 89 mL once a week.

Cotton and pepper plants were planted every 2 weeks to ensure a continuous source of young plants to rear chilli thrips and remained in the greenhouse until use in an experiment. Cotton and pepper plants were infested with chilli thrips by placing the 2-week-old plants into different greenhouse colonies with thrips that were continuously maintained since 2005.

Estimation of chilli thrips colony population density. Cotton and jalapeño pepper plants were checked routinely to observe chilli thrips population abundance. Random samples of one cotton leaf were examined and the number of thrips was recorded. A total of 10 leaves were observed per sample. Once at least five thrips per leaf were obtained, the colony population was considered sufficient to begin the study.

Maintenance of hydroponic system and host plants. A recirculating hydroponic drip system was used with five different N concentrations. This system was comprised of a 37.85-L nutrient solution reservoir and a 61 × 122 cm tray. A water pump (1,500 L/h), inside the reservoir transported the nutrient solution to the tray by 1.27-cm irrigation tubing that branched into 0.64 cm drip irrigation "dripper" tubes. Each pepper plant had a dripper tube with a maximum flow rate of 10.72 L per hour. All peppers were grown in 1.89-L plastic pots filled with coco-coir hydroponic substrate (BWI, Homestead, FL). As the solution dripped out of the bottom of each pot, it was collected in the tray and then directed back into the reservoir (Fig. 1). The system was on a timer set to fertigate for 15 min once a week at 8:00 PM to ensure that the solution was circulated and that the substrate was well saturated. Coco-coir is an inert hydroponic growing medium used as a soil alternative by commercial growers (CANNA Gardening, 2012). One of these systems was used for each level of N; hence, there were five of these hydroponic systems in the test.

Pythium spp. fungi has been known to circulate in hydroponic systems (Goldberg et al., 1992); hence, a 10% chlorine bleach solution was used to clean and soak all components of the hydroponic system before beginning the test and after the test to clean and maintain the systems. When used properly, chorine bleach is an effective disinfectant often used by growers (Smith, 2012). With the plants and nutrient solution removed, the bleach solution was circulated in the system then rinsed from the system with fresh water.

Description of hydroponic nutrient solution. A commercial two-part nutrient solution (Canna COGr Vega, CANNA Continental, Los Angeles, CA) was used. A preliminary study determined the upper and lower limits of N that could be provided to pepper plants without causing phytotoxicity. The concentrations of the other macronutrients (potassium and phosphorus) were maintained at the recommended rates described by the manufacturer (4%). The pH of the nutrient solution in each reservoir was checked weekly and maintained between 5.5 and 6.5 using either food grade phosphoric acid to lower pH or a mixture of potassium hydroxide and potassium carbonate to raise it.

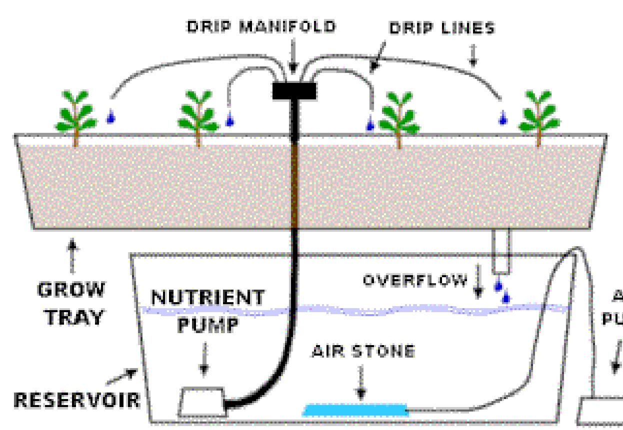

Fig. 1. Recirculating-drip hydroponics. This system includes a nutrient solution reservoir with a pump delivering the solution to the plants in a tray by drip irrigation tubing. The solution is collected in the tray as runoff from the plants, then flows back into the reservoir. Image source: Hydro-heaven.com

Description of host plant culture in the hydroponic system. All seeds were germinated in rockwool starter plugs or "slabs" (Rockwool B.V., Grodan, The Netherlands). Rockwool slabs were first soaked in slightly acidic water (5.5–6.5 pH) to neutralize the pH and prevent seedlings from burning as recommended by the manufacturer. One or two jalapeño pepper seeds were then planted in each cube-shaped slab, which was then placed in a screen cage to germinate.

Once the seeds germinated, the seedlings were fertigated with half-strength (2% N) nutrient solution. Seedlings were considered ready for placement into the hydroponic system when they had two pairs of non-cotyledonous leaves. Once transplanted, plants were separated into treatment groups and then placed into a hydroponic system with a given N concentration in the nutrient solution. Cotton plants infested with chilli thrips were then placed around each hydroponic system to allow chilli thrips to migrate to the hydroponic peppers.

Experiment 1—Resource location, distribution, and abundance of chilli thrips on three plant sections

Distribution patterns of chilli thrips were investigated on 'Jalapeno' pepper plants grown with five concentrations of N [2.5%, 4% (the recommended rate), 5.5%, 7%, and 8.5%] using hydroponic systems. Ten plants in four replications were used for each N concentration. Because N concentrations vary between heights of a plant (Mattson, 1980), the abundance of chilli thrips development stages was studied at three levels of jalapeño pepper plants (top, middle, and bottom) 4, 6, 8, 10, and 12 weeks after planting. To indicate relative amounts of photosynthesis, a SPAD meter was used to determine chlorophyll density at each plant level for each N concentration.

One leaf was collected from each plant height (top, middle, and bottom) and placed in a plastic sample cup with 50 mL of 70% ethanol, shaken for 5 s, and then removed from the alcohol. The date, N level, replication, and plant part were recorded for each plastic sample cup. Alcohol in each sample cup was checked using a 10X binocular microscope to determine the number of male and female adults and first and second instar immature chilli thrips.

Experiment 2—Determination of chilli thrips feeding injury on pepper plants grown in five N concentrations

The objective of this experiment was to determine a rate of N fertilizer that will cause significant marketable fruit yields without causing significant increases in the chilli thrips populations. Pepper plants were raised under the same conditions as in the previous study. With N concentration as the independent variable, eight hydroponic systems, each with a different N concentration was used. We observed the numbers of thrips found on these plants and recorded other life cycle data.

Information was collected on the jalapeño pepper plant's height and width, number of marketable fruit and fruit weight. Other parameters were considered to assess the effects of chilli thrips feeding as follows:

Approximate volume of each plant. Height was measured from the surface of the soil to the tip of the topmost leaf. Width was measured at the widest spread of each plant and again after rotating the plant 90°. These three values were then multiplied to provide the approximate volume of the plant.

Number of fruit and number of marketable fruit. The number of mature fruit was recorded for each plant at each N level. Number and total weight of marketable fruit per plant was also recorded.

Results and Discussion

Resource location, distribution, and abundance of chilli thrips on three plant sections. There were more chilli thrips per leaf found on the lower plant section than on the middle or top sections (Fig. 2). The top and middle plant sections had similar numbers of chilli thrips per leaf, except for the 7% N treatment, which had a larger difference between the two sections. Because there was a higher mean number of chilli thrips on the lower sections than on the middle or top plant sections across all of the N concentrations, the lower section seems to be the best part of the plant to examine when scouting for chilli thrips. Results from the SPAD meter indicated there was a higher chlorophyll density, hence a higher rate of photosynthesis, in the top and middle than

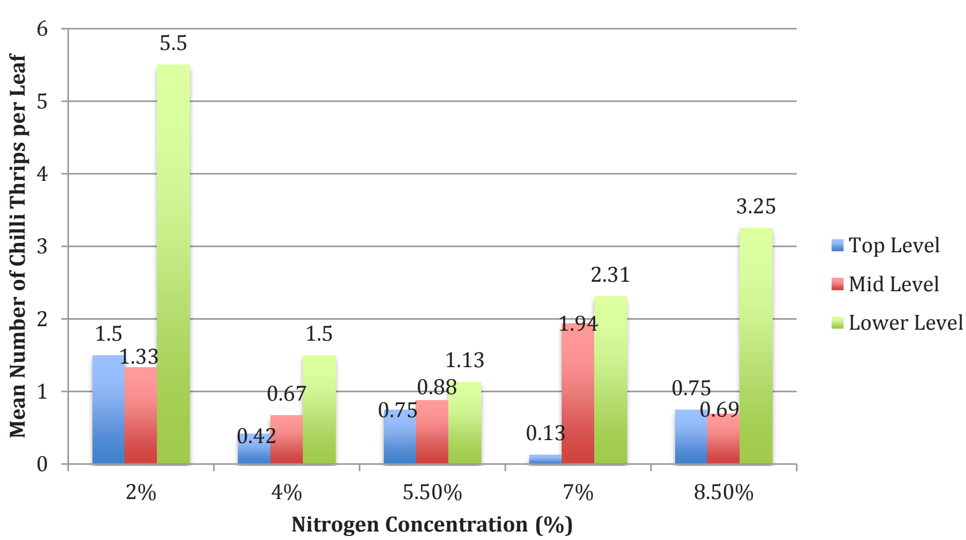

Fig. 2. Mean numbers of chilli thrips per leaf found on the top, middle, and lower plant sections at each nitrogen treatment level.

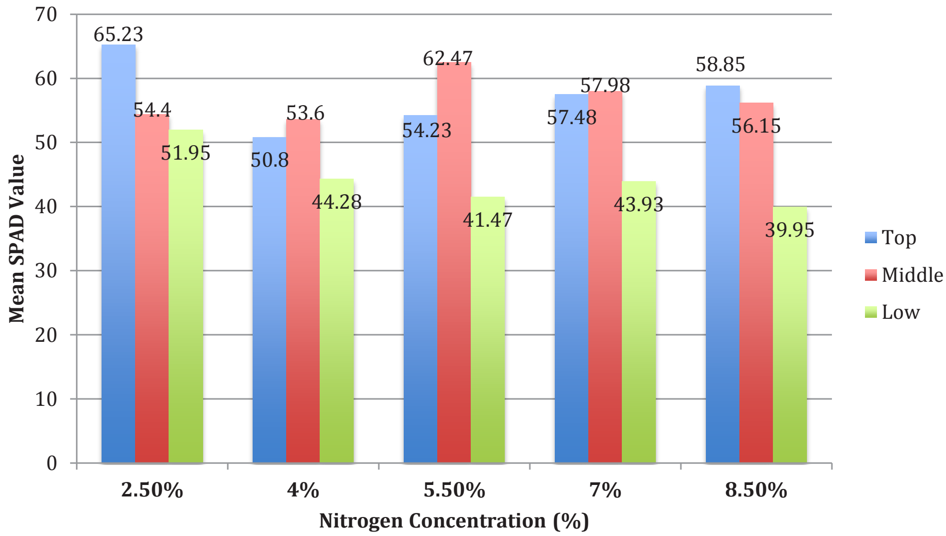

Fig. 3. Mean chlorophyll density as indicated by the SPAD meter in the top, middle, and lower plant sections at each nitrogen treatment level. The SPAD meter uses a numerical index value with a higher number indicating a higher chlorophyll density.

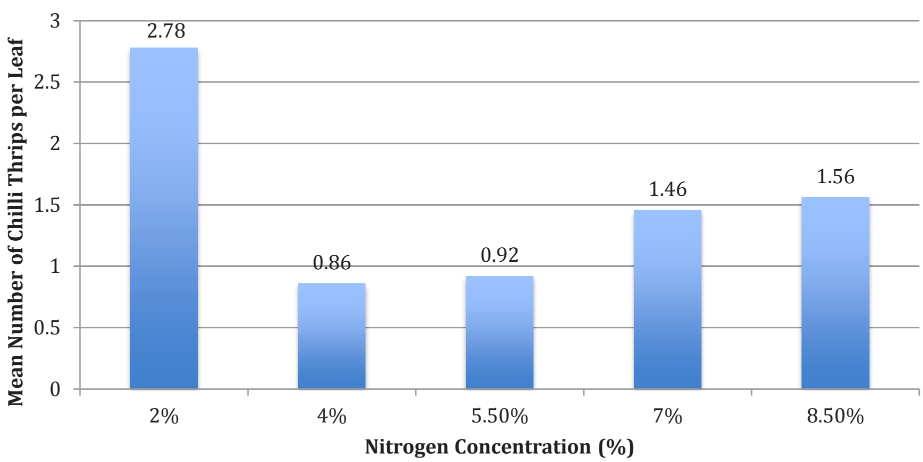

Fig. 4. Mean numbers of chilli thrips per leaf at each nitrogen treatment level.

in the lower plant sections (Fig. 3), which was consistent with across all five N treatments. There were more chilli thrips per leaf found on the 2% N treatment than on the other treatments, while the 8.5% N treatment was second highest (Fig. 4). The 4% N treatment had the lowest mean number of chilli thrips per leaf. The N concentration recommended by the manufacturer (4%), with an average of 0.86 chilli thrips per leaf, was hence the best at controlling the thrips population. The 5.5% N treatment also provided relatively good control at 0.92 chilli thrips per leaf.

Determination of chilli thrips feeding injury on jalapeño pepper plants grown in five nitrogen concentrations. The 2% N concentration resulted in the lowest mean plant volume (Fig. 7), lowest mean number of fruit per plant, and the second smallest mean number of marketable fruit per plant (Fig. 5). The 7% N concentration had the highest plant volume at 1,228 cc. However, the 7% N treatment did not produce the largest mean number of marketable fruit (Fig. 6). The N treatment with the largest number of marketable fruit (9.75 per plant), the largest mean weight per fruit per plant (85.76), and the second highest plant volume (994 cc) was the 4% N concentration. The next highest concentration (5.5%), produced the lowest average number of marketable fruit per plant (1.5). Hence, higher N concentrations did not produce more marketable fruit per plant than the 4% N recommended by the manufacturer. Increasing the N concentration on pepper plants actually had the opposite effect and caused a decrease in the mean number of fruit per plant. In conclusion, the manufacturer's recommended rate of 4% N was the best concentration because it produced the most marketable fruit per plant, the largest marketable fruit per plant, and had the lowest mean number of chilli thrips per leaf.

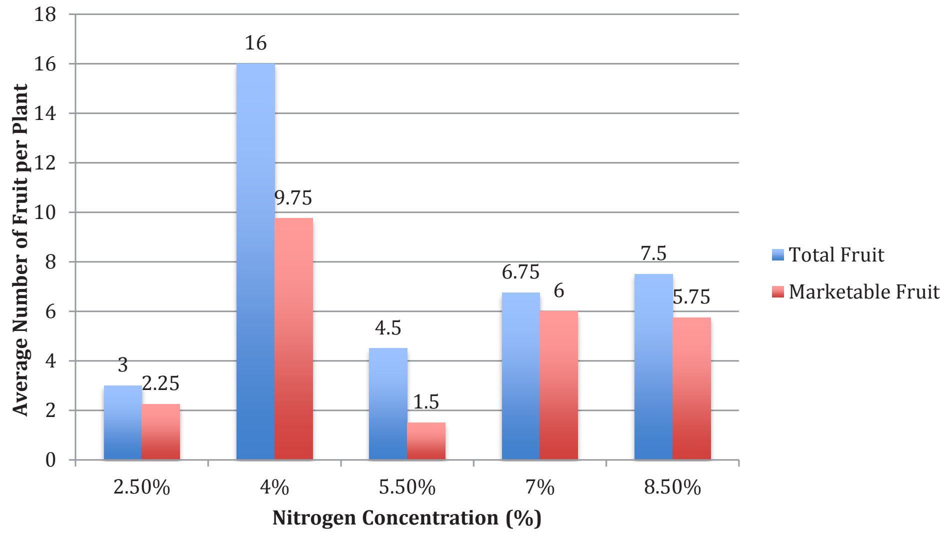

Fig. 5. Mean numbers of Jalapeno pepper fruit per plant compared to mean numbers of marketable fruit per plant at each nitrogen treatment level.

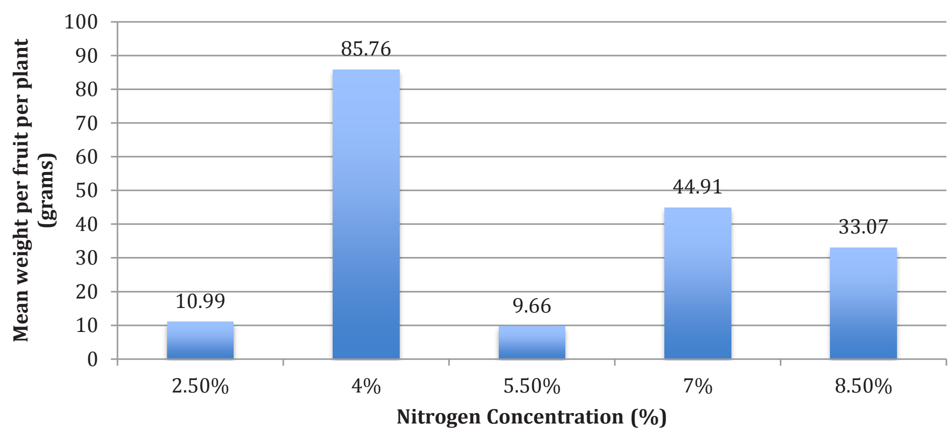

Fig. 6. Mean weight of fruit per plant at each nitrogen treatment level.

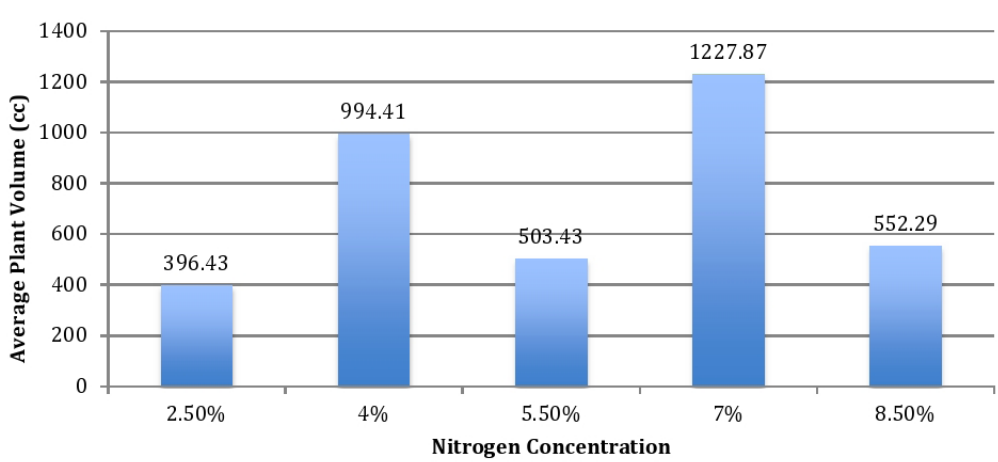

Fig. 7. Mean approximate volume per pepper plant at each nitrogen treatment level, determined by multiplying the canopy width (measured twice, at 0° and 90°) and height.

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