

Soil Moisture and Nutrient Dynamics in the Root Zone of Collard Greens in Different Organic Amendment Types and Rates

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Abstract. *Understanding how organic amendment affects the soil-water-plant-atmosphere continuum has become imperative as the use of organic amendments in conventional and organic agricultural production is increasing. A study was conducted at the Prairie View A&M University Research Farm to investigate the effect of organic amendment types (Chicken manure, Cow manure, and Milorganite) and application rates (0, 168, 336, 672 kg total N ha⁻¹) replicated three times on soil moisture and nutrient dynamics within and below the root zone of collard greens. Soil moisture sensors were installed at all 36 plots to monitor soil moisture within and below the root zone. Suction cups were used to collect soil water samples from 15 and 45 cm depths. Soil water samples were collected six times during the growing season at each plot and analyzed for different nutrients (N, P, K, Ca, Mg, Na, Fe, Mn, Zn, and Cu). The preliminary results showed that both organic amendment types and rates affect the soil moisture and nutrient dynamics. The Chicken manure treatments seemed to have the higher water contents consistently for a major portion of the growing season. However, the water contents of the Cow manure and Milorganite treatments were very comparable and relatively lower than that of the Chicken manure treatments. Most of the total Nitrogen concentration increment occurred after irrigation and rainfall. The Cow manure treatments had the lowest value of total Nitrogen concentration in soil solutions collected within and below the root zone in all amendment rates.*

Keywords. soil moisture, nutrients, collard greens, organic amendments

Introduction

In order to meet the increasing demand for food currently and in the future, it is important to optimize crop yields by minimizing inputs, mainly water, and nutrient application. Many approaches have been developed to improve water management (Feres and Goldhamer 1990) approaches such as real-time soil water content monitoring sensors (Hanson et al. 2000a) or plant water status monitoring sensors (Goldhamer and Feres 2001; Intrigliolo and Castel, 2004; Hedley and Yule, 2009).

The role of soil moisture in the unsaturated zone plays a key role in many agricultural and environmental studies (Wang and Qu, 2009; Walker, 1999). Therefore, it is important to accurately monitor and estimate variations of soil moisture within and below the root zone to optimize irrigation scheduling that will minimize crop water stress and excess water leaching below the root zone that can have adverse environmental effects (Fares and Alva, 2000). Real-time soil moisture monitoring used for irrigation scheduling helps conserve water and nutrients (Vellidis et al., 2008). The soil moisture data is used to quantify the water content of root zone that needs to determine when and how much to irrigate to replenish the water content in the root zone to its field capacity level and prevent nutrient leaching due to over irrigation. Good irrigation management is vital for optimum crop production and minimum nutrient losses that might contaminate our water resources (Jones, 2004).

Cow manure, Poultry manure, and Milorganite are sources of Nitrogen (N) as well as other macro- and micro-nutrients (Reiter et al., 2014). As such, organic farmers use manure to achieve adequate crop yield (Lim, 2015). However, improper application of manure may affect the environment through nitrate leaching (Paramasivam et al., 2009; Fares et al., 2008). Once leached below the root zone, nitrate (NO_3^- -N) is no longer available for plant uptake and may eventually end up in groundwater (Chinkuyu and Kanwar, 2001; Ahmad et al., 2009). The mobility of nutrients in the vadose zone is a function of manure rate and time of application. Leaching of nutrients also depends on the soil water inputs and uptakes. Water flow and nutrient movement through the vadose zone are affected by the soil physical and hydrological properties; it is equally known that organic amendments impact soil physical properties (Fares et al., 2008). The main objectives of this study are: i) to establish a site-specific irrigation scheduling for collard greens under Southeast Texas conditions, and ii) quantify the effect of organic amendment types and rates on the water and nutrients dynamics under this crop. In order to achieve these objectives, first we need to understand the dynamics of soil water content in the root zone of the collard greens in order to establish site-specific irrigation scheduling, and then evaluate nutrients fates and concentrations within and below the root zone.

Materials and Methods

Study Site

The research was conducted at the University Research Farm of the College of Agriculture and Human Sciences, Prairie View A&M University.

Experimental Design

Three organic amendments: (i) Cow manure, (ii) Chicken Manure, and (iii) Milorganite and four application rates (non-amendment control [0 kg N/ha], half recommended rate [168 kg N/ha], recommended rate [336 kg N/ha], and double the recommended rate [672 kg N/ha]) were applied on 36 raised bed plots of size (300 cm x 150 cm). Figure 1 shows the 36-plot experimental layout. The organic

amendments applied to each plot and then mixed into the top 15 cm of the soil using hoes and rakes. Soil moisture sensors, suction cups, and collars for CO₂ monitor were installed on each plot before they were seeded. Plots were seeded with collard greens in October 2017. A three line-drip irrigation system was installed at each bed. A complete weather station was also installed at the site. The experimental site was hand weeded throughout the growing season.

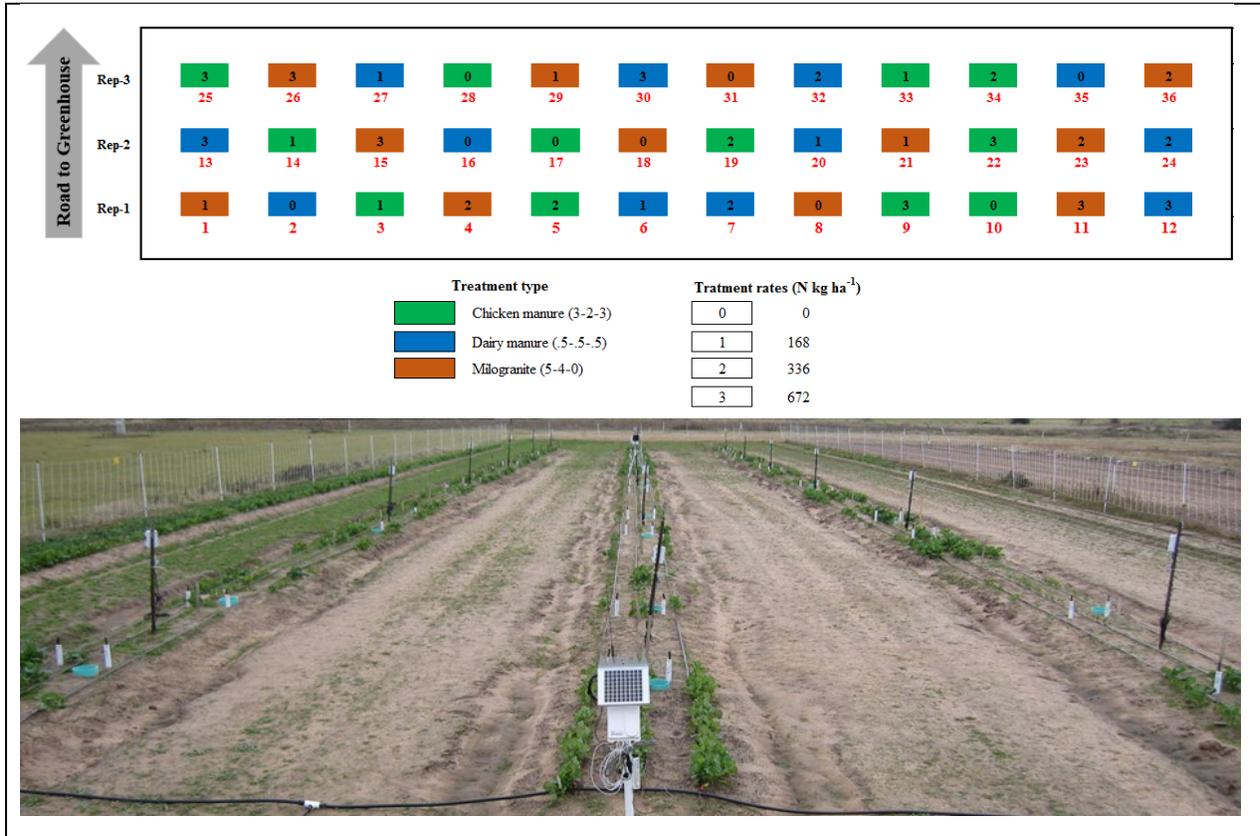


Figure 1. Experimental layout of plots.

Data Collection

Two 10HS soil moisture sensors (METER Group, Inc., Pullman, WA, USA) were installed at each plot to monitor soil moisture in the top 5 cm and below the root zone (at 30 cm). The soil solution suction cups were installed to sample the soil solution at 15 and 45 cm depths. Soil solutions were collected six times during the growing season at each location and analyzed for different nutrients e.g., Total Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sodium (Na), Iron (Fe), Manganese (Mn), Zinc (Zn), and Copper (Cu).

Preliminary Results

Soil Moisture Dynamics

We calibrated the 10HS soil moisture sensors in non-amendment control plots at the same field. The standard calibration equation overestimated the water content (Figure 2). The findings of Fares et al.

(2016) highlighted the need to account for the effect of soil organic matter content to improve the accuracy and precision of the 10HS sensor. However, in this study, we used the same field calibration equation for all plots ignoring amendment types and rates.

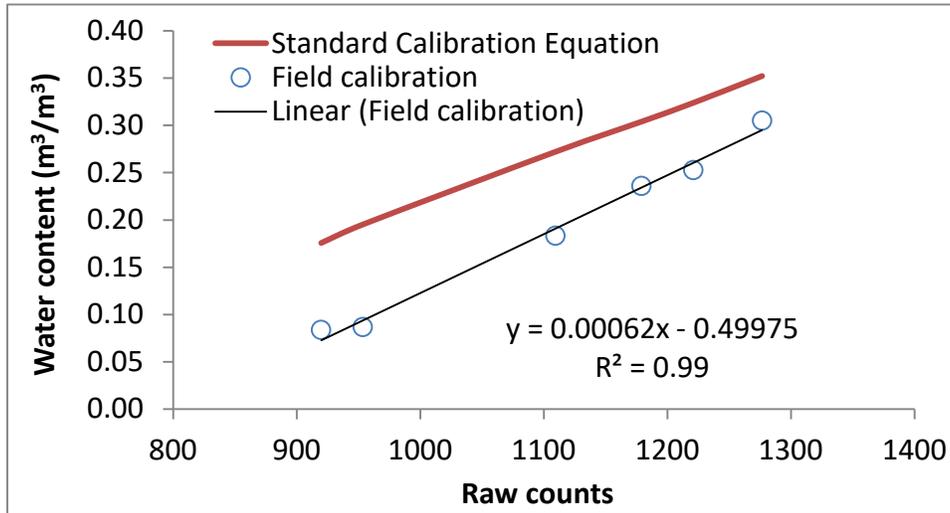


Figure 2. Site-specific calibration equation for the 10HS at University Farm of Prairie View A&M University.

Figure 3 shows the temporal variation of soil moisture within and below the root zone for all amendment types (Chicken manure, Cow manure, and Milorganite) and treatment rate 3 (672 kg N/ha). The soil water content within the root zone was very dynamic across the growing season; it went as high as 0.35 cm³ cm⁻³ and as low as 0.12 cm³ cm⁻³. Increases of the water content within the root zone are in clear response to rainfall and irrigation events; however, the staircase shape of the water content curve, especially during the rain and irrigation free days is in clear response mainly plant water uptake. The Chicken Manure treatments seem to consistently have the higher water contents for a major portion of the growing season. However, the water contents of the Cow manure and Milorganite are very comparable and relatively lower than that of the chicken manure.

The water contents below the root zone were almost consistently higher than those within the root zone; in addition, they were very close to each other; they increased from about 0.29 cm³ cm⁻³ in the beginning of the growing season to 0.33 cm³ cm⁻³ right before the end of the experiment. The lack of strong dynamics is an indicator that not a substantial amount of crop roots, if any, were able to explore that region of the soil. It is important to note that this soil is duplex soil with the top 30 cm as sandy loam and the part below that has relatively high clay content. Differences in soils properties and lack of plant roots could be the main reason for this slow water content dynamics below the root zone.

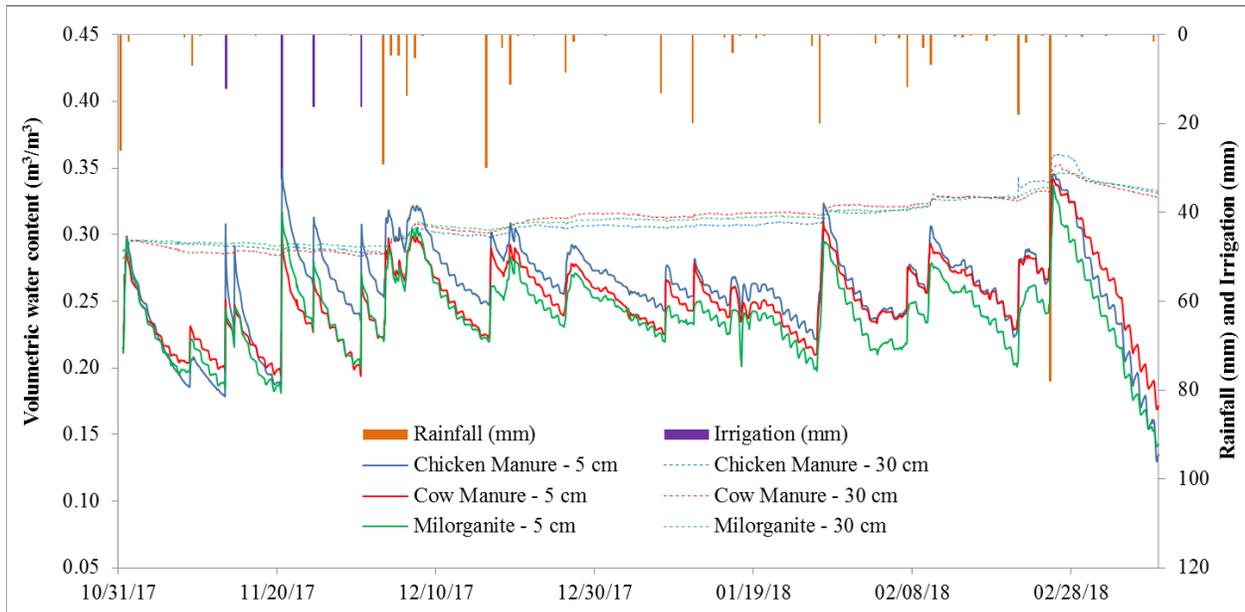


Figure 3. Temporal variation of soil moisture within and below the root zone (Treatment rate 3).

Figure 4 shows the temporal variation of soil moisture within and below the root zone for all treatment rates of Cow manure, from October 2017 to February 2018. The temporal variation of moisture content within the root zone varies in different treatment rates. We also carried out a similar analysis for Chicken and Milorganite amendment rates.

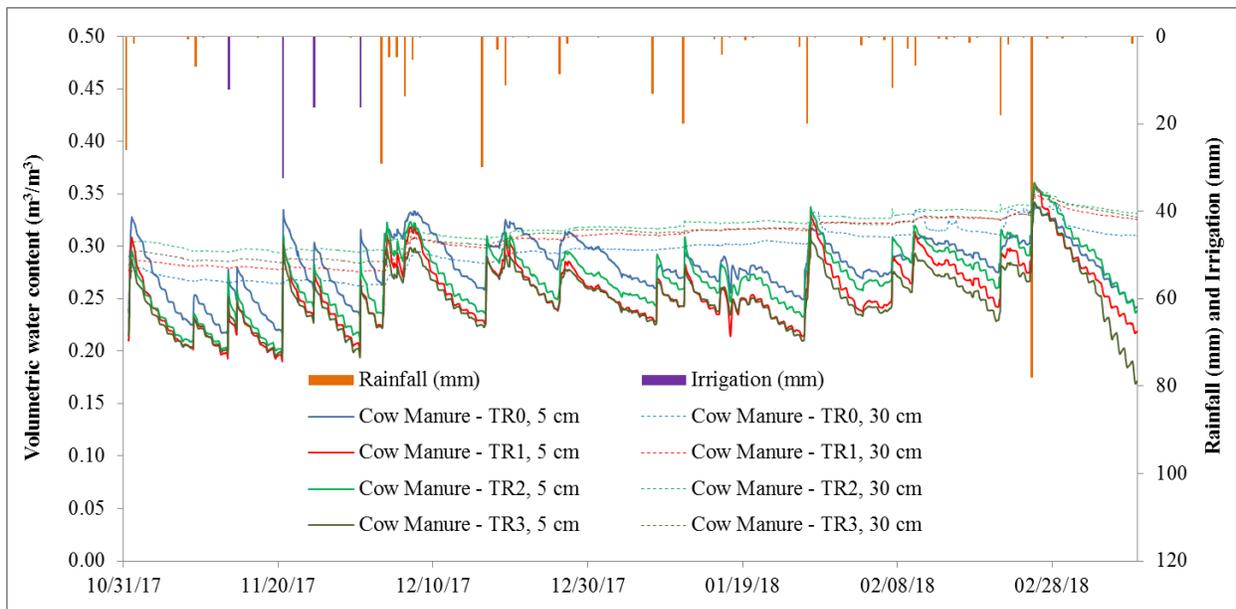


Figure 4. Temporal variation of soil moisture within and below the root zone (Cow manure, treatment rates 0, 1, 2, and 3).

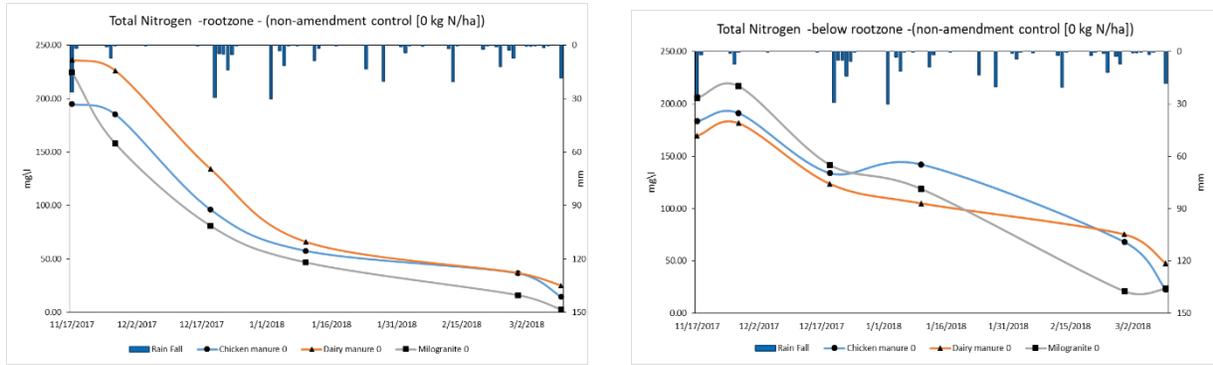
Nutrient Dynamics

Total Nitrogen

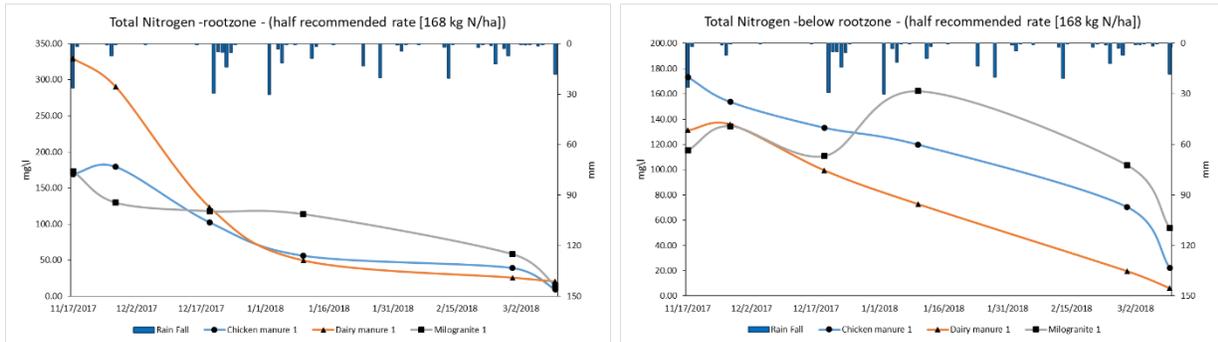
Six batches of samples were collected. Each batch contains 72 samples. The samples were analyzed for nutrients including total N, P, K, Ca, Mg, Na, Fe, Mn, Zn, and Cu. The preliminary analysis of total Nitrogen concentration rate within and below root zone after applying different amendment types, and rates are as follows:

- Figure 5a shows the existence of Nitrogen in the control plots (non-amendment) which is due to the long period of non-agricultural activities in the experimental field. The concentration of total Nitrogen in the control plots gradually decreased during the samples collection period within and below the root zone that can be the effect of rainfall and irrigation. In addition, a slight reduction of Nitrogen concentration in the root zone and below root zone might be due to the growth of collard greens in the control plots.
- The concentration of total Nitrogen had a significant increase in below root zone, after 32 days in the plots of half recommended rate of Milorganite (Figure 5b). Same significant increase in Milorganite had occurred for recommended (Figure 5c) and double recommended rates (Figure 5d).
- The chicken manure had the highest concentration in the root zone and after 32 days in the below root zone among all amendments (Figure 5c).
- In the double recommended rate plots (Figure 5d), the concentration of N in all amendments, remain almost constant after 10 days, within and below root zone.
- Most of the total Nitrogen concentration increment occurred after irrigation and rainfall (Figures 5b, 5c, and 5d).
- The dairy manure had the lowest value of concentration in all cases (Figure 5).
- Figure 6a shows that the total Nitrogen concentration rate for both control and half-recommended plots of chicken manure within and below root zone are almost the same. In addition, the total Nitrogen concentration resulted from the recommended rate was almost remained constant after 30 days in the root zone (Figure 6a).
- The total N concentration from dairy manure in all rates is about the same after 32 days within the root zone. The highest concentration below the root zone had occurred from the recommended rate of dairy manure (Figure 6b).
- After 10 days, the recommended and double recommended rate of Milorganite had approximately the same and highest values of concentration within the root zone. The double recommended rate had the highest concentration below the root zone after the same period (Figure 6c).

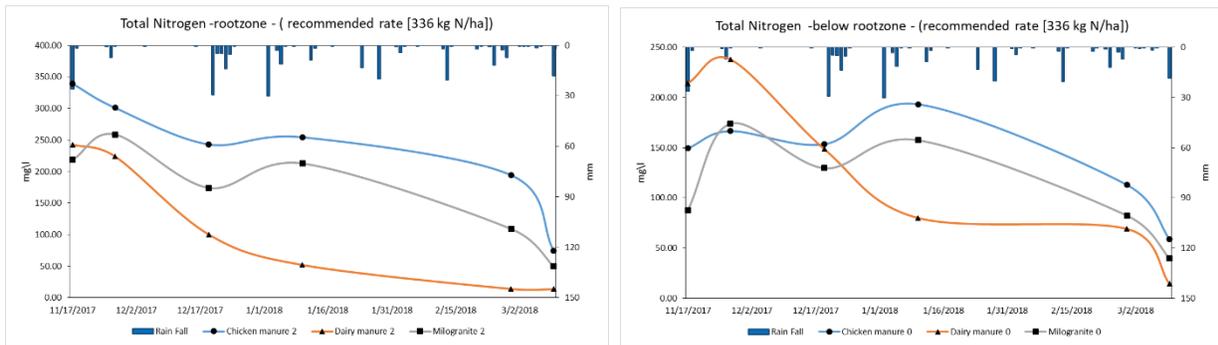
We conducted a similar analysis for other nutrients (P, K, Ca, Mg, Na, Fe, Mn, Zn, and Cu) which will be reported in the near future.



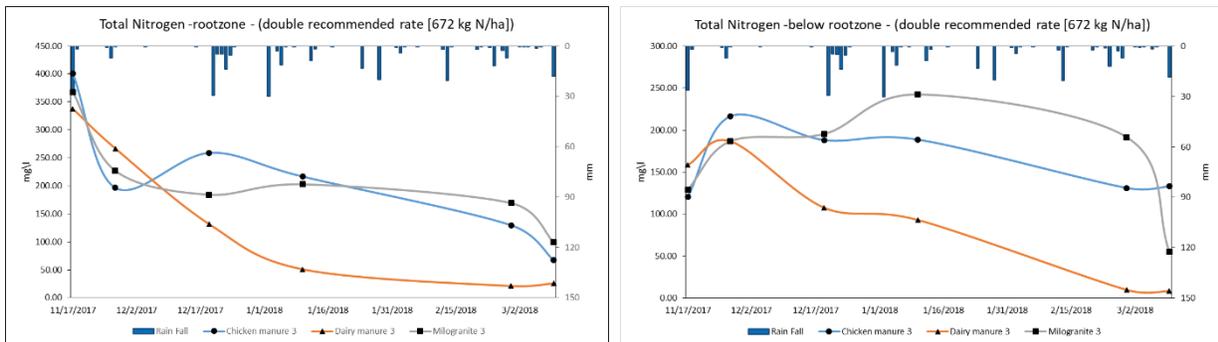
(a) Control plots



(b) Half recommended rate [168 kg N/ha]

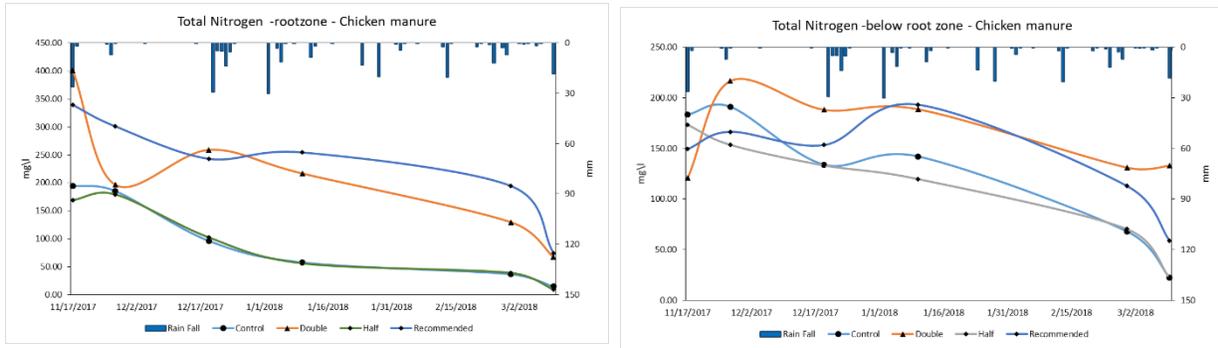


(c) Recommended rate [336 kg N/ha]

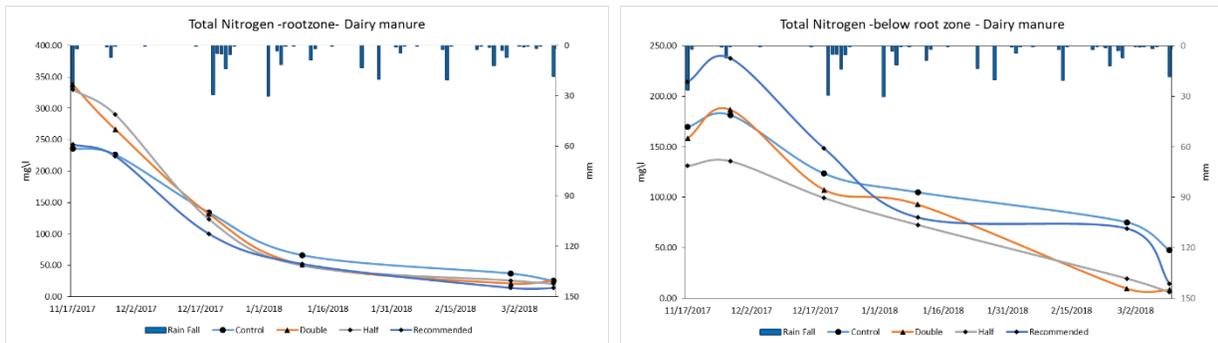


(d) Double recommended rate [672 kg N/ha]

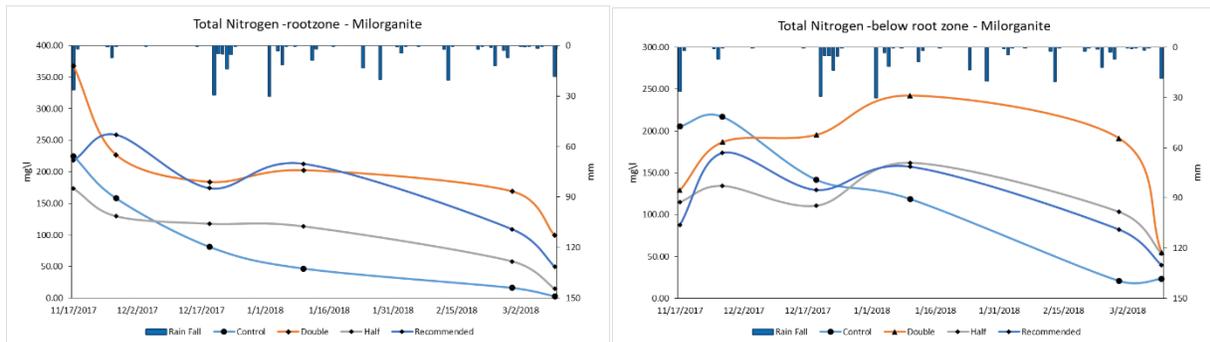
Figure 5. Total Nitrogen concentration (mg/l) from 11/17/2017 to 3/10/2018 at the root zone and below the root zone of (a) Control, (b) Half recommended rate [168 kg N/ha], (c) Recommended rate [336 kg N/ha], and (d) double recommended rate [672 kg N/ha] application plots.



(a) Chicken manure amendment plots



(b) Dairy manure amendment plots



(c) Milorganite amendment plots

Figure 6. Total Nitrogen concentration (mg/l) from 11/17/2017 to 3/10/2018 at the root zone and below the root zone of (a) Chicken manure, (b) Dairy (Cow) manure, and (c) Milorganite amendment plots.

Summary

We monitored soil moisture and nutrient dynamics in the root zone and below the root zone of collard greens grown in different organic amendment types and rates. The preliminary results showed that both organic amendment types and rates affect the soil moisture and nutrient dynamics. The Chicken manure treatments seemed to have the higher water contents consistently for a major portion of the growing season. However, the water contents of the Cow manure and Milorganite treatments were very comparable and relatively lower than that of the Chicken manure treatments. Most of the total Nitrogen concentration increment occurred after irrigation and rainfall. The Cow manure treatments had the

lowest value of total Nitrogen concentration in soil solutions collected within and below the root zone in all amendment rates.

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