Effects of anaerobic dairy digestate on growth and yield of lettuce in a hydroponic greenhouse production system – a feasibility study

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Introduction

- Anaerobic digestion is a used as low-cost waste management method and produces renewable energy from the dairy waste which could be used as a bio-fertilizer for vegetable production.
- Lettuce (*Lactuca sativa* L.) is a one leafy vegetable, contains high amount of minerals (Squire et al., 1987), phenolics, vitamin C, folates and carotenoids (Nicolle et al., 2004).
- These phytochemicals are known to reduce chronic diseases in human beings (Qu et al., 2005). Therefore, the intake of lettuce can be helpful not only to lessen the diseases but also to overcome the food insecurity and malnutrition issues.
- Organic fertilizers enhance sustainable growth, yield, and quality of vegetables. For example, anaerobic digestate have been reported to achieve more sustainable growth and yield and is considered as a good alternative to synthetic chemical fertilizers due to wide range of macro and micro-nutrients availability (Makádi et al., 2012).
- Despite the fact that few agronomic studies have been conducted on aerobic and anaerobic digestion (Goddek et al., 2016), however, the impact of DD and NS alone and combination of DD with standard nutrient solution (NS+DD) on plant growth and yield needs to be investigated.

Objectives

- Therefore, we conducted hydroponics experiments in greenhouse settings with the following objectives:

I. to study the feasibility of using DD in hydroponic vegetable production system

II. to investigate the effects of DD, synthetic NS alone and combination of both nutrient solutions on growth and yield of lettuce genotypes in hydroponic systems.

Materials and Methods

- **Site and time**: Greenhouse, St. David's NL (latitude 51.8812° N, longitude 5.2660° W), NL, Canada 2019.
- Initially, Lettuce seeds of the Newham and Romaine varieties purchased from High Mowing Organic Seeds (Wolcott, VT, USA) were sown in pre-soaked nursery trays containing peat pellets (Jeffy-7, Lorain, OH, USA).
- One-week old lettuce nursery plants were transplanted in small opaque water containers (28.60 cm × 37.60 cm × 20.40 cm, 15L capacity) placed in greenhouse. The greenhouse growth conditions were 25/17 °C day/night temperature, 75 - 80% relative humidity and 400 – 600 ppm CO_2 (Zandvakili et al. 2019).
- Uniclife aquarium air pumps with an adjustable flow rate of 76 to 379 L min^{-1} were purchased and connected to each water container to supply oxygen to lettuce roots using a bubbling stone. Four plants were transplanted in each container using styrofoam without disturbing the plant roots. There were total 36 plants in 9 containers, 3 containers for each treatment and replicated thrice.
- NS was prepared following the method of Hoagland and Arnon (1950). The DD was sourced from anaerobic digester of New World Dairy Inc. St. Dsavid, NL. DD was diluted 10 times to reduce NH_4^+-N concentration in solution to avoid NH_4^+ toxicity. DD solution was prepared in a 1000 L plastic tank following 1:10 ratio of DD and water. Combination of NS and DD treatment (50% NS + 50% DD) was prepared considering 50% N from DD and 50% N from NS.
- DD and DD + NS treatments showed variation in pH compared to NS during entire growth period (Figure 1). However, the pH of feed solution was maintained between 5.8 – 6.2 by adding nitric acid (HNO_3).
- Leaf area - LA (cm2), total chlorophyll content, root dry weight and yield of two lettuce varieties were measured at harvest (45 days after sowing - DAS).
- Briefly, LA of randomly selected two plants were measured with portable LA meter (LI-3000C - LI-COR Biosciences, Lincoln, NB, USA), yield and root dry weight were measured using the weighing balance (RADWAG, PS 6000/C/2, Poland).
- Chlorophyll content (Chl a & Chl b) were determined from the same fresh plant leaves following the method of Arnon (1949).

Results

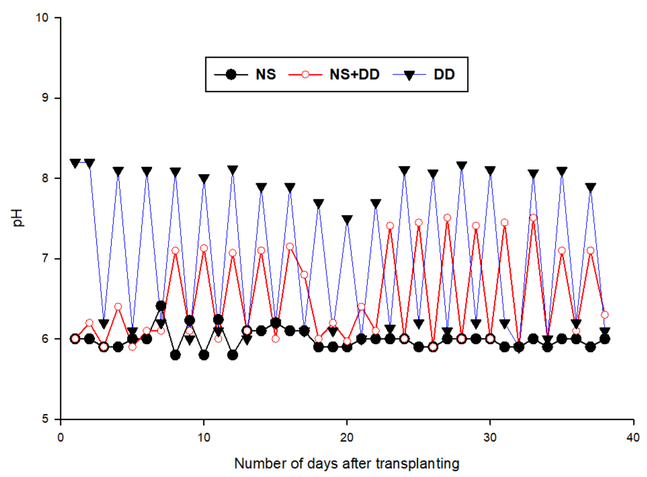

Figure 1: Temporal variation in mineral feed solution's pH used in hydroponics to grow lettuce in greenhouse settings. NS = nutrient solution; NS+ DD= 50% NS + 50% DD; DD= 100% dairy digestate

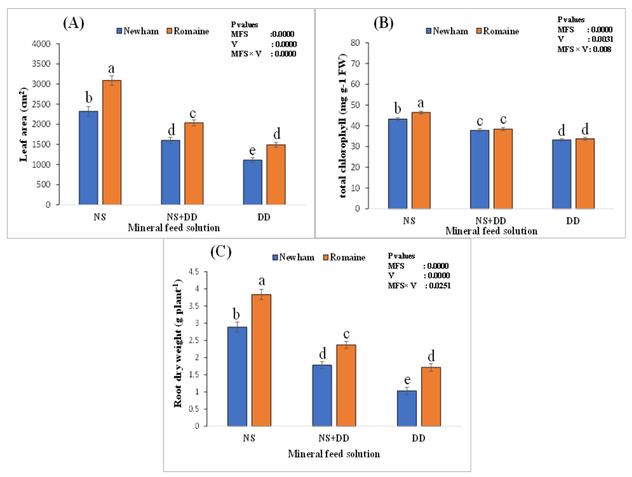

Figure 2: Effects of DD and inorganic nutrient solution on leaf area (A), total chlorophyll (B) and root dry weight (C) of two lettuce varieties under hydroponic cultivation. Vertical bars are means of three replications ±SE. Bars sharing the same letter, for individual factors and interaction, do not differ significantly at LSD ≤ 0.05; NS = nutrient solution; NS+DD = 50% NS + 50% DD; DD = dairy digestate; MFS= mineral feed solution; V = varieties; MFS × V = interaction between mineral feed solution and varieties

Figure 3: Response of Newham (a) and Romaine (b) varieties to root growth cultivated in different mineral feed solutions (MFS) before harvest.

Figure 4: Growth performance of lettuce varieties, Newham (a) Romaine (b) cultivated in different nutrient solution.

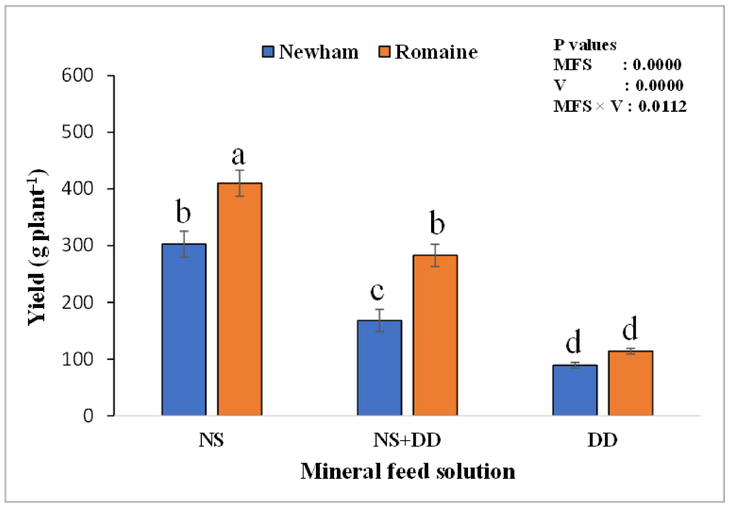

Figure 5: Effects of DD and inorganic nutrient solution on yield of two lettuce varieties tested in hydroponic system. Vertical bars are means of three replications ±SE. Bars sharing the same letter, for individual factors and interaction, do not differ significantly at LSD ≤ 0.05; NS = nutrient solution; NS+DD = 50% NS + 50% DD; DD = dairy digestate; MFS= mineral feed solution; V = varieties; MFS × V = interaction between mineral feed solution and varieties

Conclusion

- Nutrients availability and balance is very important for growth, development and yield of crops especially when grown in hydroponic systems.
- Lettuce plants grown in standard nutrient solution (NS) showed higher LA, chlorophyll content, root dry weight, and yield. However, when dairy digestate (DD) was used as a sole mineral nutrient source for lettuce production, it resulted in lower LA, chlorophyll content, root dry weight and final yield.
- These reduced growth parameters could be associated with high NH_4^+: NO_3^- in DD treatment solution which showed toxic effects on root growth which reduced the essential nutrients uptake and consequently resulted in reduced final yield. Romaine produced significantly higher plant growth parameters and yield compared to Newham irrespective of Mineral feed solution under hydroponic systems with tested treatments.
- It can be concluded that DD could be used as a sustainable biofertilizer source for production of hydroponic lettuce if NH4+: NO3- is reduced without diluting DD. When dilution was done to reduce the NH4+, other macro and micronutrient levels also reduced in DD resulting overall poor plant performances.

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