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Original Research Paper

Studies on production of Anaheim pepper in greenhouse media supplemented with organic and inorganic nutrient sources, and water conservation

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ABSTRACT

An experiment was conducted in the greenhouse to study growth, development, yield and water-use by Anahein pepper grown in a potting mixture supplemented with MiracleGro® (9:4:12) and milled alfalfa (3:1:2) as sources of nutrient. The study was comprised of 5 treatments, control (C), 3 gL^{-1} MiracleGro® (MG), 9 g alfalfa mill supplement (SA-1), 18 g (SA-2), and 27 g (SA-3), and replicated 6 times. Ten physiological and morphological parameters were used to evaluate growth, development and yield of the Anaheim pepper, and two parameters used to evaluate the water holding capacity of the potting mixture. The results indicate that the potting medium supplemented with alfalfa mill required significantly less water to support growth and development of the species. Also, growth, development and yield of Anaheim pepper was significantly higher in the organic supplements at SA-2 and SA-3.

Keywords: *Capsicum* species, alfalfa, MiracleGro, growth and development, greenhouse

INTRODUCTION

Anaheim pepper is an important versatile chilli peppers of the *Capsicum annum* species. It grows mostly in hardiness zones five through twelve (USDA, 2012). It is rich in vitamins A & C, and used as therapy to reduce the risk of heart diseases, diabetes, and cancer (Bray, 2019). It is a perennial grown as annual by farmers and greenhouse growers. It grows up to 46 cm and can yield fruits (15.24-25.4 cm long) over three years (Stephens, 2018), and is one of the two economically important varieties of the *Capsicum* species (Blanco-Rios et al., 2017). Climatic and edaphic conditions affect its pungency and flavor resulting to differences in the variety's pungency (Lillywhite et al., 2013). The Scoville Heat Units of the variety ranges from 500 and 1000 depending on location. Anaheim pepper tolerates a wide range of temperatures and grows best in 18°C - 30°C on sandy loamy well-drained soils (Olatunji & Afolayan, 2018).

Allabi (2006) and Chellemi & Lazarovits (2002) noted that macro and micro-nutrients are crucial for boosting productivity of pepper crops. Nagavardhanam (2017) concurred by adding that chemical fertilizers release nutrients fast for plant uptake and the result was a higher crop yield. However, Rajasekharan et al. (2012) cautioned that excessive use of chemical fertilizers might have a negative impact on soil fertility, while Tiwari et al. (2000) warned that continuous cropping supplemented only with inorganic fertilizers may not meet the expected yield without the addition of organic matter. Pandey et al. (2020) noted that both soil fertility and crop production are adversely affected by misuse of inorganic fertilizers, while, Amen (2020) noted the abundance of plant and animal biomass as organic soil amendments, but Bhatia & Prasad (2005) stressed that maintenance of soil fertility using plant and animal biomass could only occur by the process of microbial decomposition and gradual release of nutrients. This single factor is the main attraction to inorganic fertilizers by farmers and greenhouse growers. Most chemical fertilizers solubilize instantaneously to release their nutrient load thereby making nutrients readily available for plant absorption (Brust, 2019).

MiracleGro® is the inorganic fertilizer used in this study because of its popularity and wide spread use in home gardens and greenhouses across the United States. The NPK composition of the fertilizer is 9:4:12 while alfalfa (*Medicago sativa*) used as the organic nutrient source is 3:1:2. Alfalfa is a member of the *Fabaceae* family and is often used as a soil amendment because of its biological nitrogen fixation (BNF) propensity. Qian et al. (2011) noted that powdered alfalfa was highly successful at providing nutrients, particularly N, for plant growth and development.

The main objectives of the study are to compare growth, development and yield of Anaheim pepper grown in a potting mixture supplemented with inorganic fertilizer (MiracleGro®) and organic soil amendment (alfalfa), and to understand freshwater retention of potting mixture supplemented with the two plant nutrient sources.

MATERIALS AND METHODS

The study was conducted in a greenhouse with average day and night time temperatures of 29°C and 21°C throughout the plant growth phase. The study design comprised of five treatments *viz.*, control (C) plants grown without either nutrient supplement, MiracleGro® (MG) plants grown with inorganic nutrient supplement, soil amendment (SA) plants grown with milled alfalfa supplement in three concentrations, SA-1, SA-2, and SA-3.

The recommended application rate of the MiracleGro® was 3 gL^{-1}. Because the inorganic fertilizer NPK is 9:4:12, and 3:1:2 for alfalfa, we used 9, 18, and 27 g of milled alfalfa for SA-1, SA-2, and SA-3, respectively. The 9 g of alfalfa for SA-1 was intended to bring the concentration of nitrogen per unit of potting mixture close to the inorganic nitrogen content. SA-2 and SA-3 were intended to double and triple the nitrogen content of the inorganic fertilizer per unit of potting mixture. The inorganic fertilizer was dissolved in water and given every 14 days at the rate of 3 gL^{-1} for 7.5 pots until the crops were harvested. There was a total of 30 pots per treatment *i.e.* 5 pots per replication. Each pot in the SA treatments received either 9, 18 or 27 g of milled alfalfa based on the treatment group. The milled alfalfa was mixed with the potting medium before transplantation into 0.003 m^3 pots.

Anaheim pepper seedlings were transplanted into 0.003 m^3 pots containing 2:1:1 top soil:peat moss:perlite 35 days after sowing. The transplants were randomly divided into 5 treatments and replicated 6 times in 6 blocks in a randomized complete block design (RCBD). The pots were placed in saucers for leachate collection. Watering was 300 mL/pot and leachate, collected 10 minutes after watering, was measured to determine the amount of water retained by the potting mixture.

Physiological and morphological measurements were collected every two weeks. Potting mixture pH was measured immediately after transplanting and every two weeks thereafter. Average potting mixture pH was 7.03 for the C, 7.33 for MG, 7.21 for SA-1, 7.24 for SA-2, and 7.21 for SA-3. Height was measured from plant base to stem tip, and used to calculate relative growth rate (RGR) computed as the height difference between succeeding measurements divided by the interval between the measurements.

Rate of transpiration was measured by gravimetric water loss. This involves drenching the potting mixture and sealing the pots in plastic after draining so water loss is by transpiration. The pots are weighed immediately after sealing and left for 7 days or longer and weighed again before the plastic sealing is removed. The rate of transpiration per hour was computed as weight difference divided by the interval in hours between the measurements.

Stomatal conductance was measured using the leaf porometer by Decagon Devices, Washington, USA. Similarly, chlorophyll content was measured using SPAD-502 Plus chlorophyll meter (Konica Minolta Inc., Japan) in SPAD Units. Leaf area was measured using CI-202 Portable Laser Leaf Area Meter by CID Bio-Science.

Nitrate nitrogen (NO_3^- N) was determined from the leachate using DR300 pocket colorimeter, method No. 8039 (Hach Company, Colorado, USA). The leachate was filtered with Whatman No.1 filter paper immediately after collection and 10 ml of the filtrate, used as blank, was used to zero the instrument. Another 10 mL of the filtrate was mixed with Nitra Ver 5 powder and shaken vigorous for a few minutes for color development. Color intensity depends on the amount of NO_3^- N in the leachate which was measured for NO_3^- N content.

At maturity, harvested fruits and vegetative parts were weighed fresh and dried at 80°C until constant weight to obtain the dry weight. The roots were washed and weighed fresh, and dried at 80°C to obtain dry root biomass weight. All physiological and morphological measurements were analyzed using SAS 9.40.

RESULTS AND DISCUSSION

Repeated measure ANOVA, unpaired t-test and regression analyses were adopted to decipher the effects of the treatments on the species and water

Table 1 : Parameter indicators of growth and development of Anaheim pepper

Parameter	C	MG	SA-1	SA-2	SA-3	P-value
Chlorophyll content (SPAD units)	30.75[a]	39.66[c]	37.90[b]	39.31[c]	41.01[c]	<0.0001
Transpiration rate (mL/h)	1.04[a]	2.88[c]	2.15[b]	2.98[c]	3.69[d]	<0.0001
RGR (cm/day)	0.33[a]	0.6[c]	0.54[b]	0.69[c]	0.71[c]	<0.0001
Stomatal conductance ($mmol/m^2s$)	44.46[a]	173.74[c]	163.48[b]	188.13[c]	219.66[c]	<0.0001
Nitrate nitrogen (mg/L)	6.78[a]	12.39[b]	9.65[c]	10.94[c, b]	9.35[c]	0.0005
Leachate (mL)	136.36[a]	88.55[c]	92.11[c]	77.24[b]	74.70[b]	<0.0001
Flower count	0.83[a]	1.73[b]	1.31[b]	1.46[b]	2.02[b]	0.0480
Fruit count	0.53[a]	1.57[b]	1.21[b]	1.34[b]	1.33[b]	0.0388
Fruit Fresh weight (g)	2.50[a]	8.36[b]	3.89[a]	11.74[b]	9.29[b]	0.0110
Fruit dry weight (g)	1.00[a]	2.28[a]	1.25[a]	2.56[a]	3.51[a]	0.1136
Vegetative fresh weight (g)	18.23[a]	28.77[b]	25.77[c]	31.70[d]	36.17[e]	<0.0001
Vegetative dry weight (g)	13.97[a]	18.77[b]	17.73[b,c]	20.57[b, d]	22.53[d]	<0.0001
Fresh root weight (g)	2.00[a]	5.17[b]	6.17[b]	7.50[b]	18.33[c]	<0.0001
Dry root weight (g)	0.70[a]	1.92[b]	2.23[b]	3.17[b]	9.17[c]	<0.0001
Leaf area (cm^2)	363.73[a]	398.24[b]	380.61[b]	390.80[b]	401.28[b]	0.03635

Rows with the same letter superscripts are not significantly different

holding capacity of the medium (Table 1). The values indicate that all parameters are statistically significantly different except fruit dry weight. Fruit dry weight indicates that increased water absorption was induced by the treatments and the rate of transpiration bears out this result. The treatments resulted to increased rates of transpiration which was significantly different from the control. Also, the rate of transpiration was different between the treatments but similar for MG and SA-2 (Table 1). SA-2 and MG results are similar in most of the parameters measured, while, SA-3 outperformed MG, an indication that greenhouse growers can achieve the same or higher yields with media amended with organic nutrient source on short rotation agriculture crops.

We used a simple regression to validate our transpiration method. The leaf porometer used to measure stomatal conductance is a modern cutting-edge instrument, while, transpiration was measured with the gravimetric method. The analysis indicates an R^2 of 92% with Y= -4.895+63.889x predictability of the transpiration rate (Fig. 1). This is a confirmation of the reliability of the information obtained with the experimental design and methodology used in the study.

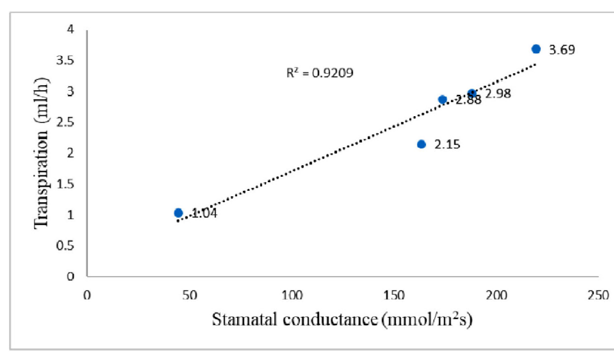

Fig. 1: Relation between stomatal conductance and transpiration rate of Anaheim pepper

The leachate result has real-life significance in freshwater conservation. Freshwater constitutes only 3% of the earth's water resource (Manzoor et al., 2007) and agriculture uses 75% of the freshwater. Agricultural use goes up to 90% in some parts of the world (Sophocleous, 2004). Additionally, there are 463,365 ha of fresh harvest producing greenhouses in the United States (Wright, 2021), and each hectare uses 83 kl of fresh water per day (Bilderback, 2017). This amounts to 38,459,295 kl of fresh water per day. Leachate analysis indicates that the potting mixture amended with milled alfalfa (SA-2 and SA-3) had higher water holding capacity and thus, less watering for crop use. This saves greenhouse operational fund including labor cost. These cost savings increase the grower's profit margin. The result is also significant for fresh water conservation in bourgeoning human population and its associated increases in fresh water demand.

The results of NO_3^-N in the leachate are not surprising with the highest nitrogen in the MG treatment leachate. The similarity between MG, SA-2 and SA-3 in the other parameter indicators further confirm that greenhouse growers can eliminate inorganic fertilizers without compromising yield, if the organic nutrient source is treated to shorten or circumvent decomposition. Because agricultural crops are short rotation crops, a nutrient amendment must be capable of releasing nutrients readily else yield will be compromised. Nutrient release delay due to decomposition creates the attraction to inorganic fertilizers by growers. We circumvented decomposition in this study by milling alfalfa and thus increased cellular hydration and nutrient leach-out of alfalfa cells into the potting medium.

We considered nitrogen only in factoring the comparable amounts of alfalfa mill per unit of potting mixture. Because the MG used has NPK ratio of 9:4:12, and 3:1:2 for alfalfa and the factory recommended application rate of the MG is 3 gL^{-1}, we used 9 g (SA-1), 18 g (doubled for SA-2), and 27 g (tripled for SA-3). This amount, example 9 g of alfalfa, is theoretically designed to supply a comparable amount of nitrogen in the potting mixture as 3 g of MG dissolved in a liter of water. Because cellulose cell walls of milled alfalfa cannot dissolve in water, it was added directly into the potting mixture, while, the MG was dissolved in water and treated every two weeks until the crops were harvested. The results indicate that the 9 g of alfalfa, intended to produce similar results as the MG, failed to do so. Instead the doubled concentration (18 g alfalfa) gave similar results as the MG, while, the tripled concentration (27 g of alfalfa) outperformed the MG in most parameters. Erisman et al. (2008) reported that about 50% of the global human population is fed with agricultural produce grown with inorganic nitrogen. This study has shown that humans fed with produce grown with inorganic fertilizers can be reduced because organic nutrient sources can be used without compromising crop yield. Additionally, the adverse consequences of inorganic nitrogen in the environment (Rajasekaran et al., 2012; Nagavardhanam, 2017; Pandey et al., 2020) can be reduced.

Randomization experiment in the greenhouse ensures that micro environmental conditions are equally distributed. Greenhouse environmental conditions are fairly uniform but the apparent movement of the sun casts shadow through the day which could result to different effects in parts of the same greenhouse. This could become a problem for north-south and east-west facing parts of a greenhouse. The randomized complete block design took care of this potential experimental error. Also, based on the initial dry run of the experiment we collected leachate 10 minutes after watering to avoid loss of leachate by evaporation. The time is long enough for complete drainage of excess water but short to avoid loss of leachate to evaporation.

CONCLUSION

Human population growth and concerns about food insecurity, sustainable agriculture, and environmental health, the study concludes that organic nutrient sources can be used in short rotation cropping in greenhouse production. This, by extension, can be applied to field agriculture as long as the organic nutrient source is treated to shorten and/or circumvent the natural decomposition delay which limits timely release of plant nutrients. Decomposition time required before organic materials release their nutrient load is one single reason greenhouse growers and farmer rely on inorganic fertilizers. Also, the study concludes that supplementing greenhouse potting mixtures with treated organic nutrient source conserves fresh water use in greenhouse crop production and so reduces labor cost and increases the grower's profit margin.

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