Microirrigation equipment for okra cultivation in the U.S. Virgin Islands

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Abstract. Drip irrigation presents higher irrigation efficiency when compared to sprinkler irrigation. Proper system design and the use of pressure-compensating emitters plays an important role in irrigation uniformity and efficiency, directly affecting plant growth. This study evaluated the performance of pressure-compensating and non-compensating emitters and the effect of irrigation equipment in different okra varieties in the U.S. Virgin Islands. Experiments were performed in two seasons (Spring and Fall, 2016), and tested four irrigation equipment (“Toro Aqua-Traxx FC”, “Eurodrip Thinwall Classic”, “Jain Top Drip AS”, and “Netafim Dripnet PC”) and three varieties of okra (‘Clemson Spineless 80’, ‘Clemson Spineless’, and ‘Chant’), arranged on a complete randomized block design with three replications. Irrigation was performed based on reference evapotranspiration, measured daily using an automated weather station. Soil moisture, electrical conductivity and soil temperature were monitored using capacitance sensors. The irrigation equipment responses to increasing pressure were evaluated in the lab, on experimental modules using clean water and simulating three different slopes (leveled, uphill and downhill). Yield and leaf physiological parameters were influenced by season ($P<0.05$), while fruit morphological parameters and soluble solids content were variety-dependent ($P<0.01$). The pressure-compensating emitters maintained water flow within the range indicated by the manufacturers. The distribution uniformity decreased overtime in all equipment except “Netafim Dripnet PC” in Fall 2016. Irrigation equipment did not impact plant growth. The equipment should be selected based on price and irrigation efficiency.

Keywords. Okra (*Abelmoschus esculentus*), Irrigation efficiency, Drip irrigation, Water-saving technologies, Variety trial, Tropics

Introduction

Agriculture uses the majority of the potable water available on the planet, with irrigation accounting for 70% of global water withdrawals. The irrigation equipment used plays an important role in water use and irrigation efficiency. For an irrigation system to be considered efficient, water distribution needs to be uniform within the line (≈10%) and pressure variation across the secondary line should be lower than

20% (Burt et al., 1997). After installing the irrigation system, growers must ensure it matches the project design in the field. Pressure, water flow and distribution, and efficiency coefficients are necessary in order to evaluate system performance (Silva and Silva, 2005).

Drip irrigation has become the most common system used in agriculture due to the high irrigation efficiency (>90%) and the application of low water volumes (1 to 150 L/h), resulting in water savings when compared to sprinkler irrigation (Testezlaf, 2011). Drip irrigation applies water directly to the root zone, increasing water and nutrient use efficiency, incrementing yield and crop quality, and maximizing profitability (Borssoi et al., 2012). On the other hand, the initial deployment cost is usually higher than overhead/sprinkler systems. Drip irrigation demands constant maintenance, and requires efficient filtration due to the possibility of emitter clogging (Testezlaf, 2011).

The University of the Virgin Islands (UVI), Agricultural Experiment Station (AES) initiated an irrigation research project in the early 1980s with the objective to increase vegetable production while conserving water resources (Palada et al., 1995). Since then, farmers shifted from sprinkler to drip irrigation (also known as microirrigation). Most of the U.S. Virgin Islands local farmers use drip tapes with non-compensating emitters. Non-pressure compensating emitters' water output vary as the line pressure changes. That may result in inefficient water application (<70%) (Dogan and Kirnak, 2010). Pressure compensating emitters apply the same amount of water at each emitter over a range of different line pressures (i.e. 10-50 psi). These emitters can be used in long lines, irregular or mountainous areas and where precise watering is desired (Dogan and Kirnak, 2010). When water resources start becoming limited, especially in years affected by severe drought, there is a need to improve irrigation management and equipment efficiency in order to save water and pumping energy.

Performance evaluations of several drip irrigation systems are available in the literature (Pereira et al., 2005). However, the application of such tests on commercial operations is still scarce. This is due to the lack of knowledge about the importance of managing irrigation systems properly. Consequences include reduced crop yields and waste of water resources. To improve irrigation performance, it is necessary to promote implementation of irrigation scheduling methods, improve system design and equipment performance, and enhance farmers' skills to manage irrigation systems efficiently (Pereira et al., 2005).

Okra (*Abelmoschus esculentus*) is one of the most important and widely grown crops found throughout the tropical and sub-tropical regions (Eshiet and Brisibe, 2015). It is an annual, erect growing, high yielding crop with numerous cultivars varying in plant height, degree of branching and pigmentation of the various parts, period of maturity, and pod shape and size. Okra is mainly grown for its tender green pods, which are cooked and commonly consumed as boiled vegetables. Despite its enormous economic benefits, okra rarely reaches its maximum yield potential due to several constraints (Eshiet and Brisibe, 2015). Some of the major factors limiting okra production include the use of locally unimproved varieties, high incidence of pests and diseases, a narrow genetic base of existing varieties, and lack of proper irrigation to control plant growth.

Driven by the desire to indicate the best irrigation equipment for local growers to save water and select more adapted genotypes in okra, the objective of the current study is to determine the performance of pressure-compensating and non-compensating emitters and the effect of irrigation equipment on different okra varieties in the U.S. Virgin Islands.

Material and Methods

Location. The studies were evaluated from Mar. 24 to July 11, 2016 (Spring) and from Aug. 12 to Dec 1, 2016 (Fall) at the University of the Virgin Islands (UVI) Agricultural Experiment Station (AES), Kingshill, U.S. Virgin Islands (lat. 17°43’08” N, long. 64°47’46” W, 30 m above sea level).

Environmental conditions. Environmental data were recorded throughout the studies using a weather station (ET107; Campbell Scientific, Logan, UT). The equipment was located 50 m from the experiment site, and measured wind speed and direction, rainfall, air temperature, and solar radiation. The vapor pressure deficit (VPD) was calculated from the saturated and actual air vapor pressure using the air temperature and relative humidity data (Fig. 1).

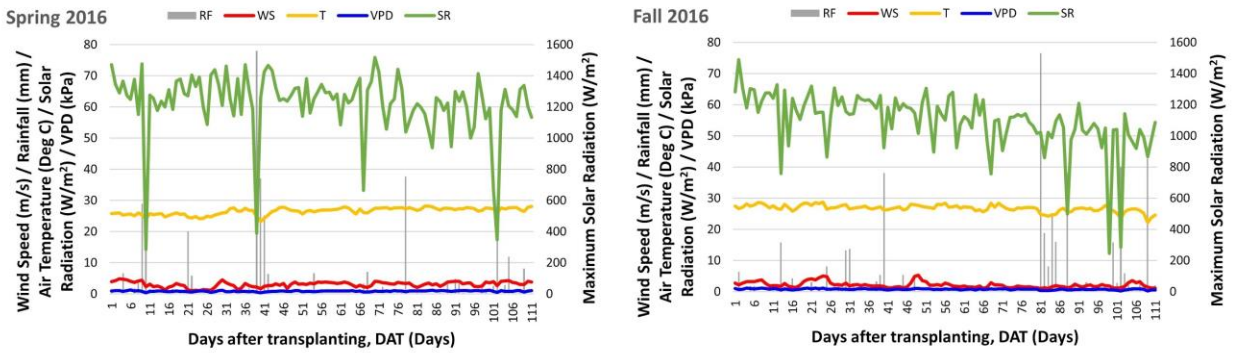


Fig. 1. Wind speed, rainfall, air temperature, solar radiation, and vapor pressure deficit (VPD) during the experiments performed in Spring (left) and Fall (right), 2016. Kingshill, U.S. Virgin Islands.

Plant material and Cultural practices. The experimental area had been used for bell peppers preceding the first planting. The crop was terminated by mowing, followed by two passes with a disc harrow and two passes with a rototiller. To improve soil health prior to the okra studies, the field was planted in cover crop by using ‘IAC-1’ sunn hemp (*Crotalaria juncea*) (800,000 plants/ha) in Fall, 2015. Sunn hemp seeds were inoculated prior to planting with *Bradyrhizobium* sp. inoculant. The cover crop was terminated 90 days after planting by mowing with a rotary mower/shredder.

Okra seeds were sown in 72-cell trays on Feb. 19, 2016 (Spring) and July 25, 2016 (Fall). Transplants were fertigated with a 12N-48P-8K starter fertilizer (Plant Agra; Two-Way Trading Co, Headland, AL). Seedlings were transplanted to the field on Mar. 23, 2016 (Spring) and Aug. 11, 2016 (Fall). Plants were spaced 0.3 m in-row × 1.22 m between-row (representing 26,909 plants/ha).

The fields were scouted for insect pests and plant diseases weekly until first harvest and then at every harvest. Lepidoptera (*Lepidoptera* sp.) was controlled using *Bacillus thuringiensis* (DiPel DF; Valent Biosciences, Walnut Creek, CA) and spinosad (Entrust SC; Dow AgroSciences, Indianapolis, IN). Aphids (Aphidoidea) and leaf miner (*Liriomyza sativae*) were controlled using paraffinic oil (Agri-Dex; Helena Chemical, Collierville, TN) a pyrethrin-based spray (PyGanic Crop Protection EC 1.4II; McLaughlin Gormley King, Minneapolis, MN), and neem oil (Trilogy; Certis USA, Columbia, MD). Powdery mildew was controlled using copper sulphate pentahydrate (Phyton 35; Phyton Corporation, New Hope, MN). Weeds were manually controlled at 55, 66, and 88 (Spring) and 30 days after transplanting (DAT) (Fall).

To reduce the need for manual weeding a 15-cm thick layer of hay was spread on the field at 61 DAT (Spring) and 37 DAT (Fall).

Soil. The soil on the experimental site is a Sion clay (SiB) according to the USDA soil survey (USDA, 2015). Samples for soil nutrient concentration were collected approximately 15 d prior transplanting for both seasons. Results are available in Table 1.

Table 1. Nutrient concentration of Sion clay soil in Spring and Fall, 2016. Average of three samples. Kingshill, U.S. Virgin Islands.

Nutrient	**Spring**	**Fall**
Soil pH	7.6	7.7
Phosphorus (P), lb/acre	62.0	92.7
Potassium (K), lb/acre	614.7	1010.7
Calcium (Ca), lb/acre	17,172	23,058
Magnesium (Mg), lb/acre	612.0	716.7
Sulfur (S), lb/acre	57.3	76.0
Boron (B), lb/acre	4.5	5.9
Copper (Cu), lb/acre	4.6	6.4
Iron (Fe), lb/acre	66.0	38.0
Manganese (Mn), lb/acre	60.0	76.7
Zinc (Zn), lb/acre	8.8	9.9
Sodium (Na), lb/acre	236.7	283.3
Organic Matter, %	4.0	4.3
Nitrate Nitrogen, lb/acre	40.0	52.7
Ammonium Nitrogen, lb/acre	54.7	4.7

Treatments. We tested four different drip irrigation equipment {“Toro Aqua-Traxx FC” [0.27 gallons per hour (GPH, 1.02 L) at 10 psi], “Jain Top Drip Thin Wall” [0.26 GPH (0.98 L) at 12 psi], “Netafim Dripnet PC” [0.26 GPH (0.98 L) at 12 psi], and “Eurodrip Thinwall Classic” [0.25 GPH (0.94 L) at 12 psi]} and three okra varieties (‘Clemson Spineless 80’, ‘Clemson Spineless’, and ‘Chant’). We used one drip line and one drip tape with pressure compensating emitters and two drip tapes with non-compensating emitters, all from different manufacturers. Equipment was selected based on water flow to provide the same amount of water to all treatments.

Irrigation. The irrigated area had two submain lines (right and left), divided into 16 lateral lines (15.4 m each) per derivation line. The experiments had a dedicated 3,780-L water tank attached to a ½-HP booster pump with 22.7-L pressure tank (94525; Everbilt, Wilmington, DE) to guarantee stable pressure throughout the studies. Each experimental unit had a 12-psi pressure regulator, except for the plots with “Toro Aqua-Traxx FC”, which needed a 10-psi pressure regulator to achieve the desired flow rate and an irrigation manifold built using 1-inch (2.54 cm) PVC pipe connected to three lines of drip tape / tubing with 1.02 L per emitter and 30-cm spacing.

Reference evapotranspiration (ETo) was calculated from the environmental data by the American Society of Civil Engineers (ASCE) Environment and Water Resources Institute (EWRI) standardized Penman-Monteith (ASCE-PM) equation (ASCE-EWRI, 2005) Irrigation was performed based on ETo and the water balance method (Fig. 2).

Fertigation. The fertilizer solution was based on soil nutrient analysis and okra nutritional requirements. The concentrated stock solution was prepared with a commercial Jack's Professional soluble 20N-20P-20K fertilizer (Peters, Allentown, PA) and applied 112 kg N/ha (final concentration of 100 mg N /L) using a fertilizer injector (D45RE15; Dosatron, Clearwater, FL).

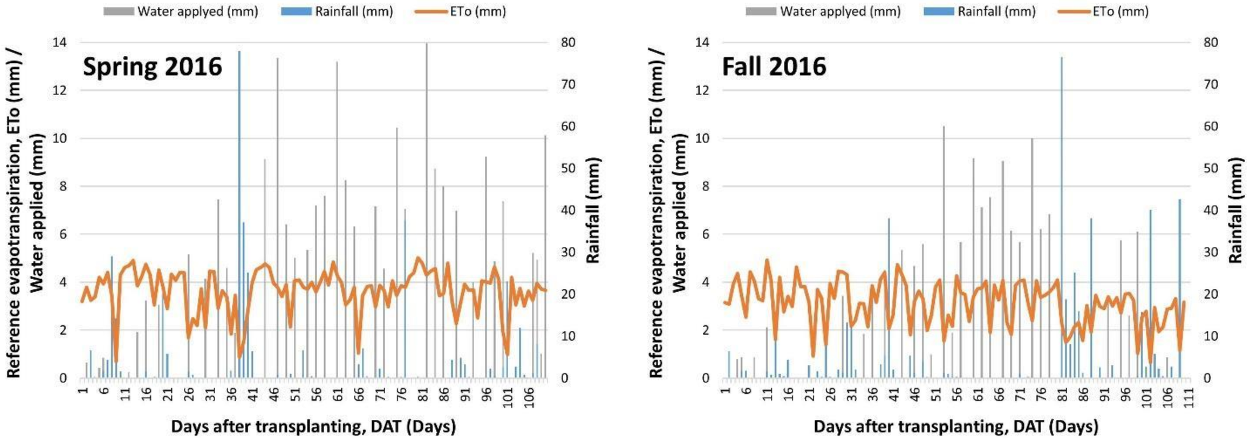


Fig. 2. Reference evapotranspiration (ETo) calculated by the American Society of Civil Engineers (ASCE) Environment and Water Resources Institute (EWRI) standardized Penman-Monteith equation (ASCE-PM), water applied and rainfall in Spring (left) and Fall (right), 2016). Kingshill, U.S. Virgin Islands.

Lab measurements. The irrigation equipment water flow responses to increasing pressure using clean water and three different slopes were evaluated in an experimental module assembled in the lab using three 20-ft long roof gutters (Fig. 3A and 3B) attached to a ½-HP booster pump (maximum pressure of 67 psi) with 6-gal pressure tank (94525; Everbilt, Wilmington, DE) (Fig. 3C). We used a 6.1-m long irrigation line with emitters spaced 0.3 m apart. The setup used calibrated pressure gauges to precisely monitor the applied pressure (Fig. 3B).

Incoming pressure was increased in multiple values up to the maximum recommended by the manufacturer ("Toro Aqua-Traxx FC" from 3 to 27 psi in multiples of 3 psi; "Jain Top Drip Thin Wall" from 4 to 40 psi in multiples of 4 psi; "Netafim Dripnet PC" from 6 to 60 psi in multiples of 6 psi; and "Eurodrip Thinwall Classic" from 2 to 22 psi in multiples of 2 psi).

The emitter evaluation was performed at the beginning, 1/4, 1/2, 3/4 and at the end of the line. In each position, the water flow was measured in three sequential emitters for 3 min (Borssoi et al., 2012). Tests were repeated three times and in three different levelling conditions (leveled, uphill and downhill) to simulate field conditions.

Fig. 3. Experimental module designed and installed to evaluate the effect of increasing operational pressures on drip irrigation equipment water flow. Kingshill, U.S. Virgin Islands.

Field measurements. The lateral lines were evaluated in the field to determine the irrigation system efficiency. We measured the water flow using catch cans at the initial position, 1/4, 1/2, 3/4 and the end of each line (Keller and Bliesner, 1990). With the emitter water flow information, we determined the Christiansen uniformity coefficient (CUC) [Eq. 1], the statistics (CUE) [Eq. 2] and the distribution uniformity coefficient (CUD) [Eq. 3] (Borssoi et al., 2012). The coefficients were classified according to the ASABE (1994) and ASABE (2001) standards (Table 1).

$$CUC = 100 \cdot \left(1 - \frac{\sum_{i=1}^{N} \left| Xi - \overline{X} \right|}{N \cdot \overline{X}} \right) \quad \text{[Eq. 1]}$$

where: N = number of samples, Xi = depth of water applied to the n-th point on the soil surface, and X = average depth of water applied.

$$CUE = 100 \cdot \left(1 - \frac{S}{\overline{X}} \right) \quad \text{[Eq. 2]}$$

where: S = emitter standard deviation, and X = average depth of water applied.

$$CUD = 100 \cdot \frac{x}{X}$$ [Eq. 3]

where: x = average depth of water applied on the 25% lowest volumes of catch cans, and X = average depth of water applied (considering all catch cans).

We also calculated the application efficiency (EA) [Eq. 4] (Bernardo, 1995).

$$AE = 0.9 \times CUD$$ [Eq. 4]

where: AE = application efficiency (%), and CUD = distribution uniformity coefficient (%).

Table 1. Irrigation efficiency parameters classification according to the ASABE (1994) and ASABE (2001) standards. Where CUC: Christiansen uniformity coefficient, AE: application efficiency, and CUD: distribution uniformity coefficient. Kingshill, U.S. Virgin Islands.

Classification	**CUC**	**AE**	**CUD**
		-------------- % -------------	
Excellent	> 90	90 - 100	> 84
Good	80 - 90	80 - 90	68 - 84
Fair	70 - 80	70 - 80	52 - 68
Poor	60 - 70	60 - 70	36 - 52
Unacceptable	< 60	< 60	< 36

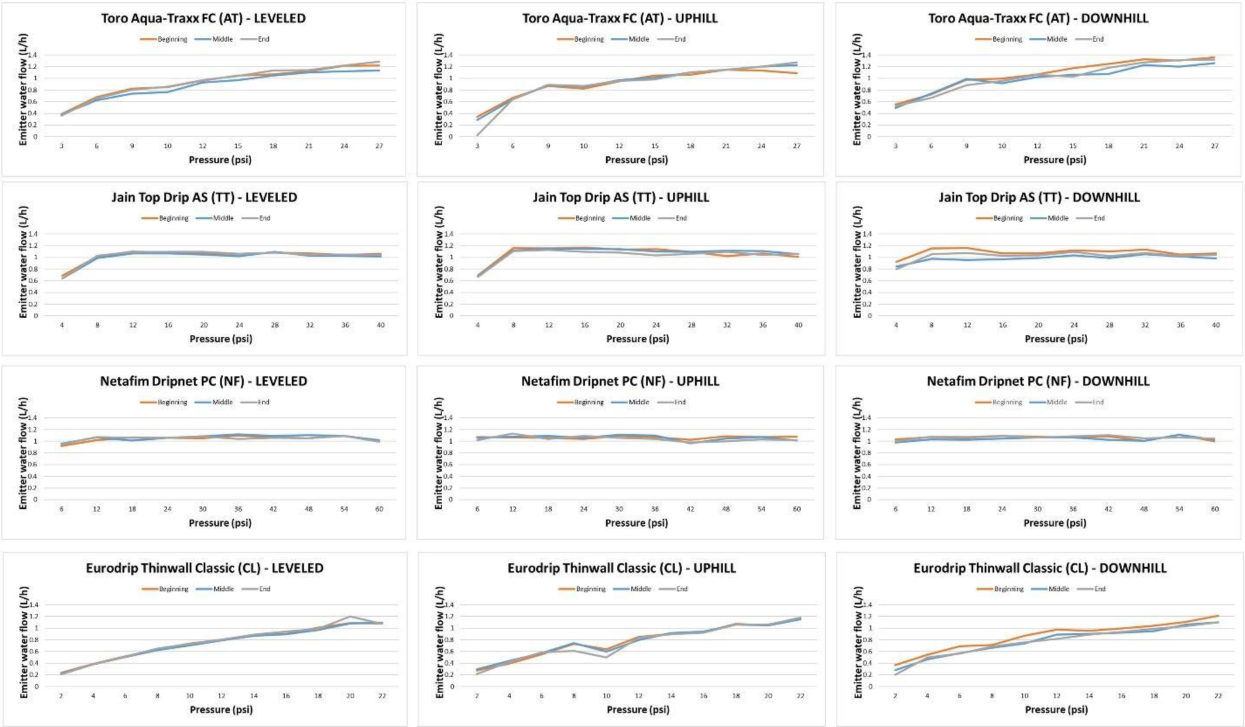
Soil water content, soil temperature and bulk electrical conductivity were monitored using 36 capacitance sensors (24 10HS and 12 GS3; Decagon Devices, Pullman, WA). The monitoring system was built using a data logger (CR1000; Campbell Scientific, Logan, UT), multiplexer (AM16/32B; Campbell Scientific, Logan, UT) and the capacitance sensors. The controller was powered using a 20-W solar panel (Infinium; ML Solar, Campbell, CA), connected to a 12/24-VDC 10-A Tracer solar charge controller (1210RN; EPSolar, Beijing, China) and two 12-VDC 7.2-Ah rechargeable batteries (Yuasa, Ebbw Vale, United Kingdom). The data collected were transmitted to a computer using a RF401A radio frequency module (Campbell Scientific, Logan, UT). Radios sent the collected information to the computer using Omnidirectional 900 MHz 3 dBd and Yagi 900 MHz 9 dBd antennas (both from Campbell Scientific, Logan, UT).

Total and marketable yield were determined weekly and totalized at the end. Leaf anthocyanin and chlorophyll content indexes (non-destructive analysis) were measured in Spring (day 108) and Fall (day 103). Anthocyanin was measured with a portable anthocyanin content meter (ACM-200 plus; Opti-Sciences, Hudson, NH), and chlorophyll using a chlorophyll concentration meter (MC-100; Apogee Instruments, Logan, UT). Plant growth index {[(height + width 1 + width 2) / 3]}, fruit size (weight, length, and width), fruit hardness using a digital penetrometer (FHP-802; Agriculture Solutions, Strong, ME), and fruit soluble solids content using a refractometer (RF15; Extech Instruments, Nashua, NH) were measured on days 100 (Spring) and 103 (Fall).

Experimental design and Statistical analysis. Treatments were arranged on a complete randomized block design with three replications. Each experimental unit had 30 plants / variety for a total of 270 plants per variety and 1,080 per trial. Data were analyzed using a mixed model procedure in SAS (version 9.4; SAS Institute, Cary, NC). Errors were assumed to be normally and independently (NID) distributed. Probability values ≤ 0.05 were considered statistically significant.

Results and Discussion

Lab measurements. The lab test provided water flow information under different conditions (leveled, uphill and downhill). "Toro Aqua-Traxx FC" and "Eurodrip Thinwall Classic" (non-compensating emitters) increased water flow with increase in pressure. "Jain Top Drip Thin Wall" and "Netafim Dripnet PC" (pressure compensating emitters) provided a steady water flow for pressure > 10 psi (Fig. 4). These results were expected since that is the technology outlined by the equipment manufacturer. Our results clearly indicated that a more uniform water distribution can be achieved by replacing the irrigation equipment. "Toro Aqua-Traxx FC" cost \$0.074/ft (\$0.24/m), "Eurodrip Thinwall Classic" \$0.024/ft (\$0.08/m), "Jain Top Drip Thin Wall" \$0.046/ft (\$0.15/m) and "Netafim Dripnet PC" \$0.298/ft (\$0.98/m) (cost for the U.S. Virgin Islands with shipping included). "Eurodrip Thinwall Classic" is the cheapest equipment, while "Netafim Dripnet PC" the most expensive. "Jain Top Drip Thin Wall" had proven to be efficient but cost almost the double than the equipment most used in the territory.


Toro Aqua-Traxx FC (AT) - LEVELED

Toro Aqua-Traxx FC (AT) - UPHILL

Toro Aqua-Traxx FC (AT) - DOWNHILL

Jain Top Drip AS (TT) - LEVELED

Jain Top Drip AS (TT) - UPHILL

Jain Top Drip AS (TT) - DOWNHILL

Netafim Dripnet PC (NF) - LEVELED

Netafim Dripnet PC (NF) - UPHILL

Netafim Dripnet PC (NF) - DOWNHILL

Eurodrip Thinwall Classic (CL) - LEVELED

Eurodrip Thinwall Classic (CL) - UPHILL

Eurodrip Thinwall Classic (CL) - DOWNHILL

Fig. 4. Emitter water flow of four drip irrigation equipment {[AT] “Toro Aqua-Traxx FC” (1.02 L at 10 psi), [TT] “Jain Top Drip Thin Wall” (0.98 L at 12 psi), [NF] “Netafim Dripnet PC” (0.98 L at 12 psi), and [CL] “Eurodrip Thinwall Classic” (0.94 L at 12 psi)} subjected to increasing operational pressures in three conditions (leveled, uphill and downhill). Kingshill, U.S. Virgin Islands.

Field measurements. According to the ASABE standards (Table 1), “Toro Aqua-Traxx FC” and “Eurodrip Thinwall Classic” were classified as fair and good, while “Netafim Dripnet PC” and “Jain Top Drip Thin Wall” as good in Spring 2016. All irrigation tapes were classified as good and excellent in Fall 2016, indicating that our systems met the efficiency requirements for drip irrigation to water the three okra varieties properly (Fig. 5). The efficiency decreased over time for “Toro Aqua-Traxx FC” and “Eurodrip Thinwall Classic” probably due to clogging from suspended solids.

Volumetric water content (Fig. 6A), soil temperature (Fig. 6B) and bulk electrical conductivity (Fig. 6C) presented large variation in the tested treatments. Replication differences are expected, and explained by the use of independent experimental units, variations in moisture caused by soils, sensor position and plants, which was also reported by Ferrarezi et al. (2017). Data collected during Spring 2016 were consistently more stable than Fall 2016. The reason for such variation is unknown. In Fall 2016, sensors malfunctioned in the last 10 days, producing unrealistic measurements.

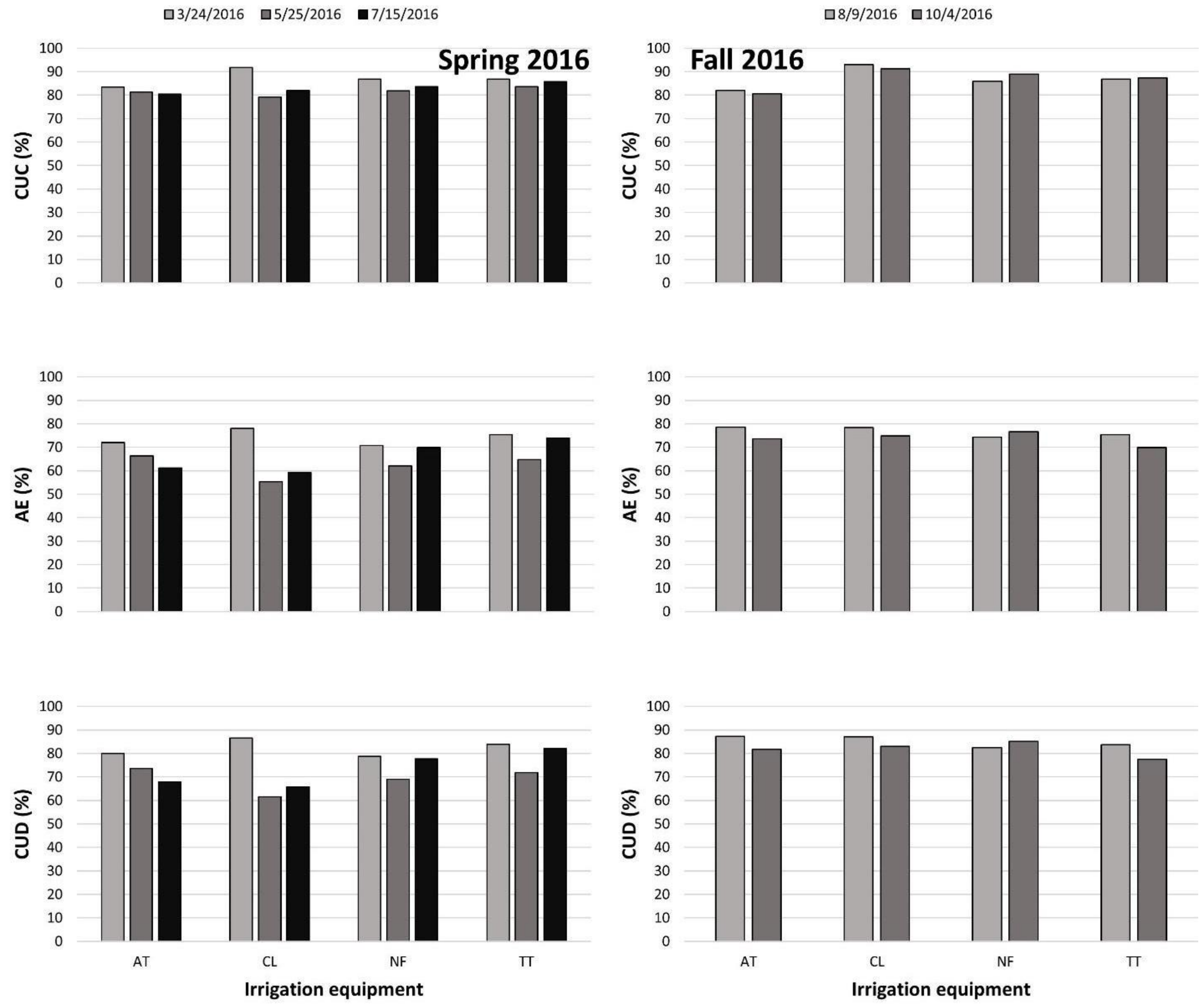


Fig. 5. Drip irrigation equipment efficiency parameters. Where: [AT] “Toro Aqua-Traxx FC” (1.02 L at 10 psi), [TT] “Jain Top Drip Thin Wall” (0.98 L at 12 psi), [NF] “Netafim Dripnet PC” (0.98 L at 12 psi), and [CL] “Eurodrip Thinwall Classic” (0.94 L at 12 psi), CUC: Christiansen uniformity coefficient, AE: application efficiency, and CUD: uniformity distribution coefficient. Kingshill, U.S. Virgin Islands.

Total and marketable yield, leaf anthocyanin, fruit weight, length and width were influenced by seasons (P<0.05, Tables 2 and 3). Total and marketable yield, fruit weight, length, width and were higher in Spring 2016 compared to Fall 2016, while leaf anthocyanin and hardness were 13% and 25% lower.

Fruit morphological parameters (length, width and hardness) and soluble solids content were variety-dependent (P<0.01, Table 3). ‘Chant’ presented higher fruit length, while ‘Clemson Spineless 80’ and ‘Clemson Spineless’ presented longer and harder fruit, with higher fruit soluble solids content.

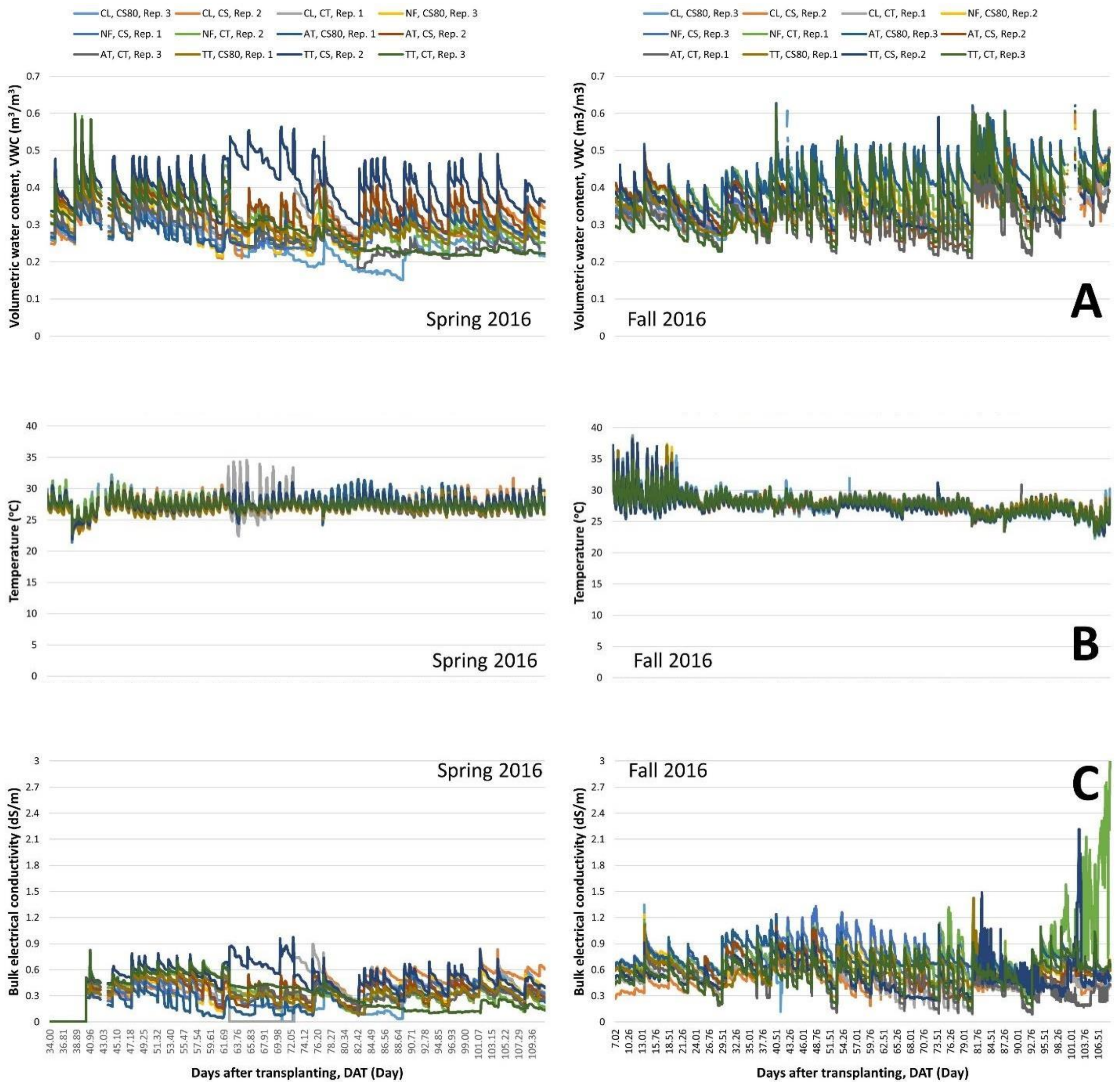


Fig. 6. Volumetric water content (A), soil temperature (B) and bulk electrical conductivity (C) monitored using capacitance sensors (GS3; Decagon Devices, Pullman, WA). Each sensor was positioned in a treatment combination: four drip irrigation equipment {[AT] "Toro Aqua-Traxx FC" (1.02 L at 10 psi), [TT] "Jain Top Drip Thin Wall" (0.98 L at 12 psi), [NF] "Netafim Dripnet PC" (0.98 L at 12 psi), and [CL] "Eurodrip Thinwall Classic" (0.94 L at 12 psi)} and three okra varieties ('Clemson Spineless 80 [CS80]', 'Clemson Spineless [CS]', and 'Chant [CT]'). Kingshill, U.S. Virgin Islands.

Table 2. Total yield, marketable yield, percent marketable yield, leaf anthocyanin, leaf chlorophyll and plant growth index of three varieties of okra (‘Clemson Spineless 80 [CS80]’, ‘Clemson Spineless [CS]’, and ‘Chant [CT]’) cultivated in two seasons (Spring and Fall, 2016) and using four irrigation equipment {[AT] “Toro Aqua-Traxx FC” (1.02 L at 10 psi), [TT] “Jain Top Drip Thin Wall” (0.98 L at 12 psi), [NF] “Netafim Dripnet PC” (0.98 L at 12 psi), and [CL] “Eurodrip Thinwall Classic” (0.94 L at 12 psi)}. Kingshill, U.S. Virgin Islands.

	Total yield (kg/ha)	**Marketable yield (kg/ha)**	**% Marketable yield**	**Leaf anthocyanin (ACI)**	**Leaf chlorophyll (CCI)**	**Plant growth index (cm)**
Season						
Spring 2016	27,315 ± 7,101 a	20,843 ± 5,368 a	76.36 ± 4.26 a	10.46 ± 1.80 b	17.09 ± 4.05	102.51 ± 5.63
Fall 2016	15,267 ± 5,305 b	11,125 ± 4,540 b	68.40 ± 5.61 b	11.91 ± 1.34 a	19.89 ± 3.30	104.73 ± 8.54
Equipment						
AT	22,360 ± 8,090	16,567 ± 5,845	73.06 ± 5.07	11.49 ± 1.43	18.70 ± 3.47	105.37 ± 7.13
CL	19,861 ± 6,449	14,905 ± 5,153	72.82 ± 5.09	11.79 ± 2.05	16.21 ± 2.76	101.91 ± 4.89
NF	22,856 ± 7,043	17,731 ± 6,573	72.21 ± 6.71	11.32 ± 1.36	19.23 ± 3.69	104.69 ± 9.00
TT	20,086 ± 7,339	14,732 ± 5,384	71.42 ± 5.22	10.15 ± 1.59	19.83 ± 4.79	102.51 ± 7.64
Variety						
CS80	20,788 ± 7,893	15,309 ± 6,080	70.41 ± 6.04	10.98 ± 1.24	17.39 ± 2.56	103.78 ± 5.79
CS	23,121 ± 7,531	16,741 ± 5,748	69.96 ± 4.41	11.24 ± 1.96	17.18 ± 2.65	100.82 ± 6.30
CT	19,963 ± 6,047	15,901 ± 5,429	76.76 ± 5.11	11.34 ± 1.68	20.91 ± 5.18	106.26 ± 9.07
			p-value			
Season (S)	0.0002*	0.0001*	0.0003*	0.0312*	0.0549	0.4837
Equipment (E)	0.8436	0.7663	0.9426	0.3198	0.3038	0.8384
S*E	0.9609	0.8507	0.3952	0.5584	0.1810	0.7128
Variety (V)	0.6626	0.8790	0.0143*	0.8940	0.0655	0.3772
S*V	0.9813	0.9158	0.5568	0.5573	0.6547	0.6218
E*V	0.9248	0.9366	0.9170	0.1375	0.2082	0.3730
S*E*V	0.9686	0.9311	0.4383	0.7618	0.4116	0.9370

* Significant at P<0.05.

Table 3. Fruit weight, fruit length, fruit width, fruit hardness, and fruit soluble solids content of three varieties of okra (‘Clemson Spineless 80 [CS80]’, ‘Clemson Spineless [CS]’, and ‘Chant [CT]’) cultivated in two seasons (Spring and Fall, 2016) and using four irrigation equipment {[AT] “Toro Aqua-Traxx FC” (1.02 L at 10 psi), [TT] “Jain Top Drip Thin Wall” (0.98 L at 12 psi), [NF] “Netafim Dripnet PC” (0.98 L at 12 psi), and [CL] “Eurodrip Thinwall Classic” (0.94 L at 12 psi)}. Kingshill, U.S. Virgin Islands.

	Fruit weight (g)	**Fruit length (cm)**	**Fruit width (cm)**	**Fruit hardness (kgf)**	**Fruit soluble solids content (%)**
Season					
Spring 2016	24.19 ± 2.47 a	13.73 ± 1.85 a	2.00 ± 0.09 a	5.86 ± 0.01 b	4.35 ± 0.15
Fall 2016	15.89 ± 1.48 b	11.29 ± 1.26 b	1.74 ± 0.07 b	7.86 ± 0.37 a	4.33 ± 0.13
Equipment					
AT	19.85 ± 3.13	12.58 ± 1.83	1.85 ± 0.11	6.89 ± 0.65	4.26 ± 0.16
CL	20.34 ± 3.16	12.50 ± 1.57	1.89 ± 0.11	6.86 ± 0.63	4.36 ± 0.14
NF	20.61 ± 3.41	12.84 ± 1.90	1.87 ± 0.12	6.80 ± 0.61	4.37 ± 0.17
TT	19.37 ± 3.13	12.11 ± 1.71	1.87 ± 0.11	6.90 ± 0.71	4.37 ± 0.07
Variety					
CS80	19.25 ± 2.85	10.91 ± 0.93 b	1.93 ± 0.10 a	7.11 ± 0.77 a	4.39 ± 0.15 a
CS	19.88 ± 3.01	11.04 ± 0.96 b	1.95 ± 0.10 a	6.92 ± 0.66 a	4.45 ± 0.10 a
CT	20.99 ± 3.60	15.57 ± 1.59 a	1.74 ± 0.08 b	6.56 ± 0.42 b	4.18 ± 0.12 b
			p-value		
Season (S)	<0.0001*	<0.0001*	<0.0001*	<0.0001*	0.6413
Equipment (E)	0.7740	0.6447	0.7027	0.7725	0.3502
S*E	0.8418	0.9293	0.4450	0.7962	0.2094
Variety (V)	0.2868	<0.0001*	<0.0001*	<0.0001*	0.0003*
S*V	0.3479	0.0541	0.4465	0.0701	0.8383
E*V	0.9879	0.8395	0.9824	0.0854	0.6660
S*E*V	0.6410	0.5134	0.3741	0.0695	0.5333

* Significant at P<0.01.

Conclusions

The pressure-compensating emitters maintained water flow within the range indicated by the manufacturers. Distribution uniformity decreased overtime in all equipment except “Netafim Dripnet PC” in Fall 2016. Irrigation equipment did not impact plant growth. The equipment should be selected based on price and irrigation efficiency.

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