Evapotranspiration Rates of Three Sweet Corn Cultivars under Different Irrigation Levels

Haimanote K. Bayabil[1], Fitsum T. Teshome[1],
Sandra M. Guzman[2], and Bruce Schaffer[3]

KEYWORDS. **crop coefficient, south Florida, water stress, *Zea mays* var. *saccharata***

ABSTRACT. **Understanding plants' response to different irrigation levels is essential for developing effective irrigation scheduling practices that conserve water without affecting plant growth and yield. The objective of this study was to evaluate the responses of three sweet corn (*Zea mays* var. *saccharata*) cultivars 1170, 8021, and Battalion under three irrigation levels (50%, 75%, and 100%). Irrigation treatments were based on soil moisture management allowable depletion. Replicated trials were conducted, in an open field using 1-gal containers, at the Tropical Research and Education Center, Homestead, FL. A drip system with microsprinklers was used for irrigation. Daily crop evapotranspiration (ET_c) rates were measured using a digital scale based on differences in weights of soil containers and plants. Reference evapotranspiration (ET_o) was calculated using the FAO-Penman-Monteith equation. Crop-coefficient (K_c) values for the three cultivars were calculated from measured ET_c and calculated ET_o. In addition, leaf area, stomatal conductance, and fresh biomass were measured. Total irrigation amounts corresponding to the 50%, 75%, and 100% treatments were 116, 162, and 216 mm, and total ET_c values were 128, 157, and 170 mm, respectively. The two deficit irrigation treatments (50% and 75%) resulted in a reduction of ET_c for the three cultivars compared with the 100% irrigation treatments. Results also showed that under 75% and 100% treatments, K_c values were usually greater than 1 for the three cultivars and reached as high as 1.5. Additionally, leaf area and fresh biomass weight in the 50% treatment were mostly lower than in the 75% or 100% treatments.**

Florida's vegetable industry covers a total land area of more than 251,000 acres and had an economic value of $1.34 billion in 2016 (Dittmar et al. 2022). In 2021, sweet corn (*Zea mays* var. *saccharata*) was grown on 34,400 acres with an estimated economic value of $208 million (U.S. Department of Agriculture, National Agricultural Statistics Service 2021). Proper irrigation management is essential to achieve optimal sweet corn yield and quality. Reports show that growing sweet corn under deficit irrigation reduced biomass accumulation (Stone et al. 2000). Similarly, plant growth, development, and physiological processes of field corn (*Z. mays*) were negatively affected by water stress, which resulted in a significant reduction in biomass, the number of kernels per ear, kernel weight, and grain yield (Payero et al. 2009; Traore et al. 2000).

Previous studies have investigated yield responses of sweet corn and field corn under different irrigation levels with a goal of developing irrigation strategies that conserve water without significantly affecting yield. A study showed that field corn yield was significantly correlated with crop evapotranspiration (Payero et al. 2008). Yazar et al. (1999) evaluated the effect of six irrigation levels on field corn and found that the highest grain yield, dry matter, kernel numbers, and water use efficiency were obtained from both the fully irrigated treatment and the treatment receiving 80% of the required irrigation water. Similarly, Djaman et al. (2013) reported that 60% and 75% irrigation based on soil field capacity resulted in field corn yield that was comparable with the 100% irrigation. In contrast, Karam et al. (2003) found a 305 $g \cdot m^{-2}$ yield reduction of field corn irrigated with 60% irrigation compared with the 100% based on crop evapotranspiration. Irrigation frequency was also found not to have a significant effect on field corn yield as long as available soil water was maintained at 80% or above (Caldwell et al. 1994). Stockle and James (1989) reported that economic returns were higher for crops subjected to slight water deficits compared to fully irrigated crops. The general expectation is that

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
29.5735	fl oz	mL	0.0338
0.3048	ft	m	3.2808
0.0929	ft^2	m^2	10.7639
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
6.4516	$inch^2$	cm^2	0.1550
0.0418	Langley(s)	$MJ \cdot m^{-2}$	23.9006
0.4536	lb	kg	2.2046
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
1.6093	mile(s)	km	0.6214
0.4470	mph	$m \cdot s^{-1}$	2.2369
28.3495	oz	g	0.0353
33.9057	$oz/yard^2$	$g \cdot m^{-2}$	0.0295
6.8948	psi	kPa	0.1450
(°F − 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

Received for publication 11 Aug 2022. Accepted for publication 11 Oct 2022.

[1] Department of Agricultural and Biological Engineering, Tropical Research and Education Center, University of Florida, Homestead, FL 33031, USA

[2] Department of Agricultural and Biological Engineering. Indian River Research Center, University of Florida, Fort Pierce, FL 34945, USA

[3] Horticultural Sciences Department, Tropical Research and Education Center, University of Florida, Homestead, FL 33031, USA

Funding for this research was provided by the University of Florida, Institute of Food and Agricultural Sciences, through an Early Career Scientist Seed Grant, Award #212-2100-00129077. Additional funding was from the National Institute of Food and Agriculture, U.S. Department of Agriculture (USDA), under award number 2020-67021-31965, and the Hatch Project No. FLA-TRC-005751. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the USDA.

H.K.B. is the corresponding author: E-mail: hbayabil@ufl.edu.

https://doi.org/10.21273/HORTTECH05114-22

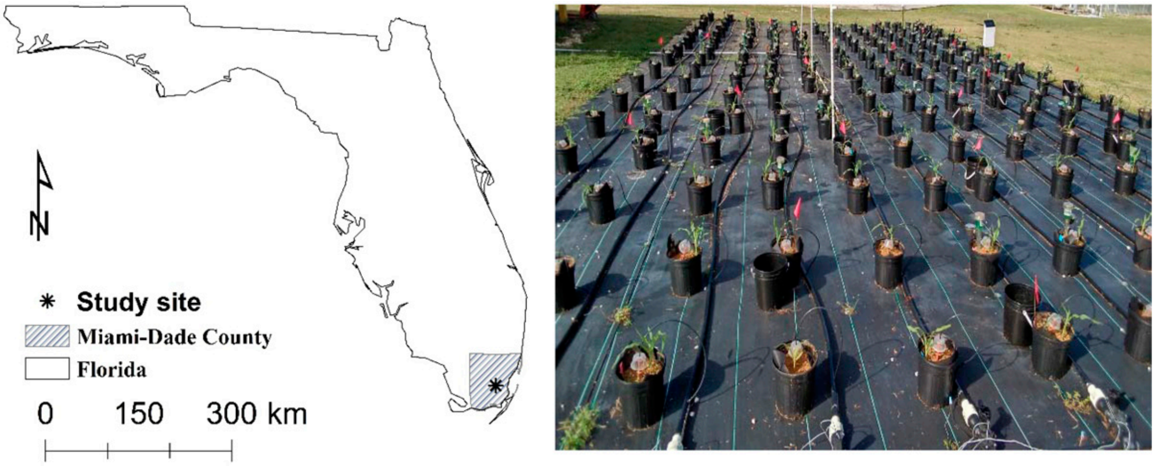

Fig. 1. Study site location and experimental setup of sweet corn irrigation study at the University of Florida, Tropical Research and Education Center, Homestead, FL. 1 km = 0.6214 mile.

irrigation water use efficiency decreases with an increase in irrigation rate (Ko and Piccinni 2009; Panda et al. 2004; Payero et al. 2008; Rivera-Hernández et al. 2010). Viswanatha et al. (2002) reported that with an increase in the amount of irrigation, water use efficiency of sweet corn was decreased. Similarly, water-stressed field corn had a higher irrigated water use efficiency compared with nonstressed corn as a result of reduced plant transpiration due to reduced leaf area (Karam et al. 2003).

Ertek and Kara (2013) reported that ~70% to 80% of crop water use is induced by plant transpiration. Plant transpiration is regulated by stomatal conductance (Lavoie-Lamoureux et al. 2017; Tuzet et al. 2003; Urban et al. 2017). Understanding the effects of different irrigation levels on evapotranspiration and selected crop physiological parameters including stomatal conductance is critical for developing irrigation management options that conserve water without affecting crop yield and yield components. As a result, this study was conducted to investigate the responses of three sweet corn cultivars (1170, 8021, and Battalion) under three irrigation levels (50%, 75%, and 100%).

Materials and methods

EXPERIMENTAL SETUP. This study was conducted at the Tropical Research and Education Center (TREC) of the University of Florida, Homestead, FL (Fig. 1). The study site has a subtropical climate with a major rainy season from June to September (Zhang et al. 2018). The experiment was conducted under open-field conditions. Sweet corn plants were grown in 1-gal plastic containers (7 inches depth, 7 inches diameter) with drainage holes at the bottom (Fig. 1). Plastic containers were set up on a black weed mat used to cover the ground. The holes were covered with a nylon net to retain soil but allow the free drainage of water. Each container was filled with Krome gravelly loam soil collected from the top 8 inches of an agricultural field at TREC. The bulk soil was mixed thoroughly and sieved through a 5-mm sieve before being packed in the containers. Pots were filled up to 6 inches leaving a 1-inch head space to avoid overflowing of irrigation or rainfall. In each container, five seeds of one of three sweet corn cultivars (1170, 8021, and Battalion; Syngenta Seeds, Woodland, CA) were planted. After germination, plants were thinned leaving only one plant per container. Plants were irrigated with an automated drip irrigation system with one microsprinkler per container. The microsprinkler spray pattern was adjusted by installing an inverted plastic cup above the microsprinkler to ensure that water was delivered only within the container for accurate water balance. The sprinkler system had an average application rate of 200 $\mathrm{mL{\cdot}min^{-1}}$ and distribution uniformity of 90%.

A randomized complete block experimental design was used with three irrigation levels, three cultivars, and four replications. This resulted in a total of 180 plants (3 cultivars × 3 irrigation levels × 4 replications × 5 plants within each replication). Irrigation scheduling for the three irrigation treatments; i.e., 50%, 75%, and 100% were performed based on maximum allowable depletion (Fig. 2). Irrigation levels were targeted to replenish 100%, 75%, or 50% of maximum allowable depletion values. Maximum allowable depletion was set at half of the soil water holding capacity

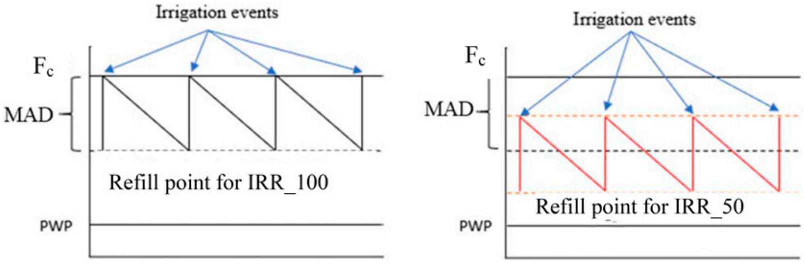

Fig. 2. Schematic of irrigation refill points corresponding to the 100% and 50% irrigation treatments (IRR). F_c = soil field capacity; PWP = soil permanent wilting point; IRR_50 = 50% maximum allowable depletion (MAD); IRR_100 = 100% MAD.

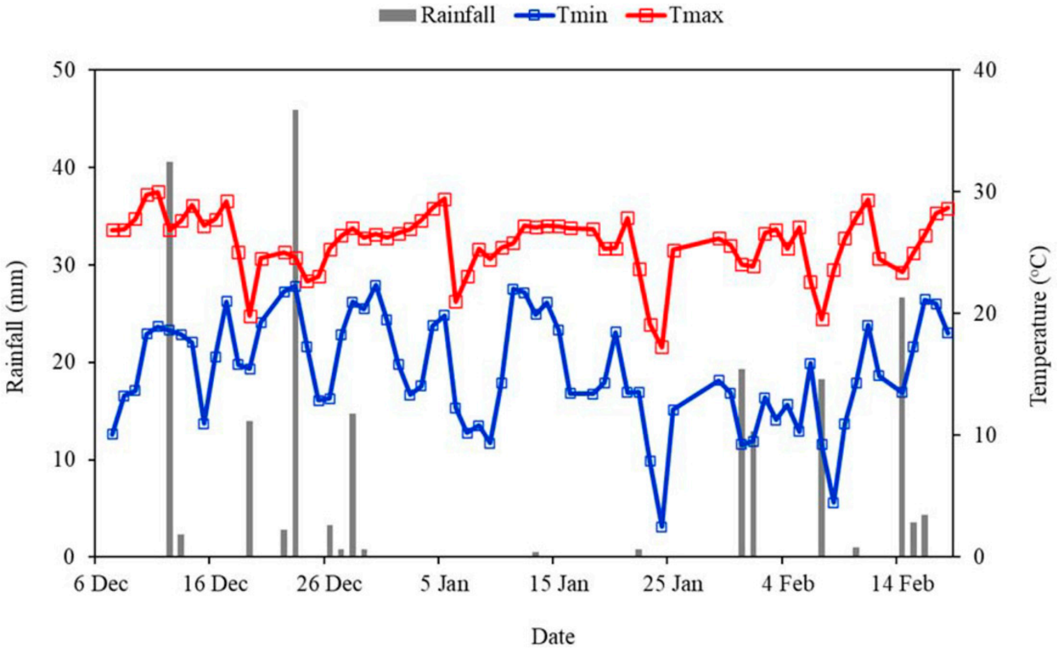

Fig. 3. Rainfall, and minimum (Tmin) and maximum (Tmax) temperatures from the Homestead, FL, weather station of the Florida Automated Weather Network. 1 mm = 0.0394 inch; (°C × 1.8) + 32 = °F.

calculated as the difference between field capacity and the permanent wilting point. In the 100% treatment, the soil was allowed to dry to maximum allowable depletion, equivalent to 50% of soil water holding capacity and then irrigated to field capacity or 100% maximum allowable depletion. In the 75% treatment, the soil was allowed to dry to 37.5% water holding capacity and then irrigated to 87.5% field capacity, equivalent to 75% maximum allowable depletion. In the 50% treatment, the soil was allowed to dry to 25% water-holding capacity and then irrigated to 75% field capacity, equivalent to 50% maximum allowable depletion. Thus, the soil moisture in the three treatments was maintained between 50% to 100%, 37.5% to 87.5%, and 25% to 75% of field capacity, respectively (Fig. 2).

Of the 180 pots, 36 pots (three irrigation treatments × three cultivars × four replications) were selected for daily weight measurement to determine evapotranspiration, drainage, and soil water balance. These pots were nested with a secondary container with no drainage holes to allow the collection of excess water draining from the first container with soil. To create sufficient space for drainage water in the additional pots, the inside pot with soil was placed on a 5-cm-high polyvinyl chloride ring. Nitrogen (N), phosphorous (P), and potassium (K) were supplied using a fertilizer, obtained from a local fertilizer distributor in Homestead, FL, with 6N–2.3P–8.3K. Initial fertilizer application rate was applied at the rate of

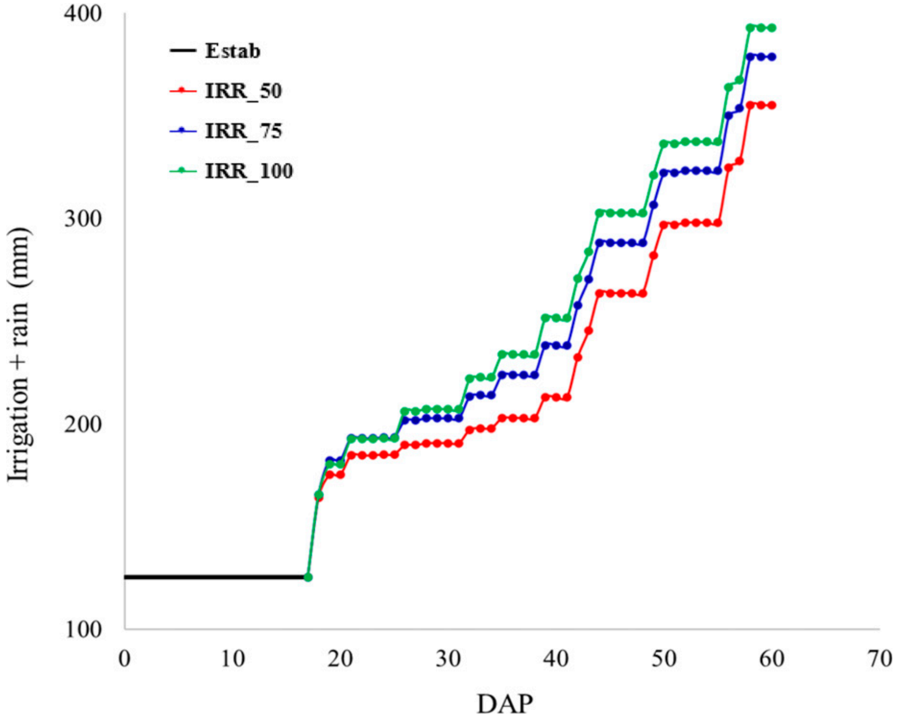

Fig. 4. Cumulative irrigation application and rainfall during the sweet corn growth period in the IRR_50, IRR_75, and IRR_100 irrigation treatments (IRR); DAP = days after planting, Estab = crop establishment period, IRR_50 = 50% maximum allowable depletion (MAD), IRR_75 = 75% MAD, IRR_100 = 100% MAD. 1 mm = 0.0394 inch.

2 g/pot: equivalent to 75, 65, and 125 kg·ha^{-1} N, P, and K, respectively. The fertilizer rates were calculated based on average soil weight (8 lb). The weighed amount of fertilizer was mixed uniformly within the top 10 cm soil depth before planting. Then, seeds were planted, and irrigation was applied for 2 min (i.e., 400 mL water per container).

A top-dressing fertilizer was applied to each container at 11 and 37 d after emergence using a 22N–1.5P–8.3K fertilizer at the rate equivalent to 150 kg·ha^{-1} N. Due to excess rainfall-related leaching of nutrients, one more N topdressing was applied at 40 d after emergence using urea (45N–0P–0K) for an N rate equivalent to 200 kg·ha^{-1}. The experiment was conducted during the 2019–20 cropping season with planting on 6 Dec 2019 and harvesting on 18 Feb 2020.

Data collection and analysis. Irrigation treatments were initiated 22 d after emergence once the plants had between two to three leaves. The 36 pots were weighed daily. Water loss by leaching was measured by weighing the leachate collected from the second nested container without drainage holes. Evapotranspiration rate from each container was measured daily using a digital scale and daily crop evapotranspiration losses were calculated based on the daily weight differences of containers. Soil water deficit was estimated by subtracting the total weight of the plant and container on a given day from the weight recorded on the previous day. It was assumed that biomass accumulation was a slow process compared to evapotranspiration losses. Daily evapotranspiration losses were recorded until the maximum allowable depletion was reached before irrigation was triggered. Additional measurements included stomatal conductance using a porometer (Meter Group, Inc., Pullman, WA) during a later stage of the rop growth period, total fresh biomass, and ear weight. Stomatal conductance was measured on a mature leaf in the middle of the canopy. Biomass was measured by cutting plants from the soil surface and separating them into different organs. Leaves were separated and leaf area was measured with a leaf area

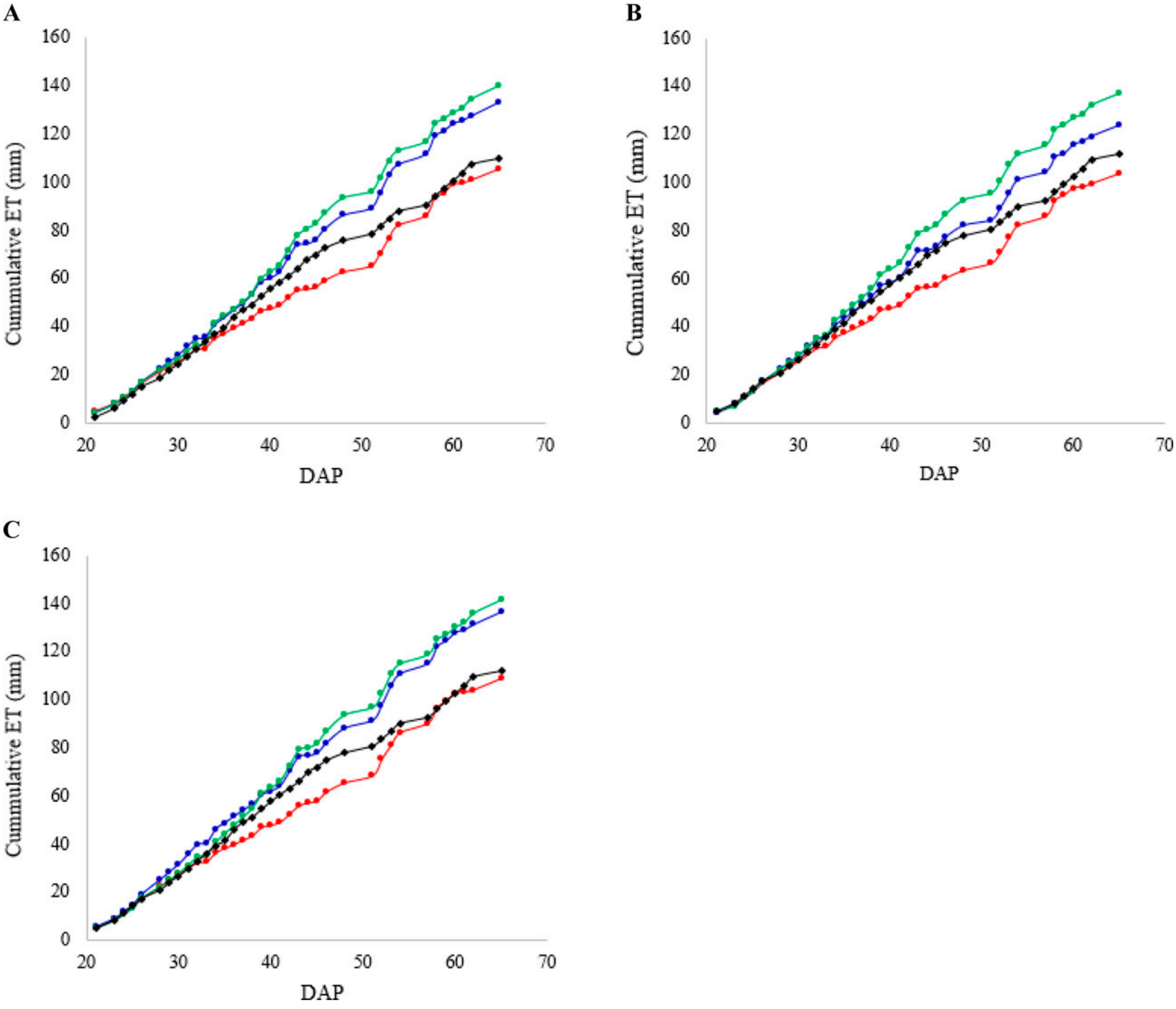

Fig. 5. Cumulative reference evapotranspiration (ET$_o$) and measured sweet corn evapotranspiration (ET$_c$) under three irrigation levels for three cultivars [(A) 1170, (B) 8021, (C) Batallion]. DAP = days after planting; IRR_50 = 50% maximum allowable depletion (MAD); IRR_75 = 75% MAD; IRR_100 = 100% MAD. 1 mm = 0.0394 inch.

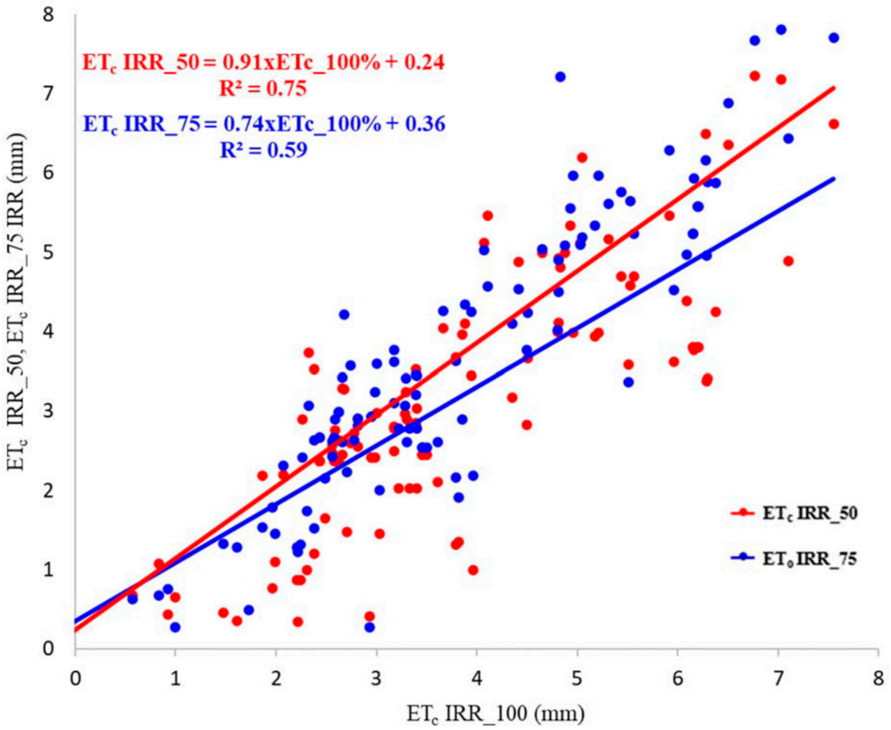

Fig. 6. Correlation between measured sweet corn evapotranspiration (ETc) from IRR_100 vs. ET_c from IRR_50 and IRR_75 irrigation treatments (IRR). IRR_50 = 50% maximum allowable depletion (MAD); IRR_75 = 75% MAD; IRR_100 = 100% MAD. 1 mm = 0.0394 inch.

meter (LiCor Biosciences, Lincoln, NE). During the experiment, selected plants were harvested every 2 weeks for biomass and leaf area measurements. Data normality test using the Kolmogorov–Smirnov test confirmed that normality was not met. A nonparametric Kruskal–Wallis statistical test was used to evaluate the effect of irrigation treatment. When treatment effects were significant, mean comparison tests were performed using the Dunn's

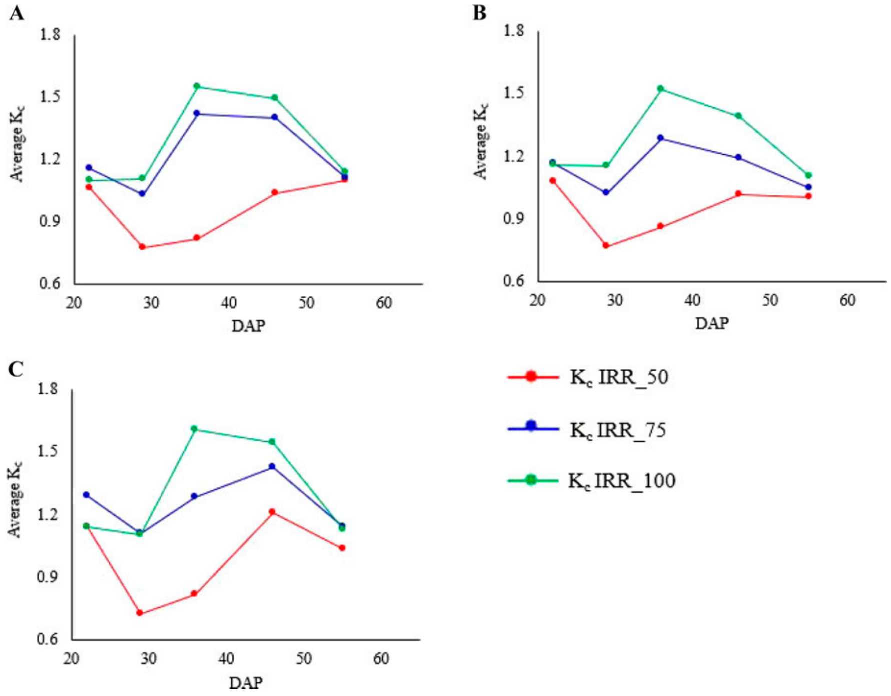

Fig. 7. Average crop coefficient (K_c) values at different growth stages of three sweet corn cultivars [(A) 1170, (B) 8021, (C) Batallion] under three irrigation levels (IRR). IRR_50 = 50% maximum allowable depletion (MAD); IRR_75 = 75% MAD, IRR_100 = 100% MAD. 1 mm = 0.0394 inch.

test with Bonferroni correction at a 5% significance level. In addition, Pearson's correlation coefficient (r) and the coefficient of determination (r^2) were used to evaluate relationships between evapotranspiration rates from irrigation treatments.

Crop coefficient. Reference evapotranspiration (ET_o) was calculated using the FAO–Penman–Monteith equation (Eq. [1]) based on weather and crop-specific information (Allen et al. 1998). For each cultivar, crop coefficient values were then calculated, for different crop growth stages, as the ratio of measured ET_c and calculated ET_o (Eq. [2]). Weather data were obtained from the University Florida's Homestead weather station located ~1 mile from the study site.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34\ u_2)}; \qquad [1]$$

where ET_o is daily reference evapotranspiration (millimeters per day), R_n is daily net radiation at the crop surface (megajoules per square meter per day), G is the soil heat flux density (megajoules per square meter per day), T is the mean daily air temperature at a 2m height (degrees Celsius), u_2 is the wind speed at a 2m height (meters per second), e_s is the saturation vapor pressure (kilopascals), e_a is the actual vapor pressure (kilopascals), e_s-e_a is the saturation vapor pressure deficit (kilopascals), Δ is the slope of the vapor pressure curve (kilopascals per degree Celsius), and γ is a psychrometric constant (kilopascals per degree Celsius).

$$K_c = \frac{ET_c}{ET_0}; \qquad [2]$$

where K_c is the crop coefficient, ET_c is the crop evapotranspiration (millimeters per day), and ET_o is the reference evapotranspiration (millimeters per day).

The results provided in this study can contribute to the establishment of sweet corn irrigation scheduling plans for south Florida and the improvement of evapotranspiration-based decision support tools that incorporate crop coefficients.

Results and discussion

Irrigation and rainfall. There was average rainfall during the planting and initial plant phenological stages, while during the plant development period the weather was relatively dry (Fig. 3). This is consistent with Florida's uneven rainfall distribution and to overcome this issue all horticultural crops including vegetables are irrigated (Dukes et al. 2010). Total rainfall during this experiment was 171 mm. The temperature ranged between 10 to 30 °C except for toward the end of January when the minimum temperature was below 10 °C for 3 d. Total irrigation applied for the three (50%, 75%, and 100%) irrigation treatments were 116, 162, and 216 mm, respectively (Fig. 4). Consumptive water uses for the 100% irrigation treatment was 387 mm, followed by 75% with 333 mm and 50% with 287 mm. As a result, for the 50% and 75% irrigation treatments, approximately one-third and half of the water applied came from irrigation, while for the 100% treatment, irrigation represented more than 56% of the total water applied.

Cultivar 1170 received slightly higher irrigation water than the 8021 and Batallion. Our results were very low compared with other studies that reported that consumptive water use of sweet corn between the ranges of 465 to 1078 mm under multiple environmental and field conditions (Grassini et al. 2011; Hao et al. 2015; Kuscu et al. 2013; van Donk et al. 2013). The consumptive water use results presented in this study are the first approximation to establish the water needs for these three cultivars.

Evapotranspiration and crop coefficients. Cumulative evapotranspiration rates for the three cultivars

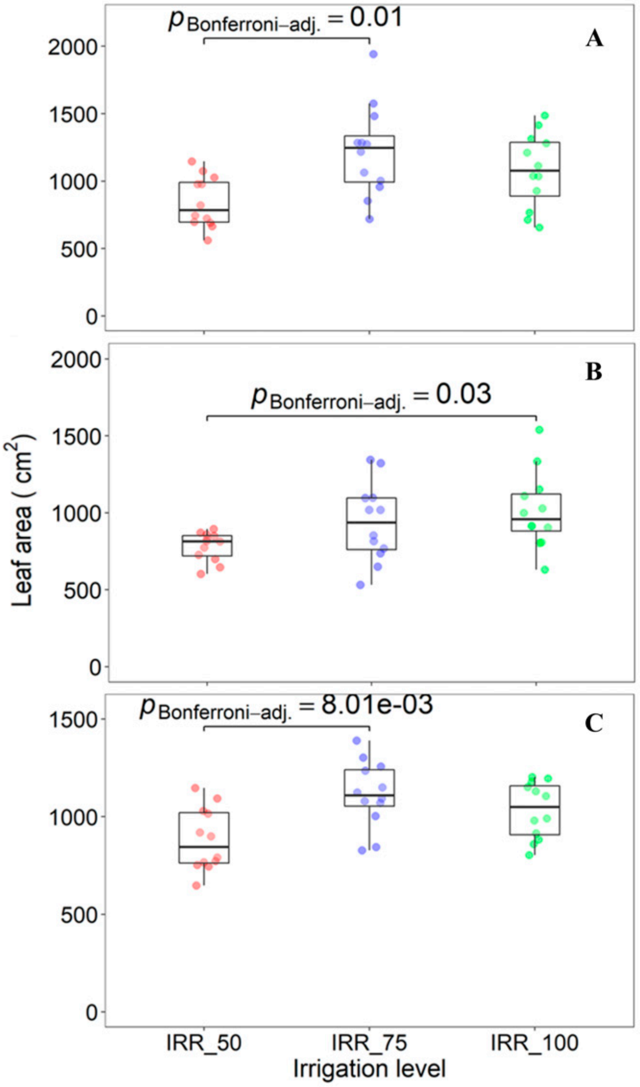

Fig. 8. Leaf area of three sweet corn cultivars (1170, 8021, Batallion) in the three irrigation treatments (IRR). IRR not sharing the same letter within the same cultivar type are significantly different at $P < 0.05$. IRR_50 = 50% maximum allowable depletion (MAD); IRR_75 = 75% MAD; IRR_100 = 100% MAD. 1 cm^2 = 0.1550 inch^2.

showed that fully irrigated plants had the highest ET$_c$, whereas plants that received 50% irrigation had the lowest ET$_c$ (Fig. 5). It is also worth noting that starting on ~15 Jan 2020, ET$_c$ from the 75% and 100% irrigation treatments were greater than ET$_o$ values; however, ET$_c$ from the 50% irrigation treatment was always below ET$_o$ (Fig. 5). Differences between cumulative crop evapotranspiration rates from the 75% and 100% irrigation treatments were higher for cultivar 1170 compared with 8021 and Batallion. Differences in ET$_c$ values between the three irrigation levels seem slightly higher than observed differences in ET$_c$ of the three cultivars. Overall, calculated ET$_o$ based on weather and crop information was smaller than ET$_c$ for the 75% and 100% irrigation treatments regardless of cultivar.

On the basis of measurements of the three cultivars, ET$_c$ from the 75% irrigation showed a better correlation with ET$_c$ from the 100% irrigation treatment ($r^2 = 0.75$) compared with correlations between ET$_c$ from the 50% and 100% IRRs ($r^2 = 0.59$). In addition, a 25% reduction in irrigation leads to a 10% reduction in ET$_c$, whereas a 50% reduction in irrigation leads to a 26% reduction in ET$_c$ (Fig. 6). This indicates that up to 25% of water savings could be achieved at a 10% reduction in ET$_c$. Rasool et al. (2020) reported that ET$_c$ of field corn ranged between 207 to 407 mm and between 165 and 244 mm under 100% and 60% irrigation treatments, respectively. Similarly, Di Paolo and Rinaldi (2008) reported irrigation requirements for field corn to be between 185 mm at 50% of crop evapotranspiration and 373 mm at 100% irrigation under a Mediterranean climate. Hao et al. (2019) reported that the seasonal ET$_c$ for 100%, 75%, and 50% irrigation treatments were 673, 561, and 484 mm, respectively, with a reduction in seasonal ET$_c$ of 16.6% and 28.1% for 75% and 50% irrigation treatments compared with the 100% irrigation treatment.

On the basis of observed ET$_c$ and ET$_o$ results, it was apparent that average K$_c$ values at different crop growth stages were greater than 1 for the 75% and 100% irrigation treatments regardless of cultivar (Fig. 7). However, K$_c$ values for the 50% irrigation treatment were less than 1 during most of the experiment except toward the end of the crop growth period, where K$_c$ values were 1 or slightly greater than 1 (Fig. 7). Peak K$_c$ values were observed during the vegetative crop growth stage when K$_c$ values reached as high as 1.5.

LEAF AREA AND STOMATAL CONDUCTANCE. Overall, results showed that the 75% and 100% irrigation treatments resulted in a slightly higher leaf area for the three cultivars compared with the 50% irrigation treatment (Fig. 8). Among the three cultivars, however, 1170 had slightly greater leaf area in the 75% and 100% irrigation treatments compared with 8021 and Batallion. However, the average leaf area in this study was less than that observations by Williams (2008), who reported 0.25 and 0.35 m^2/plant from a 2-year study.

Water stress during the vegetative and tasseling stages reduced plant height and leaf area of field corn (Çakir 2004; Singh et al. 2007). Several studies have found that maximum leaf area index (LAI) occurred under full irrigation (Dağdelen et al. 2006; Oktem 2008; Panda et al. 2004) and LAI decreased under soil moisture stress conditions (Acevedo et al. 1971; Oktem 2008; Song et al. 2019; Stone et al. 2001). Studies showed a strong correlation between LAI and seasonal water consumption (ET$_c$) (Kang et al. 2003; Oktem 2008).

Overall, stomatal conductance measurements did not show clear trends between the three cultivars and irrigation levels (Fig. 9). However, the 75% and 100% irrigation treatments, at most sampling times, had a slightly higher stomatal conductance than the 50% irrigation treatment for each cultivar (Fig. 9). This was in agreement with our observations of the leaf area (Fig. 8). However, differences were not significant because stomatal conductance showed high variability except on the

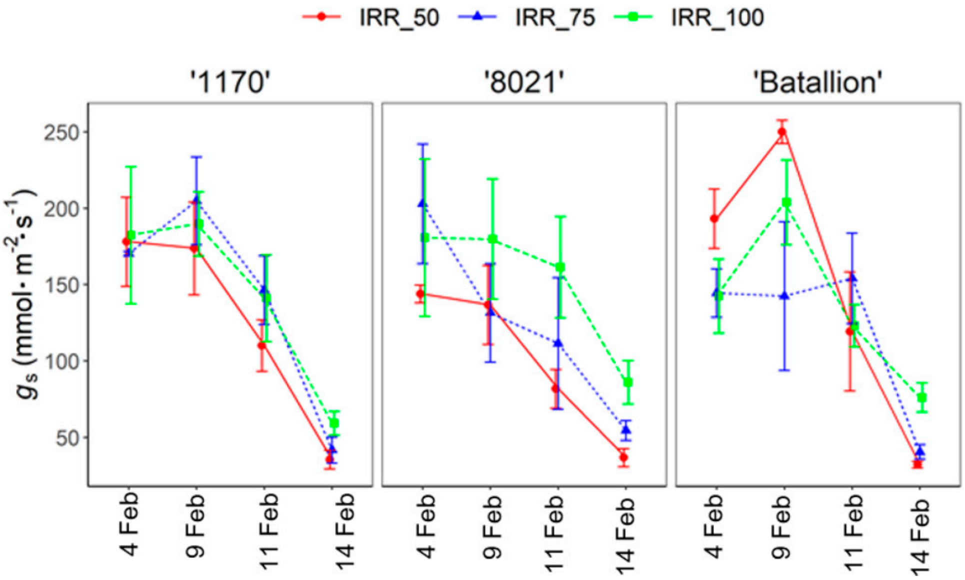

Fig. 9. Average stomatal conductance (g_s) values with error bars of three sweet corn cultivars (1170, 8021, Batallion) under three irrigation treatments (IRR); IRR_50 = 50% maximum allowable depletion (MAD); IRR_75 = 75% MAD; IRR_100 = 100% MAD.

last measurement date. In addition, stomatal conductance showed a decreasing trend as plants matured and with the senescence of leaves. On the basis of limited information, it appears that the three cultivars evaluated in this study do not have significant variation concerning their drought tolerance and/or the range of stress imposed across different irrigation treatments. Stomatal conductance regulates carbon dioxide (CO_2) exchange as well as leaf water loss to prevent desiccation of leaves. Stomatal conductance can be a good indicator of plant response to drought; that is, reduction in stomatal conductance is much greater in drought-tolerant cultivars compared with drought-susceptible cultivars (Ray and Sinclair 1997). Sabagh et al. (2017) also reported stomatal conductance as a valuable tool to screen corn's response to drought stress. They reported that increases in stomatal conductance were correlated with greater yield. Sinclair et al. (1975) found that water use efficiency of field corn decreased as stomatal conductance decreased. Increases in soil moisture deficit led to a decrease in stomatal conductance in corn leaves, which in turn resulted in a reduction in transpiration rates, photosynthesis, and total plant biomass accumulation (Shani and Dudley 2001).

Fresh biomass and ear yield. Results for fresh biomass were consistent with results observed for other crop variables including the crop coefficient, crop evapotranspiration, and leaf area (Fig. 10). Similar to other crop variables measured in this study, fresh ear yield was not significantly affected by irrigation and cultivar type (Fig. 11). However, ear yields were numerically higher, but not significantly so, in the 75% irrigation treatment compared with the 100% and 50% irrigation treatments. Fresh ear weight was 29% and 45% less in the 100% and 50% irrigation treatments compared to the 75% irrigation treatment, respectively. This was in contrast to the general expectation that 100% irrigation is needed for optimal ear yield.

Overall, observed yield from this study for the three cultivars was low compared with other studies. However, among the three cultivars evaluated in this study, fresh weight was less for 8021 compared with 1170 and Battalion under the same irrigation level (Fig. 11). Fresh biomass was 25% less in 8021 compared with 'Battalion'. This was also evident in the leaf area (Fig. 8). Moteva et al. (2016) reported that sweet corn yield was the same under drip and sprinkler irrigation systems, but irrigation amount had a significant effect on yield. Their study showed marketable ear yield ranged between 177 and 188 g under drip and sprinkler irrigation systems. Ertek and Kara (2013) reported that sweet corn fresh ear yield and quality were affected by irrigation levels. Yazar et al. (1999) evaluated the effect of six irrigation levels on field corn water stress and grain yield. They stated that the highest grain yield, dry matter, kernel numbers, and water use efficiency were obtained from the fully irrigated and 80% of required irrigation treatments. Similarly, Stockle and James (1989) found that corn under slight deficit irrigation resulted in greater net economic benefits than full irrigation. Dağdelen et al. (2006) recommended a 30% reduction in irrigation water use for corn as a deficit irrigation management strategy in semiarid areas with limited water availability. In contrast, Çakir (2004) observed a significant negative effect of water stress on corn dry matter accumulation. It was found that a short period of water deficit during the rapid vegetative growth stage caused a 28% to 32% loss of dry matter weight (Çakir 2004).

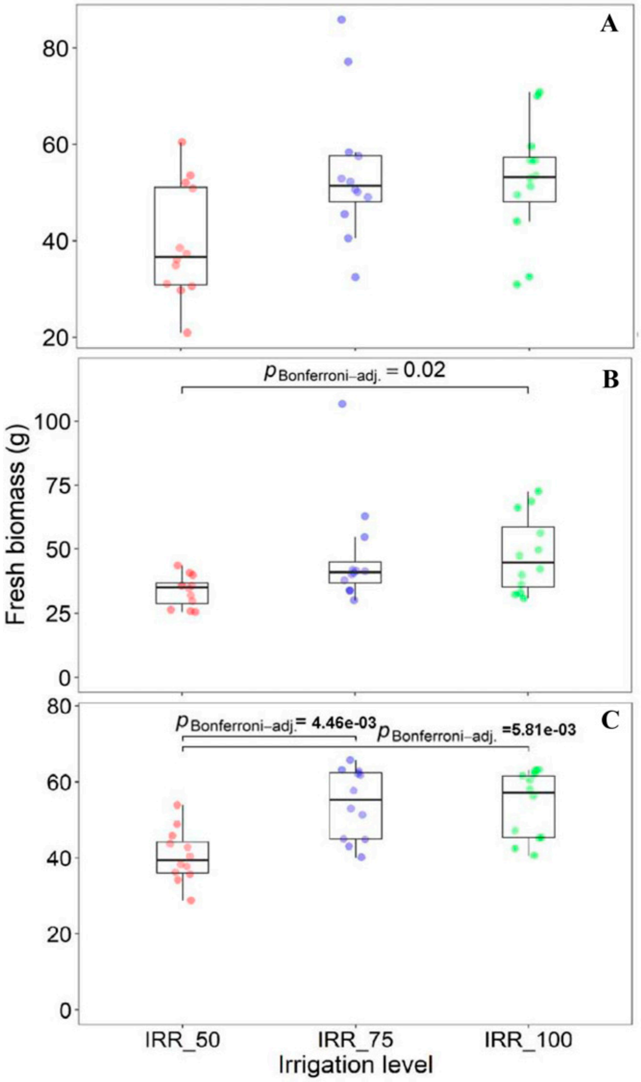

Fig. 10. Fresh above-ground biomass weight per plant for three sweet corn cultivars, (A) 1170, (B) 8021, (C) Batallion, subjected to three irrigation treatments (IRR). Fresh biomass weight does not include ear weight; IRR_50 = 50% maximum allowable depletion (MAD), IRR_75 = 75% MAD, IRR_100 = 100% MAD. 1 g = 0.0353 oz.

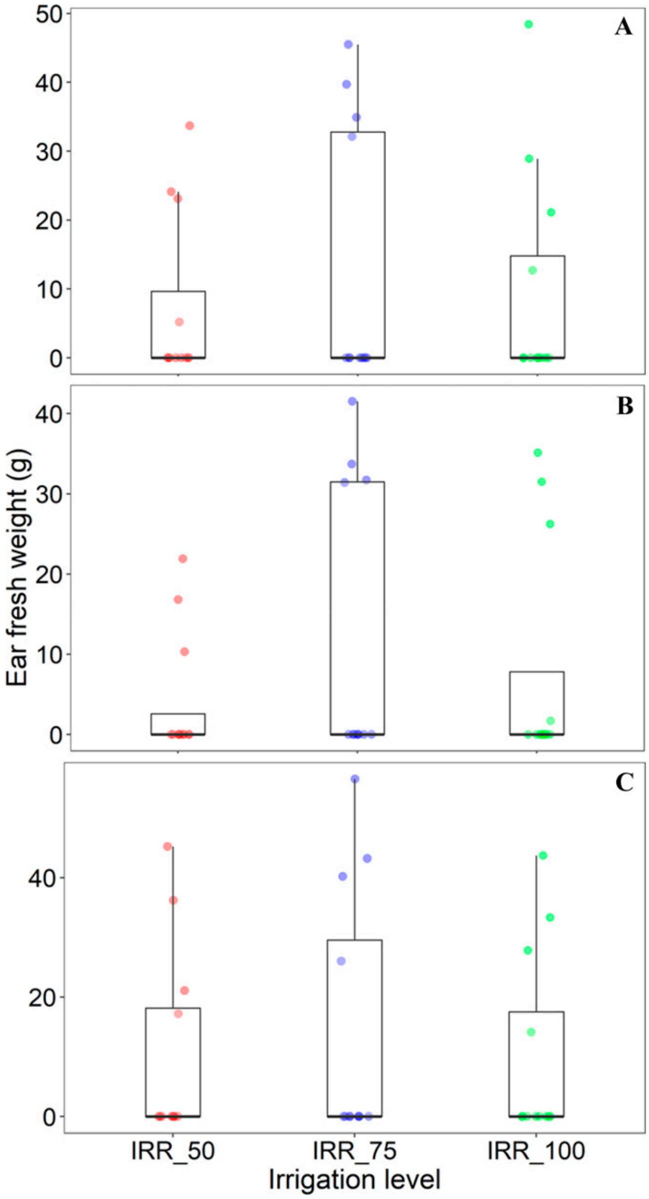

Fig. 11. Fresh ear weight per plant for three sweet corn cultivars, (A) 1170, (B) 8021, (C) Batallion, subjected to three irrigation treatments (IRR). IRR_50 = 50% maximum allowable depletion (MAD); IRR_75 = 75% MAD; and IRR_100 = 100% MAD. 1 g = 0.0353 oz.

A significant linear relationship was observed between seasonal water consumption and fresh ear yield (Irmak et al. 2000; Oktem 2008; Yazar et al. 2002). Increasing the level of water stress decreased the fresh ear yield (Darusman et al. 1997; Oktem 2008; Viswanatha et al. 2002). However, applying only 25% of required irrigation resulted in significant reduction in yield, biomass, and leaf area. These adverse effects of water stress on corn plant growth as well as yield are consistent with the published results of Payero et al. (2009) and Traore et al. (2000).

Conclusions

Developing optimal irrigation management practices is critical for achieving optimal plant yield and conserving water. Evapotranspiration is the major component of the soil water balance. Understanding how evapotranspiration rates and crop coefficients are affected by different water stress levels and whether crop response to water stress levels is affected by cultivar type is critical for developing effective irrigation scheduling methods. This study investigated the effects of irrigation level on evapotranspiration rates, selected crop variables (e.g., leaf area, stomatal conductance, fresh biomass, and ear yield); and crop-coefficient values for three sweet corn cultivars (1170, 8021, and Battalion) under south Florida weather conditions. Rain events interfered with the experiment and the intended water stress levels were not fully implemented throughout the crop growing season. However, crop evapotranspiration rates showed differences between irrigation levels with 50%, 75%, and 100% irrigation treatments corresponding to 116, 162, and 216 mm total irrigation, respectively. The three cultivars tested in this study had similar consumptive water uses under similar irrigation levels. On average, a 25% reduction in irrigation led to a 10% reduction in crop evapotranspiration, whereas a 50% reduction in irrigation led to a 26% reduction in evapotranspiration. Evapotranspiration, leaf area, stomatal conductance, fresh biomass, and ear yield for the 75% and 100% irrigation treatments were comparable regardless of cultivar. However, in the 75% and 100% irrigation treatments, '1170' had a slightly greater leaf area than '8021' or 'Batallion'. In general, the three sweet corn cultivars evaluated in the present study could tolerate at least a 25% moisture deficit without significantly affecting crop evapotranspiration, the crop coefficient, and other crop variables. This suggests that up to 25% of water savings could likely be achieved without considerably reducing evapotranspiration and yield. However, it is also worth noting that while findings from this study provide useful insights into how irrigation levels affect crop physiological processes, further studies are needed to verify these findings under field conditions.

References cited

Acevedo, E., T.C. Hsiao, and D.W. Henderson. 1971. Immediate and subsequent growth responses of maize leaves to changes in water status. Plant Physiol. 48(5):631–636, https://doi.org/10.1104%2Fpp.48.5.631.

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. Crop evapotranspiration—Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No. 56. Food and Agriculture Organization of the United Nations, Rome, Italy.

Çakir, R. 2004. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Res. 89(1):1–16, https://doi.org/10.1016/j.fcr.2004.01.005.

Caldwell, D.S., W.E. Spurgeon, and H.L. Manges. 1994. Frequency of irrigation for subsurface drip-irrigated corn. Trans. ASABE 37(4):1099–1103, https://doi.org/10.13031/2013.28181.

Dağdelen, N., E. Yõlmaz, F. Sezgin, and T. Gürbüz. 2006. Water-yield relation and water use efficiency of cotton (*Gossypium hirsutum* L.) and second crop corn (*Zea mays* L.) in western Turkey. Agric. Water Manage. 82(1-2):63–85, https://doi.org/10.1016/j.agwat.2005.05.006.

Darusman, D., A. Khan, L. Stone, and F. Lamm. 1997. Water flux below the root zone vs. drip-line spacing in drip-irrigated corn. Soil Sci. Soc. Amer. J. 61(6):1755–1760, https://doi.org/10.2136/sssaj1997.03615995006100060029x.

Di Paolo, E. and M. Rinaldi. 2008. Yield response of corn to irrigation and nitrogen fertilization in a Mediterranean environment. Field Crops Res. 105(3):202–210, https://doi.org/10.1016/j.fcr.2007.10.004.

Dittmar, P.J., N.S. Dufault, and S. Agehara. 2022. Chapter 1. Commercial vegetable production in Florida. UF/IFAS Ext. Factsheet HS710. https://doi.org/10.32473/edis-cv100-2022.

Djaman, K., S. Irmak, W.R. Rathje, D.L. Martin, and D.E. Eisenhauer. 2013. Maize evapotranspiration, yield production functions, biomass, grain yield, harvest index, and yield response factors under full and limited irrigation. Trans. ASABE 56(2): 373–393, https://doi.org/10.13031/2013.42676.

Dukes, M.D., L. Zotarelli, and K.T. Morgan. 2010. Use of irrigation technologies for vegetable crops in Florida. HortTechnology 20(1):133–142, https://doi.org/10.21273/HORTTECH.20.1.133.

Ertek, A. and B. Kara. 2013. Yield and quality of sweet corn under deficit irrigation. Agric. Water Manage. 129:138–144, https://doi.org/10.1016/j.agwat.2013.07.012.

Grassini, P., H. Yang, S. Irmak, J. Thorburn, C. Burr, and K.G. Cassman. 2011. High-yield irrigated maize in the western U.S. corn belt. II. Irrigation management and crop water productivity. Field Crops Res. 120(1):133–141, https://doi.org/10.1016/j.fcr.2010.09.013.

Hao, B., Q. Xue, T.H. Marek, K.E. Jessup, J.D. Becker, X. Hou, W. Xu, E.D. Bynum, B.W. Bean, P.D. Colaizzi, and T.A. Howell. 2019. Grain yield, evapotranspiration, and water-use efficiency of maize hybrids differing in drought tolerance. Irrig. Sci. 37:25–34, https://doi.org/10.1007/s00271-018-0597-5.

Hao, B., Q. Xue, T.H. Marek, K.E. Jessup, X. Hou, W. Xu, E.D. Bynum, and B.W. Bean. 2015. Soil water extraction, water use, and grain yield by drought-tolerant maize on the Texas high plains. Agric. Water Manage. 155:11–21, https://doi.org/10.1016/j.agwat.2015.03.007.

Irmak, S., D.Z. Haman, and R. Bastug. 2000. Determination of crop water stress index for irrigation timing and yield estimation of corn. Agron. J. 92(6):1221–1227, https://doi.org/10.2134/agronj2000.9261221x.

Kang, S., B. Gu, T. Du, and J. Zhang. 2003. Crop coefficient and ratio of transpiration to evapotranspiration of winter wheat and maize in a semi-humid region. Agric. Water Manage. 59(3):239–254, https://doi.org/10.1016/S0378-3774(02)00150-6.

Karam, F., J. Breidy, C. Stephan, and J. Rouphael. 2003. Evapotranspiration, yield and water use efficiency of drip irrigated corn in the Bekaa Valley of Lebanon. Agric. Water Manage. 63(2):125–137, https://doi.org/10.1016/S0378-3774(03)00179-3.

Ko, J. and G. Piccinni. 2009. Corn yield responses under crop evapotranspiration-based irrigation management. Agric. Water Manage. 96(5):799–808, https://doi.org/10.1016/j.agwat.2008.10.010.

Kuscu, H., A. Karasu, M. Oz, A.O. Demir, and İ. Turgut. 2013. Effect of irrigation amounts applied with drip irrigation on maize evapotranspiration, yield, water use efficiency, and net return in a sub–humid climate. Turk. J. Field Crops 18:13–19.

Lavoie-Lamoureux, A., D. Sacco, P.A. Risse, and C. Lovisolo. 2017. Factors influencing stomatal conductance in response to water availability in grapevine: A meta-analysis. Physiol. Plant. 159(4): 468–482, https://doi.org/10.1111/ppl.12530.

Moteva, M., N. Gadjalska, V. Kancheva, T. Tashev, V. Georgieva, N. Koleva, I. Mortev, and V. Petrova-Brahicheva. 2016. Irrigation scheduling and the impacts of irrigation on the yield and yield components of sweet corn. Sci. Papers Ser. A Agron. (Univ. Agron. Sci. Vet. Med. Buchar.) 59:332–339.

Oktem, A. 2008. Effect of water shortage on yield, and protein and mineral compositions of drip-irrigated sweet corn in sustainable agricultural systems. Agric. Water Manage. 95(9):1003–1010, https://doi.org/10.1016/j.agwat.2008.03.006.

Panda, R.K., S.K. Behera, and P.S. Kashyap. 2004. Effective management of irrigation water for maize under stressed conditions. Agric. Water Manage. 66(3):181–203, https://doi.org/10.1016/j.agwat.2003.12.001.

Payero, J.O., D.D. Tarkalson, S. Irmak, D. Davison, and J.L. Petersen. 2009. Effect of timing of a deficit-irrigation allocation on corn evapotranspiration, yield, water use efficiency, and dry mass. Agric. Water Manage. 96(9):1387–1397, https://doi.org/10.1016/j.agwat.2009.03.022.

Payero, J.O., D.D. Tarkalson, S. Irmak, D. Davison, and J.L. Petersen. 2008. Effect of irrigation amounts applied with subsurface drip irrigation on corn evapotranspiration, yield, water use efficiency, and dry matter production in a semiarid climate. Agric. Water Manage. 95(8): 895–908, https://doi.org/10.1016/j.agwat.2008.02.015.

Rasool, G., X. Guo, Z. Wang, I. Ullah, and S. Chen. 2020. Effect of two types of irrigation on growth, yield and water productivity of maize under different irrigation treatments in an arid environment. Irrig. Drain. 69(4):732–742, https://doi.org/10.1002/ird.2480.

Ray, J.D. and T.R. Sinclair. 1997. Stomatal closure of maize hybrids in response to drying soil. Crop Sci. 37(3):803–807, https://doi.org/10.2135/cropsci1997.0011183X003700030018x.

Rivera-Hernández, B., E. Carrillo-Ávila, J.J. Obrador-Olán, J.F. Juárez-López, and L.A. Aceves-Navarro. 2010. Morphological quality of sweet corn (*Zea mays* L.) ears as response to soil moisture tension and phosphate fertilization in Campeche, Mexico. Agric. Water Manage. 97(9):1365–1374, https://doi.org/10.1016/j.agwat.2010.04.001.

Sabagh, A.E., C. Barutçular, M.S. Islam. 2017. Relationships between stomatal conductance and yield under deficit irrigation in maize (*Zea mays* L.). J Exp Biol Agric Sci. 5(1):014–021. https://doi.org/10.18006/2017.5(1).014.021.

Shani, U. and L.M. Dudley. 2001. Field studies of crop response to water and salt stress. Soil Sci. Soc. Amer. J. 65(5): 1522–1528, https://doi.org/10.2136/sssaj2001.6551522x.

Sinclair, T., G. Bingham, E. Lemon, and L. Allen. 1975. Water use efficiency of field-grown maize during moisture stress. Plant Physiol. 56(2):245–249, https://doi.org/10.1104/pp.56.2.245.

Singh, A.K., A.K. Roy, and D.P. Kaur. 2007. Effect of irrigation and NPK on nutrient uptake pattern and qualitative parameter in winter maize and potato intercropping system. Int. J. Agric. Sci. 3(1):199–201.

Song, L., J. Jin, and J. He. 2019. Effects of severe water stress on maize growth processes in the field. Sustainability 11(18):5086, https://doi.org/10.3390/su11185086.

Stockle, C.O. and L.G. James. 1989. Analysis of deficit irrigation strategies for corn using crop growth simulation. Irrig. Sci. 10:85–98. http://dx.doi.org/10.1007/BF00265686x.

Stone, P.J., D.R. Wilson, J.B. Reid, and R.N. Gillespie. 2001. Water deficit effects on sweet corn. I. Water use, radiation use efficiency, growth, and yield. Aust. J. Agric. Res. 52(1):103, https://doi.org/10.1071/AR99146.

Stone, P., D. Wilson, J. Reid, and R. Gillespie. 2000. Water deficit effects on sweet corn. I. Water use, radiation use efficiency, growth, and yield. Crop Pasture Sci. 52(1):103–113, https://doi.org/10.1071/AR99146.

Traore, S.B., R.E. Carlson, C.D. Pilcher, and M.E. Rice. 2000. Bt and non-Bt maize growth and development as affected by temperature and drought stress. Agron. J. 92(5):1027–1035, https://doi.org/10.2134/agronj2000.9251027x.

Tuzet, A., A. Perrier, and R. Leuning. 2003. A coupled model of stomatal conductance, photosynthesis and transpiration. Plant Cell Environ. 26(7):1097–1116, https://doi.org/10.1046/j.1365-3040.2003.01035.x.

US Department of Agriculture, National Agricultural Statistics Service. 2021. Florida state agriculture overview. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=FLORIDA [accessed 15 Sep 2022].

Urban, J., M. Ingwers, M.A. McGuire, and R.O. Teskey. 2017. Stomatal conductance increases with rising temperature. Plant Signal. Behav. 12(8):e1356534, https://doi.org/10.1080/15592324.2017.1356534.

van Donk, S.J., J.L. Petersen, and D.R. Davison. 2013. Effect of amount and timing of subsurface drip irrigation on corn yield. Irrig. Sci. 31:599–609, https://doi.org/10.1007/s00271-012-0334-4.

Viswanatha, G.B., B.K. Ramachandrappa, and H.V. Nanjappa. 2002. Soil–plant water status and yield of sweet corn (*Zea mays* L. cv. Saccharata) as influenced by drip irrigation and planting methods. Agric. Water Manage. 55(2):85–91, https://doi.org/10.1016/S0378-3774(01)00189-5.

Williams, M.M. 2008. Sweet corn growth and yield responses to planting dates of the north central United States. HortScience 43(6):1775–1779, https://doi.org/10.21273/HORTSCI.43.6.1775.

Yazar, A., T.A. Howell, D.A. Dusek, and K.S. Copeland. 1999. Evaluation of crop water stress index for LEPA irrigated corn. Irrig. Sci. 18:171–180, https://doi.org/10.1007/s002710050059.

Yazar, A., S.M. Sezen, and B. Gencel. 2002. Drip irrigation of corn in the Southeast Anatolia Project (GAP) area in Turkey. Irrig. Drain. 51(4):293–300, https://doi.org/10.1002/ird.63.

Zhang, M., C. de Leon, and K. Migliaccio. 2018. Evaluation and comparison of interpolated gauge rainfall data and gridded rainfall data in Florida, USA. Hydrol. Sci. J. 63(4):561–582, https://doi.org/10.1080/02626667.2018.1444767.