High-density grapefruit production in open hydroponics system

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Abstract

Precise irrigation and fertigation management provide a less-limiting environment to roots while minimizing over irrigation and leaching of nutrients. This concept can improve tree growth in the presence of HLB and help optimize water and nutrient use. Higher tree density can increase fruit yield per area under high HLB pressure. This study evaluated the efficiency of open hydroponics on 'Ray Ruby' grapefruit production under different irrigation systems and tree density. We tested a combination of rootstocks (Sour orange and US897), tree spacing [standard and high density staggered (HDS)], fertilization (dry granular and fertigation), and irrigation systems (drip and microjet), arranged on five treatments: RR/SO_STD_dry_MS) SO + standard spacing + dry granular fertilizer + micro jet, RR/SO_HDS_fert_DD) SO + HDS + fertigation + drip, RR/897_HDS_fert_MS) US897 + HDS + fertigation + microjet, RR/897_HDS_fert_DD) 'US897' + HDS + fertigation + drip, and RR/SO_HDS_fert_MS) SO + HDS + fertigation + microjet. Foliar nutrient, insecticide and fungicide were sprayed using standard practices. We scouted for psyllids, leaf minors and other citrus pests monthly. HLB incidence reached 100% after five years of planting. Trunk diameter and canopy volume increased over time, and were higher on RR/SO_STD_dry_MS compared to other treatments. Total number of fruit and fruit yield were 226% and 183% higher in 2016 compared to 2015. RR/SO_STD_dry_MS yielded 7,309 kg/ha in 2017 compared to an average of 22,153 kg/ha for other treatments. Soluble solid contents, acidity, and ratio were not significant (p>0.05). Total solids per hectare was always low in RR/SO_STD_dry_MS. High density staggered (HDS) planting resulted in higher fruit yield, irrespective of rootstock and irrigation system, representing an important advance to the grapefruit production system. However, labor cost and effect on plant growth over time still need to be determined for commercial recommendation.

Keywords

High density, plant performance, fruit yield, fruit quality.

Introduction

Citrus (*Citrus* spp.) is Florida's most important agricultural commodity. The state produces citrus for different markets: round oranges (*C. sinensis*) for juice; navels, mandarins (*C. reticulata*), grapefruit (*C. paradisi*) and lemons (*C. limon*) for the fresh fruit industry; and lemons for extracting peel oil for processing. However, citrus production in Florida has declined drastically since 2005 due to citrus greening or Huanglongbing (HLB), caused by *Candidatus* Liberibacter asiaticus (*C*Las), in addition to canker (*Xanthomonas axonopodis*), urban development, and recent hurricanes (Morgan et al., 2009; Kadyampakeni et al., 2016).

The decline in citrus productivity has resulted in an aggregate loss of $ 3 billion in citrus growers' revenue from 2006 through 2014 (Hodges et al., 2014). The Indian River Citrus District maintains approximately 13.5% of Florida's total citrus acreage inventory since 2000/01 (excluding the crop years 2004/05 due to hurricane damage) with drastic reduction in recent years. The number of grapefruit trees planted has increased since 2000/01; conversely, total bearing acreage and total bearing trees in the state have both declined by 38% in the last decade (USDA, 2017). The total number of boxes of grapefruit produced in Florida has decreased from 40.9 million in 2003/04 to 10.8 million in 2015/16 (USDA, 2017). Excluding season 2004/05, Florida's average grapefruit yield is quickly decreasing over time – from 497 boxes/acre in 2000/01 to only 288 boxes/acre in 2016/17 (USDA, 2017).

Once citrus is affected by HLB, it becomes gradually less productive. HLB alters the plants' physiology (reducing photosynthesis and xylem flux) and morphology (e.g. phloem translocation, bloated and corky veins, root length and density) affecting nutrient uptake, translocation, and utilization (Kadyampakeni et al., 2014).

Nutrients are vital in disease control as nutrients influence plant resistance and pathogen growth (Handique et al., 2012). Huanglongbing inhibits root growth, reduces nutrient uptake, promotes leaf and fruit drop, results in deformed fruit with unpleasant flavor, and results in whole tree decline that is often lethal (Handique et al., 2012). Fibrous root length and density are not consistent in HLB-affected trees and are affected by distance from the tree trunk (lateral and vertical), type of rootstock, and age of the tree (Kadyampakeni et al., 2014). Moreover, HLB induced reduction in root density reduces water and nutrient uptake (Graham et al., 2013). The decline in fibrous density is manifested as weak canopy volume, poor fruit quality, and yield losses.

Precise irrigation and fertigation management provide a non-limiting environment to roots while minimizing over irrigation and leaching of nutrients. This concept can improve tree growth in the presence of HLB and help optimize water and nutrient use. Higher tree density can increase fruit yield per area under high HLB pressure.

This study evaluated the efficiency of open hydroponics on grapefruit cultivated under different tree spacing (standard and high-density), fertilizer sources (dry granular and water-soluble fertilizer) and irrigation methods (drip and micro jet).

Material and Methods

The study was conducted at the UF/IFAS Indian River Research and Education Center in Fort Pierce, FL (lat. 27º26'01.8" N, long. 80º26'49.80" W and elevation 10 m). 'Ray Ruby' grapefruit trees were planted in Sept/2013 (total of 2,769 trees in 3.23 hectares).

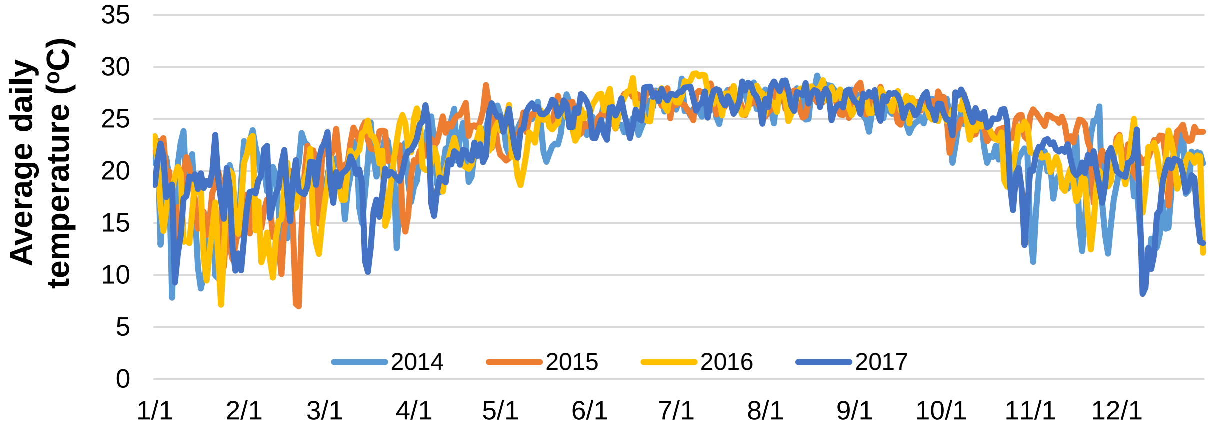

Fig. 2. Average daily temperature during the 2014-2017 experiment. Fort Pierce, FL.

We tested a combination of rootstocks {'Sour orange' [*C. aurantium*] and 'US897' [Cleopatra (*C. reticulata*) × Flying Dragon (*Poncirus trifoliata*)]}, tree spacing [standard and high-density staggered planting (HDS)], fertilization (dry granular and water-soluble fertilizer), and irrigation systems (drip and micro jet), arranged on five treatments:

- RR/SO_STD_dry_MS) 'Ray Ruby' on Sour Orange + standard spacing (3.8 × 7 m, 358 trees/ha) + 16N-2.2P-8.3K dry granular fertilizer applied in-ground + micro jet (one emitter per tree; blue microsprinklers - 40.5 LPH @ 20 psi)
- RR/SO_HDS_fert_DD) 'Ray Ruby' on Sour Orange + HDS [(2.74 × 1.5 × 0.9 m) × 6.1 m, 953 trees/ha)] + 15N-2.6P-22.4K applied by fertigation + drip irrigation (four emitters per tree, installed on double rows; blue dripper - 3.8 LPH)
- RR/897_HDS_fert_MS) 'Ray Ruby' on US-897 + HDS + 15N-2.6P-22.4K applied by fertigation + micro jet (same as above)
- RR/897_HDS_fert_DD) 'Ray Ruby' on US-897 + HDS + 15N-2.6P-22.4K applied by fertigation + drip (same as above)
- RR/SO_HDS_fert_MS) 'Ray Ruby' on Sour Orange + HDS + 15N-2.6P-22.4K applied by fertigation + micro jet (same as above)

The experimental design was a completely randomized with five replications.

We measured HLB incidence, tree size, leaf macro and micronutrient concentrations, total number of fruit and fruit yield, fruit quality parameters (soluble solid contents, acidity, and ratio) and calculated total solids per hectare. Huanglongbing diagnosis of mature leaves for *C*Las titer and activity was measured annually by using the quantitative polymerase chain reaction (q-PCR) (Li et al. 2006). A total of 4-6 mature leaves was collected from summer flush in each of all four cardinal sections per tree, from which the petiole/midribs was used for *C*Las detection.

Tree size was assessed every year by measuring trunk diameter (~8 cm above the bud union), tree height to top of canopy (not including height of vigorous shoots that extend significantly past the top of the canopy), and canopy diameter (in parallel and perpendicular to the tree row). Canopy volume was calculated using the formula: [(diameter parallel to row × diameter perpendicular to row) × height] ÷ 4.

Leaf and soil nutrient concentrations was determined annually in August (on spring flush). Approximately 20-30 mature leaves were collected in different parts of the tree. Leaf tissue samples were dried for 72 h at 65 ^{o}C and analyzed by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) (Obreza and Morgan, 2008).

Total number of fruit and fruit diameter were determined by harvesting all tree fruit and passing them through an optical sorter (Autoline, Reedley, CA) mounted on a trailer. Measurements were converted into number of fruit per carton within a commercial category. Total fruit yield was determined by direct weighing all the fruit per tree.

Random samples of 20 fruit from each experimental unit were collected for fruit quality analysis on each year. The fruit samples were weighed, and fruit diameter at the equator was measured with a digital caliper. The fruit were weighed and juiced using a press juicer; then, juice was weighed, and expressed as a percentage of the total fruit weight. Total soluble solids content was determined with a digital refractometer (HI96801; Hanna Instruments, Woonsocket, RI) using a few drops of juice. The total acidity was determined by titration of 5 ml of fruit juice with 0.1 N sodium hydroxide (NaOH) to pH 8.1. Total solids per hectare was calculated as: (% juice in fruit ÷ 100) × (soluble solids content ÷ 100) × Yield (kg/ha).

Foliar nutrient, insecticide and fungicide were sprayed using standard practices. We scouted for psyllids, leaf minors and other citrus pests monthly.

Data were analyzed by normality (Proc univariate), analysis of variance (ANOVA) (Proc GLM), and Tukey's multiple comparisons test (Proc lsmeans) using SAS (v. 9.4; SAS Institute, Cary, NC). Probability values ≤ 0.05 were considered statistically significant.

Results and Discussion

HLB incidence increased over time, reaching 100% after 5 years of planting (Fig. 2). The disease progression warrants the rapid HLB spreading in the state of Florida.

Trunk diameter and canopy volume increased over time, and were higher on RR/SO_STD_dry_MS compared to other treatments ($p<0.001$, Fig. 3). Such response was expected, since trees planted on lower densities receive more solar radiation, water and nutrients, not competing with surrounding trees as the high density plantings.

Leaf macro and micronutrient concentrations were influenced by treatment and sampling date (data not shown).

Total number of fruit and fruit yield were 226% and 183% higher in 2016 compared to 2015. RR/SO_STD_dry_MS yielded 7,309 kg/ha in 2017 compared to an average of 22,153 kg/ha for other treatments. In 2017, data was compromised by Hurricane Irma, which caused 50%-70% fruit drop (visual observation) (Fig. 4).

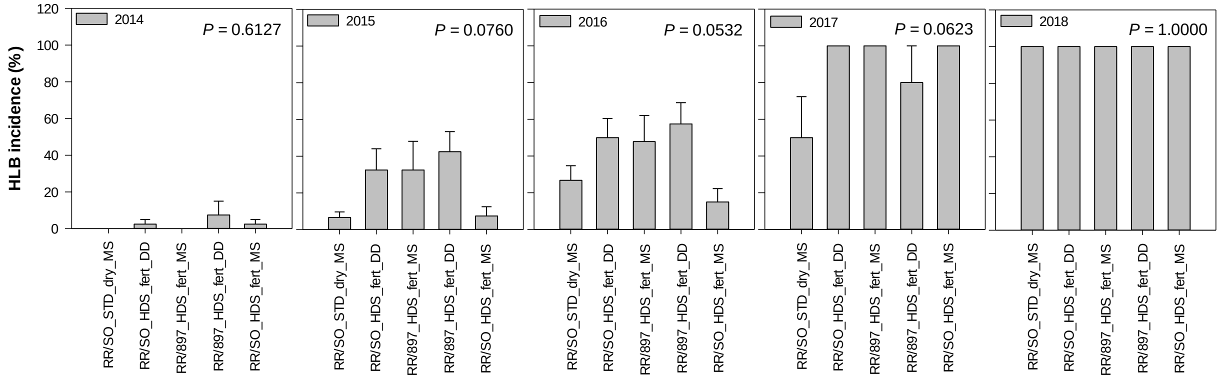

Fig. 2. Huanglongbing (HLB) incidence of 'Ray Ruby' grapefruit trees. Treatments: RR/SO_STD_dry_MS) Sour Orange (SO) + standard spacing [358 trees/ha] + dry granular fertilizer + micro jet, RR/SO_HDS_fert_DD) SO + high density staggered (HDS) [(953 trees/ha)] + fertigation + drip, RR/897_HDS_fert_MS) US-897 + HDS + fertigation + micro jet, RR/897_HDS_fert_DD) US-897 + HDS + fertigation + drip, and RR/SO_HDS_fert_MS) SO + HDS + fertigation + micro jet.

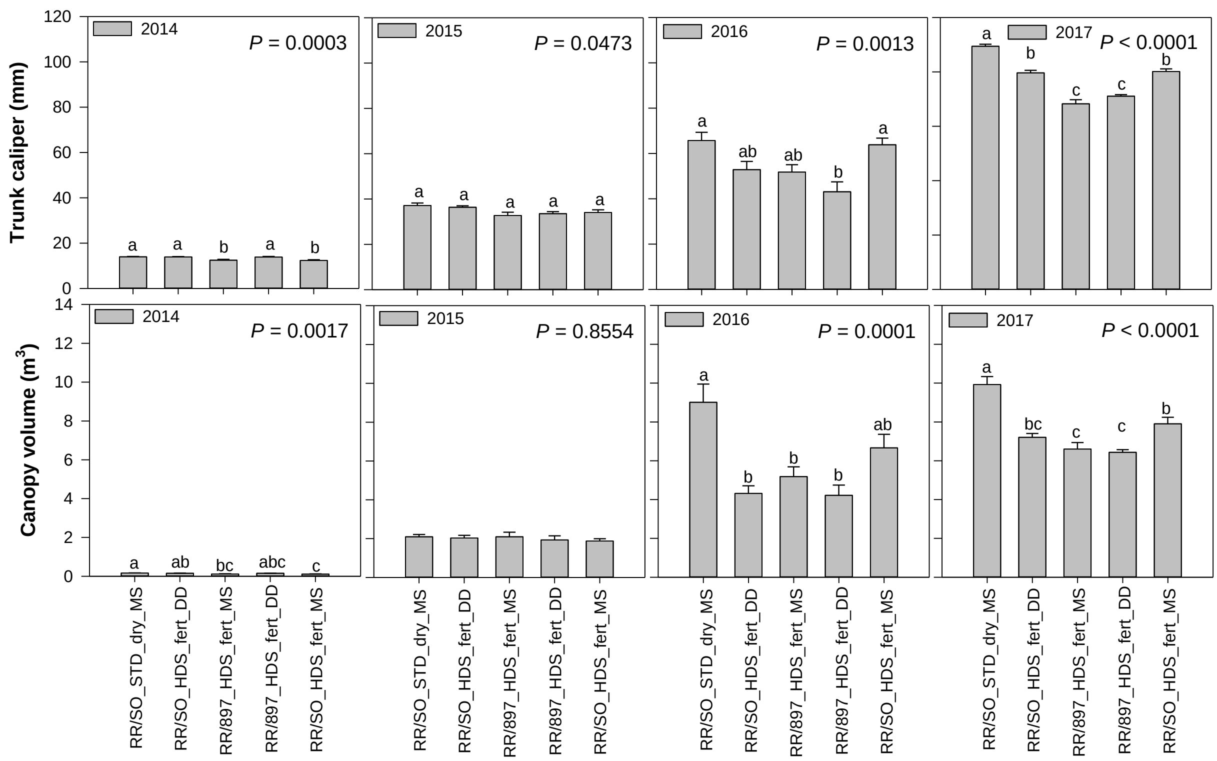

Fig. 3. Trunk caliper and canopy volume of 'Ray Ruby' grapefruit trees. Treatments: RR/SO_STD_dry_MS) Sour Orange (SO) + standard spacing [358 trees/ha] + dry granular fertilizer + micro jet, RR/SO_HDS_fert_DD) SO + high density staggered (HDS) [(953 trees/ha)] + fertigation + drip, RR/897_HDS_fert_MS) US-897 + HDS + fertigation + micro jet, RR/897_HDS_fert_DD) US-897 + HDS + fertigation + drip, and RR/SO_HDS_fert_MS) SO + HDS + fertigation + micro jet.

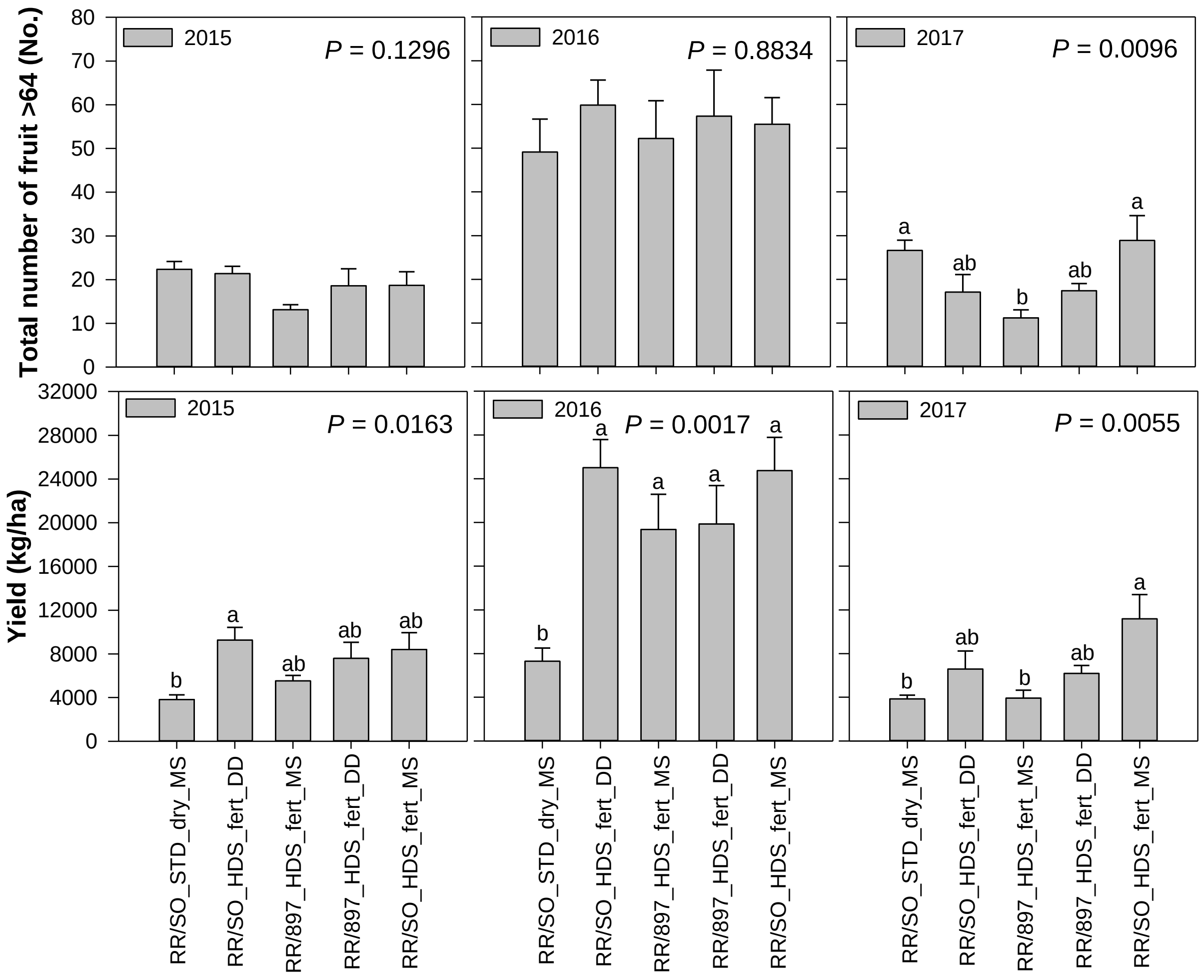

Fig. 4. Total number of fruit and fruit yield of ‘Ray Ruby’ grapefruit trees. Treatments: RR/SO_STD_dry_MS) Sour Orange (SO) + standard spacing [358 trees/ha] + dry granular fertilizer + micro jet, RR/SO_HDS_fert_DD) SO + high density staggered (HDS) [(953 trees/ha)] + fertigation + drip, RR/897_HDS_fert_MS) US-897 + HDS + fertigation + micro jet, RR/897_HDS_fert_DD) US-897 + HDS + fertigation + drip, and RR/SO_HDS_fert_MS) SO + HDS + fertigation + micro jet.

Fruit quality parameters were measured in 2016 and 2017 only. Soluble solid contents, acidity, and ratio were not significant (p>0.05). Total solids per hectare was constantly low in RR/SO_STD_dry_MS (Fig. 5). In 2017, all parameters were considerably lower than 2016 due to the negative effects of Hurricane Irma on fruit quality.

Conclusions

High density staggered (HDS) planting resulted in higher fruit yield, irrespective of rootstock and irrigation system, representing an important advance to the grapefruit production system. However, labor cost and effect on plant growth over time still need to be determined for commercial recommendation.

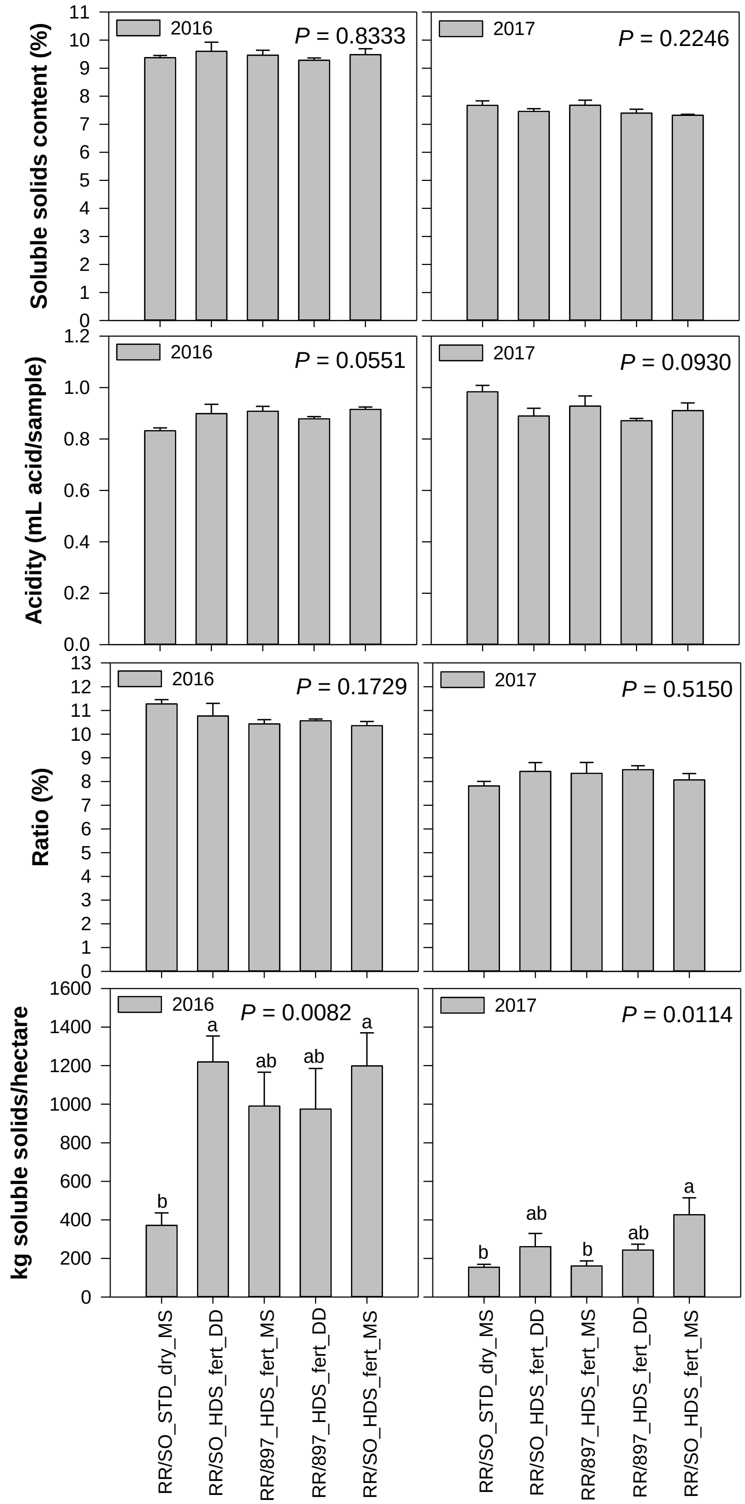

Fig. 5. Soluble solids content, acidity, ratio and soluble solids per hectare of ‘Ray Ruby’ grapefruit trees. Treatments: RR/SO_STD_dry_MS) Sour Orange (SO) + standard spacing [358 trees/ha] + dry granular fertilizer + micro jet, RR/SO_HDS_fert_DD) SO + high density staggered (HDS) [(953 trees/ha)] + fertigation + drip, RR/897_HDS_fert_MS) US-897 + HDS + fertigation + micro jet, RR/897_HDS_fert_DD) US-897 + HDS + fertigation + drip, and RR/SO_HDS_fert_MS) SO + HDS + fertigation + micro jet.

Acknowledgements

We thank R. Cave, R. Burton, C. King, R. Lesmes, D. Phuyal, H. Tom James, T. Meadows, J. Stephens and D. Davis for technical assistance; and KeyPlex micronutrients, Valent, Tessenderlo Group, UPI, Bayer, Hunter, FMC. Harrell's, ICL Specialty Fertilizers, Plant Food Systems and Arysta LifeScience for product donation toFerrarezi's Citrus Horticulture Lab. Funding for this research was provided by UF/IFAS, UF/IFAS Citrus Initiative, USDA-FDACS-SCBG (award #00092195).

References

Graham, J.H., E.G. Johnson, T.R. Gottwald, and M.S. Irey. 2013. Presymptomatic fibrous root decline in citrus trees caused by huanglongbing and potential interaction with *Phytophthora* spp. *Journal of Plant Disease* 97:1195–1199.

Handique, U., R. Ebel, and K.T. Morgan. 2012. Influence of soil-applied fertilizer on greening development in new growth flushes of sweet orange. *Proc. Fla. State. Hort. Soc.* 125:112:9–14.

Hodges, A.W., M. Rahmani, T.J. Stevens, and T.H. Spreen. 2014. Economic impacts of the Florida citrus industry in 2012-13. Gainesville, Florida.

Kadyampakeni, D.M., K.T. Morgan, A.W. Schumann, and P. Nkedi-Kizza. 2014. Effect of irrigation pattern and timing on root density of young citrus trees infected with huanglongbing disease. *HortTechnology* 24:209–221.

Kadyampakeni, D.M., K.T. Morgan, and A.W. Schumann. 2016. Biomass, nutrient accumulation and tree size relationships for drip- and microsprinkler-irrigated orange trees. *Journal of Plant Nutrition* 39:5, 589–599.

Li, W., J.S. Hartung, and L. Levy. 2006. Quantitative real-time PCR for detection and identification of Candidatus *Liberibacter* species associated with citrus huanglongbing. *Journal of Microbiological Methods* 66(1) 104-115.

Morgan, K.T., T.A. Wheaton, S.C. William, and L.R. Parsons. 2009. Response of young and maturing citrus trees grown on a sandy soil to irrigation scheduling, nitrogen fertilizer rate, and nitrogen application method. *HortScience* 44:145–150.

Obreza, T.A. and K.T. Morgan. (eds.) 2008. Nutrition of Florida Citrus Trees. Univ. Florida, Inst. Food Agr. Sci., Electronic Data Info. Source, SL 253.

U.S. Department of Agriculture. 2017. Florida Citrus Statistics 2015-2016. 31 May 2017. Available at https://www.nass.usda.gov/Statistics_by_State/Florida/Publications/Citrus/Citrus_Statistics/2015-16/fcs1516.pdf