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Impact of Irrigation Method on Water Savings and 'Rio Red' Grapefruit Pack-Out in South Texas

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ABSTRACT

Citrus production in the Lower Rio Grande Valley (LRGV) of South Texas is primarily known for its red grapefruit varieties. Citrus production in this region requires supplemental irrigation as annual rainfall distribution is generally insufficient to supply the water requirements for this perennial crop. The majority of growers utilize large pan flood (FLD) irrigation methods to irrigate citrus. Other irrigation practices used in the LRGV are narrow border flood (NBF), drip (DRP) and micro-jet spray (MJS) sprinkler irrigation. The objective of this project was to evaluate the impact of these different irrigation practices on irrigation quantity, grapefruit yield, production pack-out, and overall profitability. These objectives were assessed at the on-farm level from various citrus producers in the LRGV over five (2005-2009) growing seasons. Average irrigation results over this period showed that total irrigation water followed FLD>NBF>DRP>MJS, whereas average grapefruit yields followed FLD<NBF=DRP<MJS for 38.6<47.3=47.3<50.4 Mg ha^{-1}, respectively. A larger fraction of grapefruit was categorized in the 'fancy' class for NBF irrigation compared to the other irrigation methods, and for this reason NBF was found to be the most economically productive irrigation method in regards to pack-out and economic gain. Thus, NBF is recommended for LRGV citrus growers as both a water conserving and increased revenue generating practice.

Additional Index Words: profitability, fruit quality, citrus, irrigation use efficiency.

INTRODUCTION

One of the major high value horticultural crops for which the Lower Rio Grande Valley of Texas (LRGV) is known is the red fleshed 'Rio Red' grapefruit (*Citrus paradisi* Macfad. var. 'Rio Red') that produces a deep red color and sweet, low acid fruit. The desired variety scion is typically grown on sour orange (*Citrus aurantium* L.) rootstock for the large majority of citrus trees planted in the LRGV. This is in large part due to improved scion vigor on sour orange that provide trees with moderate drought tolerance, and which thrive well on fertile (Davies and Albrigo, 1994), heavier-textured (Rice et al., 1986), high pH (Wutscher, 1979), calcareous soils that are predominant throughout the LRGV of South Texas. Furthermore, sour orange is an excellent rootstock for fresh marketable citrus fruit production in areas free of citrus tristesa virus (Castle, 1987).

Total citrus production in the LRGV is approximately 11,260 ha [27,825 acres] (Rosson et al., 2007), with grapefruit production accounting for 70% of the total citrus acreage in the region. Fresh and processed juice grapefruit sales contribute significantly to the overall economy of the region and agriculture industry of the state. Since 2005, grapefruit sales have contributed to 80.0 % of all citrus sales in the state of Texas with average annual revenue exceeding $50 million dollars U.S. (Sauls, 2008a). The LRGV citrus growers' main source of profit and revenue come from fresh market sales, with approximately 91% of gross revenue arising from fresh market grapefruit sales. Grapefruit that is sorted for the 'juice' market may provide some revenue for the grower to cover part of his input costs to grow the fruit, but is commonly not a significant source of income for the grower. This stresses the importance for the South Texas citrus grower to grow fruit of high quality that it will be marked for sale in the fresh market.

Thus, the grower's overall profitability for the citrus crop is directly linked to the 'pack-out' or a combination of quantity and quality of the fruit produced and sold each year to the fresh market. The preferred pack-out grade is categorized as 'Fancy,' followed by 'Choice', which are essentially determined by the level of blemish on the fruit with none to minimal corresponding to 'Fancy' and 'Choice', respectively (Taylor et al., 2008). The remaining fruit is largely processed for juice. Within the fancy and choice grades, fruit is separated into different size classes with the largest, highest quality fruit receiving the higher prices for sale to the fresh market.

Several factors can influence the size, shape, look and quality of grapefruit that result in down-grading of the fruit from the fresh to the processed juice market. Abiotic, environmental factors such as periodic freezes and extended drought can suppress bloom and fruit development (Sauls, 2008a), while high winds cause scratching and scarring of the outer rind of the fruit (Rice et al., 1986). Biotic factors common to the subtropical warm climate of the LRGV are consistent pressure from mites, insects and fungal diseases that cause fruit down grading. Fertilization source and amount can also impact grapefruit production and shape, with timing and the amount of nitrogen fertilization potentially impacting the amount of misshapen fruit, 'sheep nosing', where the shape of the grapefruit is more oval than round and limits its packing into fruit boxes. Wiedenfeld et al. (2009) found that split applications of high levels of N from ammonium sulfate fertilized to citrus trees resulted in increased oblong, sheepnose shaped grapefruit. Irrigation quantity and timing are also considered important variables that influence citrus crop production and fruit quality (Enciso et al., 2005).

The majority of citrus in the LRGV is irrigated using traditional large-pan flood irrigation (Swietlik, 1992), where several rows of trees (3 to 5 tree rows) are irrigated all at once within a block surrounded by raised berms to prevent water movement outside of the berms. Traditional flood (FLD) irrigation is thought to not be a very water conserving practice, when compared to alternative irrigation practices (Figure 1 a -d) such as narrow border flood (NBF), microjet sprinkler spray (MJS), or drip (DRP) irrigation (Uckoo et al., 2005). NBF irrigation is thought to be a more water conserving practice than FLD irrigation in that berms are raised between the center of every tree row creating a means to apply water underneath the tree canopy in a shorter period of time. Conventional FLD irrigation practices make up approximately 85% of all irrigated citrus practices in the LRGV, mainly due to the manner in which irrigation delivery systems in this region were established with canals for large water volume application to irrigate agricultural crops.

Since citrus is a perennial crop, irrigation is required year-round in the LRGV. It is one of the most water demanding crops grown in this region, second only to sugarcane. Although this area receives 60 cm annual average precipitation, it is not uncommon for citrus producers to apply an additional 60 cm of irrigation water annually to meet crop ET demands (Sauls, 2008b). Although total rainfall in this region of the U.S. may seem high, rainfall patterns are often irregularly distributed across Hidalgo and Cameron counties (Sauls, 2008b). Thus, this region is considered to be a semiarid climate due to its high evapotranspiration demand throughout nine months of the year and high value horticulture crop production requires supplemental irrigation for good crop yields and quality (Enciso et al., 2005).

A major challenge facing producers in the LRGV is the threat of limited irrigation supplies due to drought. Irrigation waters in this region stem solely from the Rio Grande River as water is allocated by irrigation districts that order water held back from one of two reservoirs, Falcon and Amistad. The close proximity to the Gulf of Mexico prevents the use of groundwater supplies, as water is typically of poorer quality below ground compared to rain fed surface waters held back in these two reservoirs. Surface water supplies are used by not only growers, but homeowners and industry throughout the LRGV. The LRGV region has one of the fastest growing population centers in the U.S., placing added emphasis of water allocations to supply the need of individuals as a result of this rapid and constant urban growth. For this reason, there is an increasing need to evaluate water conservation practices in the LRGV to anticipate alternative irrigation practices other the conventional flood irrigation to maintain high value citrus production in South Texas for future generations.

In anticipation for lower water allocation for agriculture producers in the future, the Texas Water Development Board (TWDB) in 2004 funded a 10-year on-farm demonstration project aimed at determining current irrigation consumption by citrus producers, and investigating possible alternative irrigation practices that might conserve water while still producing high quality citrus yields. The TWDB contracted with the Harlingen Irrigation District to initiate the Agricultural Water Conservation

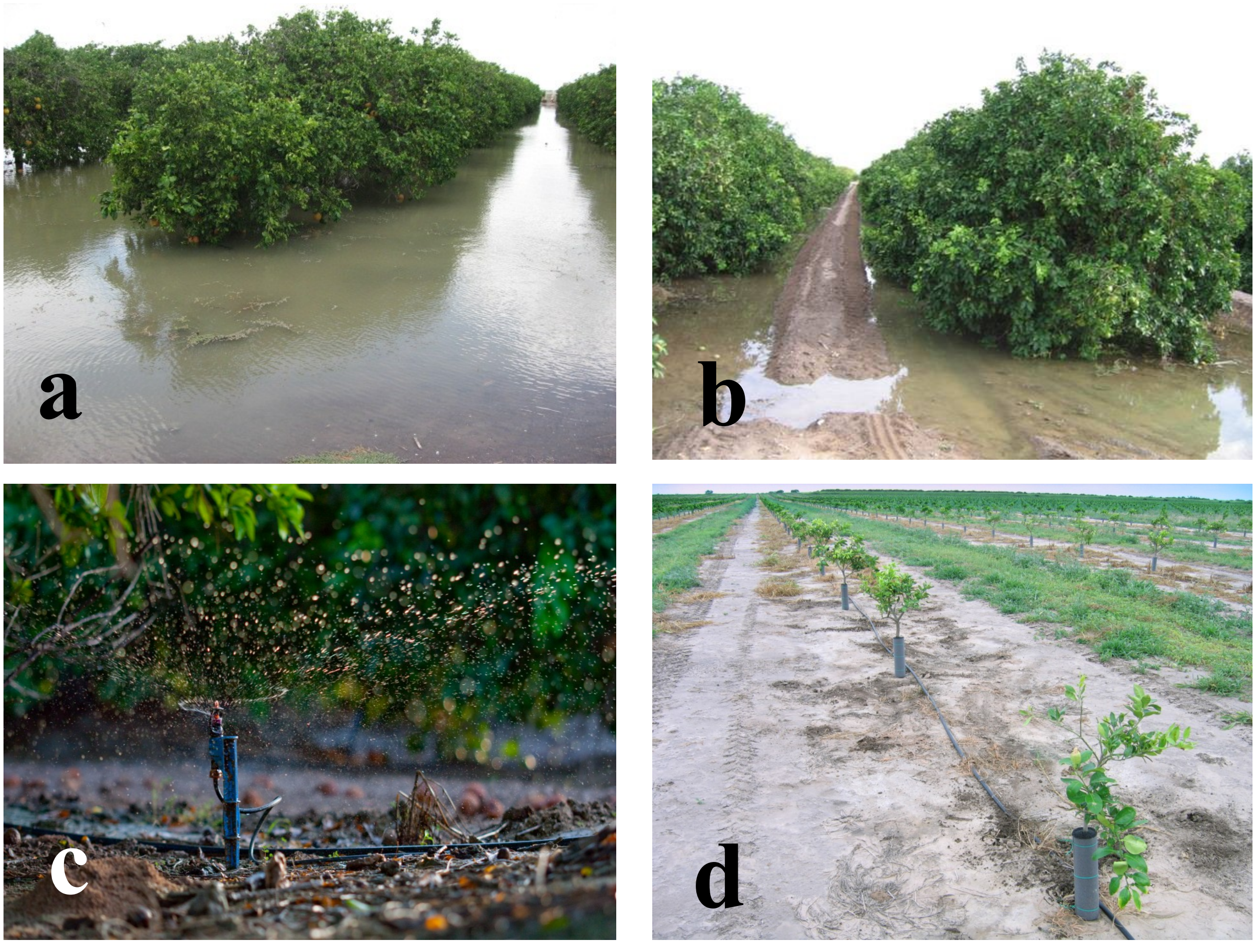

Fig. 1. Examples of four different irrigation systems: conventional large-pan flood (a), narrow border flood (b), close up of microjet spray sprinkler (c), and example of single-line drip on newly planted citrus (d) irrigation under new citrus planting. All data used in this study from mature trees (≥8 years old) only.

Demonstration Initiative (ADI) project in collaboration with scientists from Texas A&M University-Kingsville and Texas AgriLife Extension Service. The aim of the ADI project is to demonstrate state-of-the-art water distribution management and on-farm, cost-effective irrigation technologies to maximize surface water use efficiency. The project includes maximizing the efficiency of irrigation water diverted from the Rio Grande River for water consumption by various field, vegetable and citrus crops.

Texas A&M System research and extension scientists work with citrus growers to gather data on water use, yield production and irrigation use efficiency. Analyzing grapefruit fresh pack-out vs. juice production is one way in which researchers measure the cost-effectiveness of alternative irrigation methods as efficient water delivery systems in citrus production. Whereas, extension economists conduct the economic analyses of ADI demonstration results, evaluating the potential impact of adopting alternative water conserving technologies. Extension economists work individually with agricultural producers using the Financial And Risk Management (FARM) Assistance financial planning model to analyze the impact and cost-effectiveness of the alternative irrigation technologies.

The purpose of this 5-year study (harvest years 2005-2009) was to evaluate four typical irrigation technologies (FLD, NBF, MJS, DRP) used in producing Rio Red grapefruit and to compare their impact on fresh pack-out and the potential profitability of using alternative irrigation methods other than FLD (Table 1).

MATERIALS AND METHODS

Table 1. Average 2005-2009 'Rio Red' grapefruit pack-out yield percentages separated according to fruit class and irrigation type used.

Irrigation Type	Fruit Class	Low	Grapefruit Pack-Out High	Percent 'Rio Red' Average
Traditional Flood	Fancy	37.3	53.1	43.6
	Choice	23.6	19.3	21.0
	Juice	39.1	27.6	35.4
Narrow Border Flood	Fancy	41.3	56.7	47.3
	Choice	22.7	21.2	23.0
	Juice	36.0	22.1	29.7
Microjet Spray	Fancy	39.3	48.1	46.8
	Choice	19.4	13.8	17.3
	Juice	41.3	38.1	35.9
Drip	Fancy	42.2	51.9	45.4
	Choice	22.6	11.7	16.7
	Juice	35.2	36.4	37.9

Total annual irrigation consumption and citrus yields were collected from various 'Rio Red' grapefruit citrus producers throughout two South Texas counties, Hidalgo and Cameron. Data from packing shed 'pack out' from each grower was taken and used for economic assessment on fruit quantity, size class, and price return to the grower. Data was collected in 2005-2009 from six growers evaluating citrus production under four irrigation types (FLD, NBF, MJS, DRP) with two to three different field sites represented for each of the four irrigation types. On-farm field sites ranged in size from 1.5 to 15 hectares and data was calculated on a per hectare basis. At each grower site, the same variety and similar grove care practices were used with the exception of type of irrigation. The following analysis evaluates the potential financial incentives for using the various irrigation systems. The investment costs of micro-jet spray and drip systems were also included.

Economic Model Assumptions. The Financial And Risk Management (FARM) Assistance financial planning model was used to evaluate and illustrate the individual financial impacts of varying irrigation management strategies on a representative citrus farm in South Texas. FARM Assistance is a farm-level stochastic simulation model and is the basis of an outreach program by Texas AgriLife Extension. It is a decision support system (DSS) available to any Texas producer which addresses the decision steps of formulating strategic business alternatives and evaluating their likely financial impact. The technical simulation methodology and the philosophy of the FARM Assistance model is described in Klose and Outlaw (2005). As a DSS, the FARM Assistance model simplifies the evaluation process for growers to more accurately evaluate whether or not changes in management strategies at the farm level are economically feasible to implement (Klose and Outlaw, 2005). For growers involved in the ADI project, the FARM Assistance process provides a unique combination of a state-of-the-art decision-support tool in tandem with an experienced extension risk management specialist that works one-on-one with the producer to provide an individualized economic and risk assessment evaluation that is specific to that grower's farm (Kasse et al., 2003). In order to meet this objective, a baseline is created that serves as a benchmark to evaluate the long-term financial implications of alternative management plans over a 10-year future outlook (Kasse et al., 2007). In this study, the FARM Assistance model was used to develop financial projections for a citrus producer considering one of four distinct irrigation management scenarios, based on actual yields, pack-out and total water applied by ADI grower participants from 2005-2009. The analysis output can provide a grower with insight into the risk and return expectations anticipated by using the various on-farm management strategies.

Table 1 provides average pack-out percentages over five consecutive growing seasons (2005-2009) for Rio Red grapefruit by irrigation method. Pack-out percentage data for each growing season represents the average pack-out across multiple ADI participants (two growers per irrigation method). Annual pack-out percentages were categorized (low, average or high) by the amount or quantity of fancy fruit produced. Estimated 2010 production, irrigation and systems costs were based on information provided by collaborators involved in the ADI project and was assumed to be typical for the purpose of this case analysis. Actual yields were adjusted for 'shrink' or the loss of product weight due to dust, twigs, debris, and loss of moisture. Yields were held constant and based on pack-out averages obtained from citrus growers during 2005-2009.

The cost, yield and price data utilized in the economic analysis included information from two or more ADI producers for each irrigation method. Soil types, rainfall and management practices were assumed identical, and except for irrigation costs, all input costs and management practices were assumed to be the same across irrigation scenarios. Actual annual irrigation amount applied by the citrus growers in the ADI project from 2005-2009 (Table 2) was used for assessing the impact of irrigation type on fruit yield and pack-out. For each 10-year outlook projection, input prices and overhead cost trends follow projections provided by the Food and Agricultural Policy Research Institute (FAPRI), at the University of Missouri.

Average U.S. grapefruit crop prices were calculated from actual 2005-09 prices received by producers in the ADI program, with fruit classified as 'Fancy' receiving $308.96/ton, 'Choice' $103.22/ton, and 'Juice' $11.99/ton. These were the net prices received by the ADI collaborators, after prices were adjusted for harvest, packing, and commission charges. In this economic assessment, average prices for all collaborators were used to minimize price differences due to differences among packing shed rates, tree age, harvest timing and management. Projected 2010-2019 prices were held constant at expected levels. These assumptions are intended to make the analysis relevant to typical grapefruit and citrus producers throughout the LRGV region.

RESULTS AND DISCUSSION

Average 'Rio Red' grapefruit yield from growers between 2005 to 2009 growing seasons was 38.6, 47.3, 50.4, and 47.3 Mg ha^{-1} (or 42.5, 52.1, 55.6, and 52.1 tons ha^{-1}), for FLD, NBF, MJS, and DRP growers, respectively. Statistical analyses showed that grapefruit yields when comparing the type of irrigation were not significantly different at the 95% confidence level, therefore, only average yields are discussed here as it is important to observe that lowest yields were obtained consistently under conventional FLD irrigation practices. Some possible reasons why higher yields were obtained with NBF, MJS and DRP over conventional FLD can be in part due to better fertilizer efficiency, soil aeration, and lower nutrient loss due to decreased weed growth under these different irrigation systems. For example, soils can generally only hold 5-7 cm total water within a 30 cm soil depth, thus a single 15-cm FLD irrigation event will leach nitrate fertilizers well beyond the upper rooting depth where the majority of feeder roots are located. Therefore, NBF, MJS and DRP may increase the fertilizer efficiency as it more adequately distributes nutrients within the upper root zone of citrus trees as most of

Table 2. Average annual irrigation applied from citrus growers over 5 years (2005-2009) using four different irrigation methods.

Irrigation Type	Irrigation Applied [±1 stdev] (cm y^{-1})	Water Saved† (cm y^{-1})	Water Savings (%)	Total Water Savings (m^3 ha^{-1} y^{-1})
Traditional Flood	86.9 [19.6]	0	0	0
Narrow Border Flood	67.0 [13.5]	19.9	22.9	1,987
Microjet Spray	63.6 [18.4]	23.2	26.8	2,325
Drip Irrigation	64.2 [29.0]	22.6	26.1	2,264

†Calculations compared to average irrigation applied under traditional flooding.

the nutrients are taken up within the upper 40 cm soil depth, thus resulting in the higher observed yields. Another possible reason for the higher yields may be that DRP, MJS and NBF serve to partially wet the soil better than FLD practices causing better aeration of the soil and a less stressful environment for root growth.

The average amount of grapefruit classified in the highest paying pack-out category (Fancy) was greater for NBF than FLD, MJS, and DRP citrus producers in this five year study. NBF irrigators had 47.3% of fruit going to Fancy, compared to 46.8% MJS, 45.4% DRP, and 43.6% FLD (Table 1). Although these differences were not significantly different due to year to year variability, the real difference comes to play when you consider the amount of fruit sent to the 'juice' market. Growers using NBF irrigation lost only 29.7% of their fruit to the juice market as compared to 35.4, 35.9, and 37.9% for FLD, MJS, and DRP irrigators, respectively. Thus, a larger fraction of fruit is classified for the fresh market in both the 'Fancy' and 'Choice' categories for growers using NBF irrigation over other irrigation practices.

It was shown that for every year assessed, all growers using an alternative irrigation practice to conventional FLD saved water, with an average water savings of 22.9, 26.8, and 26.1% for NBF, MJS, and DRP irrigation, respectively (Table 2). The higher water use by FLD irrigators is a combination of having to apply water over a larger land area, with an estimated 15-cm average water application depth for each irrigation event. Whereas, NBF growers not only apply water more directly to the tree canopy area, but at a faster rate that approximately only 10-cm water depth is applied during each application event. Table 2 further demonstrates the variability among total irrigation water applied year-to-year by citrus producers (as demonstrated by the standard deviation (±1 stdev) about the mean) for each irrigation system. During this 5 year span 2005-2009 the LRGV experienced a year with significantly higher than normal rainfall and a year of extended drought for 13 months with negligible precipitation. Thus, we feel confident that the irrigation data supplied by the growers is a good estimate of not only the average irrigation needs for citrus production, but also the extreme highs and lows applied for grapefruit production. Although, MJS and DRP irrigation are considered to be low use water systems, the high variability in the amount of irrigation water actually applied by MJS and DRP growers is due to the need for more frequent irrigation events during periods of high heat and drought stress. Thus, growers turn on the MJS and DRP systems on more frequently and for longer periods of time to ensure that the trees do not become stressed and significantly diminishing crop production and yield quality. Other reasons why growers prefer pressurized systems over FLD systems may because these systems allow to apply small amounts of water and fertilizers with high uniformity

Table 3. 10-year prediction of average per hectare financial indicators for 'Rio Red' grapefruit production for citrus producers in the Lower Rio Grande Valley

Irrigation Type	Pack-Out Scenario	10-Year Average Per Hectare			Cumulative
		Total Cash Receipts ($1000)	Total Cash Costs ($1000)	Net Cash Farm Income ($1000)	10-Year Cash Flow/ ha ($1000)
Traditional Flood	High	8.10	4.96	3.14	34.26
	Average	6.99	4.97	2.03	22.31
	Low	6.32	4.96	1.36	14.89
Narrow Border Flood	High	10.55	4.94	5.61	61.26
	Average	9.21	4.94	4.27	46.83
	Low	8.30	4.94	3.38	36.95
Microjet Spray	High	9.56	5.26	4.27	46.81
	Average	9.51	5.26	4.22	45.30
	Low	8.40	5.26	3.14	34.28
Drip	High	9.44	5.19	4.25	46.31
	Average	8.67	5.19	3.48	38.04
	Low	8.45	5.19	3.24	35.54

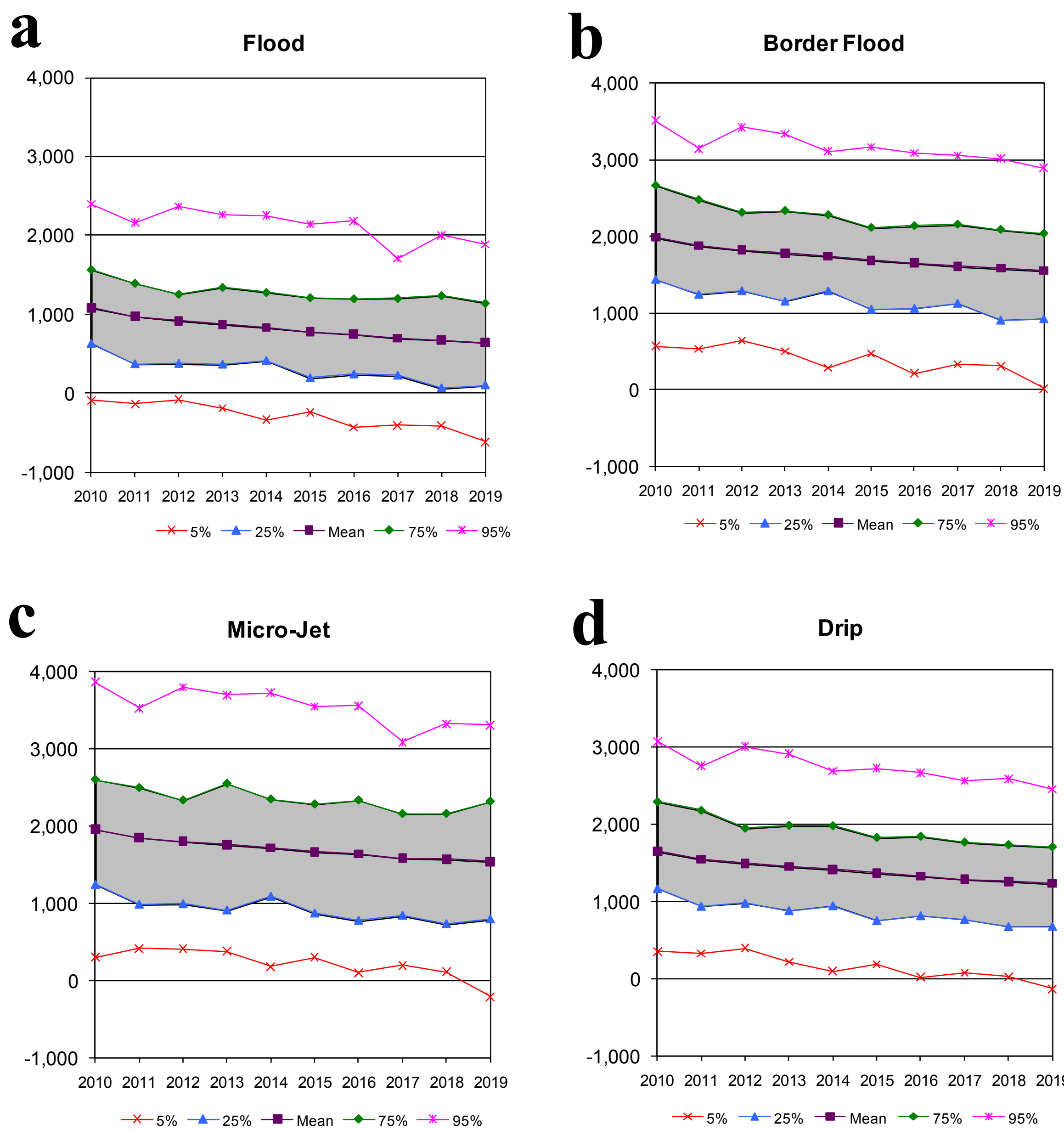

Fig. 2. 10 years (2010-2019) of projected variable net cash farm income (NCFI) per acre for grapefruit using four different irrigation systems [traditional flood (a), narrow border flood (b), microjet spray (c), and drip (d)], based on average pack-out results and economic returns to growers from 2005-2009. Percentages indicate the probability that NCFI is below or above the mean indicated level, where the shaded area contains 50% of the projected outcomes. Note: The Y-axis is displayed as $US/acre; to convert to $/hectare multiply by 2.47.

and efficiency; they allow better weed control when the soil is partially wet; and there is easier access of the machinery for spraying chemicals and hedging with these systems. All these factors may also have contributed to obtain higher yields on NBF, MJS, and DRP systems.

Comprehensive projections, including price and yield risk, for the four irrigation methods are illustrated in Table 3 and Figures 2a-d. Table 3 presents the average outcomes for selected financial projections, while Figures 2 a-d illustrate the full range of possibilities for net cash farm income for each irrigation system. By using 5-year average pack-out percentages, results indicate that the highest net cash farm income (NCFI) was with NBF (Table 3 and Figures 2a-d). The projected 10-year average NCFI for NBF was \$4,270 ha^{-1} (\$1,730 ac^{-1}), which was 1.2% more than MJS, 22.7% more than DRP, and more than double that of FLD. An assessment of high to low pack-out also reflects similar results. The advantage of NBF over conventional FLD is largely reflective of higher average yields (47.3 Mg ha^{-1} for NBF and 38.6 Mg ha^{-1} for FLD). The advantage of NBF over MJS and DRP is directly linked to overall costs. Average cash costs were approximately \$5,000 ha^{-1} for NBF, which was respectively 4.8% and 6.1% less than DRP and MJS. The cost per hectare differences largely reflects additional initial investment costs for establishment of DRP and MJS systems that override water and operating cost savings.

The NCFI advantage of NBF is also reflected in the ability to generate cash flow (Table 3). The 10-year cumulative cash flow balances illustrate the potential pre-tax cash requirements or flows generated using the four irrigation methods. On average, NBF generated a cumulative cash flow of \$46,830 ha^{-1}, which was 3.4% more than MJS, 23.1% more than DRP, and more than double that for FLD. Cumulative cash flow results assessing variations in pack-out also favor grapefruit production under NBF irrigation.

CONCLUSIONS

The results indicate that NBF may have a NCFI and cost advantage over FLD, MJS, and DRP irrigation systems in grapefruit production when evaluated using fresh vs. juice pack-out as a barometer. Whereas actual yields and pack-out percentages may vary based on rainfall, soil types, tree age, pruning, and other management practices, the five -year averages lend credence to the results that raising borders between every citrus tree row may be the best option. NBF also has a cost advantage over the other three irrigation systems. However, other issues such as terrain, availability of labor, water savings, and cost of water may also play a role in deciding which system is the best fit for an individual producer.

We recommend that NBF irrigation can be put into practice immediately by citrus producers throughout the LRGV as it poses a minimal cost in adapting to raising berms between each citrus row. Meanwhile, this study demonstrates that producers will be able to sustain better quality yields while preserving water supplies for current and future water needs. In this respect, citrus growers can take a proactive approach to water conservation throughout the LRGV while increase profits at the on-farm level.

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