Irrigation scheduling and economic viability of watermelon production in a coarse-textured soil

by

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Abstract

This study aimed to evaluate the use of irrigation scheduling strategies to enhance irrigation management in watermelon production, and to analyze its economic viability of different. Water management practices for watermelon production in Alabama. Field experiments were conducted at the E.V Smith Research and Extension Center, Shorter, AL in 2022 and 2023. Three irrigation scheduling treatments were tested: systematic irrigation (SYS), crop water demand (CWD), and soil water status method (SWS). Results from trials conducted in 2022 and 2023 indicated that SWS had a higher biomass accumulation, increased yield, and allowed for the best economic viability between years. Fruit quality had significant differences for soluble solids, in which SWS and CWD had higher soluble solids levels compared to SYS. Irrigation water savings were higher in SWS compared to other treatments, resulting in 54% water savings compared to SYS and 16% to CWD in 2022. In 2023, SMS used 100% less water than SYS, and 19.5% than CWD. The main effect of irrigation scheduling treatments within year had no significant differences in 2022, conversely, the SWS (76,335 kg ha^{-1}) had a higher yield compared to CWD (46,426 kg ha^{-1}) and SYS (50,231 kg ha^{-1}) in 2023. Economic analysis indicates that SWS was the most economically viable treatment, in particular SWS had constantly higher profits in both years that were significantly different for the weather conditions.

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SYS	Systematic irrigation
SWS	Soil water status
CWD	Crop water demand
GDD	Growing degree days
DAT	Days after transplant

Chapter 1

Literature review

1. WATER MANAGEMENT IN VEGETABLE PRODUCTION

Water management in vegetable production is important to ensure abiotic stresses will not lead to extensive losses to crop production (Boyer, 1982). Vegetable crops may experience water stress in two ways: drought, in which there is a deficit of water in the soil, or soil saturation, in which there is excess of water in the soil. Drought stress is caused by poor timing of water application, insufficient volumes of water applied, or both, limiting the amount of soil water availability to plants (Boyer, 1982). Contrarily, soil saturation is caused by long periods of irrigation or excessive volumes of water applied via irrigation and rainfall events, which wastes water, saturates the soil, and induces nutrient leaching (Singh & Kumar, 2017; Nouri et al., 2021).

In general, water stresses are limiting factors for vegetable production, and proper irrigation management is important to ensure soil water availability to plants. Particularly, irrigation scheduling is an important part of managing irrigation systems that allows for an optimal water application that will translate into maximum crop production (Dong, 2023).

2. IRRIGATION SCHEDULING

Irrigation scheduling consists of the application of water at the right time and right volume. The objective is to carefully manage the soil water volumetric content and ensure plants receive adequate moisture for their growth and development, resulting in improved crop yields (Jones, 2004). After all, a proper strategy of irrigation scheduling requires continuous monitoring and adjustment of irrigation events throughout the growing season. Consequently, factors such as crop growth stages, weather conditions (i.e., rainfall events and daily air temperature), and soil physical proprieties must be accounted for the selection of a proper method of irrigation scheduling (Malik et al., 2019).

Currently, there are six methods of irrigation scheduling ranked according to the level of management required for water application (Dong, 2023). Those methods range from irrigation events with no scheduling at all to irrigation events determined based on both the crop water requirements and soil water availability. Most vegetable growers irrigate using systematic irrigation scheduling, which consists of the water application based on a time or water volume, regardless of weather and soil water conditions. However, in this study, three methods of irrigation scheduling were evaluated:

a) **Systematic irrigation (SYS) method:** As aforementioned, the SYS is a method of irrigation scheduling that involves the application of water automatically or manually for the same frequency and duration every day (da Silva et al., 2022). In short, water is applied at the same volume every day regardless of environmental conditions (i.e., weather conditions and soil physical proprieties) or crop growth stages. Because of that, there is a high likelihood of under or over irrigated crops (Jones, 1990). Particularly, over-irrigation is commonly reported in fields under SYS, which leads to water and nutrient leaching; consequently, negative impacts on crop yield (Zotarelli et al., 2006; da Silva et al., 2018).

b) **Crop water demand (CWD) method:** The CWD method of irrigation scheduling describes two processes of water loss from agricultural fields: the evaporation, which is the volume of water lost from the surface of the soil to the atmosphere; and the transpiration, which is the volume of water from the soil is uptake by plants' root system, moved through the plant, and evaporates from leaves (Allen et al., 1999). These two processes are also called crop evapotranspiration (ETc), which is the daily measurement of water volume that has been lost from an agricultural system in inches or millimeters per unit of time. In short, the CWD accounts for stages of crop development and weather conditions, therefore, water is precisely applied to supply the daily or weekly ETc (Jones, 2004).

c) **Soil water status (SWS) method:** The SWS method consisted of the management of irrigation events based on the soil water availability in the crop root zone using soil moisture sensors. Soil moisture sensors are a technology that help growers to determine the soil volumetric water content (Smith et al., 2018); consequently, daily irrigation events only replace the water depleted from the soil (Jones, 2004). The SWS offer precise monitoring of the soil volumetric water content, enabling for accurate determination of the timing and volume of irrigation events; however, the implementation of this method requires knowledge on soil physical proprieties of the irrigated area (Jones, 2004). Furthermore, it should be noted that the cost of soil moisture sensors is a disadvantage of the SWS, since it can be relatively expensive compared to other irrigation scheduling methods (Gardner et al, 2001).

Overall, the CWD and SWS are more accurate methods of irrigation scheduling compared to the SYS. Zotarelli et al. (2006) compared the SWS against the SYS method on zucchini production and identified that the SWS could reduce irrigation water volume by 33-80%, enhance biomass and nutrient uptake, and increase fruit yield. Similarly, when the CWD was compared against the SYS on corn, Ko et al. (2006) mentioned that crop water demand has proven to be an efficient water delivery that requires less water input during critical growth stages, resulting in higher grain yield. Clearly, there are potential benefits related to water savings and crop responses associated to using the CWD and SWS methods of irrigation scheduling; however, the adoption of these methods is still limited in vegetable production and there is a need to better understand the response of vegetable crops to such methods (Da silva et al., 2022).

3. WATERMELON PRODUCTION

Watermelon is a member of the Cucurbitaceae family, which includes squash, pumpkins, cucumbers, muskmelons, and gourds (Wehner, 2008). Watermelon fresh market contributes to 127800 acres e valued at $488,343.00 in the U.S. (USDA/NASS, 2015). Florida, Georgia, Texas, California, and Alabama are the top 5 states for watermelon production in U.S. Particularly; watermelon is grown on approximately 2778 acres in Alabama, which can be considered much lower than the 22,000 acres grown in Florida, the number one state (USDA/NASS, 2022). Because of a large number of small-scale operations (20 – 50 acres) in Alabama, growers lean on farmers' markets or attend to micro-regions close to the farm location to sell their fruit, which is contrary to large acreage operations where watermelon is sold via contracts between growers and retails stores. Nevertheless, Alabama can potentially increase the acreage of watermelon production due to its environmental conditions and logistical location for distribution across the country (Zwingli et al., 1987).

Regardless of the production area, the development of best management practices for watermelon production is important to maximize the sustainable intensification of this crop, particularly in Alabama. Sustainable intensification is the term used to increase crop productivity with a reduction in resources used, such as irrigation water (Wang et al., 2022). Therefore, the use of a proper irrigation scheduling method is important for growers to attend to the growing demand for watermelon (Li et al., 2018).

Irrigation management in watermelon

Watermelon cultivation practices have evolved significantly from traditional methods of bare-ground cultivation and direct seeding without irrigation. Recent approaches include the use of raised beds, polyethylene mulch, transplanting, and drip irrigation for cucurbit production. The use of raised beds helps improve soil drainage, enhances root aeration, and provides a well-defined planting area for optimal crop growth. The plastic mulch acts as a barrier, reducing weed competition, conserving soil moisture, and maintaining a more stable soil temperature (Waggoner et al., 1960). Drip irrigation offers maneuverable irrigation options and efficient application of fertilizers, resulting in increased yields, enhanced plant and fruit growth, improved root development, and superior fruit quality (Hartz, 1996). However, effective irrigation scheduling becomes crucial to fully capitalize on the benefits of drip irrigation (Li et al., 2018). Proper timing and volume of water application play a central role in maximizing the potential of drip irrigation for watermelon production (Di Gioia et al., 2009). Through a global meta-analysis, Yang et al. (2023) demonstrated that drip irrigation conserves water and ensures crop yield; when drip irrigation attends crop's water requirement, yield increases of 28.92%, 14.55%, 8.03%, 2.32%, and 5.17% compared to flooding irrigation, border irrigation, furrow irrigation, sprinkler irrigation, and micro-sprinkler irrigation, respectively. By implementing appropriate irrigation management practices, watermelon growers can optimize crop yield and minimize water usage.

4. ECONOMIC ANALYSIS

a. Watermelon economic panorama

On average 5.1 billion pounds were consumed in 2019, a 4-percent increase from 2010, but a 5-percent decline from 2016 when consumption reached its highest level in over a decade. Watermelon (Citrullus lanatus) production domestically is still the most important source of consumption in the U.S, combined production reaching 3.9 billion pounds in 2016, but average numbers are decreasing since 2010 (USDA, 2020 - NASS). Roughly 80 percent of all U.S. watermelon production comes from four States—Florida, Georgia, Texas, and California. Florida production rises from all other States as the main supplier of watermelons, reaching a production level of 907 million pounds, which is more than a quarter of domestic supplies in 2019 (USDA, 2020 - NASS).

Watermelons are among the most widely grown vegetable crops in the warmer parts of the world (Maynard, 2001, 2001; Wehner, 2008). Considered one of the most consumed fresh fruits in the US territory, consistently Florida ranks first place as the major producer accounting for 19% of the 3.9 billion pounds grown. The following states in this list are Georgia, California, and Texas (USDA, Economic Research Service). According to the USDA, an estimated number of 100.000 acres of watermelon were cultivated in 2020 acquiring accumulated production of 38 million pounds.

Although the demand for watermelons has been increasing for the last past decades, the necessity to improve productivity is rising (Colquhoun, 2018). It is important to recognize the capacity of watermelon production inside U.S territory, hence, yield prevenient from U.S growers is still not sufficient to supply the uprising market. This situation creates a dependency on other countries to supply watermelon, whereas Mexico as the biggest commercial partner contributes around 80% of all watermelon imported. In 2019, imports reached their peak due to the stagnation of the U.S capability to afford watermelon units (Martin et al, 2020). In addition to the rising imports, reaching a pinnacle of 1.7 billion pounds in 2019, considering the amount consumed by the American population sums more than 30% of all watermelon bought from outside countries.

One crucial topic to consider is the potential for increasing watermelon revenue margins through multidisciplinary inputs (Bravo-Ureta et al., 2012). The use of enterprise budgeting to predict future revenue and minimize loss for watermelon growers is key. Watermelon is grown on approximately 2778 acres in Alabama (USDA/NASS, 2022) being the fifth major producer, according to Zwingli et al. (1987), the environmental conditions and strategic distribution location of Alabama present a promising opportunity for expanding watermelon production acreage in the region. Growers can use enterprise budgeting to develop an agricultural strategy, identifying watermelon potential profits and how much to invest on operation before reaching breaking even (Featherstone et al, 1993), consequently, it increases watermelon potential to grow in Alabama.

b. Enterprise budget definition

Enterprise budgets assess a farm's future income, costs, profitability, or losses. Enterprise budgets are a benchmark for monitoring business activity after establishment and estimating income and costs for a given farm enterprise on a per-production-unit basis for one production cycle (Wade, 2021). The primary goals of establishing these budgets are to discover which agricultural practices are the most lucrative and to determine breakeven costs for use in marketing/farming strategies (Zepeda et al., 2000). Enterprise budgets, also known as cost-and-return estimates, capture project revenues and costs connected with manufacturing and marketing a particular item (Wade, 2021). Therefore, an enterprise budget can be considered a financial plant since it allocates costs to all the information in the commodity's production to mitigate risks and uncertainties (Morgan et al. 2021). In essence, enterprise budgets help producers determine what to produce, how many acres to grow, and how much it costs to grow profitably.

c. Enterprise budget parameters and expenses

Growers must make decisions every day about how to allocate their resources. Financial information is essential to help guide these decisions. This is especially true when growers are considering new enterprises or changes to existing operations. The farm financial planning process can be challenging because each manager faces challenges and opportunities specific to their operation. In an enterprise budget, costs are classified as variable, fixed, or joint (Estes et al. 2003).

Variable cost

Zapeda et al. (2000) conducted a comprehensive literature review exploring the concept of variable costs and their significant impact on business size and management decisions within the realm of agricultural production. Variable costs refer to expenses that emerge at the initiation of the production cycle, encompassing items like media, fertilizer, and seed (Estes et al., 2003). These expenses play a pivotal role in shaping the size of the agricultural enterprise and exert influence on various management choices, such as determining whether to employ a ridge-tooled tractor or a furrow plow for efficient tillage operations in each field. Unlike fixed costs, which remain constant regardless of production levels, variable costs dynamically fluctuate with the volume of production (Keske et al., 2020). This variability implies that as production scales up or down, the magnitude of variable costs correspondingly adjusts, directly impacting the overall financial health and profitability of the agricultural venture (Keske et al., 2020). Examples of variable costs: include fertilizers, water, electricity, diesel fuel, human labor, seedling tray (polystyrene), and other materials (e.g., grafting clips (polypropylene), grafting sticks, and polypropylene (Moosavi-Nezhad et al., 2022)

Fixed costs

Estes et al (2003) highlights that fixed costs in agricultural enterprises encompass expenses like depreciation, insurance, taxes, and interest, which remain constant irrespective of whether production is initiated or not. These costs are associated with durable goods, such as structures and machinery, which are long-term investments expected to last beyond a single season. In order to forecast operational profitability, companies incorporate predicted yield and pricing into their budgets (Estes et al., 2003). Moreover, joint costs represent fixed expenses that can be allocated to more than one crop. These standard costs include depreciation for equipment used on multiple crops and property taxes that cannot be attributed to individual firms (Frank, 1997). Examples of fixed costs: Fixed costs refer to the costs incurred for equipment and devices that do not need to be replaced regularly, such as steel, data loggers, sensors, weather station, water pumps and electromotor, humidity meters, thermometers, electric cables, pipes, hoses (Moosavi-Nezhad et al., 2022).

Cash flow

Cash flow planning in business refers to the meticulous management and monitoring of financial resources associated with various aspects of the enterprise, including investment, production, and marketing (Libbin et al., 1994). It involves understanding, projecting, and regulating the flow of money in and out of the company to ensure its financial stability and success (Libbin et al., 1994).

Effective cash flow planning begins with assessing the expected inflows and outflows of funds over a specified period, usually on a monthly or quarterly basis (Kirwan, 2008). This analysis encompasses revenue generated from sales, investments, loans, and other sources, as well as the expenses incurred for materials, labor, operating costs, and debt payments (Van Tassel et al. 2020).

Net return

Net return is a vital metric within the enterprise budget in agriculture. It enables farmers to assess profitability, make informed decisions, manage costs, mitigate risks, plan investments, and ensure the financial sustainability of their agricultural operations (Sahs et al., 2020). Understanding and optimizing net returns are crucial for driving profitability and achieving long-term success in the agricultural industry.

d. Purpose of economic analysis in agriculture

During the growing season, a significant portion of a grower's expenses are devoted to agricultural inputs, such as pesticides, fertilizers, seeds, and irrigation water (Mishra et al., 2007). These expenses are categorized as operating costs (Estes et al., 2003). To assess the profitability of different enterprises and create an effective farming plan, growers can utilize enterprise budgets (Van Tassel et al. 2020). This involves evaluating what to produce, selecting the most suitable cultivation techniques to maximize crop potential, determining the appropriate acreage for cultivation, and setting viable selling prices (Serra, 2012).

One crucial aspect of the farming plan is optimizing water usage, reducing utility bills, ensuring adequate crop nutrient availability, preventing fertilizer misapplication, and mitigating the impact of drought during the growing season. Precise irrigation practices play a pivotal role in addressing these factors, ultimately leading to improved overall performance and profitability in farming operations (Molden et al., 2010). Furthermore, enterprise budgets offer the advantage of requiring less data compared to the whole farm budget. By making realistic and accurate cost allocations for each enterprise, growers can effectively measure the comparative profitability of different ventures (Smith et al., 2019). This valuable information contributes to enhancing revenue and promotes sustainability throughout the growing seasons.

5. OBJECTIVES

The main goal of this research dissertation was to evaluate different irrigation scheduling strategies for conventional watermelon production in Alabama. The specific objective of this study aimed to explore various irrigation scheduling approaches and their impact on crop vegetative development, yield, and fruit quality. In addition, the study assessed the cost-effectiveness and economic viability of different irrigation scheduling for watermelon production. Consequently, offering valuable insights and practical recommendations to watermelon growers.

Chapter 2

Irrigation scheduling strategies for conventional watermelon production in Alabama

Introduction

Watermelon (*Citrullus lanatus*) is a widely cultivated and economically important crop in the U.S. Watermelon fresh market contributes to 127800 acres e valued at $488,343.00 in the U.S. (USDA/NASS, 2015). Particularly, watermelon is grown on approximately 2778 acres in Alabama, which can be considered much lower than the 22,000 acres grown in Florida, the number one state (USDA/NASS, 2022). Watermelon production is concentrated in several states known for their favorable growing conditions, such as Florida, Georgia, Texas, California, and Alabama (USDA, 2022). In the southeastern U.S., including Alabama, watermelon is grown coarse-textured soils with low water holding capacity. Consequently, irrigation management in watermelon production is a challenge for growers, who must adjust irrigation events according to ensure maximum yield (Jones, 2004).

Efficient irrigation management is essential for optimizing watermelon production (Kour et al., 2018), ensuring sufficient water supply to meet crop water requirements while minimizing irrigation water waste (Hamdy et al., 2003). By matching water application to the crop's water requirements at different growth stages, growers can optimize plant health, fruit quality, and overall crop yield (Jones, 2004). Proper irrigation management plays a vital role in maximizing water use efficiency and ensuring sustainable watermelon production practices. In a study conducted in Turkey, soil moisture sensors were used to optimize irrigation scheduling for watermelon, resulting in a 25% reduction in water use and a 33% increase in yield compared to systematic irrigation scheduling (Bilgili et al., 2018). Similarly, a study conducted in China found that using soil moisture sensors for irrigation scheduling increased watermelon yield by 22% and reduced water consumption by 31% compared to systematic irrigation (Li et al., 2019).

Therefore, the object of this study was to evaluate different irrigation scheduling strategies for conventional watermelon production in Alabama. By investigating the performance of crop vegetative development, yield, fruit quality, and water savings with different irrigation scheduling approaches. This study seeks to provide valuable insights and practical recommendations for watermelon growers in optimizing irrigation practices and enhancing the sustainability of watermelon production systems in the region.

Materials and Methods

Site description

Field experiments were conducted in 2022 and 2023 at the E.V. Smith Research and Extension Center from Auburn University, Shorter AL. The area is classified as humid subtropical climate (CFa) with dry winter and wet summers (Köppen, 1928). The soil is classified as a Cahaba sandy loam soil (a fine-loamy, siliceous, semiactive, thermic Typic Hapludults) with poor soil water holding capacity (USDA, 2023).

Crop management

Watermelon seeds (c.v. Sugar Baby) were planted in 200 cell trays filled with soilless media (Pro-Mix BX; Premier Tech, Riviere-du-Loup, QC, Canada) and greenhouse grown until transplanting. During seedling production, fertilizer was applied using a water-soluble NPK of 20-20-20, applied once a week at a rate of 0.5 g per liter of water. Seedlings were irrigated twice a day and the greenhouse temperature was maintained at 25°C during the day and 20°C at night.

Seedlings were transplanted on 15 cm raised beds spaced 2 m center to center and with an in-row spacing of 1 m. Raised beds were laid using a white on black polyethylene mulch (Total Blockade - Berry Global Inc., Evansville, IN) with a drip line irrigation system (30.48 cm emitter spacing, 1.89 L per min per 30.48 m at 68.95 kPa; Chapin DLX; Jain USA, Haines City, FL) installed under the plastic mulching in the center of each bed. Fertilizer application supplied 78.45 kg of N ha^{-1} using a NPK of 10-10-10 (Rainbow Plant Food; Agrium, Tifton, GA) before laying plastic mulch. A week after transplanting, plants were fertirrigated with 13.45 kg of N ha^{-1} weekly until harvest using a NPK of 20-20-20 (ICL Inc., Peters Professional; Everis, NA). Pests and disease management were conducted following the 2022 Southeast U.S. Vegetable Handbook.

Experimental design

A one factorial experiment design of irrigation scheduling strategies was arranged in a randomized complete block design with four replications in both years. Irrigation strategy treatments were initiated at 20 DAT to allow for a seedling establishment in the field and consisted of a systematic irrigation method (SYS) treatment using fixed irrigation to determine irrigation events, a crop water demand method (CWD) treatment using the crop evapotranspiration (ETc) to determine irrigation events, and a soil water status method (SWS) treatment using the soil volumetric water content to determine irrigation events. Soil volumetric water content data were collected after the implementation of soil moisture sensors 30 DAT until harvesting.

In the SYS, irrigation water was applied daily to supply 6.34 mm d^{-1}. In the CWD, the ETc was weekly calculated using the daily reference evapotranspiration (ETo) multiplied the watermelon crop coefficients (Kc) of 0.8 during the vegetative stage or 1.1 from full leaf expiation to harvest (Allen et al. 1998). Subsequently, water in the CWD was daily applied to supply the weekly ETc. In the SWS, an undisturbed soil core sample was collected at the 15 cm soil depth at pre-planting and the soil water retention curve (SWRC) estimated using an adaptation of the evaporation method (Schindler and Müller, 2006). Using the SWRC, the soil saturation was identified at 0.45 m^3 m^{-3}, soil field capacity was assumed to be 0.22 m^3 m^{-3} at -6 kPa, and permanent wilting point assumed to be 0.04 m^3 m^{-3} at -1500 kPa. Irrigation events then occurred when the soil volumetric water content reached the threshold of 70% (0.16 m^3 m^{-3}) of the soil field capacity, and water was applied until soil volumetric water content reached the soil field capacity.

Weather conditions and soil volumetric water content

During both growing seasons, daily air temperature, rainfall events, and ETo were monitored using an on-site weather station (WatchDog Wireless Station, WD Wireless ET

Weather Station, LTE-M 50500102). Growing degree days (GDD) were calculated by subtracting the watermelon base air temperature of 10°C from the daily average air temperature (Onsinejad et al., 1999) Soil volumetric water content was monitored every 15 minutes using soil moisture sensors (Sentek Probe© 2023 Sentek Technologies; BMP Logic, Trenton, FL). Soil moisture sensors were connected to a data logger (YDOC Data Logger version ML-017; BMP Logic, Trenton, FL) and data remotely accessed, allowing for a manual starting of irrigation events in the SWS treatment.

Plant growth and development.

Watermelon biomass accumulation was evaluated 5 times during the growing season at transplanting establishment, foliar development, foliage expansion, flowering and harvesting. Samples were collected at 19, 33, 47, 61, 75 DAT in 2022 and 35, 49, 63, 77, 91 DAT in 2023. A sample consisted of 2 representative plants of each plot dried at 65^{o} C until constant weight. Watermelon vine length and stem diameter were also measured in 5 plants of each plot in the same days. Vine length was measured at base of the hypocotyl until the end of the stretched marked vine, while stem diameter was measured at the hypocotyl before the first node of the vine.

Fruit Yield and Quality

At maturity, watermelon fruit were harvested, and each fruit was individually weight and graded on 30, 36, 45, and 60 count, meaning fruit higher than 9.7 kg, 8 to 9.6 kg, 6.2 to 7.9 kg, and lower than 6.1 kg, respectively, according to the USDA (2005), respectively. Total yield was calculated as the sum of the yield of all sizes, and the irrigation water productivity (IWP) calculated as the ratio between yield per unit of irrigation water use (IWP, kg/m3) (Expósito et al., 2019)

Post harvesting measurements evaluated fruit quality, which was measured in 5 individual watermelons randomly selected from each plot. Fruit quality measurements were fruit length, flesh length, and rind thickness. In addition, watermelon fruit Ca^{2+}, K^+, and NO_3^- were measured (Horiba Ca-11 laquatwin calcium ion (Ca^{2+}) meter; Horiba K-11 laquatwin potassium ion (K^+) meter; Horiba NO_3^-11 laquatwin Nitrate Ion (Meter, Horiba, Tokyo, Japan), as well as the soluble solids (Atago PAL-1 (3810) Refractometer; (Krüss Optronic, Hamburg, Germany).

Statistical analysis

All data was analyzed using the generalized linear mixed in the R Studio (RStudio Team 2023, Boston, MA). Watermelon biomass accumulation, vine length, and stem diameter was analyzed using year, irrigation scheduling, growth stage of sampling, and their interaction as a main effect. Watermelon yield of fruit size, total yield, and fruit quality parameters were analyzed using year, irrigation scheduling and their interaction as a main effect. Block was always used as a random effect. For all analyses, when the F value was significant, least square means comparisons were performed using the Tukey adjusted probability value of 0.05, and means were portioned as needed.

Results

Weather conditions and soil moisture availability

Daily average air temperature was mostly higher in 2022 compared to 2023 (Fig. 1). Particularly, daily air temperatures in 2022 were considerably higher after the 20 days after transplanting. For instance, daily air temperature at 30 DAT was 13.5 ºC higher in 2022 than in 2023 and maintained higher throughout the entire season. The higher daily air temperature in 2022 compared to 2022 impacted the GDD, which accumulated faster in 2022 than in 2023. Consequently, watermelon was harvested at 75 DAT in 2022 with 1098 GDD and 91 DAT in 2023 with 950 GDD.

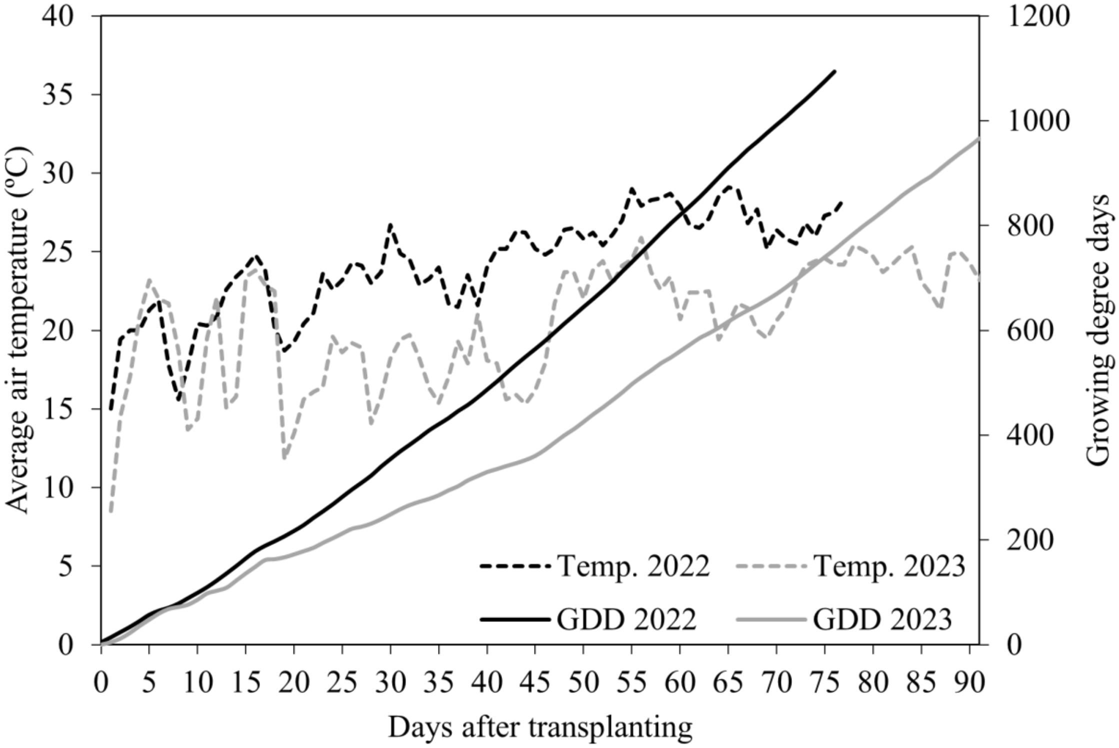

Figure 1. Daily average air temperature and accumulated growing degree days for the watermelon seasons of 2022 and 2023 in Shorter, AL.

Rainfall events were well distributed during both growing seasons but accumulated 197 and 491 mm in 2022 and 2023, respectively. In 2022, there were few rainfall events right after the start of irrigation scheduling treatments and two main events of 37 and 29 mm in 69 and 72 DAT. Contrarily, rainfall events after starting of irrigation strategy treatments were often in 2023 (Figure 2.). Regardless of year, the SWS treatment maintained the soil volumetric water content between 16% and 25%, which were the pre-determine irrigation threshold and soil field capacity, respectively. The CWD treatment maintained the soil volumetric water content within the irrigation threshold and field capacity in 2022 (Figure. 2A), but the soil volumetric water content increased to levels above field capacity (25%) after rainfall events in 2023 (Figure. 2B). Soil volumetric water content in the SYS treatment was above the soil field capacity (25%) but below soil saturation (45%) points in both years. In general, rainfall events had minimal impact on irrigation scheduling treatments, in which the SWS, CWD, and SYS applied 4522, 6595, and 7066 m^3 ha^{-1} of water in 2022, and 4239, 5065, and 8479 m^3 ha^{-1} of water in 2023, respectively.

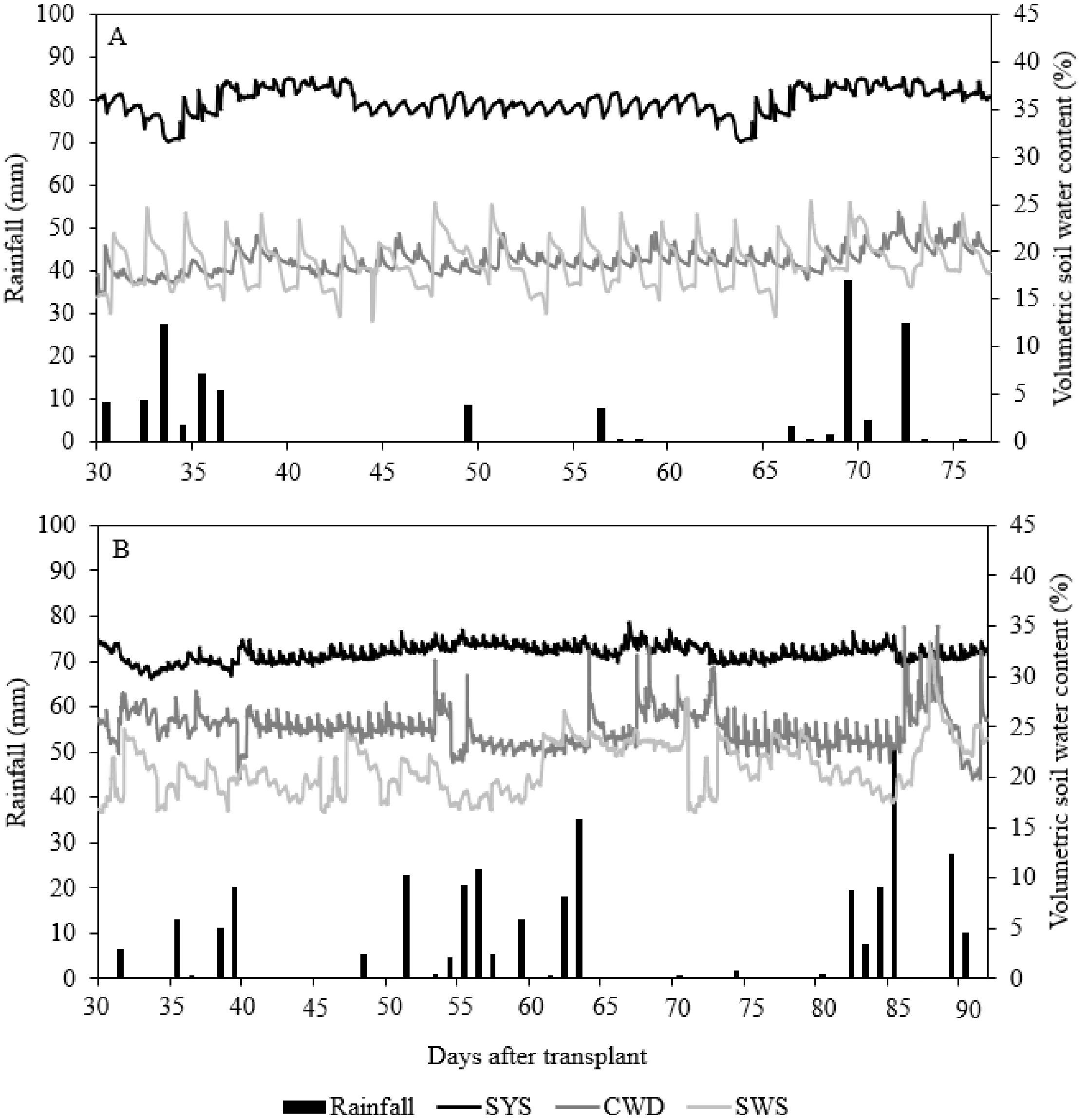

Figure 2. Rainfall events and volumetric soil water content for the watermelon seasons of 2022 (A) and 2023 (B) in Shorter, AL.

Plant growth and biomass

Watermelon biomass accumulation increased during growing seasons, and biomass accumulation was significantly different for the interaction of year and irrigation scheduling (Table.1). For the main effect of year within irrigation scheduling, SWS (195.5 kg ha^{-1}) and SYS

(176 kg ha^{-1}) had higher biomass accumulation in 2022 compared to SWS (259.7 kg ha^{-1}) and SYS (91.6 kg ha^{-1}) in 2023. However, in 2022, CWD (193.4 kg ha^{-1}) had no significant difference compared to 2023 (140.4 kg ha^{-1})

Table 1. Interaction effect between year and irrigation scheduling on watermelon total yield, irrigation water productivity fruit flesh length, and dry biomass

Irrigation scheduling	2022	2023
	Total yield (kg ha^{-1})	
SWS	73,470 aA	76,335 aA
CWD	80,347 aA	46,426 bB
SYS	72,501 aA	50,231 bB
	IWP (kg/ m^3)	
SWS	16.2 aA	22.8 aB
CWD	12.2 abA	12.8 bA
SYS	10.3 bA	7.0 cB
	Flesh length (cm)	
SWS	23.3 aA	22.1 aA
CWD	23.9 aA	19.5 bB
SYS	22.8 aA	19.5 bB
	Dry Biomass (kg ha^{-1})	
SWS	191 aA	259.7 aB
CWD	193 aA	140.8 bA
SYS	176 aA	91.6 bB

ns—not significant according to the ANOVA; *p<0.05; **p<0.01; ***p<0.001.
Values followed by different lowercase letter within year indicates significant differences ($P < 0.05$) among irrigation scheduling treatments according to Tukey test.
Values followed by different uppercase letter within irrigation scheduling indicates significant differences ($P < 0.05$) between years according to Tukey test.

Watermelon stem diameter was significantly different for the interaction between year and growth stage (Fig. 3). For the main effect of year within growth stage, during the establishment stage, the diameter in 2022 (5.48 mm) was significantly higher than the diameter in 2023 (4.46 mm). Similarly, during the foliar development and foliage expansion stages, the diameter in 2022 was significantly larger than in 2023. There were no significant differences in the watermelon stem diameter at flowering and harvesting between years. For main effect of growth stage within year, watermelon stem significantly increased until flowering in 2022 but continuously increased until harvesting in 2023.

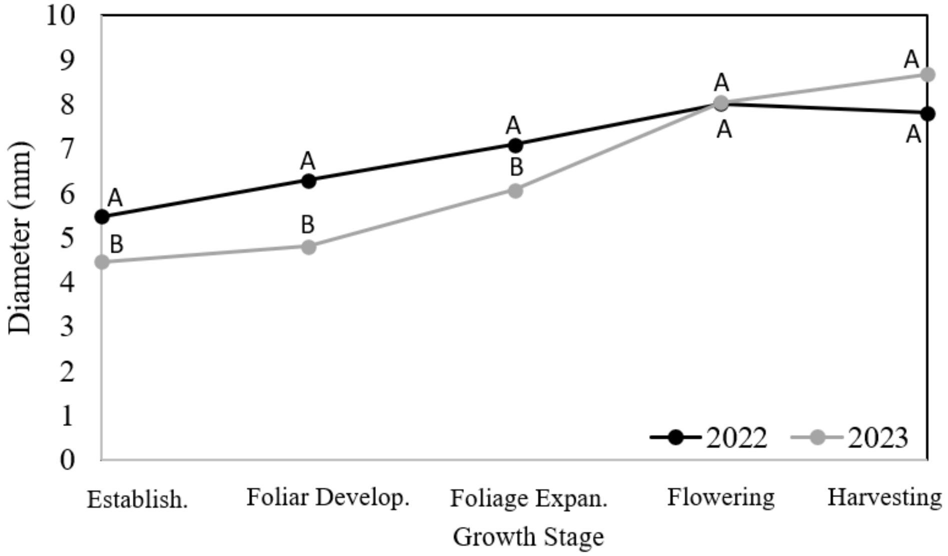

Figure 3. Effect of the interaction between year and growth stage on watermelon stem diameter in Shorter, AL. Means followed by different letters within growth stages indicate significant difference between years according to Tukey test adjusted at $p < 0.05$.

Vine length was significantly different for the interaction of year and growth stages (Fig. 4) and for the main effect of irrigation scheduling.

In the interaction between year and growth stage, there was no significant difference between years at transplant establishment when the main effect of year was evaluated within growth stage. During the foliar development stage, vine length in 2022 (140.1 cm) was significantly longer than in 2023 (70.7 cm). During the foliage expansion, vine length in 2022 (191.1 cm) was significantly longer than in 2023 (164.0 cm). In the flowering stage, the vine length in 2022 (220.0 cm) was also significantly longer than in 2023 (186.2 cm); however, there was no significant difference between years for watermelon vine length at harvest. For the main effect of growth stages within years, there was a significant increase in vine length from establishment to flowering but vine length had no significant difference from flowering to harvesting in both years.

For the main effect of irrigation scheduling on watermelon vine length, the SWS (253.3 cm) and CWD (212.3 cm) had a higher vine length compared to SYS (178.3 cm).

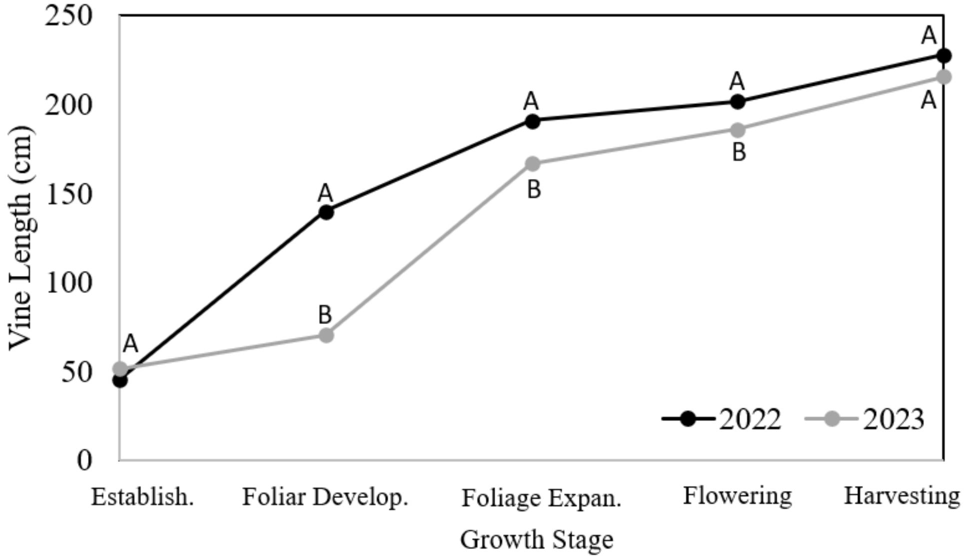

Figure 4. Effect of the interaction between year and growth stage on watermelon vine length (cm) in Shorter, AL. Means followed by different letters within growth stages indicate significant differences between years according to Tukey test adjusted at $p < 0.05$.

Yield and irrigation water productivity

The yield of watermelon fruit sizes, total yield, and IWP is shown in Table 1. Year, irrigation scheduling, and their interaction had no significant impact on 30 count watermelons. The main effect of year had significant impact on the yield of 36 count, in which the growing season of 2022 (13,555 kg ha^{-1}) had higher yield of 36 count compared to 2023 (6,332 kg ha^{-1}). The yield of 36 count was significantly impacted by the main effect of irrigation scheduling, in which SWS (13,399 kg ha^{-1}) had the highest yield of 36 count, followed by CWD (9,470 kg ha^{-1}), and SYS (6,960 kg ha^{-1}). The yield of 45 count watermelons was significant for the main effect of year and main effect of irrigation scheduling. Similar to the yield of 36 count, the main effect of year had higher yield of 45 count watermelons in 2022 (29,479 kg ha^{-1}) compared to 2023 (20,765 kg ha^{-1}), while there was a higher yield of 45 count watermelons for SWS (33,175 kg ha^{-1}) compared to

CWD (22,206 kg ha^{-1}) and SYS (19,984 kg ha^{-1}). The yield of 60 count watermelon was not significantly impacted by year, irrigation scheduling, or their interaction.

Watermelon total yield had a significant interaction between year and irrigation scheduling (Table 2). For the main effect of irrigation scheduling within year, there was no significant difference among irrigation scheduling treatments in 2022, while the SWS (76,335 kg ha^{-1}) had a higher total yield than CWD (46,426 kg ha^{-1}) and SYS (50,231 kg ha^{-1}) in 2023. For the main effect of year within irrigation scheduling treatments, watermelon total yield had no significant difference among years within the SWS treatment but were higher in 2022 compared to 2023 for CWD and SYS.

The IWP was significantly impacted by the interaction between year and irrigation scheduling (Table 2). For the main effect of irrigation scheduling within year, the IWP was higher in the order of SWS ≥ CWD ≥ SYS in 2022, while IWP was the highest for SWS, followed by CWD, and the lowest for SYS in 2023. For the main effect of year within irrigation scheduling treatments, the IWP was higher in 2022 compared to 2023 for SWS and SYS, but there were no significant differences among years within the CWD treatment.

Table 2. Main effect of year and irrigation scheduling on watermelon categorized yield, total yield, and irrigation water productivity.

Effect	30 count	36 count	45 count	60 count	Total yield	IWP
Year			kg ha^{-1}			kg m^{-3}
2022	5,930	13,555 a	29,479 a	26,474	75,439 a	12.9
2023	2,082	6,332 b	20,765 b	28,483	57,664 b	14.2
p value	ns	*	*	ns	**	ns
Irri. Sched.						
SWS	6,308	13,399 a	33,175 a	24,191	74,902 a	19.5 a
CWD	4,136	9,470 b	22,206 b	27,623	63,386 b	11.5 b
SYS	11,569	6,960 c	19,984 b	30,623	61,366 b	9.6 c
p value	ns	*	**	ns	*	***
*Year*Irri. Sched.*						
p value	ns	ns	ns	ns	*	***

ns—not significant according to the ANOVA; *p<0.05; **p<0.01; ***p<0.001. Means followed by different letters of watermelon counts (30, 36, 45, 60), total yield, and IWP indicate significant differences of year or irrigation scheduling according to Tukey test adjusted at $p < 0.05$.

Watermelon fruit quality

Table 3 shows the impact of year, irrigation scheduling, and their interaction on fruit length, flesh length, rind thickness, Ca^{2+}, K^-, NO^{3-}, and soluble solids.

The interaction between year and irrigation scheduling was significantly only for flesh length (Table 1), in which flesh length had no significant difference between year within the SWS treatment but was higher in 2022 compared to 2023 for CWD and SYS. For the main effect of irrigation scheduling within year, flesh length had no significant difference among irrigation scheduling in 2022 but was higher for SWS than CWD and SYS in 2023.

The main effect of year was significant for fruit length, rind thickness, and K^- (Table 3). In general, watermelon fruit length, rind thickness, and K^- were higher in 2022 compared to 2023. There was no main effect of year on Ca^{2+}, NO^{3-}, and soluble solids.

The main effect of irrigation scheduling was significant for rind thickness and soluble solids (Table 2). Rind thickness was the highest for SWS (13.7 mm) and the lowest for CWD (11.6 mm). There was no significant difference between SYS (12.8 mm) and SWS, and SYS and CWD for rind thickness. Soluble solids were the highest for the SWS, followed by CWD, and the lowest for SYS. Irrigation scheduling treatment had no significant impact on fruit length, Ca^{2+}, K^-, NO^{3-}.

Table 3. Main effect of year and irrigation scheduling on watermelon fruit quality: fruit length, flesh length, rind thickness, Ca^{2+}, K^-, NO^{3-}, and soluble solids (SS).

		Fruit length	Flesh length	Rind thickness	Ca^{2+}	K^-	NO^{3-}	SS
		cm		mm		ppm		%
Year								
	2022	26.2 A	23.4 A	15.8 A	11.2 A	1393 A	156 A	10.6 A
	2023	22.7 B	20.4 B	9.5 B	12.5 A	1218 B	187 A	10.0 A

	p value	**	***	***	ns	**	ns	ns
Irrigation Scheduling								
	SWS	26.0	22.7 A	13.7 A	10.5	1302	193 A	10.8 A
	CWD	23.6	21.7 B	11.6 B	12.1	1359	157 A	10.2 AB
	SYS	23.7	21.2 B	12.8 AB	12.9	1256	164 A	9.7 B
	p value	ns	*	*	ns	ns	ns	*
*Year*Irri. Sched.*								
	p value	ns	*	ns	ns	ns	ns	ns

ns—not significant according to the ANOVA; *p <0.05; **p<0.01; ***p <0.001 Means followed by different letters of fruit length, flesh length, rind thickness, Ca^{2+}, K^{-}, NO^{3-}, and soluble solids indicate significant differences of year or irrigation scheduling according to Tukey test adjusted at $p < 0.05$.

Discussion

Daily air temperature in 2022 was higher compared to 2023. This difference is evident in figure 1, in which the maximum air temperature reached 29ºC in 2022, whereas it was 25ºC in 2023. High temperatures generally promote increased metabolic activity, leading to faster rates of photosynthesis, transpiration, and nutrient uptake (Yamori et al., 2020). These favorable conditions of 2022 resulted in enhanced plant growth and development (Rossi et al, 2015). Conversely, low temperatures of 2023 limited plant growth and development (Thakur et al., 2010). Plant physiological processes slow down as temperatures decrease, including photosynthesis, nutrient absorption, and enzymatic reaction, which lead to reduced growth, delayed development, and decreased crop yields (Digrado et al, 2018). Daily air temperature directly impacted watermelon GDD, which were similar from day 0 to 19 DAT in both years. After this point, the accumulated GDD in 2023 reduced compared to 2022 because of the lower temperatures in 2023 that were not conducive to a rapid plant growth and development (Francini et al., 2019; Hatfield et al., 2015). Consequently, watermelon harvesting was delayed to 2023, when watermelon was harvested with 91 DAT. In 2022, watermelon fruit were harvested with 75 DAT.

Rainfall patterns affected the performance of irrigation scheduling treatments (Zhou et al, 2017). In 2022, there were fewer rainfall events compared to 2023; consequently, the SWS and CWD successfully maintained the soil volumetric water content within the optimal range in 2022. However, the increased frequency of rainfall events in 2023 led to a soil volumetric water content higher than the soil field capacity in both the CWD and SYS treatment. Particularly, the SWS was the only irrigation scheduling strategy that maintained the soil volumetric water content within the pre-determined range, considered optimum for watermelon production in the studied soil, regardless of year. Previous studies also reported the ability of this irrigation scheduling strategy on managing soil volumetric water content at optimum ranges in coarse textured soils on tomato and zucchini, regardless of weather conditions (Zotarelli et al, 2010).

Despite the effect of year on biomass accumulation, the SWS consistently maintained a higher biomass compared to CWD and SYS in 2023, when weather conditions of rainfall events induced waterlogging conditions. This can be attributed to the soil volumetric water content under the SWS, which was within optimum range in the watermelon root zone (Zotarelli et al., 2009). Furthermore, biomass accumulation is positively correlated to watermelon yield (Shukla et al., 2004); consequently, the SWS treatment consistently resulted in the highest yields, followed by CWD and SYS treatments, which highlights the importance of effective irrigation scheduling strategies in optimizing watermelon productivity (McCann et al., 2007).

In general, watermelon total yield was similar to the average yield of 22600 kg ha^{-1} for Alabama in 2001 (USDA/NASS). Total yield was responsive to the yield of 36 and 45 counts, which are considered the most profitable marketable fruit size (USDA), and the SWS consistently had a higher yield of 36 and 45 counts compared to CWD and SYS. As aforementioned, this is associated to the SWS ability in providing optimum soil volumetric water content in the crop root zone regardless of weather conditions, which positively influenced plant growth and fruit development (Dukes, 2003). Zotarelli et al. (2009) compared the SWS with SYS for zucchini production in two consecutive years and reported that plant nitrogen uptake increased by 16% for the SWS treatment. This increase in nitrogen uptake led to an increase of 26% on zucchini fruit yield. In the present study, nitrogen uptake was not evaluated; however, the waterlogging conditions of SYS in 2022, and SYS and CWD in 2023 likely led to soil nitrogen leaching, which is commonly reported in coarse textured soils of southeastern U.S. (da Silva et al., 2018; da Silva et al., 2022). Consequently, the lower yields of SYS and CWD compared to SWS can be associated to both waterlogging conditions and lack of soil nitrogen availability in the crop root zone.

The IWP is the ratio between the total yield and volume of water applied, indicating how much weight is harvested by volume of water applied (Expósito et al., 2019). In the present study, the SWS had the highest IWP, indicating greatest to translate water use in fruit weight (Bossio et al., 2010). According to Ierna et al (2012), various irrigation scheduling methods resulted in similar tuber yields, but they exhibited notable differences in irrigation water productivity (IWP) and water savings across the treatments. Specifically, IWP was approximately 74% higher in the first year and 45% higher in the second year for certain treatments. Consequently, implementing a water supply strategy of up to 50% of tuber growth could lead to substantial water savings, reducing irrigation water usage by approximately 77 mm.

Watermelon fruit quality parameters play a crucial role in consumer acceptance and marketability. Flesh length, rind thickness, and soluble solids are important attributes perceived for quality of watermelon fruits that were affected by irrigation scheduling treatments, similar results were found, Wei et al (2017) by maintaining soil moisture content around 65–70% of the field water moisture capacity, it is possible to fulfill the water demand during mango growth and development. This approach ensures maximum irrigation efficiency and enhances fruit quality by increasing total soluble solids, soluble sugar, starch, titratable acid, and vitamin C content.

Conclusion

Overall, weather conditions had a direct impact on watermelon growth and development. Temperature was an important factor to determine the watermelon crop season duration from transplanting to harvest, while rainfall events affected irrigation strategies. Among the irrigation scheduling treatments evaluated, SWS demonstrated superior performance in terms of fruit growth, biomass accumulation, and total yield compared to CWD and SYS. Under conditions of regular rainfall events and accumulation, all irrigation scheduling treatments yielded similar results. However, during unfavorable weather conditions, particularly with high rainfall accumulation, SWS outperformed CWD and SYS, suggesting that adopting soil water status irrigation scheduling could serve as a viable alternative for growers in the southeastern U.S. to achieve higher watermelon yields regardless of weather uncertainties and variability.

Chapter 3

Economic analysis and viability for conventional watermelon using different irrigation scheduling in Alabama

Introduction

Agricultural inputs for specialty crop production represent a large share of growers' expenditures during the growing season. Investments are necessary to acquire feedstuff, fertilizers, licenses, seeds/transplants, and irrigation, all of which are extremely important to result in a profitable farming program (Mishra et al., 2007). Increasing revenue margins with multidisciplinary inputs brings another important element (Wade, 2021). Irrigation scheduling can be effective in diminishing water use that may lead to crop revenue increase Effective water management could enhance farming production of every potential benefit with respect to better water usage, decrease in utility bills, increase in nutrient availability to the crop, decreased fertilizer misapplication, and minimizing drought impact during the growing season are aspects to improve production by using accurate irrigation (Naseem et al., 2018). Beyond revenue increments through different methods, environmental benefits are also increased, such as soil conservation being maintained due to cohesive structures and groundwater reserves being preserved (Jones, 2020).

Studies have investigated the economic viability of using irrigation scheduling in watermelon production. For instance, in a study conducted in Georgia, USA, the use of soil moisture sensors for irrigation scheduling in watermelon resulted in a net revenue increase of $498 per acre compared to traditional irrigation practices (Rogers et al., 2018). Similarly, a study conducted in Turkey found that the use of soil moisture sensors for irrigation scheduling in watermelon resulted in a net income increase of 12.5% compared to traditional irrigation practices (Bilgili et al., 2018).

In this study, we conducted an economic analysis of different irrigation scheduling in conventional watermelon production in Alabama. We evaluated the cost-effectiveness and economic viability of soil water status, crop water demand, and systematic irrigation scheduling practices with the adoption and implementation of precision irrigation technologies in watermelon production. Therefore, the objective of this study was to identify the most profitable irrigation scheduling to improve crop revenue.

Materials and Methods

All data collected throughout trials in 2022 and 2023 were used in the economic analysis. Every aspect of disposal during the experimental trial described in chapter 2 contributed to evaluate economic viability. Additional variables were added to the assessments, inputs, and outputs (human labor, machinery, fuel, fertilizer NPK, chemicals, electricity, water for irrigation, and transplants).

The agricultural study evaluated the effectiveness of different irrigation scheduling strategies to enhance economic viability. Field experiments were conducted at the E.V Smith Research and Extension Center in Shorter, AL, during the years 2022 and 2023. Three irrigation scheduling treatments were tested: systematic irrigation (SYS), crop water demand (CWD), and soil water status method (SWS).

Results from the trials conducted in both years indicated that the SWS method resulted in higher biomass accumulation and increased yields. Moreover, both SWS and CWD showed higher levels of soluble solids in fruit quality compared to SYS (table 1).

The irrigation water savings achieved with the SWS method were substantial, resulting in a 54% water savings compared to SYS and a 16% savings compared to CWD in 2022. In 2023, the SWS method saved 100% more water than SYS and 19.5% more than CWD.

This thorough research provides valuable insights into the consistency and reliability of the implemented protocols and procedures, offering valuable guidance and recommendations to the agricultural community. The dataset utilized in this research covers essential aspects, including historical production records, prevailing market prices, comprehensive labor requirements, detailed input costs, and other pertinent details specifically related to watermelon production in the agricultural of Alabama. By exploring these various dimensions, a more holistic understanding of watermelon production is acheived in Alabama.

Identify Production Inputs

The inputs required for watermelon production were quantified to develop a watermelon enterprise budget based on 2022/2023 trials conducted at E.V. Smith Research and Extension Center. These inputs encompassed various essential components, including land, seeds, fertilizers, pesticides, irrigation water, machinery, soil moisture sensors, data loggers, subscriptions, installation energy, and labor. To determine the quantities of each input, the specific requirements for the watermelon cycle were considered, including factors such as crop density, desired yield and agricultural practices used in Alabama. By incorporating information on irrigation practices, the budget captured the necessary input quantities.

In estimating the prices of each input, a comprehensive analysis of the local market conditions was conducted. Collecting prices from several agricultural suppliers such as “Waters” (Camilla GA) Soil sampling analysis, “Berry Hill Irrigation”, “Growirrigation”, “Irrigation Supply Parts”, “Pro-tect plastics”, and “Farm Plastic Supply” for irrigation materials and cultural activities. To develop the watermelon plants throughout the crop cycle. This assessment considered factors such as supply and demand dynamics, seasonal variations, and any relevant pricing trends. For every product used in this research data was collected from three different suppliers, considering the quantity used by each experiment.

Estimated Costs

The watermelon enterprise budget is an estimation of the costs associated with watermelon production, considering the gathered data and production practices. This approach aimed to capture both fixed and variable costs, ensuring a thorough evaluation of the financial aspects involved. Separate by segments, the enterprise budget was categorized by, “Land preparation”, “Planting”, “Fertilizers”, “Weed control”, “Disease and Insects control”, “Irrigation”, “Harvest”, “Total Variable Costs (TVC)”, “Fixed costs”, and “Total Labor Cost (TLC)”.

Fixed costs, such as machinery depreciation, were considered and quantified. Each combined activity (Tractor + implements) was calculated using the "Farm Machinery Cost Calculations" (Johnson, 2018) developed by Mississippi State University “Image (1). Depreciation costs for machinery were estimated based on their expected useful life and current market value, providing an accurate reflection of the equipment's value over time.

In addition to fixed costs, variable costs played a crucial role in the budget estimation. These costs include transplants, fertilizers, and labor. Fertilizer costs were calculated by considering the recommended application rates, fertilizer types, and market prices. Labor costs were estimated based on the local wage rates and the required labor hours for various production activities, such as planting, harvesting, and field maintenance.

To ensure accuracy in cost estimation, specific inputs for every agriculture activity was evaluated:

- Land preparation, the costs include soil sampling for nutrient analysis and physical properties. The costs associated with soil preparation are mentioned in table 4,5,6,7,8, and 9. The irrigation-related costs consist of drip tape and black TIF plastic mulch for irrigation and bedding, respectively.
- Labor costs are also included in the variable costs, which account for the time spent on activities such as soil sampling, planting, fertilization, weed control, disease/insect control,

machinery operation, and harvest. The labor costs are calculated based on hours worked and hourly wages.

- Fertilizers contribute significantly to the variable costs. Which includes various fertilizers such as Fertigation 20.20.20, Fertigation 4.0.13, and Fertigation 9.0.0.11, along with their respective quantities and costs per pound.
- Weed control is reflected in the use of herbicides such as Curbit and Profine, along with their quantities and costs. Disease and insect control costs include the use of different products such as Velum, Ridomil Gold, Abound, Manzate, Spinosad, Besiege, Cuprofix Ultra 40, and Endigo. The quantities used and their respective costs are mentioned in table 4,5,6,7,8,9.
- Machinery and implement costs include the operation of various equipment such as disks, plastic layers, sprayers, and wagons. The costs are calculated based on hours of usage and the associated hourly rates.
- Harvest costs encompass the labor involved in the harvesting process, along with the use of crates for different fruit sizes (30, 36, 45, and 60 counts).
- Irrigation water and energy costs are also taken into account (gallons of water used and the cost of energy per kilowatt-hour).

Consider Risk and Uncertainty

Weather variability, a significant risk in agricultural production, was considered. The budget incorporated the potential impact of adverse weather conditions, such as droughts, excessive rainfall, or extreme temperatures, on watermelon yields and production costs. Historical weather data, climate projections, and local expertise were utilized to assess the probability and severity of weather-related risks. It leads to the importance of using new approaches and technologies to prevent income losses in agricultural business.

Furthermore, the budget accounted for the risks associated with pests and diseases that commonly affect watermelon crops. The potential impact of pests, such as aphids, spider mites, as well as diseases like gummy stem blight, was evaluated. Strategies for pest and disease management, including integrated pest management practices, were considered to create a chemical protocol to control the potential losses and expenses associated with these challenges.

Revenues calculation

When estimating potential revenues from watermelon sales for the enterprise budget, a comprehensive approach was undertaken to consider various market channels and sales options available in the region. The estimation process incorporated multiple factors to provide a more accurate assessment of the revenue potential. The expected yield of watermelon crops played a central role in revenue estimation. Yield was based on chapter 1 results. By considering these factors, the budget could provide a realistic estimate of the quantity of watermelons that could be available for sale based on the size of the fruit, quantity, and quality, considering different revenues for each category. The estimated revenue is based on the wholesale prices per count for different watermelon sizes (30, 36, 45, and 60 counts) in the Atlanta market in July 2023. The sales per count and the total revenue are mentioned in table 2. The income above variable costs and projected profits are calculated for yield variations of -15%, -10%, +10%, and +15% from the projected yield to provide a sensitivity analysis for these results.

Analyze the Budget

The estimated costs and revenues were subject to a review process aimed at evaluating the overall profitability and feasibility of the watermelon enterprise budgeting. This evaluation encompassed an in-depth analysis of key financial indicators that played a crucial role in assessing the economic viability of the venture.

Net income provided a clear snapshot of the profitability of the watermelon enterprise by deducting all expenses, including both fixed and variable costs, from the total revenues. This allowed for a detailed understanding of the financial performance and the potential returns generated by the enterprise (revenue – total costs). This then provides a return to owners capital investment and land rental or ownership costs.

Return on investment (ROI) was another vital financial metric calculated during the evaluation process. ROI measured the efficiency of the invested capital by comparing the net profit generated from the watermelon enterprise to the initial investment made. This indicator provided valuable insights into the potential returns on the capital deployed and helped stakeholders assess the attractiveness of the investment by dividing total costs per revenue.

Sensitivity Analysis

To ensure a robust evaluation of the watermelon enterprise budget, a sensitivity analysis was conducted to assess the impact of fluctuations in key factors on profitability. This analysis aimed to uncover the sensitivity of the budget to changes in variables such as input costs and market prices, which are known to exert significant influence on the financial performance of agricultural enterprises. By varying critical factors, the sensitivity analysis provided valuable budget projections. It enabled a thorough examination of the potential risks and uncertainties associated with the enterprise, highlighting the factors that could have the most impact on its profitability.

Results and Discussion

Analysis of 2022 Watermelon enterprise budget results

The watermelon Enterprise budget in 2022 had positive financial performance for SWS, CWD, and SYS. Tables 4, 5, and 6 provided information on total variable costs, income above variable costs, total fixed costs, total costs, total revenue, net income, and return on investment for each irrigation scheduling method in 2022.

The analysis of total variable costs revealed that the CWD had the highest total variable cost per acre at $9,745.60, followed by the SYS method at $9,537.90, and SWS method at $9,390.08. These findings indicate that the CWD method incurred the highest expenses due to the additional costs such as weather station and subscription associated with water application based on crop water requirements (Jones, 2004). The SWS had the lowest expenses, which can be associated to the lowest irrigation water spent (Zotarelli et al., 2006), combined with the lowest cost for energy per acre.

The total costs, combining both variable and fixed costs per acre, for the SYS at $9,976.12, followed by CWD at $10,912.82, and the SWS at $12,206.30. It shows that the SYS had the lowest total costs among the three irrigation strategies due to the lower spending on equipment and less technological approach to the irrigation (da Silva et al., 2022). The SWS had an initial investment of $2.807.00 spent on probes, loggers, and subscriptions, followed by CWD with $729.00 spent on the weather station and subscription service.

The CWD achieved the highest net income per acre at $19,352.18, followed by the SYS at $18,468.88, and the SWS at $16,733.62. These results suggest that all irrigation scheduling were financially viable, with positive net incomes. Furthermore, calculating ROI indicated that the Crop

Water Demand achieved the highest ROI at 177%, followed by the Systematic Irrigation at 185%, and the Soil Water Status at 137% in 2022.

Analysis of 2023 Watermelon enterprise budget results

The year 2023 had an adverse climate compared to 2022, in which air temperature was considerably lower (Figure 1.), in addition to rainfall accumulation of 491 mm throughout the season (Figure 2.). Results (Tables 7, 8 and 9) provide valuable insights into the financial performance and return on investment of three different irrigation scheduling methods for the adverse year of 2023.

Among the three methods, the Crop Water Demand irrigation scheduling ($8,512.1) incurred the lowest total variable cost per acre, followed by the Systematic Irrigation method ($8,914.8) and the Soil Water Status method ($9,464.1). The variation in total Moosavi-Nezhad et al (2022) suggests that variable costs can be attributed to differences in input requirements, labor hours, post-harvest operations, quantity of irrigation water applied, energy spent, etc. Since CWD and SYS irrigation does not consider the soil water status, the moment soil is saturated, irrigation events still occur, increasing irrigation water and energy spending (Moosavi-Nezhad et al., 2022).

Total fixed costs maintained the same values as 2022 since the irrigation scheduling equipment was replicated to the following year. In addition, the SYS irrigation scheduling had the lowest total costs per acre ($9,353.02), followed by the CWD scheduling ($9,679.32), and the SWS irrigation scheduling ($12,280.32).

Total revenue was significantly impacted by the total yield (Table 1.) in 2023. Environmental effects such as rainfall events and lower temperatures affected the productivity of CWD and SYS, leading to a lower total revenue per acre. The Soil Water Status ($29,800.00) had the highest total revenue per acre, followed by the SYS ($20,030.00) and the SWD ($18,105.00).

SWS treatment had the best management of the available water content in the soil as mentioned by Smith (2004) which the soil to maintain the optimal moisture for nutrient uptake and vegetative development compared to CWD and SYS.

The total revenue affected the net income and return on investment. The SWS ($17,519.68) had the highest net income per acre, followed by the SYS ($10,676.98) and the CWD ($8,425.68). Return on investment (ROI) measures the profitability of an investment relative to the total cost, which SWS had (143%), followed by SYS (114%) and CWD (87%).

Among these methods, the Soil Water Status method proved to be the most profitable, generating the highest net income and return on investment. The results indicate that soil water status led to improved financial performance in watermelon production despite environmental conditions. By effectively managing water resources based on the soil's moisture content, farmers can minimize their variable costs and enhance profitability (Pereira et al., 2002).

Analysis of Enterprise budget between years

Soil Water Status - the comparative analysis of watermelon performances between 2022 and 2023 using the SWS irrigation method had improvements in key financial parameters. Particularly, total variable cost and total costs experienced a minimal increase of approximately 0.79% and 0.61%, respectively. Income over variable costs, total revenue, net income, and return on investment had significant positive changes with increases of approximately 4.03%, 2.97%, 4.70%, and 4.38%, respectively. The watermelon enterprise utilizing soil moisture sensors experienced increased profitability and financial success in 2023 compared to the previous year. Implementing SWS scheduling method improved water management (Smith, 2004), energy savings, and overall cost-efficiency, resulting in improved financial outcomes.

Crop Water Demand - the comparative analysis of watermelon performances between 2022 and 2023 using the CWD irrigation scheduling indicated contrasting results. While the total variable costs and total fixed costs remained relatively stable there were notable differences in financial outcomes. There was a decrease in income above variable costs (-53.24%), total revenue (-40.15%), net income (-56.50%), and return on investment (-50.85%) in 2023 compared to 2022. Economic parameters indicate a decline in profitability and financial performance.

Systematic Irrigation - According to a comparative analysis of watermelon performance based on the SYS irrigation scheduling between 2022 and 2023, contrasting results can be observed. There were some notable differences in financial performance, although the total variable costs and total fixed costs remained the same. There was a decline in income over variable costs (-41.28%), revenue (-29.56%), net income (-48.18%), and return on investment (-38.38%) in 2023, indicating a decline in profitability and financial performance. The decrease in revenue and net income could suggest that external factors influenced the lower yields (Boyer, 1982) and financial outcomes in 2023.

Conclusion

Overall, the implementation of the SWS irrigation scheduling resulted in enhanced profitability and financial success in both years. This can be primarily attributed to the improved water management, energy savings, and overall cost-efficiency achieved through the utilization of soil moisture sensors. The ability to monitor and adjust irrigation practices based on real-time soil moisture data allowed for optimized water usage and a reduction in operational costs, leading to a more consistent yield regardless of abiotic stresses and environmental conditions.

Table 4. Watermelon Production Cost - Irrigation Scheduling: Soil Water Status (SWS) in Shorter, AL – 2022.

VARIABLE COST	UNIT	QUANTITY	COST PER UNIT ($)	TOTAL PER ACRE ($)
Land preparation				
Soil sampling (Nutrient analysis)	unit	1	$ 15.00	$ 15.00
Soil sampling (Physical properties)	unit	1	$ 13.50	$ 13.50
Soil preparation	unit	1	$ -	$ -
Irrigation (Drip tape 12in)	linear ft	7260	$ 0.03	$ 214.50
Bedding (Black TIF plastic mulch)	linear ft	7260	$ 0.03	$ 193.48
LABOR	hour	2.2	$ 18.43	$ 39.66
Planting				
Transplant cost (plants per acre)	plants	2420	$ 1.00	$ 2.420.00
LABOR	hour	5.0	$ 18.43	$ 92.92
Fertilizers				
Fertigation 20.20.20	lb.	40	$ 19.31	$ 778.72
Fertigation 4.0.13	lb.	10	$ 43.17	$ 435.11
Fertigation 9.0.0.11	lb.	5	$ 13.31	$ 67.06
LABOR	hour	7	$ 18.43	$ 132.47
Weed Control				
Curbit (ethalfluralin) Sibakab HFP Specialty	pts.	3	$ 11.50	$ 34.49
Profine (Halosulfuron-methyl) Profine 75	oz.	1	$ 47.30	$ 47.30
LABOR	hour	0.1	$ 18.43	$ 2.24
Disease/Insects Control				
Velum (fluopyram) Velum Prime	fl.oz.	6	$ 9.29	$ 63.17
Ridomil Gold (mefenoxam) Ridomil Gold SL	pts.	38.4	$ 5.77	$ 221.87
Abound (azoxystrobin) Abound	fl.oz.	15.5	$ 3.09	$ 47.94
Manzate (mancozeb) Manzate Pro-Stick	lb.	2	$ 9.00	$ 17.99
Spinosad (spinosyn a/d) Radiant SC	fl.oz.	10	$ 13.59	$ 135.93
Besiege (chlorantraniliprole) Acelepryn	oz.	24	$ 3.81	$ 91.39
Cuprofix Ultra 40 (mancozeb+Cu) Manzate Pro	lb.	2	$ 9.00	$ 17.99

Endigo (lambda-cyhalothrin) Cyonara 9.7	oz.	45.3	$ 0.60	$ 27.00
LABOR	hour	0.8	$ 18.43	$ 14.54
Machinery and implements				
Disk	hour	0.2	$ 69.87	$ 10.60
Plastic layer	hour	0.5	$ 74.48	$ 37.24
Sprayer	hour	0.9	$ 71.85	$ 65.38
Weagon	hour	3	$ 73.35	$ 220.06
LABOR		4.6	$ 18.43	$ 84.07
Harvest				
Harvesting	hour	30.0	$ 18,43	$ 552.90
30 count crates	unit	4	$ 22,00	$ 94.60
36 count crates	unit	21	$ 22,00	$ 459.80
45 count crates	unit	51	$ 22,00	$ 1.115.40
60 count crates	unit	34	$ 22,00	$ 743.60
Labor	hour	30	$ 18,43	$ 552.90
Irrigation Water				
Gallons of water	gallons	483489	0.00	0,00
Energy	kWh	3292.8	0.10	$ 329.28
TOTAL VARIABLE COSTS				**$ 9.390,08**
INCOME ABOVE VARIABLE COSTS				**$ 19.549,83**
FIXED COST				
Irrigation				
Sentec probes	unit	1	$ 1150.00	$ 1.150.00
Data logger	unit	1	$ 995.00	$ 995.00
Subscription	unit	1	$ 233.00	$ 233.00
Dosatron	unit	1	$ 429.00	$ 429.00
LABOR	HOUR	0.5	$ 18.43	9.22

TOTAL FIXED COSTS	**$ 2816.22**

TOTAL COSTS	**$ 12206.30**

Seeded Watermelon - Whole Sale Terminal Market - Atlanta July 5 (USDA) - SWS 2022				
Watermelon Count	30	36	45	60
Price per - Count ($)	$ 190.00	$ 250.00	$ 275.00	$ 265.00
Soil Water Status - Boxes Per Count	4	21	51	34
Sales per Count	$ 814.35	$ 5220.45	$ 13953.42	$ 8951.70
Total Revenue				**28939.92**

NET INCOME	**$ 16733.62**

Table 5. Watermelon Production Cost - Irrigation Scheduling: Crop Water Demand (CWD) in Shorter, AL – 2022.

VARIABLE COST	UNIT	QUANTITY	COST PER UNIT ($)	TOTAL PER ACRE ($)
Land preparation				
Soil Sampling (Nutrient analysis)	unit	1	$ 15.00	$ 15.00
Soil Sampling (Physical properties)	unit	1	$ 13.50	$ 13.50
Soil preparation	unit	1	$ -	$ -
Irrigation (Drip tape 12in)	linear ft	7260	$ 0.03	$ 214.50
Bedding (Black TIF plastic mulch)	linear ft	7260	$ 0.03	$ 193.48
LABOR	hour	2.2	$ 18.43	$ 39.66
Planting				
Transplant cost (plants per acre)	plants	2420	$ 1.00	$ 2.420.00
LABOR	hour	5.0	$ 18.43	$ 92.92
Fertilizers				
Fertigation 20.20.20	lb.	40	$ 19.31	$ 778.72
Fertigation 4.0.13	lb.	10	$ 43.17	$ 435.11
Fertigation 9.0.0.11	lb.	5	$ 13.31	$ 67.06
LABOR	hour	7	$ 18.43	$ 132.47
Weed Control				
Curbit (ethalfluralin) Sibakab HFP Specialty	pts.	3	$ 11.50	$ 34.49
Profine (Halosulfuron-methyl) Profine 75	oz.	1	$ 47.30	$ 47.30
LABOR	hour	0.1	$ 18.43	$ 2.24
Disease/Insects Control				
Velum (fluopyram) Velum Prime	fl.oz.	6	$ 9.29	$ 63.17
Ridomil Gold (mefenoxam) Ridomil Gold SL	pts.	38.4	$ 5.77	$ 221.87
Abound (azoxystrobin) Abound	fl.oz.	15.5	$ 3.09	$ 47.94
Manzate (mancozeb) Manzate Pro-Stick	lb.	2	$ 9.00	$ 17.99
Spinosad (spinosyn a/d) Radiant SC	fl.oz.	10	$ 13.59	$ 135.93
Besiege (chlorantraniliprole) Acelepryn	oz.	24	$ 3.81	$ 91.39
Cuprofix Ultra 40 (mancozeb+Cu) Manzate Pro	lb.	2	$ 9.00	$ 17.99

Endigo (lambda-cyhalothrin) Cyonara 9.7	oz.	45.3	$ 0.60	$ 27.00
LABOR	hour	0.8	$ 18.43	$ 14.54
Machinery and implements				
Disk	hour	0.2	$ 69.87	$ 10.60
Plastic layer	hour	0.5	$ 74.48	$ 37.24
Sprayer	hour	0.9	$ 71.85	$ 65.38
Weagon	hour	3	$ 73.35	$ 220.06
LABOR		4.6	$ 18.43	$ 84.07
Harvest				
Harvesting	hour	30	$ 18.43	$ 552.90
30 count crates	unit	17	$ 22.00	$ 374.00
36 count crates	unit	25	$ 22.00	$ 550.00
45 count crates	unit	38	$ 22.00	$ 836.00
60 count crates	unit	39	$ 22.00	$ 858.00
Labor	hour	30	$ 18.43	$ 552.90
Irrigation Water				
Gallons of water	gallons	705092	0.00	0.00
Energy	kWh	4802	0.10	$ 480.20
TOTAL VARIABLE COSTS				**$ 9745.60**
INCOME ABOVE VARIABLE COSTS				**$ 20519.40**
FIXED COST				
Irrigation				
weather station	unit	1	$ 496.00	$ 496.00
subscription	unit	1	$ 233.00	$ 233.00
Dosatron	unit	1	$ 429.00	$ 429.00
LABOR	HOUR	0.5	$ 18.43	9.22

TOTAL FIXED COSTS	**$ 1167.22**

TOTAL COSTS	**$ 10912.82**

Seeded Watermelon - Whole Sale Terminal Market - Atlanta July 5 (USDA) - SWS 2022				
Watermelon Count	30	36	45	60
Price per - Count ($)	$ 190.00	$ 250.00	$ 275.00	$ 265.00
Soil Water Status - Boxes Per Count	17	25	38	39
Sales per Count	$ 3230.00	$ 6250.00	$ 10450.00	$ 10335.00
Total Revenue				**30265.00**

NET INCOME	**$ 19352.18**

Table 6. Watermelon Production Cost - Irrigation Scheduling: Systematic Irrigation (SYS) in Shorter, AL – 2022.

VARIABLE COST	UNIT	QUANTITY	COST PER UNIT ($)	TOTAL PER ACRE ($)
Land preparation				
Soil Sampling (Nutrient analysis)	unit	1	$ 15.00	$ 15.00
Soil Sampling (Physical properties)	unit	1	$ 13.50	$ 13.50
Soil preparation	unit	1	$ -	$ -
Irrigation (Drip tape 12in)	linear ft	7260	$ 0.03	$ 214.50
Bedding (Black TIF plastic mulch)	linear ft	7260	$ 0.03	$ 193.48
LABOR	hour	2.2	$ 18.43	$ 39.66
Planting				
Transplant cost (plants per acre)	plants	2420	$ 1.00	$ 2.420.00
LABOR	hour	5.0	$ 18.43	$ 92.92
Fertilizers				
Fertigation 20.20.20	lb.	40	$ 19.31	$ 778.72
Fertigation 4.0.13	lb.	10	$ 43.17	$ 435.11
Fertigation 9.0.0.11	lb.	5	$ 13.31	$ 67.06
LABOR	hour	7	$ 18.43	$ 132.47
Weed Control				
Curbit (ethalfluralin) Sibakab HFP Specialty	pts.	3	$ 11.50	$ 34.49
Profine (Halosulfuron-methyl) Profine 75	oz.	1	$ 47.30	$ 47.30
LABOR	hour	0.1	$ 18.43	$ 2.24
Disease/Insects Control				
Velum (fluopyram) Velum Prime	fl.oz.	6	$ 9.29	$ 63.17
Ridomil Gold (mefenoxam) Ridomil Gold SL	pts.	38.4	$ 5.77	$ 221.87
Abound (azoxystrobin) Abound	fl.oz.	15.5	$ 3.09	$ 47.94
Manzate (mancozeb) Manzate Pro-Stick	lb.	2	$ 9.00	$ 17.99
Spinosad (spinosyn a/d) Radiant SC	fl.oz.	10	$ 13.59	$ 135.93
Besiege (chlorantraniliprole) Acelepryn	oz.	24	$ 3.81	$ 91.39
Cuprofix Ultra 40 (mancozeb+Cu) Manzate Pro	lb.	2	$ 9.00	$ 17.99

Endigo (lambda-cyhalothrin) Cyonara 9.7	oz.		45.3	$ 0.60	$ 27.00
LABOR	hour		0.8	$ 18.43	$ 14.54
Machinery and implements					
Disk	hour		0.2	$ 69.87	$ 10.60
Plastic layer	hour		0.5	$ 74.48	$ 37.24
Sprayer	hour		0.9	$ 71.85	$ 65.38
Weagon	hour		3	$ 73.35	$ 220.06
LABOR			4.6	$ 18.43	$ 84.07
Harvest					
Harvesting	hour		30	$ 18.43	$ 552.90
30 count crates	unit		5	$ 22.00	$ 110.00
36 count crates	unit		16	$ 22.00	$ 352.00
45 count crates	unit		44	$ 22.00	$ 968.00
60 count crates	unit		43	$ 22.00	$ 946.00
Labor	hour		30	$ 18.43	$ 552.90
Irrigation Water					
Gallons of water	gallons	755452		0.00	0,00
Energy	kWh	5145		0.10	$ 514,50
TOTAL VARIABLE COSTS					**$ 9537.90**
INCOME ABOVE VARIABLE COSTS					**$ 18907.10**
FIXED COST					
Irrigation					
Dosatron	unit		1	$ 429.00	$ 429.00
LABOR	HOUR		0.5	$ 18.43	9.22
TOTAL FIXED COSTS					**$ 438,22**

TOTAL COSTS	**$ 9.976,12**

Seeded Watermelon - Whole Sale Terminal Market - Atlanta July 5 (USDA) - SWS 2022				
Watermelon Count	30	36	45	60
Price per - Count ($)	$ 190.00	$ 250.00	$ 275.00	$ 265.00
Soil Water Status - Boxes Per Count	5.0	16.0	44.0	43.0
Sales per Count	$ 950.00	$ 4000.00	$ 12100.00	$ 11395.00
Total Revenue				**28445.00**

NET INCOME	**$ 18468.88**

Table 7. Watermelon Production Cost - Irrigation Scheduling: Soil Water Status (SWS) in Shorter, AL – 2023.

VARIABLE COST	UNIT	QUANTITY	COST PER UNIT ($)	TOTAL PER ACRE ($)
Land preparation				
Soil Sampling (Nutrient analysis)	unit	1	$ 15.00	$ 15.00
Soil Sampling (Physical properties)	unit	1	$ 13.50	$ 13.50
Soil preparation	unit	1	$ -	$ -
Irrigation (Drip tape 12in)	linear ft	7260	$ 0.03	$ 214.50
Bedding (Black TIF plastic mulch)	linear ft	7260	$ 0.03	$ 193.48
LABOR	hour	2.2	$ 18.43	$ 39.66
Planting				
Transplant cost (plants per acre)	plants	2420	$ 1.00	$ 2.420.00
LABOR	hour	5.0	$ 18.43	$ 92.92
Fertilizers				
Fertigation 20.20.20	lb.	40	$ 19.31	$ 778.72
Fertigation 4.0.13	lb.	10	$ 43.17	$ 435.11
Fertigation 9.0.0.11	lb.	5	$ 13.31	$ 67.06
LABOR	hour	7	$ 18.43	$ 132.47
Weed Control				
Curbit (ethalfluralin) Sibakab HFP Specialty	pts.	3	$ 11.50	$ 34.49
Profine (Halosulfuron-methyl) Profine 75	oz.	1	$ 47.30	$ 47.30
LABOR	hour	0.1	$ 18.43	$ 2.24
Disease/Insects Control				
Velum (fluopyram) Velum Prime	fl.oz.	6	$ 9.29	$ 63.17
Ridomil Gold (mefenoxam) Ridomil Gold SL	pts.	38.4	$ 5.77	$ 221.87
Abound (azoxystrobin) Abound	fl.oz.	15.5	$ 3.09	$ 47.94
Manzate (mancozeb) Manzate Pro-Stick	lb.	2	$ 9.00	$ 17.99
Spinosad (spinosyn a/d) Radiant SC	fl.oz.	10	$ 13.59	$ 135.93
Besiege (chlorantraniliprole) Acelepryn	oz.	24	$ 3.81	$ 91.39
Cuprofix Ultra 40 (mancozeb+Cu) Manzate Pro	lb.	2	$ 9.00	$ 17.99

Endigo (lambda-cyhalothrin) Cyonara 9.7	oz.	45.3	$ 0.60	$ 27.00
LABOR	hour	0.8	$ 18.43	$ 14.54
Machinery and implements				
Disk	hour	0.2	$ 69.87	$ 10.60
Plastic layer	hour	0.5	$ 74.48	$ 37.24
Sprayer	hour	0.9	$ 71.85	$ 65.38
Weagon	hour	3	$ 73.35	$ 220.06
LABOR		4.6	$ 18.43	$ 84.07
Harvest				
Harvesting	hour	30	$ 18.43	$ 552.90
30 count crates	unit	8	$ 22.00	$ 176.00
36 count crates	unit	20	$ 22.00	$ 440.00
45 count crates	unit	49	$ 22.00	$ 1.078.00
60 count crates	unit	37	$ 22.00	$ 814.00
Labor	hour	30	$ 18.43	$ 552.90
Irrigation Water				
Gallons of water	gallons	453271	0.00	0.00
Energy	kWh	3087	0.10	$ 308.70
TOTAL VARIABLE COSTS				**$ 9464.10**
INCOME ABOVE VARIABLE COSTS				**$ 20335.90**
FIXED COST				
Irrigation (SOIL WATER STATUS)				
Sentec probes	unit	1	$ 1150.00	$ 1150.00
data logger	unit	1	$ 995.00	$ 995.00
subscription	unit	1	$ 233.00	$ 233.00
Dosatron	unit	1	$ 429.00	$ 429.00
LABOR	HOUR	05	$ 18.43	9.22

TOTAL FIXED COSTS	**$ 2816.22**
TOTAL COSTS	**$ 12280.32**

Seeded Watermelon - Whole Sale Terminal Market - Atlanta July 5 (USDA) - SWS 2022

Watermelon Count	30	36	45	60
Price per - Count ($)	$ 190.00	$ 250.00	$ 275.00	$ 265.00
Soil Water Status - Boxes Per Count	8.0	20.0	49.0	37.0
Sales per Count	$ 1520.00	$ 5000.00	$ 13475.00	$ 9805.00
Total Revenue				**29800.00**

NET INCOME	**$ 17519.68**

Table 8. Watermelon Production Cost - Irrigation Scheduling: Crop Water Demand (CWD) in Shorter, AL – 2023.

VARIABLE COST	UNIT	QUANTITY	COST PER UNIT ($)	TOTAL PER ACRE ($)
Land preparation				
Soil Sampling (Nutrient analysis)	unit	1	$ 15.00	$ 15.00
Soil Sampling (Physical properties)	unit	1	$ 13.50	$ 13.50
Soil preparation	unit	1	$ -	$ -
Irrigation (Drip tape 12in)	linear ft	7260	$ 0.03	$ 214.50
Bedding (Black TIF plastic mulch)	linear ft	7260	$ 0.03	$ 193.48
LABOR	hour	2.2	$ 18.43	$ 39.66
Planting				
Transplant cost (plants per acre)	plants	2420	$ 1.00	$ 2.420.00
LABOR	hour	5.0	$ 18.43	$ 92.92
Fertilizers				
Fertigation 20.20.20	lb.	40	$ 19.31	$ 778.72
Fertigation 4.0.13	lb.	10	$ 43.17	$ 435.11
Fertigation 9.0.0.11	lb.	5	$ 13.31	$ 67.06
LABOR	hour	7	$ 18.43	$ 132.47
Weed Control				
Curbit (ethalfluralin) Sibakab HFP Specialty	pts.	3	$ 11.50	$ 34.49
Profine (Halosulfuron-methyl) Profine 75	oz.	1	$ 47.30	$ 47.30
LABOR	hour	0.1	$ 18.43	$ 2.24
Disease/Insects Control				
Velum (fluopyram) Velum Prime	fl.oz.	6	$ 9.29	$ 63.17
Ridomil Gold (mefenoxam) Ridomil Gold SL	pts.	38.4	$ 5.77	$ 221.87
Abound (azoxystrobin) Abound	fl.oz.	15.5	$ 3.09	$ 47.94
Manzate (mancozeb) Manzate Pro-Stick	lb.	2	$ 9.00	$ 17.99
Spinosad (spinosyn a/d) Radiant SC	fl.oz.	10	$ 13.59	$ 135.93
Besiege (chlorantraniliprole) Acelepryn	oz.	24	$ 3.81	$ 91.39
Cuprofix Ultra 40 (mancozeb+Cu) Manzate Pro	lb.	2	$ 9.00	$ 17.99

Endigo (lambda-cyhalothrin) Cyonara 9.7	oz.	45.3	$ 0.60	$ 27.00
LABOR	hour	0.8	$ 18.43	$ 14.54
Machinery and implements				
Disk	hour	0.2	$ 69.87	$ 10.60
Plastic layer	hour	0.5	$ 74.48	$ 37.24
Sprayer	hour	0.9	$ 71.85	$ 65.38
Weagon	hour	3	$ 73.35	$ 220.06
LABOR		4.6	$ 18.43	$ 84.07
Harvest				
Harvesting	hour	30	$ 18.43	$ 552.90
30 count crates	unit	1	$ 22.00	$ 22.00
36 count crates	unit	4	$ 22.00	$ 88.00
45 count crates	unit	22	$ 22.00	$ 484.00
60 count crates	unit	41	$ 22.00	$ 902.00
Labor	hour	30	$ 18.43	$ 552.90
Irrigation Water				
Gallons of water	gallons	541503	0.00	0.00
Energy	kWh	3687	0.10	$ 368.70
TOTAL VARIABLE COSTS				**$ 8512.10**
INCOME ABOVE VARIABLE COSTS				**R$ 9592.90**
FIXED COST				
Irrigation				
weather station	unit	1	$ 496.00	$ 496.00
subscription	unit	1	$ 233.00	$ 233.00
Dosatron	unit	1	$ 429.00	$ 429.00
LABOR	HOUR	0.5	$ 18.43	9.22

TOTAL FIXED COSTS	**$ 1167.22**

TOTAL COSTS	**$ 9679.32**

Seeded Watermelon - Whole Sale Terminal Market - Atlanta July 5 (USDA) - SWS 2022				
Watermelon Count	30	36	45	60
Price per - Count ($)	$ 190.00	$ 250.00	$ 275.00	$ 265.00
Soil Water Status - Boxes Per Count	1.0	4.0	22.0	41.0
Sales per Count	$ 190.00	$ 1.000.00	$ 6050.00	$ 10865.00
Total Revenue				**$ 18105.00**

NET INCOME	**$8425.68**

Table 9. Watermelon Production Cost - Irrigation Scheduling: Systematic Irrigation (SYS) in Shorter, AL – 2023.

VARIABLE COST	UNIT	QUANTITY	COST PER UNIT ($)	TOTAL PER ACRE ($)
Land preparation				
Soil Sampling (Nutrient analysis)	unit	1	$ 15.00	$ 15.00
Soil Sampling (Physical properties)	unit	1	$ 13.50	$ 13.50
Soil preparation	unit	1	$ -	$ -
Irrigation (Drip tape 12in)	linear ft	7260	$ 0.03	$ 214.50
Bedding (Black TIF plastic mulch)	linear ft	7260	$ 0.03	$ 193.48
LABOR	hour	2.2	$ 18.43	$ 39.66
Planting				
Transplant cost (plants per acre)	plants	2420	$ 1.00	$ 2.420.00
LABOR	hour	5.0	$ 18.43	$ 92.92
Fertilizers				
Fertigation 20.20.20	lb.	40	$ 19.31	$ 778.72
Fertigation 4.0.13	lb.	10	$ 43.17	$ 435.11
Fertigation 9.0.0.11	lb.	5	$ 13.31	$ 67.06
LABOR	hour	7	$ 18.43	$ 132.47
Weed Control				
Curbit (ethalfluralin) Sibakab HFP Specialty	pts.	3	$ 11.50	$ 34.49
Profine (Halosulfuron-methyl) Profine 75	oz.	1	$ 47.30	$ 47.30
LABOR	hour	0.1	$ 18.43	$ 2.24
Disease/Insects Control				
Velum (fluopyram) Velum Prime	fl.oz.	6	$ 9.29	$ 63.17
Ridomil Gold (mefenoxam) Ridomil Gold SL	pts.	38.4	$ 5.77	$ 221.87
Abound (azoxystrobin) Abound	fl.oz.	15.5	$ 3.09	$ 47.94
Manzate (mancozeb) Manzate Pro-Stick	lb.	2	$ 9.00	$ 17.99
Spinosad (spinosyn a/d) Radiant SC	fl.oz.	10	$ 13.59	$ 135.93
Besiege (chlorantraniliprole) Acelepryn	oz.	24	$ 3.81	$ 91.39
Cuprofix Ultra 40 (mancozeb+Cu) Manzate Pro	lb.	2	$ 9.00	$ 17.99

Endigo (lambda-cyhalothrin) Cyonara 9.7	oz.		45.3	$ 0.60	$ 27.00
LABOR	hour		0.8	$ 18.43	$ 14.54
Machinery and implements					
Disk	hour		0.2	$ 69.87	$ 10.60
Plastic layer	hour		0.5	$ 74.48	$ 37.24
Sprayer	hour		0.9	$ 71.85	$ 65.38
Weagon	hour		3	$ 73.35	$ 220.06
LABOR			4.6	$ 18.43	$ 84.07
Harvest					
Harvesting	hour		30	$ 18.43	$ 552.90
30 count crates	unit		0	$ 22.00	$ -
36 count crates	unit		5	$ 22.00	$ 110.00
45 count crates	unit		23	$ 22.00	$ 506.00
60 count crates	unit		47	$ 22.00	$ 1034.00
Labor	hour		30	$ 18.43	$ 552.90
Irrigation Water					
Gallons of water	gallons	906542		0.00	0.00
Energy	kWh	6174		0.10	$ 617.40
TOTAL VARIABLE COSTS					**$ 8914.80**
INCOME ABOVE VARIABLE COSTS					**$ 11115.20**
FIXED COST					
Irrigation					
Dosatron	unit		1	$ 429.00	$ 429.00
LABOR	HOUR		0.5	$ 18.43	9.22
TOTAL FIXED COSTS					**$ 438.22**

TOTAL COSTS	**$ 9353.02**

Seeded Watermelon - Whole Sale Terminal Market - Atlanta July 5 (USDA) - SWS 2022				
Watermelon Count	30	36	45	60
Price per - Count ($)	$ 190.00	$ 250.00	$ 275.00	$ 265.00
Soil Water Status - Boxes Per Count	0.0	5.0	23.0	47.0
Sales per Count	$ -	$ 1.250.00	$ 6325.00	$ 12455.00
Total Revenue				**20030.00**

NET INCOME	**$ 10676.98**

Chapter 4

Conclusion

The results of this graduate research dissertation highlight the significant impact of irrigation scheduling on watermelon production under different weather conditions. Over the two growing seasons, rainfall events were well distributed, with higher rainfall accumulation measured in 2023 compared to 2022. These distinct weather patterns influenced the biomass accumulation and total yield of watermelon crops under different irrigation scheduling methods.

In 2022, the SWS and SYS treatments exhibited higher biomass compared to 2023, while CWD showed consistent results across both years. Notably, SWS consistently maintained higher biomass accumulation in 2023, indicating its resilience to weather-induced waterlogging conditions. The positive correlation between biomass accumulation and watermelon yield further highlights the importance of effective irrigation strategies in optimizing crop productivity. Moreover, the SWS method increased IWP, indicating its efficiency in converting irrigation water into fruit weight. Particularly, this study’s findings strongly support the implementation of the SWS approach as an effective irrigation scheduling strategy for maximizing watermelon growth and yield.

Ultimately, the SWS increased profitability and financial success in both years. This can be attributed to improved water management, energy savings, and overall cost-efficiency by implementing soil moisture sensors. Therefore, the ability to monitor and adjust irrigation practices based on real-time soil moisture data allowed for optimized water usage and reduced operational costs. Consequently, the positive changes in financial parameters highlight the economic benefits of using the SWS method of irrigation scheduling.

Chapter 5

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