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Yield Production and Water Use Efficiency under Furrow and Drip Irrigation Systems for Watermelon in South Texas

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ABSTRACT

Effective irrigation techniques involve methods that enhance crop yield production and quality while conserving water. Crop production with supplemental irrigation is commonly practiced in south Texas due to frequent droughts and limited water supplies. Due to increasing demands on water use, there is a necessity to use efficient irrigation methods that can increase water use efficiency. When compared to furrow irrigation, drip irrigation is efficient in reducing evaporation from the soil, runoff and leaching below the root zone. There have been increasing trends to switch from furrow to drip irrigation in watermelon commercial production. The main goal of this study was to compare watermelon crop production, fruit quality, and water use efficiency under subsurface drip irrigation (with and without plastic mulch) and furrow irrigation. Field experiments were conducted during the spring of 2014, under a completely randomized block experiment with three treatments and four replications each. The treatments were: furrow irrigated, and subsurface drip irrigated with and without plastic mulch. Irrigation scheduling followed an Internet based reference ET estimator couple with a crop coefficient model reported in FAO 56. There were no differences in watermelon yield between the drip and furrow irrigation systems. However, the Drip-Plastic and Drip-Bare irrigation treatments used 46% and 60% less water respectively, than the furrow irrigated treatment, thus influencing the irrigation and water use efficiencies. The highest irrigation efficiencies for the watermelon were observed for the drip irrigated treatment with plastic mulch (27.6 kg m^{-3}) and for the bare soil (23.1 kg m^{-3}).

Additional index words: Plastic mulch, irrigation scheduling, soil water content

Texas ranks third in watermelon production in the United States. More than 42,000 acres of watermelon are grown in Texas, making it the largest annual horticultural crop in the state (Regional IPM Centers, 2012), with commercial cash value of $52 million annually and an economic impact exceeding $160 million. A significant amount of watermelon production is grown in the Lower Rio Grande Valley (LRGV) an area with recurrent droughts and limited water supplies. Furrow irrigation is the most common irrigation method in the LRGV (Enciso et al., 2015). Recently, there has been an increasing trend in this LRGV area to switch from furrow to drip irrigation in watermelon. Subsurface drip irrigation (SDI) has recently been considered more efficient in reducing evaporation and runoff while applying water at crop's root zone. SDI has been defined by American Society of Agricultural and Biological Engineers (ASABE) as the application of water below the soil surface by micro irrigation emitters with discharge rates usually less than 7.5 L h^{-1} (2 Gal/h), (ASABE Standards, 2001). The benefits of adopting drip irrigation and subsurface drip irrigation systems have to be justified by increases in productivity and fruit quality to offset the high cost of these systems. Another reason that it favors uniform germination and good stands during the critical phase of crop establishment (Lamm et al., 2012). In addition, SDI may improve water use efficiency, optimize the use of fertilizers, fungicides and other pesticides (Ayars et al., 1999) through precise applications in the root zone (Locasio, 2015). SDI can be used with plastic mulches to enhance crop production and quality (Sanders et al., 1999; Yoghi et al., 2015). The use of polyethylene film as a plastic mulch cover on crop beds can further aid in conservation of water and reduce the application of herbicides (Lament, 1993). It may also aid in pest management and in reducing weed competition resulting in healthier crops (Lamont, 2005). SDI can improve plant growth and development by modifying the soil temperature, humidity, and sunlight around the plant (Soltani, Anderson, & Hamson, 1995). The main goal of this study was to compare watermelon crop production, fruit quality, and water use efficiency under subsurface drip irrigation with plastic (Drip-Plastic), subsurface drip irrigation without plastic (Drip-Bare) and furrow irrigation.

MATERIALS AND METHODS

Experimental Design and Plant Characteristics. The experiment was conducted during the 2014 spring season at the Texas A&M AgriLife Research Center located in Weslaco, TX (lat. 97°57' W, long. 26°9' N). The region is characterized by semi-arid climate with an annual rainfall of 699.26 mm (http://southtexasweather.tamu.edu/). At the beginning of the experiment, seedless watermelon (*Citrullus lanatus*) variety SS 7197 (Abbott and Cobb; Feasterville, PA) and the pollinator POL-4370 (Abbott and Cobb; Feasterville, PA) were sowed in a greenhouse on 10 Feb. 2014, and then hand transplanted to the field on 17 Mar. 2014. Crop management practices were conducted according to common local practices (Table 1).

Table 1. Watermelon management practices conducted during 2014.

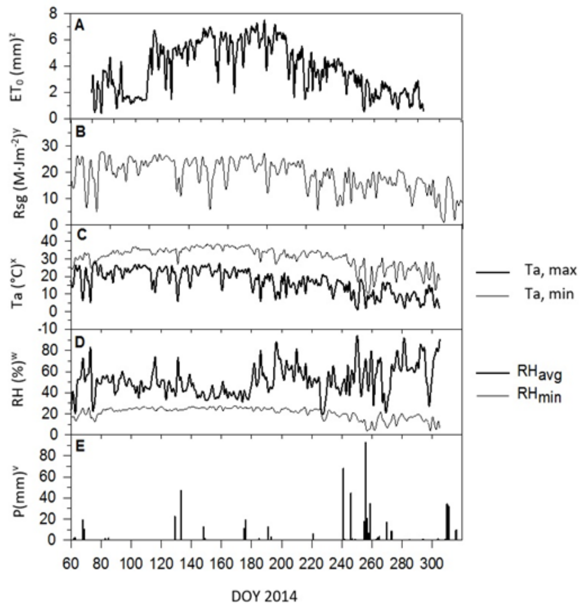
Operation	2014
Planting	17 March
First fertilizer application	21 March
Second fertilizer application	11 April
Third fertilizer application	25 April
Fourth fertilizer application	21 May
Last irrigation	28 May
Harvest	24 June, 10 July
Length of growing season (d)	115

These varieties were planted in a 3:1 ratio with pollinator POL-4370 at 12 inches between plants on raised beds centered on 80 inches. The soil profile was characterized by sandy clay loam to fine-loamy, mixed, and hyperthermic Typic Calciustolls.The experimental design consisted of a completely randomized design with three treatments: furrow irrigated, subsurface drip irrigation with plastic mulch (Drip-Plastic), and subsurface drip without plastic mulch (Drip-Bare). Treatments were arranged in separate contiguous blocks each containing four rows of watermelon. Each treatment-block consisted of four 80-inches wide beds by 321 ft long rows for an area of 2143 ft^2. Treatment-blocks were separated from each other by a space of 160 inches of bare-ground. Each treatment-block was divided into 4 sub-plots as replications from which various watermelon fruit yield and quality parameters were recorded. This type of design was used due to irrigation constraints, and to avoid cross contamination and border effects. The Rio Grande River was the source of irrigation water, and had an average electrical conductivity of 0.13 S m^{-1}, filtered with a sand media filter for the drip irrigation system, but unfiltered for the furrow water. A single dripline was installed per bed and it was buried 2 inches below the soil surface. The drip line was a Netafim Python (Netafim; Fresno, CA), with a 12.5 mil thickness (0.0125 inch or 0.317 mm), 30 cm (12 inches) emitter spacing, and a 0.91 L h^{-1} (0.24 Gal/h) nominal discharge per emitter. A black, non-degradable plastic mulch with a width of 91.44 cm and thickness of 0.032 mm was used in the drip-plastic treatments. The amount of water applied to the plots was recorded with totalized water meters connected to each drip irrigation treatment. Furrow was delivered with a flexible plastic pipe and its volume was measured with a flow meter. The furrows were blocked at the end and no runoff was produced. The fertilizers 4-29-2, 5-26-3-3 (S), and 12-12-6 were applied as sources of Nitrogen (N), Phosphorus (P), and Potassium (K) and Sulfur (S). Equal fertilizer amounts were applied for all treatments through a drip system in split applications at rates of 78 kg·ha^{-1} N, 35 kg·ha^{-1} P, and 12.1 kg·ha^{-1} K based on soil analysis recommendations of the Soil and Water Testing Laboratory at Texas A&M University. A drip irrigation system was installed in the furrow treatments to apply the same amount of fertilizers in all treatments. The driplines in the furrow irrigation system were only used to apply fertilizers. The fertilizer was injected with the drip irrigation system to assure the same amount of fertilizer was uniformly applied to all the treatments and to evaluate the yield response to water without adding fertilizer as a variable. The dripline was flushed for ten minutes after applying the fertilizer to avoid emitter plugging. The total water applied per fertilization event was 0.06 inches.

Irrigation Scheduling and Experimental Measurements. Irrigation scheduling was conducted based on a water balance approach using an internet-based program (http://southtexasweather.tamu.edu) run by Texas A&M AgriLife Research Center in Weslaco, TX (Enciso et al., 2015). Key meteorological variables such as maximum and minimum air temperature, relative humidity, total solar radiation and average wind speed for the experimental site were collected hourly and reported as a daily average from an automated, electronic weather station (model ET106; Campbell Scientific, Logan, UT). Watermelon evapotranspiration was calculated using the crop coefficients suggested by FAO-56 (Allen et al., 1998), which were 0.4 for initial, developmental phase (0.4-1.0), 1.0 for mid and 0.75 for end season. The lengths of the four growing stages were 10 d for initial, 20 d for developmental, 20 d for mid, and 30 d for the end stage. Some additional inputs needed for the internet-based program were measured such as root depth, management allowable depletion, planting date, initial water content, and soil type. The root depth for the watermelon used by the program was 2.8 ft and the maximum allowable depletion was 43%. Irrigation amounts in the furrow treatment were determined by water depletion levels, while drip plots were irrigated approximately twice per week by replacing watermelon evapotranspiration. Soil moisture sensors (EC-5; Decagon Devices; Pullman, WA) were used to monitor fluctuations in soil water status. Two soil water sensors were installed per treatment in only one replication (replication 1) and data loggers were used to record the daily readings. The sensors were placed at 6 and 18 inches below the soil surface and about 2 inches from the drip tape to monitor irrigation near the root zone.

Once watermelon reached maturity, 30 m of row length were randomly selected for harvest from each treatment per replication. Following grower practices of sequential harvesting by picking larger fruit first, our experimental plots were harvested on 24 June and 10 July 2014. Yield and fruit weight were measured, and fruit quality was determined by measuring °Brix from the extractable juice using a handheld refractometer (model REF211ATC; Grainger, Lake Forest, IL), fruit length, fruit diameter and rind thickness. Applied water amounts were measured for the three irrigation methods at the end of the season. Water productivity (WP) was calculated as the ratio of the mass of marketable yield (Y_a) to the volume of water consumed by the crop: WP (kilograms per cubic meter) = Y_a / ET_C (Geerts and Raes, 2009). Irrigation water productivity (IWP) was calculated as the ratio between marketable yield (Y_a) and irrigation amount applied (Howell, 2001). To evaluate the effect of irrigation type on watermelon yield, fruit weight, and quality, an analysis of variance was conducted (using the Proc GLM of SAS (SAS version 9.1; SAS Institute Inc., 2011). When significant differences ($p < 0.05$) were obtained, treatment means were separated using the Student-Newman-Keuls test.

Fig. 1. Time course for 2014 of the FAO-56 Penman-Monteith potential evapotranspiration.



DOY = day of year; 60 = 01 Mar.

[z]ETo, solar radiation, 1 mm = 0.0394 inch.

[y]Rsg, maximum air temperature, MJ·m-2 = 23.9006 langleys.

[x]Ta,max, max and min air temperature, Ta, min , average air humidity, (1.8 x ºC) + 32 = ºF.

[w]percentage of average, RHavg, and minimum, RHmin. relative air humidity.

[v]precipitation, 1 mm = 0.0394 inch.

RESULTS AND DISCUSSION

Meteorological Conditions. Meteorological conditions recorded – rainfall and relative humidity, solar radiation (R_s), and potential evapotranspiration (ET_o), are showed in Fig.1. The average rainfall received in 2014 was 198.9 mm during the experimental period. The highest rainfall rates were recorded from late September till the end of December. The month that received the most rainfall was December with 25 mm. The highest average relative was observed in December (83.5%) and the lowest in September (40.6%). The highest temperatures were observed during May to August, with average of 38°C. The mean annual ET_o was 4 mm/day.

Soil Water Content. Fluctuations in soil moisture during the irrigation season are shown in Fig. 2. Volumetric water content increased after irrigation or rainfall. Highest values of water content were recorded during the rainy period, started in DOY 106 (April 16) and ended in DOY 184 (July 3rd). The results demonstrated that the plastic mulch was the most effective in retaining water and consequently increasing soil moisture levels during the growing season (Fig. 2). Less water

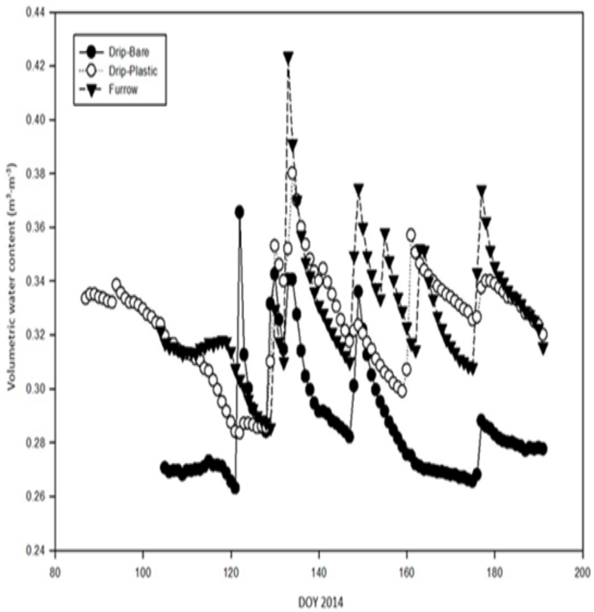


Fig. 2. Average EC-5 (Decagon Devices; Pullman WA) volumetric water content soil moisture readings, Drip-Bare, Drip-Plastic, and Furrow. DOY = day of year; 60 = 01 Mar.
[z]1 m^3 = 35.3147 ft^3.

was applied to the Drip-Plastic irrigation treatment than the Drip-Bare considering that two irrigation events were skipped during the growing season because the soil was wet. Shorter and more frequent drip irrigation cycles kept soil moisture more constant during the growing season compared to furrow irrigation. The big spikes observed on the furrow irrigation system were due to the saturation of the soil after each irrigation event. Although the irrigation applications in furrow irrigation treatments were fewer (4 irrigations, 27.4 cm^3) than those in the drip irrigated treatments (11-13 irrigations, 11.7 cm^3 for Drip-plastic, and 14.7 cm^3 for Drip-bare), the furrow treatment received a greater volume of water (27.4 cm^3).

Fruit Yield and Weight. The watermelon yields are shown in Table 2. There were no statistical differences among the yields for furrow irrigation, or Drip-Bare and Drip-Plastic irrigation. Numerically, Drip-Plastic yield (70,096 kg/ha) was slightly higher than Drip-Bare (65,871 kg/ha), while furrow irrigation was the lowest (64,960 kg/ha). Fruit weight significantly varied with the irrigation type, producing heavier fruit with Drip-Plastic irrigation (7.4 kg), and Drip-Bare irrigation (8.0 kg) than furrow irrigation (6.9 kg)

Table 2. Watermelon yield and average fruit weight.

Irrigation treatment	Yield [mean ± SD ($kg \cdot ha^{-1}$)[z]]	Fruit weight [mean ± SD (kg)[y]]
2014		
Furrow	64,960 ± 4,747 a[x]	6.9 ± 0.1 c
Drip-plastic	70,096 ± 6,738 a	7.4 ± 0.1 b
Drip-bare	65,871 ± 2,214 a	8.0 ± 0.2 a
F value	**0.31**	**16.62**
df	**2, 9**	**2, 9**
P value	**0.74**	**<0.0001**

Data represents the average ± standard deviation of each treatment.
[z]1 kg·ha-1 = 0.8922 lb/acre.
[y]1 kg = 2.2046 lb.
[x]Different letters indicate significant differences between treatments at $P < 0.001$.

(Table 2). Bigger fruit size can be sold at higher market price. Cull fruit was not counted because they were too small or defective. According to Legacy Growers Inc., a company dedicated to growing watermelon in LRGV, annual South Texas watermelon production is approximately 22,670 kg/ha. The results indicate that the use of a water balance approach to schedule irrigation resulted an almost tripling of the yield, regardless of irrigation method.

Fruit Quality. Brix for furrow (11.13%) was significantly lower than Drip-Plastic (11.91%) and Drip-Bare (11.86%), with °Brix values under Drip-Plastic and Drip-Bare being statistically similar to each other. Although not statistically different, numerically higher values of watermelon lengths were obtained in drip-bare and drip-plastic irrigation than furrow irrigation. Watermelon was also measured for diameter where results indicated no significant differences. Similarly, rind thickness values were recorded with no significant differences among the treatments. These results of higher Brix indicate that low irrigation amounts under drip irrigation systems can maintain or improve watermelon quality when compared to the traditional furrow irrigation treatments. The effect of these treatments on nutrient leaching was not tested.

Water Productivity and Irrigation Water Productivity. Irrigation amounts and frequencies for watermelon in each treatment were recorded to determine WP and IWP (Table 4). Irrigation applied in drip irrigated treatments was approximately 51% less than in furrow treatments, and the lowest yield was recorded for furrow irrigated plots. Thus, WP was considerably higher for the drip plastic and bare irrigation treatments (27.6 – 23.2 $kg.m^{-3}$) respectively than the furrow treatment (15.8 $kg.m^{-3}$). Total WP value of furrow was 43% less than Drip-Plastic and 32% less than Drip-Bare; how-

Table 3. Watermelon quality characteristics: °Brix , fruit length, fruit diameter, and rind thickness for each irrigation treatment.

Treatment	°Brix (%)[z]	Length (cm)[x]	Diameter (cm)[x]	Rind thickness (cm)[x]
2014				
Furrow	11.1 ± 0.2 b[y]	29.2 ± 0.5 a	23.6 ± 0.3 a	1.8 ± 0.1 a
Drip-plastic	11.9 ± 0.2 a	29.8 ± 0.6 a	24.5 ± 0.4 a	1.8 ± 0.1 a
Drip-bare	11.9 ± 0.1 a	30.4 ± 0.4 a	24.5 ± 0.3 a	1.8 ± 0.1 a
F-value	**7.88**	**1.61**	**2.43**	**0.35**
DF	**2, 9**	**2, 9**	**2, 9**	**2, 9**
p-value	**0.0010**	**0.2085**	**0.0971**	**0.7049**

Data represents the average ± standard deviation of each treatment.
[z] Percent of total soluble solids.
[x]1 cm = 0.3937 inch.
[y]Different letters indicate significant differences among treatments at P <0.001.

ever, furrow IWP was 39% lower than Drip-Plastic and 48% lower than Drip-Bare. IWP for Drip-Plastic and Drip-Bare were 2.5 and 1.9 times greater than furrow, respectively. These results prove that drip irrigation is the best method to use under limited water resources; not only because it provided better yield and quality, but also because it reduced water usage compared to furrow irrigation. Antony and Singandhupe (2003) observed slightly higher yields for capsicum irrigated with drip irrigation systems, but, the furrow system used approximately 60% more water. In addition, using plastic mulch was effective in preserving soil moisture and probably weed growth was visual observed and increasing overall fruit quality. The use of plastic mulch restricts the soil water evaporation, making soil water levels more constant throughout the growing season. The use of plastic mulch modifies soil temperature and moisture. Higher carbon dioxide concentrations have been observed under plastic mulch, benefiting plants during the early developmental stages (Soltani et al., 1995). A similar study comparing muskmelons with different irrigation treatments demonstrated that when irrigation is excessive, muskmelon growth can be impaired (Leskovar et al., 2001). It is important to point out both over-irrigation and under-irrigation with furrow and/or drip irrigation may result in reduced yields. Drip alternatives to conventional surface irrigation lead to improved water savings and better water productivity (Darouich et al., 2014). Other studies that have compared drip irrigation and furrow irrigation systems, resulted in fruit yield increase under drip irrigation (Ayars et al., 2001). Smaller and more frequent applications of water made through drip irrigation deliver water to crops more efficiently to meet plant and water nutrient needs while avoiding flood stress (Leskovar et al., 2001). Furrow irrigation commonly creates cycli-

Table 4. Calculation of Evapotranspiration (ET), Water Productivity (WP)[z], and Irrigation Water Productivity (IWP)[y].

Treatment	Irrigation (cm)[x]	Rainfall (cm)[x]	Irrigations (no.)	ET (cm)[x]	WP ($kg \cdot m^{-3}$)[w]	IWP ($kg \cdot m^{-3}$)[w]
2014						
Furrow	27.4	13.7	4	39.6	15.8 ± 0.1 b[v]	23.7 ± 0.2 c
Drip-plastic	11.7	13.7	11	39.6	27.6 ± 0.3 a	60.0 ± 0.6 a
Drip-bare	14.7	13.7	13	39.6	23.2 ± 0.1 a	44.7 ± 0.2 b
F-Value					**11.90**	**25.90**
DF					**2, 9**	**2, 9**
p-value					**0.0030**	**0.0002**

Data represents the average ± standard deviation of each treatment.

[z]WP = yield / total water applied (irrigation + rainfall)
[y]IWP = yield / irrigation water applied
[x]1 cm = 0.3937 inch
[w]1 kg·m-3 = 1.6856 lb/yard[a]
[v]Different letters indicate significant differences among treatments at *P* <0.001.

cal soil water deficits related to long intervals between each irrigation.

CONCLUSION

This study demonstrated that both drip and furrow irrigation systems can provide high watermelon yields when properly managed. Similar yields were observed with both furrow and drip irrigation systems. However, sweeter watermelon were obtained with the drip irrigated over furrow irrigated treatments. °Brix were similar for Drip-Plastic and Drip-Bare irrigation systems. The Drip-Plastic and Drip-Bare irrigation treatments used 46% and 60% less water, respectively, than the furrow irrigated treatment, thus influencing the irrigation and water use efficiencies. Drip irrigation may be a good option under water limiting conditions or when fruit quality and, specifically, TSS is an important parameter for the grower. The highest irrigation efficiencies for the watermelon were observed for the drip irrigated treatment with plastic mulch (27.6 kg m^{-3}) and for the bare soil (23.1 kg m^{-3}). One important note in this study observed watermelon yields that were approximately three times higher than those typically observed in LRGV watermelon production, suggesting that implementation of a water balanced approach to irrigation can lead to greater fruit production and potentially economic gains to growers.

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LITERATURE CITED

Abbasi, F., Rezaee, H.T., Jolaini, M. and Alizadeh, H.A., 2012. Evaluation of fertigation in different soils and furrow irrigation regimes. Irrigation and Drainage, 61(4), pp.533-541.

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M., 1998. Crop evapotranspiration-Guidelines for computing crop water requirements-
FAO Irrigation and drainage paper 56.FAO, Rome, 300(9), p.D05109.

Antony, E. and Singandhupe, R.B., 2004. Impact of drip and surface irrigation on growth, yield and WUE of capsicum (*Capsicum annum* L.). Agricultural water management, 65(2), pp.121 -132.

ASABE Standards. 2001 S526.2: Soil and water terminology. St. Joseph, Mich.: ASABE.

Ayars, J.E., Phene, C.J., Hutmacher, R.B., Davis, K.R., Schoneman, R.A., Vail, S.S. and Mead, R.M., 1999. Subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research Laboratory. Agricultural water management, 42(1), pp.1-27.

Ayars, J.E., Schoneman, R.A., Dale, F., Meso, B. and Shouse, P., 2001. Managing subsurface drip irrigation in the presence of shallow ground water. Agricultural Water Management, 47(3), pp.243-264.

Bang, H., Leskovar, D.I., Bender, D.A. and Crosby, K., 2004. Deficit irrigation impact on lycopene, soluble solids, firmness and yield of diploid and triploid watermelon in three distinct environments. The Journal of Horticultural Science and Biotechnology, 79(6), pp.885-890.

Darouich, H.M., Pedras, C.M., Gonçalves, J.M. and Pereira, L.S., 2014. Drip vs. surface irrigation: A comparison focussing on water saving and economic returns using multicriteria analysis applied to cotton. Biosystems Engineering, 122, pp.74-90.

Enciso, J., Porter, D. and Peries, X., 2007. Irrigation Monitoring with Soil Water Sensors (Spanish). Texas FARMER Collection.

Enciso, J., Wiedenfeld, B., Jifon, J. and Nelson, S., 2009. Onion yield and quality response to two irrigation scheduling strategies. Scientia horticulturae, 120(3), pp.301-305.

Enciso, J., Jifon, J., Anciso, J. and Ribera, L., 2015. Productivity of onions using subsurface drip irrigation versus furrow irrigation systems with an internet-based irrigation scheduling program. International Journal of Agronomy, 2015.

Geerts, S. and Raes, D., 2009. Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. Agricultural water management, 96(9), pp.1275-1284.

Howell, T.A., 2001. Enhancing Water Use Efficiency in Irrigated Agriculture Contrib. from the USDA-ARS, Southern Plains Area, Conserv. and Production Res. Lab., Bushland, TX 79012. Mention of trade or commercial names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-ARS. Agronomy journal, 93 (2), pp.281-289.

Karimi, M. and Gomrokchi, A., 2011. Yield and water use efficiency of corn planted in one or two rows and applying furrow or drip tape irrigation systems in Ghazvin Province, Iran. Irrigation and drainage, 60(1), pp.35-41.

Lamont, W.J., 2017. Plastic mulches for the production of vegetable crops. In A Guide to the Manufacture, Performance, and Potential of Plastics in Agriculture (pp. 45-60).

Lamm, F.R., Bordovsky, J.P., Schwankl, L.J., Grabow, G.L., Enciso-Medina, J., Peters, R.T., Colaizzi, P.D., Trooien, T.P. and Porter, D.O., 2012. Subsurface drip irrigation: Status of the technology in 2010. Transactions of the ASABE, 55(2), pp.483-491.

Lamont, W.J., 2005. Plastics: Modifying the microclimate for the production of vegetable crops. HortTechnology, 15(3), pp.477-481.

Leib, B.G., Jabro, J.D. and Matthews, G.R., 2003. Field evaluation and performance comparison of soil moisture sensors. Soil Science, 168(6), pp.396-408.

Leskovar, D.I., Ward, J.C., Sprague, R.W. and Meiri, A., 2001. Yield, quality, and water use efficiency of muskmelon are affected by irrigation and transplanting versus direct seeding. Hortscience, 36(2), pp.286-291.

Littell, R. C., G. A. Milliken, W. W. Stroup, R. D. Wolfinger, and O. Schabenberger. 2006. SAS® for Mixed Models, 2nd Ed.. Cary, N.C.: SAS Institute, Inc.

Miller, G., Khalilian, A., Adelberg, J.W., Farahani, H.J., Hassell, R.L. and Wells, C.E., 2013. Grafted watermelon root length density and distribution under different soil moisture treatments.HortScience,48(8), pp.1021-1026.

Regional IPM Centers: Crop Profile for Watermelon in Texas 2012. Retrieved from: http://www.ipmcenters.org/cropprofiles/docs/TXwatermelons2012.pdf

Sanders, D.C., Cure, J.D. and Schultheis, J.R., 1999. Yield response of watermelon to planting density, planting pattern, and polyethylene mulch. HortScience, 34(7), pp.1221-1223.

Soltani, N., Anderson, J.L. and Hamson, A.R., 1995. Growth analysis of watermelon plants grown with mulches and rowcovers. Journal of the American Society for Horticultural Science, 120(6), pp.1001-1009.

Yaghi, T., Arslan, A. and Naoum, F., 2013. Cucumber (Cucumis sativus, L.) water use efficiency (WUE) under plastic mulch and drip irrigation. Agricultural Water Management, 128, pp.149-157.