WATER USE AND IRRIGATION MANAGEMENT for Vegetables in Georgia: *Solanaceae* Crops

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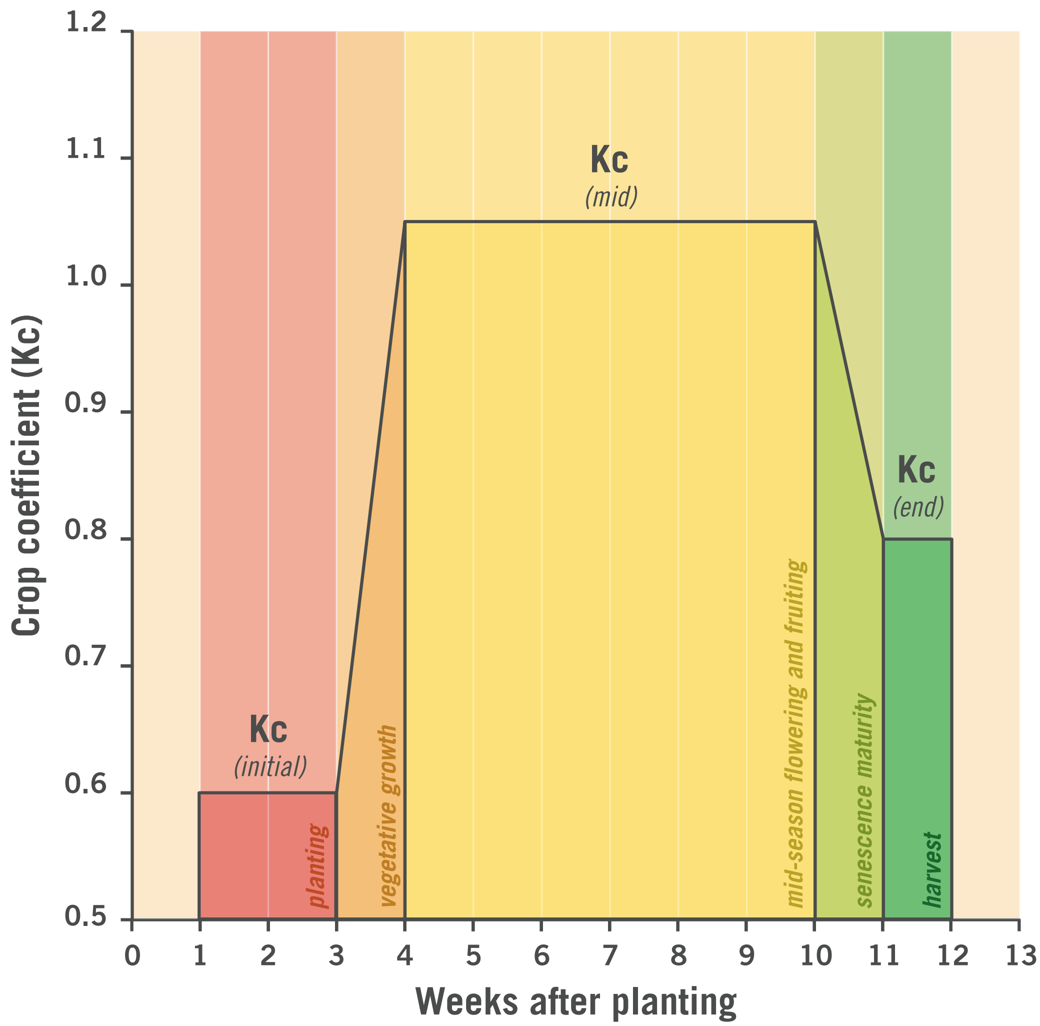
This publication is the third in a series focusing on irrigation scheduling for vegetable crops. It contains basic information on water use and irrigation management using the crop water demand method for *Solanaceae* crops such as bell peppers, tomatoes, and eggplants.

Irrigation scheduling

Growers have numerous available strategies of irrigation scheduling to supply vegetable crops with water. See UGA Cooperative Extension Bulletin 1511, "Principles of Irrigation and Scheduling for Vegetable Crops in Georgia," for information. The crop water demand method is one of the simplest and most precise methods to determine irrigation events. Using the crop water demand method, also known as crop evapotranspiration (ETc), means irrigation is supplying the daily volume of water uptake by the crop. Consequently, when properly managed, irrigation events using the ETc will minimize crop water stresses caused by the lack or excess of soil water.

The ETc is calculated by multiplying a daily reference evapotranspiration (ETo) by a crop coefficient (Kc). The ETo represents the weather portion of the ETc, and daily ETo can be gathered from the Georgia Automated Environmental Monitoring Network for several locations in the state. The Kc represents the water required by the crop and varies according to stages of the crop development. Like most vegetable crops, the Kc of *Solanaceae* crops is divided into initial (Kc_{ini}; seedling stage), midseason (Kc_{mid}), and end-season (Kc_{end}; harvest stage), and the Kc values used for each stage of crop development are 0.6, 1.05, and 0.8, respectively (Allen *et al.*, 1998); (Figure 1).

Figure 1. Crop coefficient (Kc) for *Solanaceae* crops (bell peppers, tomatoes, and eggplants) during the early season (Kc_{ini}), mid-season (Kc_{mid}), and end season (Kc_{end}) in weeks after planting.



Figures 2 and 3 show stages of crop development (i.e., Kc_{ini}, Kc_{mid}, and Kc_{end}) for bell peppers and tomatoes, respectively. The Kc_{ini} (0.6) represents the early stage of crop development and is normally used during seedling production and from transplanting until root establishment, which takes about two weeks. After root establishment, *Solanaceae* crops enter into the vegetative stage and crop water requirements increase, and consequently, the Kc_{ini} gradually changes to Kc_{mid} (1.05). The Kc_{mid} is the most critical period of crop development and should be used from the vegetative stage, through the flowering stage, until the fruiting stage. The Kc_{mid} on *Solanaceae* crops goes from three weeks after transplanting until 10 weeks after transplanting, but it can be extended if multiple harvests occur. When plants start to senesce, water uptake is used for maintenance instead of reproduction, reducing the water requirement of *Solanaceae* crops. Kc_{mid} reduces to Kc_{end} (0.8), as seen in Figures 2C and 3C. In *Solanaceae* crops for which multiple harvests can be conducted, the Kc_{end} is recommended to be used only for the final harvest.

Figure 2. Stages of crop development for bell peppers according to the crop coefficient (Kc).

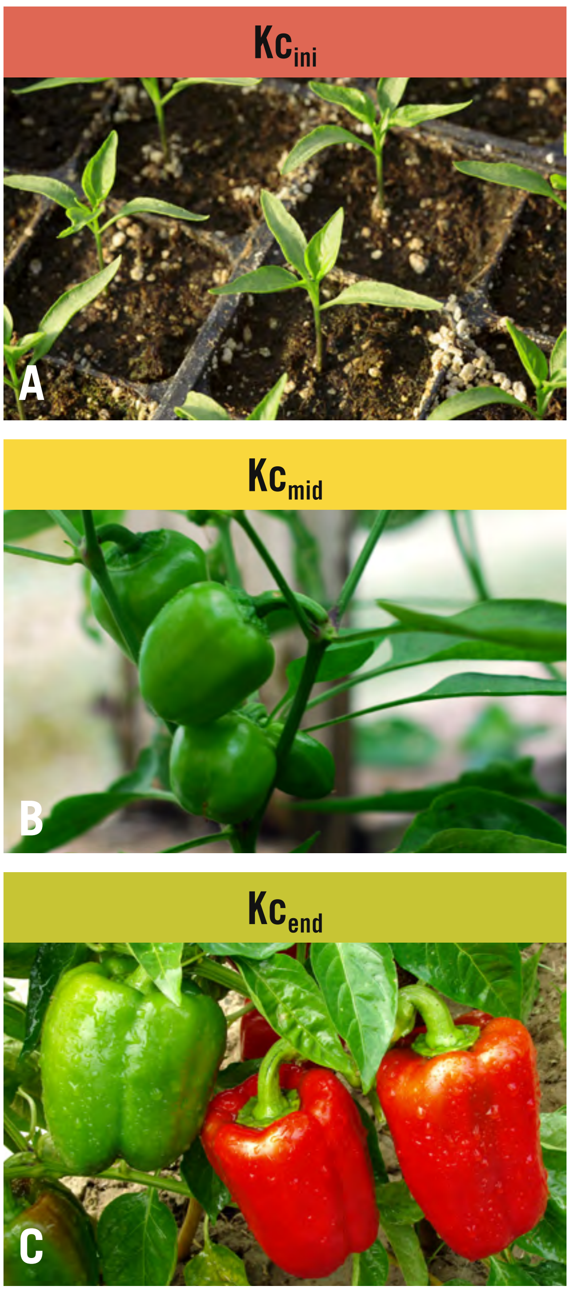
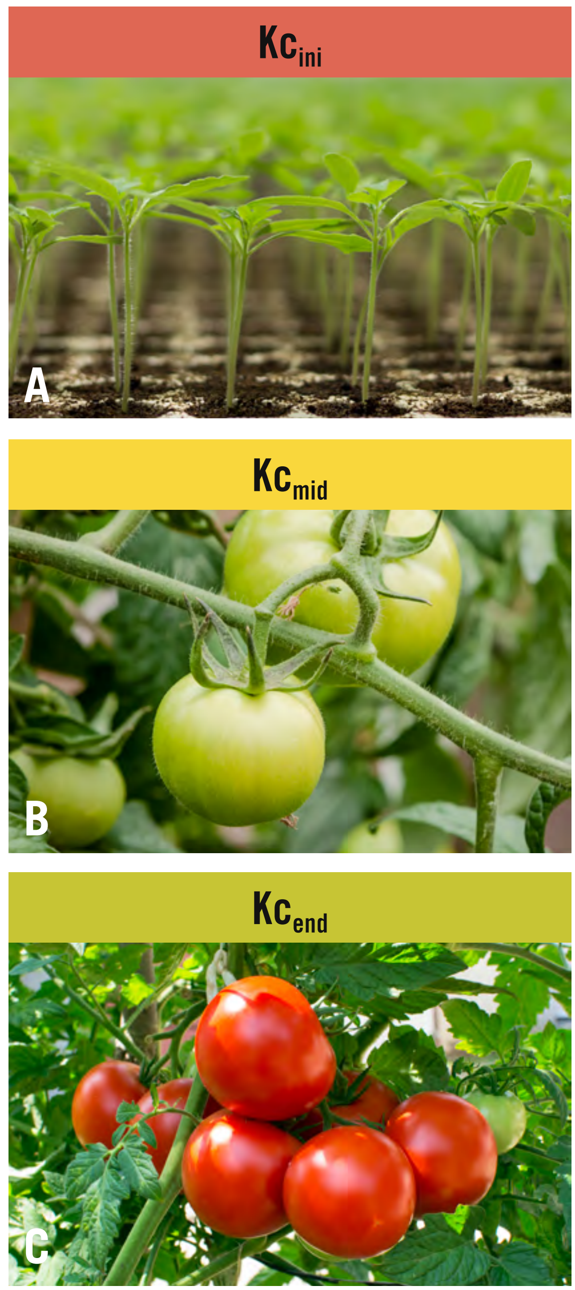


Figure 3. Stages of crop development for tomatoes according to the crop coefficient (Kc).

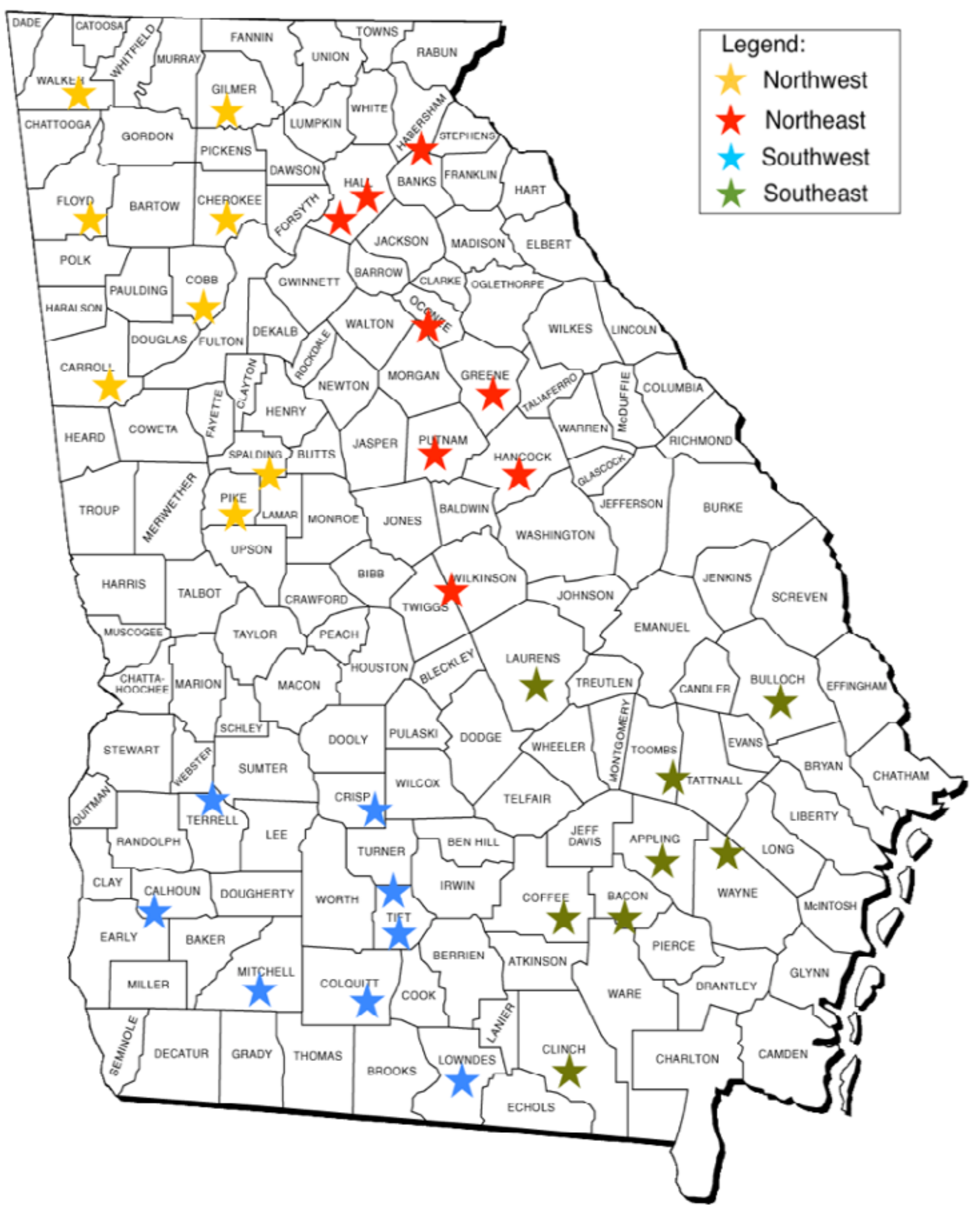


Scheduling irrigation events for *Solanaceae* crops in Georgia

Bell peppers, tomatoes, and eggplants are the main *Solanaceae* crops grown in the state. They are planted in March and April for the spring growing season and August and September for the fall growing season. In both seasons, these *Solanaceae* crops are grown under plastic mulching systems with drip irrigation, which allow growers to maximize the irrigation water use efficiency and crop yield by spoon feeding water to plants.

Researchers calculated 18 years of historical information on the ETc of *Solanaceae* crops and used the data to schedule weekly irrigation strategies for four planting dates in the spring season (i.e., March 1, March 15, April 1, and April 15) and fall season (August 1, August 15, September 1, and September 15) in the southwest, southeast, northwest, and northeast regions of Georgia. Daily ETc from 2000 to 2017 was calculated using the average ETo of eight different locations in each of the four regions of Georgia (Figure 4), and the Kc_{ini} (0.6), Kc_{mid} (1.05), and Kc_{end} (0.8) for *Solanaceae* crops (Figure 1).

Figure 4. Locations of weather stations used to collect historical weather data from each region of Georgia.

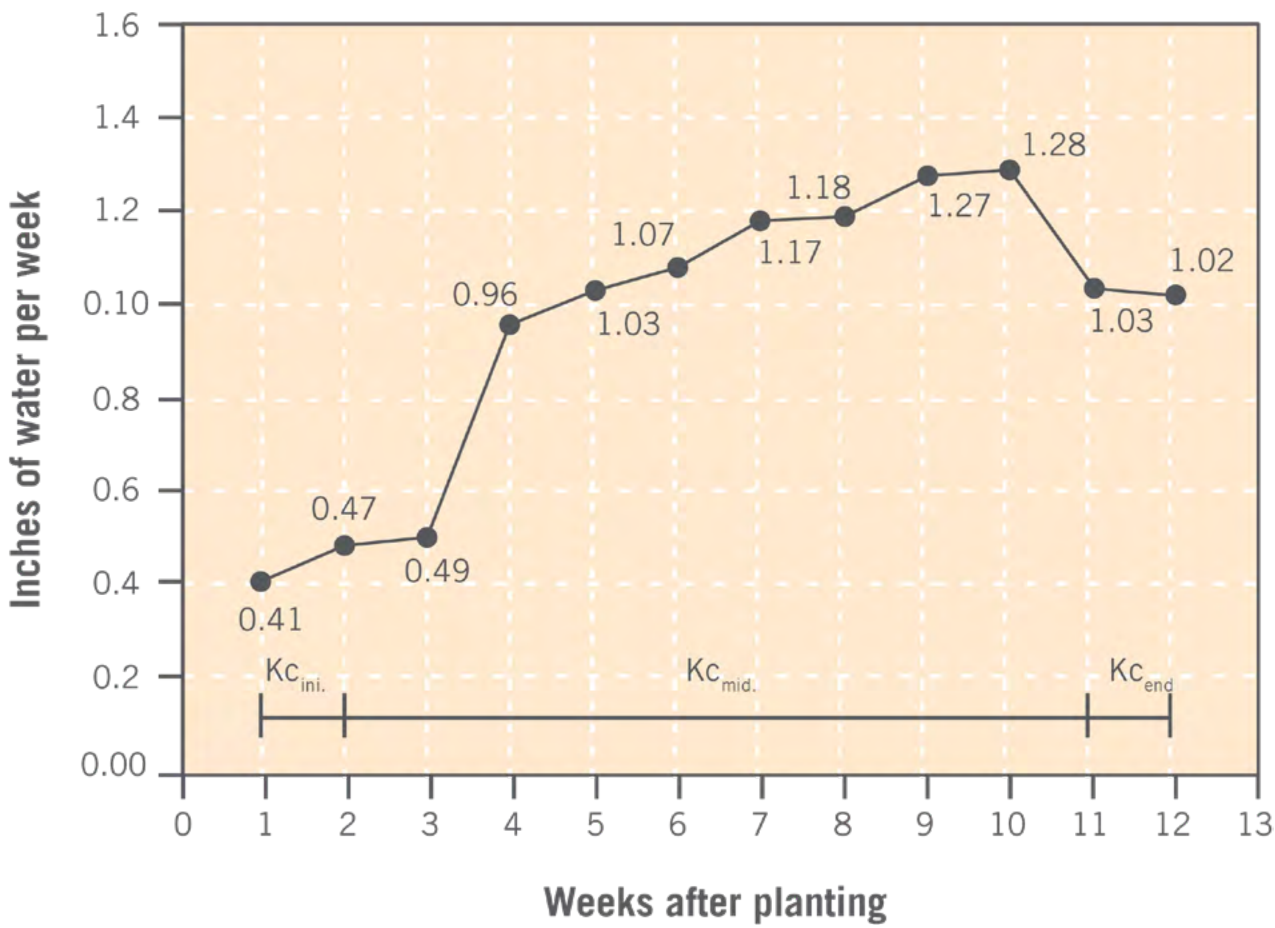


Spring

In spring, *Solanaceae* crops require low volumes of irrigation water early in the season in Georgia (Figure 5). This is due to both cold air temperatures and low crop water requirements. The fourth week after transplanting, plant leaf size rapidly increases (increase in Kc), which is associated with the constant increase in daily air temperature during the spring season. This may double the crop water requirement compared to the early season (Figure 5). Water stress during this period should be avoided. While a water deficit affects plant growth and reduces yield, excess water reduces the number of fruits per plant and fruit marketability (Smittle *et al*., 1994). In the case of multiple harvests, commonly seen in *Solanaceae* crops, irrigation must continue to ensure flowering and fruiting. It is important to highlight that the high temperatures of late spring in Georgia will stress plants if water is not sufficient. To prevent this, irrigation water should be reduced only a few days before the final harvest (Figure 5) when plants will start to senesce.

Table 1 presents a guideline for scheduling irrigation events on a weekly basis for *Solanaceae* crops planted March 1, March 15, April 1, and April 15 by location within the state of Georgia (i.e., southwest, southeast, northwest, and northeast). The weekly volume of water required for *Solanaceae* crops should assist growers to properly schedule irrigation events.

Figure 5. The average irrigation water demand in inches of water per week for *Solanaceae* crops (tomatoes, bell peppers, and eggplants) grown during the spring season in Georgia. The average was calculated from a combination of 18 years of weather data (from 2000 to 2017), four different planting dates (e.g., March 1, March 15, April 1, and April 15), and 24 locations around Georgia.

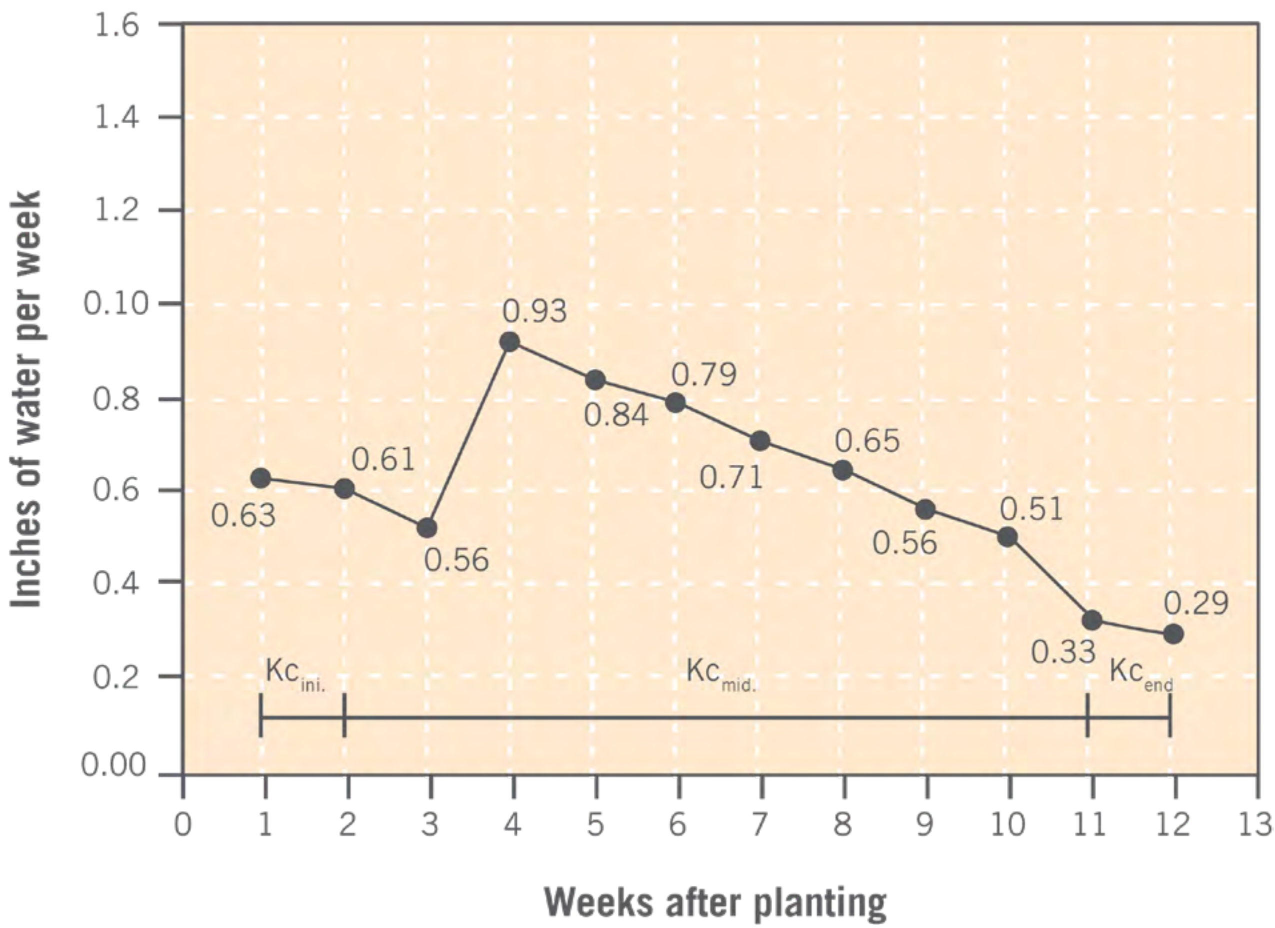


Fall

Unlike the spring season, irrigation water requirements for *Solanaceae* crops are high early on during the fall season (Figure 6). This is due to high daily air temperatures more than crop water demand. After transplanting, water demand is high and *Solanaceae* crops are still small with poorly developed root systems, so irrigation events should be more frequent in order to minimize water stress and ensure plant survival. As *Solanaceae* crops develop into the fall season, irrigation water volumes peak due to fast canopy closure, which increases crop water demand (Figure 6). From four to 11 weeks, a decrease in daily air temperature (cooler temperatures) also decreases irrigation water volumes, but this does not mean there is a reduction in crop water demand. Contrarily, irrigation water during this period is crucial to ensure flowering and fruiting (Smittle *et al.*, 1994; Dukes *et al.*, 2003). During harvest, irrigation is also important to ensure continued fruit growth and quality. Similar to spring, growers should only reduce irrigation water a few days before the last harvest in the fall season (Figure 6).

The volume of water required weekly by *Solanaceae* crops is presented in Table 2 to assist growers in scheduling irrigation events according to planting date (i.e., August 1, August 15, September 1, and September 15) and location in Georgia (i.e., southwest, southeast, northwest, and northeast).

Figure 6. The average irrigation water demand in inches of water per week for *Solanaceae* crops (tomatoes, bell peppers, and eggplants) grown during the fall season in Georgia. The average was calculated from a combination of 18 years of weather data (from 2000 to 2017), four different planting dates (e.g., August 1, August 15, September 1, and September 15), and 24 locations around Georgia.



Food safety considerations

Because most *Solanaceae* crops are drip irrigated, the U.S. Food and Drug Administration's Produce Safety Rule (PSR) does not require irrigation water testing, as irrigation water is not likely to contact the harvestable portion of the crop. However, it is still recommended to periodically test microbial water quality of irrigation sources by collecting a 100 milliliter (ml) water sample in a sterile collection bottle for generic *Escherichia coli* analysis. Growers who elect to collect water samples may use the PSR guideline of ≤ 126 colony forming units (CFU) or the most probable number (MPN) per 100 ml sample as a guideline (FDA, 2015). Growers that must comply with third-party audits (PRIMUS GFS, USDA GAP, etc.) should consult their auditor for testing frequency and *E. coli* level requirements. Your local UGA Extension office can provide you instructions on submitting a water sample for analysis by the UGA Agricultural and Environmental Services Laboratories.

Summary

Weather variabilities like temperature, solar radiation, relative humidity, and wind speed are the main factors impacting ETc (Allen *et al*., 1998). Consequently, irrigation water requirements for *Solanaceae* crops in both seasons (i.e., spring and fall) are more dependent on planting date than location in the state. While late planting dates will require higher volumes of irrigation water than early planting dates in the spring (Table 1), late planting dates require lower volumes of irrigation water than early planting dates in the fall (Table 2). Overall, irrigation water requirements reported in Tables 1 and 2 can be used for irrigation scheduling in *Solanaceae* crops. However, increased water use efficiency, which means the ratio of crop yield per volume of water irrigated, can be achieved when ETc is combined with soil moisture monitoring. This way irrigation events will never apply more water than required by crops or the soil field capacity, which is the maximum water a soil can hold. More information on irrigation scheduling using soil moisture sensors can be found in UGA Extension Bulletin 1511, "Principles of Irrigation and Scheduling for Vegetable Crops in Georgia." The efficiency of irrigation systems should also be considered before applying water. More information for drip irrigation systems can be found in UGA Extension Circular 1093, "Drip Irrigation Checklist: Start-Up."

Table 1. Historical irrigation water demand per week for *Solanaceae* crops on four planting dates (March 1, March 15, April 1, and April 15) in the spring season of southwest, southeast, northwest, and northeast Georgia.

Week after planting	Southwest				Southeast				Northwest				Northeast			
	3/1	3/15	4/1	4/15	3/1	3/15	4/1	4/15	3/1	3/15	4/1	4/15	3/1	3/15	4/1	4/15
	inches of water per week															
1	0.33	0.42	0.48	0.60	0.30	0.38	0.44	0.56	0.25	0.33	0.39	0.50	0.26	0.34	0.40	0.52
2	0.41	0.50	0.57	0.66	0.38	0.44	0.52	0.60	0.33	0.40	0.47	0.57	0.33	0.39	0.48	0.55
3	0.42	0.48	0.60	0.71	0.38	0.44	0.56	0.65	0.33	0.39	0.50	0.60	0.34	0.40	0.52	0.60
4	0.88	0.99	1.16	1.27	0.77	0.91	1.04	1.16	0.69	0.82	1.01	1.05	0.68	0.84	0.95	1.06
5	0.85	1.05	1.24	1.41	0.77	0.97	1.13	1.33	0.69	0.88	1.04	1.20	0.70	0.91	1.05	1.22
6	0.99	1.16	1.27	1.37	0.91	1.04	1.16	1.22	0.82	1.01	1.05	1.16	0.84	0.95	1.06	1.14
7	1.05	1.24	1.41	1.47	0.97	1.13	1.33	1.33	0.88	1.04	1.20	1.28	0.91	1.05	1.22	1.27
8	1.16	1.27	1.37	1.46	1.04	1.16	1.22	1.32	1.01	1.05	1.16	1.27	0.95	1.06	1.14	1.28
9	1.24	1.41	1.47	1.42	1.13	1.33	1.33	1.32	1.04	1.20	1.28	1.32	1.05	1.22	1.27	1.30
10	1.27	1.37	1.46	1.52	1.16	1.22	1.32	1.43	1.05	1.16	1.27	1.40	1.06	1.14	1.28	1.43
11	1.08	1.12	1.08	1.17	1.01	1.01	1.00	1.07	0.91	0.98	1.00	1.09	0.93	0.97	0.99	1.08
12	1.04	1.11	1.16	1.06	0.93	1.01	1.09	0.99	0.88	0.97	1.07	1.01	0.87	0.97	1.09	1.05
Total	**10.7**	**12.1**	**13.3**	**14.1**	**9.8**	**11.0**	**12.1**	**13.0**	**8.9**	**10.2**	**11.5**	**12.5**	**8.9**	**10.2**	**11.5**	**12.5**

Table 2. Historical irrigation water demand per week for *Solanaceae* crops on four planting dates (August 1, August 15, September 1, and September 15) in the fall season of southwest, southeast, northwest, and northeast Georgia.

Week after planting	Southwest				Southeast				Northwest				Northeast			
	8/1	8/15	9/1	9/15	8/1	8/15	9/1	9/15	8/1	8/15	9/1	9/15	8/1	8/15	9/1	9/15
	inches of water per week															
1	0.75	0.74	0.65	0.60	0.70	0.68	0.59	0.55	0.21	0.20	0.18	0.16	0.19	0.19	0.16	0.15
2	0.75	0.71	0.63	0.53	0.70	0.64	0.57	0.49	0.21	0.20	0.17	0.15	0.19	0.18	0.16	0.14
3	0.74	0.65	0.60	0.51	0.68	0.59	0.55	0.46	0.20	0.18	0.16	0.14	0.19	0.16	0.15	0.13
4	1.24	1.10	0.93	0.79	1.11	1.00	0.86	0.69	0.34	0.30	0.26	0.22	0.31	0.28	0.24	0.19
5	1.13	1.04	0.88	0.71	1.03	0.95	0.81	0.64	0.31	0.29	0.24	0.20	0.28	0.26	0.22	0.18
6	1.10	0.93	0.79	0.69	1.00	0.86	0.69	0.63	0.30	0.26	0.22	0.19	0.28	0.24	0.19	0.17
7	1.04	0.88	0.71	0.57	0.95	0.81	0.64	0.53	0.29	0.24	0.20	0.16	0.26	0.22	0.18	0.15
8	0.93	0.79	0.69	0.53	0.86	0.69	0.63	0.47	0.26	0.22	0.19	0.14	0.24	0.19	0.17	0.13
9	0.88	0.71	0.57	0.43	0.81	0.64	0.53	0.39	0.24	0.20	0.16	0.12	0.22	0.18	0.15	0.11
10	0.79	0.69	0.53	0.36	0.69	0.63	0.47	0.32	0.22	0.19	0.14	0.10	0.19	0.17	0.13	0.09
11	0.54	0.43	0.33	0.23	0.49	0.40	0.29	0.20	0.15	0.12	0.09	0.06	0.13	0.11	0.08	0.06
12	0.52	0.40	0.27	0.20	0.48	0.35	0.25	0.18	0.14	0.11	0.08	0.05	0.13	0.10	0.07	0.05
Total	**10.4**	**9.1**	**7.6**	**6.1**	**9.5**	**8.2**	**6.9**	**5.5**	**2.9**	**2.5**	**2.1**	**1.7**	**2.6**	**2.3**	**1.9**	**1.5**

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