Project Title: Evaluation of Drip Irrigation in Organic Spinach Production and Downy Mildew Management

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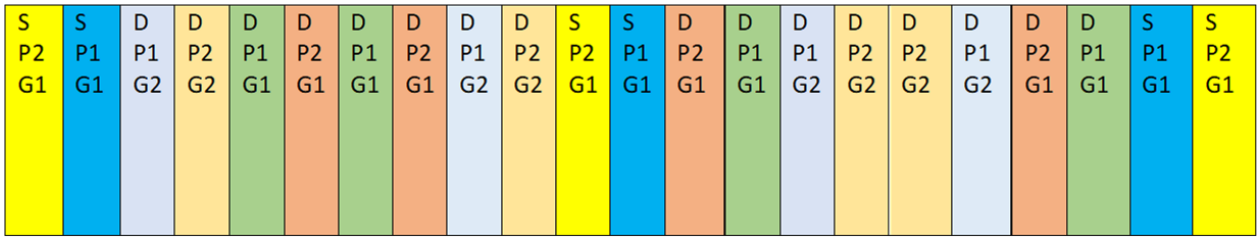
Abstract. This project aimed to evaluate the viability of drip irrigation for organic spinach production and the management of spinach downy mildew over a three-year period. Four trials were conducted in fall 2018, winter 2019, winter 2020, and winter 2021 at the UC Desert Research and Extension Center (UC DREC) in Holtville, while this report includes the winter 2021 trial. In this trial, strip and standard planting methods and germination by drip were evaluated. Sprinkler irrigation was considered as control treatment. No significant plant density difference was observed between sprinkler and drip germinated plots with similar planting methods. The canopy development model showed that the canopy cover of drip irrigated plots was 2-5 days behind in time in compared with sprinkler irrigated plots. Although downy mildew pressure was generally low in most parts of the trial and the incidence in most treatments were not statistically different, there was a clear numerical trend of lower downy mildew incidence in drip irrigated plots by a factor of at least 4. Slight yellowing issue was observed in a few beds under standard planting, but this symptom was not observed in any beds under strip planting. Statistically, no significant yield difference was found between the sprinkler treatments and most drip treatments. An average of 4% yield difference was observed as a result of planting method in drip irrigated plots. Strip planting method could be an effective approach to overcome the nitrogen management issue for producing organic spinach under drip.

Objectives. The main objective of this project is to evaluate the viability of adapting drip irrigation for organic spinach production. The project particularly aims to understand the optimal dripline spacings, and irrigation and nitrogen management practices to successfully produce spinach. The efforts attempt to assess germination by drip and the impact of drip irrigation on the management of spinach downy mildew.

Procedures. The field experiment was carried out in winter 2021 at the UC DREC in a silty clay soil (Fig. 1). Untreated Viroflay spinach seeds were planted at a rate of 2,950,000 per acre on January 7th. The experiment was arranged in a randomized complete block with four replications (each replication had three beds). Beds were 200 ft. long and on 80 in. center spacing. Irrigation treatments were sprinkler and drip with three driplines per bed. For drip treatment, strip and standard plantings, and germination by drip were tested. Both strip and standard plantings were also tested in sprinkler treatment. The driplines had an emitter spacing of 8 in. and an emitter flowrate of 0.13 gph @8 psi, and were installed at a depth of 1.5 in. A similar N application rate was considered for all treatments.



Standard planting (P1) Strip planting (P2)

S: Sprinkler
D: Drip with 3-dripline (all drip beds have three driplines)
P1: standard planting
P2: strip planting method
G1: germination by sprinkler (one week using sprinkler)
G2: germination by drip (using drip for germination)
All the drip irrigated beds are in one nitrogen application levels.

Fig. 1. Field experiment layout (not to scale) and planting methods.

True 6-6-2 (a homogeneous pelleted fertilizer) was applied at a rate of 100 lbs. of N/acre pre-plant fertilizer and 40 lbs. N/acre as top dress before first irrigation. True 4-1-3 (a liquid fertilizer from True Organic Products) was applied as complementary fertilizer over the crop season through injection into irrigation systems, totally at a rate of 100 lbs. N/acre. Following crop ET and using soil moisture data, it was tried to irrigate spinach trial more than crop water requirements to make sure there is no water stress the entire crop season, however this led to over-irrigation at some points in early and mid-crop season according to our data.

Field measurements: Images were taken on weekly basis utilizing an infrared camera (NDVI digital camera) to quantify the development of the crop canopy of each treatment. NDVI assigns for Normalized Difference Vegetation Index, a measurement of plant health. A combination of Watermarks and Decagon 5TE sensors were installed at three depths to monitor soil moisture on a continuous basis. The applied water for the irrigation treatments was measured throughout the crop season using magnetic flowmeters, and plant leaf wetness values were measured using Spectral Reflectance Sensors and dielectric leaf wetness sensors on a continuous basis. Leaf chlorophyll and SPAD were measured with a LEAF CHL STD sensor.

Plant density measurement was conducted on January 25th. The number of germinated plants were measured in three samples areas (each 2 feet length) in each bed. Yield biomass

measurements at different times (37, 42, 47, 51 days after seeding) were carried out from three sample areas of 6 ft^2 (3 ft × 2 ft) per replication and treatment. The bed located in the center of each replication in each of the treatments was selected as the sample bed (four sample beds per each treatment, for a total of 24 sample beds). Fresh weight was measured in order to determine biomass accumulation. The statistical significances were performed using general linear mixed model in SAS statistical analysis package.

Fig. 2. A view of plots irrigated by sprinkler and drip during the first irrigation event after seeding.

Downy mildew: Downy mildew incidence was assessed over the course of March 3rd by randomly selecting 3 locations in each bed for each plot and assessing the number of plants with downy mildew symptoms in a 1-meter length of bed at that position. The number of plants was converted to percent incidence by dividing by the number of plants in each segment, which in turn was calculated from the plant density evaluation.

Results.

Plan density: No significant difference was observed between plant population of sprinkler and drip germinated plots with the same planting methods. While the average plant density was 689 plant per 2 ft. length of bed in sprinkler germinated plots, the average plant density was 673 plant per 2 ft. length of bed in the drip treatments (Fig. 3). Lower plant density was observed in the strip planting method when compared with the standard planting method, while the seeding rate of strip planting was also 7% less.

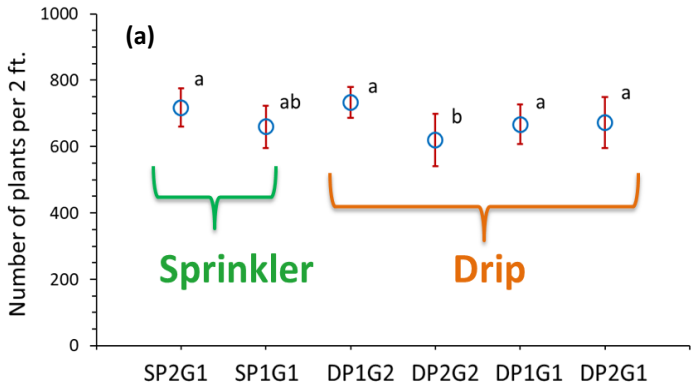


Fig. 3. Spinach plant density counted on January 25th in different treatments (a), research staff count the number of plants germinated in 2 feet length of each bed (b). The error bars show the standard deviation values.

Canopy cover over the season: The percentage of canopy cover was assessed for each of the treatments (Fig. 4). Although there were not accurate measurements of canopy cover during the first two weeks after planting, the data show that the canopy cover of drip irrigated plots was slightly behind in time (2 to 5 days) in compared with sprinkler irrigated plots. This result was also observed in the earlier trials.

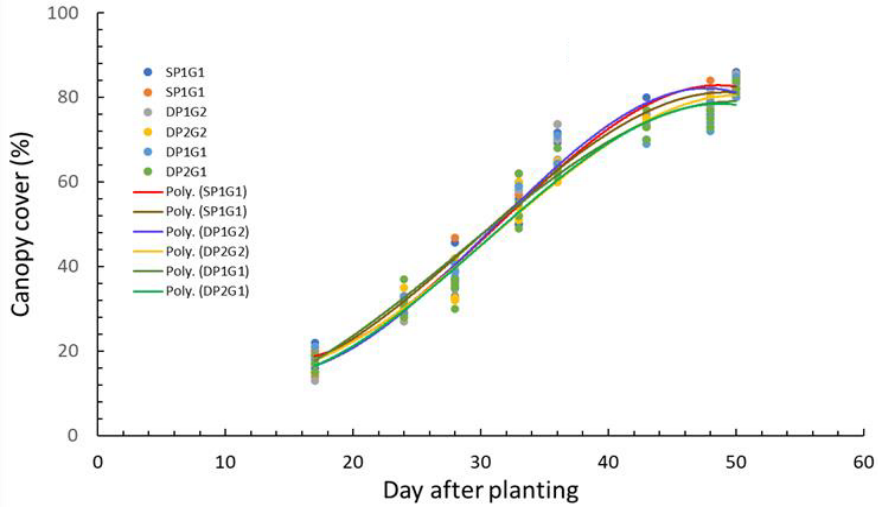


Fig. 4. Canopy crop curve over the crop season in the different irrigation treatments.

Total N content of plant tissue: No N deficiency was observed in both drip and sprinkler irrigated plots during the crop season. The mean total N content of plant tissue was 4.53% and 4.37% on DAY 35 after seeding in drip and sprinkler irrigated plots, respectively (Fig. 5). Yellowing of leaves in between driplines wasn't observed in this trial. The new fertigation strategy (top dress before the first irrigation) could be a reason for well-developed canopy and lack of nitrogen deficiency in drip irrigated plots specifically in beds with standard planting. While slight yellowing issue was still observed in a few beds with standard planting method, this symptom was not observed in any beds with the strip planting method. Figure 6 shows crop growth status in the drip strip and standard planting on 42 days after seeding.

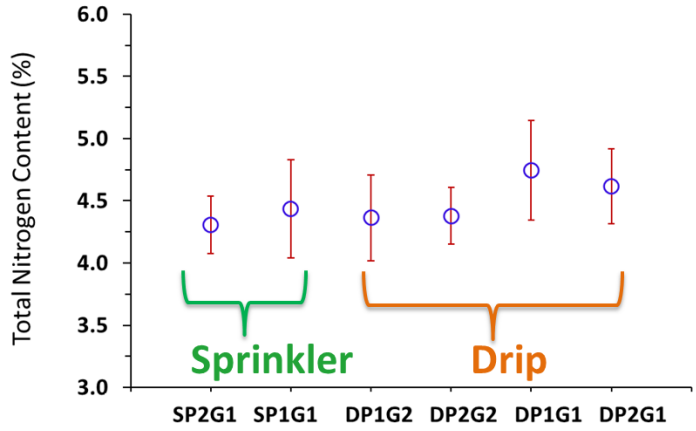


Fig. 5. Total Nitrogen Content of Plant Tissue (DAY 35). The error bars show the standard deviation values.

Fresh yields over time: The results of canopy development clearly demonstrate that a longer crop season for spinach should be expected in drip irrigated fields. In this trial, the fresh yields in the drip treatments on DAY 51 was compared with the fresh yields in the sprinkler treatments on DAY 47 (Fig. 7). A 1-6% less yield was observed in drip irrigate plots.

Fig. 6. Visual comparison of drip treatments (strip and standard planting method) on the date of 41 days after seeding.

Statistically, no significant yield difference was found between the sprinkler treatments and most drip treatments (table 1). An average of 2% yield difference was observed as a result of planting method in sprinkler irrigated plots. This yield difference was 4% resulting the impact of planting method in drip irrigated plots.

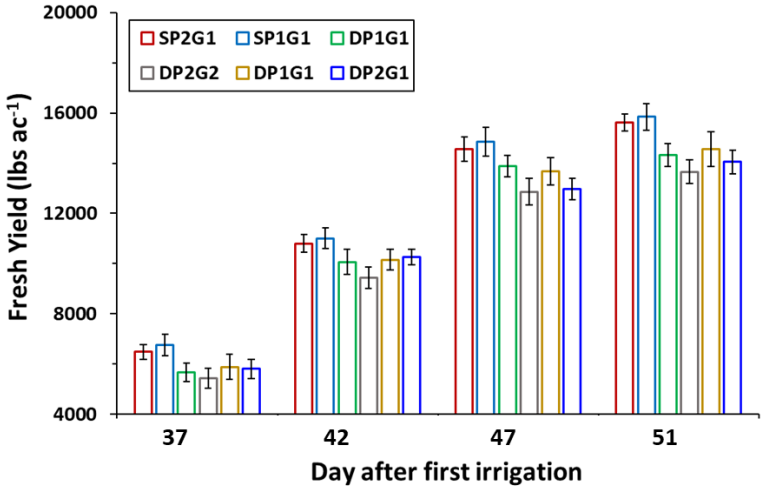


Fig. 7. Spinach fresh yields on different days after first irrigation. The error bars show the standard deviation values.

Table 1. Mean spinach fresh yields in different treatments.

Treatment	Fresh yield (lbs. /ac)
SP1G1	14,850 [a]
SP2G1	14,570 [a]
DP1G2	14,327 [a]
DP2G2	13,631 [b]
DP1G1	14,562 [a]
DP2G1	14,052 [ab]

Downy mildew: Disease pressure was generally low in most parts of the trial, but there were hot spots with >1% incidence in plots irrigated with sprinklers. Although most treatments were not statistically different, there was a clear numerical trend of lower downy mildew incidence in drip irrigated plots by a factor of at least 4 (Fig. 8). This difference was driven by the lack of hot spots in drip irrigated plots. Reducing downy mildew in drip-irrigated spinach is a solid result

that was observed in this trial and the previous trials. It can be considered as one of the main benefits of utilizing drip in spinach.

The likely mechanism for this effect is a reduction under drip irrigation of leaf wetness, which is critical for infection and sporulation by the downy mildew pathogen. The leaf wetness measurements in the three winter trials conducted in 2019-2021indicate that sprinkler irrigated crop canopies remained wet for 22% - 26% more time than crop canopies under drip irrigated plots.

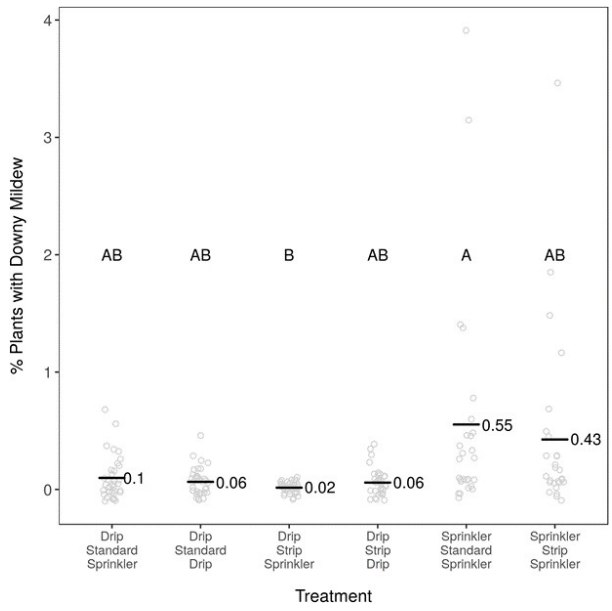


Fig. 8. Raw data of treatment means and mean separation of plants with downy mildew.

Outreach: A robust outreach program was developed to disseminate the project findings to growers and stakeholders. In addition of the publications and presentations in 2019 and 2020, the PI of project has been interviewed by different media including Holtville Tribune, Western Farm Progress, California Ag Today Radio, and Vegetables West in 2021. The findings of project were also presented in CLGRB Mid-year update (October 2020), CLGRB annual conference (March 2021), and Fall Desert Crops Workshop (December 2020). The research team will publish the findings of this three-year study in a peer-reviewed journal by the end of 2021.

Conclusions: This project demonstrated the potential for drip irrigation to produce organic spinach, reduce/manage downy mildew, and use for germinating seeds. Strip planting method could be an effective approach to overcome nitrogen management issue in organic spinach under drip. To date, no yield improvement has observed utilizing drip in spinach, while there is potential for conserving water and fertilizer. Economic feasibility of drip technology in spinach is very site specific, however, a grower case study in the Imperial Valley showed that drip irrigation could be economically feasible in spinach production.