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# Cantaloupe yield and water productivity under different irrigation systems, regimes, and soil conditions in Arizona

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## Introduction

Water conservation helps ensure the sustainability of scarce water resources in arid regions. Therefore, improving water productivity through the adoption of advanced irrigation practices is essential, especially under the persistent drought conditions in the Colorado River basin (Bennett et al., 2021; Castle et al., 2016). Strategic irrigation scheduling can optimize water management, but water-use and crop response may also vary significantly depending on the irrigation method; thus, efficient irrigation methods not only ensure optimal crop growth and yield but also play a crucial role in conserving water resources. Flood irrigation is the conventional system for many growers, but it often has low efficiency and uniformity (Pool et al., 2022; Yuan et al., 2023), resulting in considerable non-productive water use. Currently, micro-irrigation systems are emerging as an effective solution to improve water use efficiency by accurately delivering irrigation water directly to the root zone (Elnemr et al., 2019; Elsadek, 2018). Subsurface drip irrigation utilizes a buried pipe system to directly channel water or fertilizer into the soil. This allows for diffusion into the crop root zone via capillary action or gravity. This method optimizes the absorption of water and nutrients (Orta et al., 2023), considerably reducing losses from evaporation, deep percolation, or runoff (El–Metwally et al., 2022) and improving the efficiency of water and fertilizer use (Muleke et al., 2023). Overhead sprinkler irrigation, including center pivot and lateral move systems, is often adopted due to its ruggedness, versatility, and longevity. Overhead sprinkler systems reduce the amount of labor associated with irrigation and usually apply water to a crop more efficiently and uniformly than flood irrigation systems (Rogers et al., 2017).

The primary goals of a well-managed irrigated cropping system include maximizing crop yields, improving water use efficiency, and boosting economic returns (De Pascale et al., 2011). Strategies such as deficit irrigation (DI) can optimize on-farm water management by improving water use while ensuring adequate irrigation (Elshikha et al., 2023), reducing energy consumption, and raising economic returns from irrigation investments (Elsadek et al., 2023; Ragab, 2014). Furthermore, specific soil amendments have the potential to improve soil structure and increase water retention, contributing to increased crop yields (Y) and increased water use efficiency. This publication evaluates the effectiveness of three irrigation systems: flood, subsurface drip, and center pivot (overhead sprinkler) for two irrigation rates (100% and 80% of crop evapotranspiration) and soil conditions during the 2024 cantaloupe season in Arizona, USA. The goal is to guide growers in enhancing cantaloupe yield and water productivity (WP).

## Data collection and analysis

A cantaloupe irrigation assessment was conducted at the University of Arizona, Maricopa Agriculture Center (33.07 ºN latitude; 111.97 ºW longitude; 362 m AMSL) in a 15-acre field equipped with three irrigation systems: flood (F), subsurface drip (D), and center pivot (CP) during the cantaloupe growing season in 2024. The experimental area is characterized by a hot summer, with daily maximum, minimum, and average air temperatures reaching 115°F (46°C), 90°F (32°C), and 99°F (37°C), respectively, in July (Elshikha et al., 2024). The field layout was arranged in a randomized complete block design (RCBD) with three replicates (R1, R2, and R3). Two irrigation rates were applied for each irrigation system: 100% and 80% of crop evapotranspiration (ETc) with amended (a) and non-amended soil conditions (Figure 1).

Liquid Natural Clay (LNC), a commercial soil amendment composed primarily of processed natural clay minerals (https://desertcontrol.com/, last accessed on April 30, 2025), was prepared on-site using the available irrigation water from the study location to maintain consistency with local water properties. It was applied to four experimental blocks, each measuring about 30 × 30 m. Three blocks were included in the drip and flood irrigated plots, and the fourth block was under the center pivot (Figure 1).

Cantaloupe (*Cucumis melo*) was seeded on March 21, 2024, and harvested on June 24, 2024. All the irrigation methods were initiated on March 21, 2024, and ended on June 19, 2024, for flood; June 20, 2024, for drip; and June 25, 2024, for center pivot. The variable irrigation rates (100% and 80% of $ET_c$) were initiated after crop stand establishment, on April 28, 2024, under center pivot, and on May 02, 2024, under furrow and drip irrigation. The cumulative irrigation amounts applied under each irrigation system with different water rate treatments, and daily precipitation are presented in Figure 2.

The daily meteorological data, including maximum, minimum, mean air temperature, and effective precipitation ($T_{max}$, $T_{min}$, $T_{ave}$, and $P_r$, respectively) were collected from the Arizona Meteorological Network (AZMET, https://cals.arizona.edu/AZMET/06.htm) from a station located near the trial area. This data was needed to compute reference evapotranspiration ($ET_o$) as shown in Figure 3.

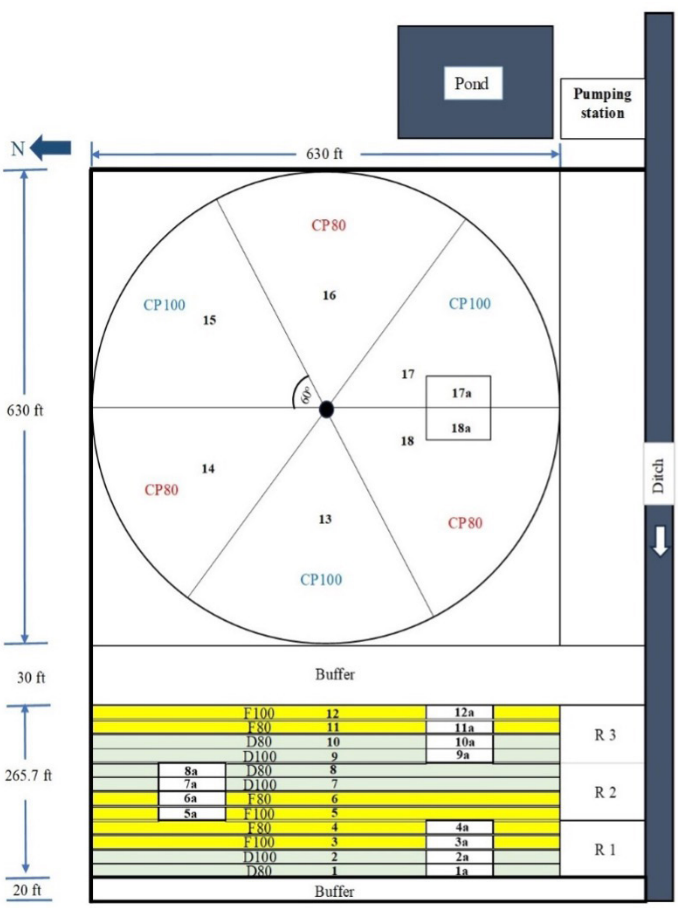


Figure 1. Field layout illustrating the flood (F), subsurface drip (D), and center pivot (CP) replicates (R) under different irrigation rates (100% and 80% crop evapotranspiration) with amended (a) and non-amended soil.

Weekly soil moisture depletion was measured using a neutron moisture probe (CPN 503 TDR HydroProbe Moisture Gauge, InstroTek Inc., CA, USA) to compute the water requirements based on the FAO56 model. Applied water amounts were measured using flowmeters at the head of each irrigation system.

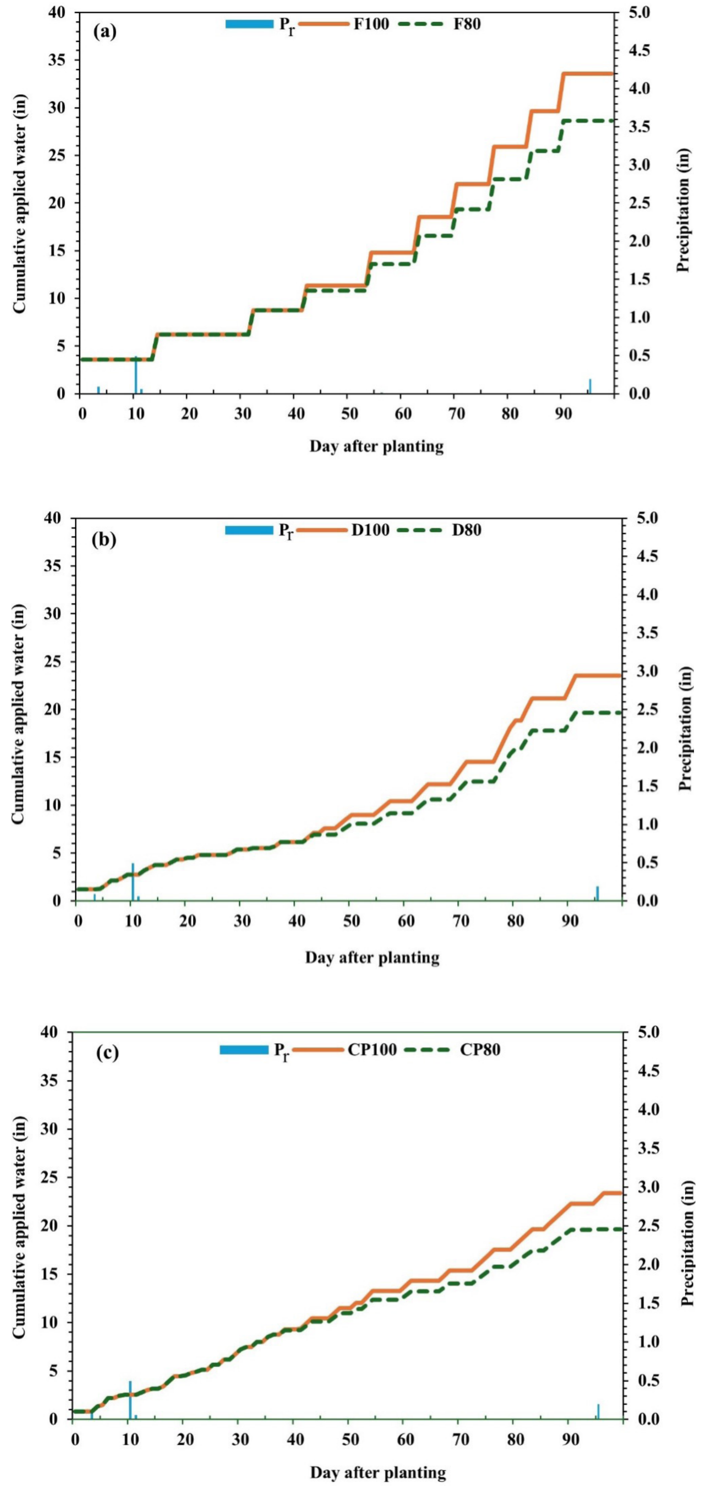


Figure 2. Cumulative irrigation and precipitation events for flood (a), subsurface drip (b), and center pivot (c) under different irrigation rates (100% and 80% of crop evapotranspiration) during the cantaloupe growing season in 2024. F, D, CP, and $P_r$ refer to flood, subsurface drip, center pivot, and precipitation, respectively.

Mature cantaloupe melons were harvested from a representative number of subplots randomly designated throughout the entire field under the irrigated areas of interest, and then the average yield ($Y_{avg}$, t/ac) was obtained. The water productivity (WP, t/ac-in) was computed following Molden et al. (2010).

$$WP = \frac{Y_{avg}}{TWA} \qquad (1)$$

where $Y_{avg}$ is the average yield, t ac$^{-1}$, and TWA is the total water applied (irrigation + $P_r$), inches (in).

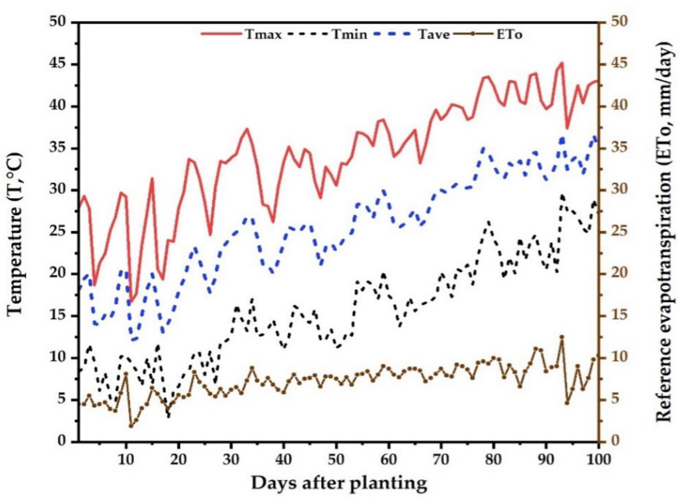


Figure 3. Daily temperatures and reference evapotranspiration patterns during the cantaloupe growing season. $T_{max}$, $T_{min}$, $T_{ave}$, and $ET_o$ refer to the maximum, minimum, and average temperature, and reference evapotranspiration, respectively.

## Main findings

### Cantaloupe yields

Average cantaloupe yield (Yavg, t/ac) for different irrigation systems, irrigation rates, and soil conditions during 2024 are summarized in Table 1. Overall, the results illustrated that the flood irrigation system was the best among the three examined systems for achieving the highest cantaloupe yield. The highest cantaloupe yields were 26.6 t/ac and 26.1 t/ac under F80a and F100a treatments, respectively. In contrast, the lowest cantaloupe yields were 10.4 t/ac and 10.8 t/ac under CP80 and D80a treatments, respectively. Application of soil amendment, LNC, led to a slight to significant increase in cantaloupe yields under flood irrigation and center pivot irrigation systems. Compared with F100 treatment, cantaloupe yield increased by 1.3% under F100a treatment. Similarly, cantaloupe yield increased by 2.5% under CP100a as compared with the CP100 treatment. However, cantaloupe yield increased by 14.8% (under F80a) and 15.1% (under CP80) when compared to F80 and CP80, respectively. On the other hand, LNC had a nonsignificant impact on cantaloupe yield under D80a treatment, whereas the yield was reduced by 2.4% as compared with the D80 treatment.

Despite the higher water use under flood irrigation compared to the other systems, the deficit irrigation strategy (F80a) resulted in a greater WP (0.91 t/acre-in). This can be attributed to the large cantaloup yield and the effective leaching of salts below the root zone under flood irrigation. The reduced yields for the subsurface drip and center pivot systems might be a result of increased salinity levels in both the water and the soil. At the time of planting, laboratory results were not yet available, so elemental sulfur and gypsum were not applied. These amendments are important for reducing soil pH and increasing soluble calcium levels, which helps replace excess sodium in the soil, improve water infiltration, and allow more effective salt leaching. The absence of these

Table 1: Cantaloupe average yield ($Y_{avg}$), total water applied (TWA), and water productivity (WP) during the 2024 growing season at Maricopa Agriculture Center, Arizona.

| System | Flood (F) | | | | Subsurface drip (D) | | | | Center pivot (CP) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | F 100 | F 100a | F 80 | F 80a | D 100 | D 100a | D 80 | D 80a | CP 100 | CP 100a | CP 80 | CP 80a |
| Y, t/ac | 25.8 | 26.1 | 23.2 | 26.6 | 16.1 | 18.8 | 11.1 | 10.8 | 15.2 | 15.6 | 10.4 | 11.9 |
| TWA, in | 34.2 | | 29.3 | | 24.2 | | 20.3 | | 24.0 | | 20.3 | |
| %TWA relative to F100 | -- | | -14.5 | | -29.4 | | -40.6 | | -29.9 | | -40.7 | |
| WP, t/ac-in | 0.75 | 0.76 | 0.79 | 0.91 | 0.67 | 0.78 | 0.55 | 0.53 | 0.63 | 0.65 | 0.51 | 0.59 |

Note: The letter "a" denotes the soil amendment.

treatments, especially under the center pivot and drip systems, most likely contributed to poorer soil conditions and consequently lower yield and water productivity.

Elevated salt content in the irrigation water and soil increases the osmotic pressure, which causes osmotic stress in crops. Thus, it limits the ability for roots to absorb water and disrupts the internal water balance causing plant water stress, leading to adjustments in various physiological, morphological, and biochemical responses (Duan et al., 2007; Farooq et al., 2009). Several metabolic functions, such as enzyme activity, protein synthesis, and photosynthesis, can be impacted by this imbalance, which can result in nutritional deficits (Singh et al., 2024). As a result, this negatively affects plant growth and development, leading to significant reductions of yield under reduced irrigation rates (Sirisuntornlak et al., 2019; Ullah et al., 2017, 2018). Also, the salinity levels under the center pivot were relatively greater, which resulted in soil crusting and consequently delayed germination by approximately 7 days. These factors may also have negatively impacted plant establishment and final yield.

### Cantaloupe yields

Total water applied (TWA, in) and water productivity (WP, t/ac-in) for flood, subsurface drip, and center pivot under different irrigation rates (100% and 80% of crop evapotranspiration) during the cantaloupe growing season are shown in Figure 3 and listed in Table 1. The mean TWA varied between 34.2 inches (under F100) and 20.3 inches (under D85, D85a, CP85, and CP85a) during the growing season (Table 1). Under flood irrigation, the horizontal growth of cantaloupe branches inhibited irrigation water from reaching the end of the field, leading to a high TWA (34.2 inches) and deep percolation. With respect to the drip irrigation treatment, a similar irrigation amount was reported by Sanchez et al. (2023) for cantaloupe cultivated under drip/bare soil (22.8 inches) in Yuma, Arizona.

The highest WP was 79-0.91 t/ac-in under the flood irrigation (80% treatments), followed by the subsurface drip irrigation (D100a) at 0.78 t/ac-in). The lowest WP was recorded under the center pivot (CP80 treatment) at 0.51 t/ac-in. Adopting the deficit irrigation strategy improved water productivity under flood irrigation; however, similar water productivity values were not observed under subsurface drip and center pivot, due to lower yield. As previously noted, the lower water productivity under subsurface drip and especially the center pivot might be attributed to the increased soil and water salinity.

## Conclusion and recommendations

The present study focused on multiple factors that would affect crop water productivity, including different irrigation methods, various irrigation rates, and soil conditions. The results illustrated that the flood irrigation system gave the greatest cantaloupe yield and water productivity, likely due to effective leaching of salts below the root zone. Application of the soil amendment, Liquid Natural Clay (LNC), led to a slight-to-notable increase in yield under flood irrigation and the center pivot irrigation system. On the other hand, LNC had a nonsignificant impact on yield under the deficit (D80a) treatment.

It is recommended that all three systems implement management practices to effectively leach soluble salts below the root zone as in arid systems, soil salinity is a major component affecting crop yield. This should be guided by pre-planting soil and water analyses and by incorporating an appropriate leaching fraction into the irrigation scheduling calculations. Any soil condition that may decrease the efficacy of the leaching fraction, such as high exchangeable sodium may need to be addressed through a soil amendment application such as calcium sulfate, or gypsum. Effective leaching is critical to manage salts under highly saline soil and water conditions. Furthermore, in situations where high water salinity is likely to cause foliar damage, drip and flood irrigation methods are preferable over systems with overhead sprinklers. Moreover, proper irrigation scheduling with subsurface drip can help mitigate salinity issues by maintaining wet soil around the root zone and continuously moving the salt to the edge of the wetted area.

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