

ARE EVAPORATION LOSSES IN SPRINKLER IRRIGATION HIGH?

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Summary

Evaporation losses during sprinkler irrigation are perceived by the irrigation community to be high and is a major impediment to the adoption of sprinkler irrigation. Previous overseas experimental studies have reported losses up to 45% of the applied water and that a large proportion of the loss is droplet evaporation. However, a recent field experimental study conducted over a cotton crop at the University of Southern Queensland showed that the total evaporation is low (about 8%) and that droplet evaporation would be less than 1%. The additional evaporation during sprinkler irrigation would be about 4% of the applied water.

Introduction

Sprinkler irrigation is becoming a preferred method as the water available for irrigation around the world becomes increasingly scarce, especially in arid and semi-arid regions. The irrigators are still less interested to adopt this system due to the lack of accurate information regarding the losses in sprinkler irrigation often citing high evaporation losses along with high cost of operation. Previous experimental results have shown that losses may vary from 0 to 45% of the applied water and that a large proportion of the loss is droplet evaporation in the atmosphere. However, recent theoretical studies (Thompson et al., 1993, 1997) reported that the total losses should not be much more than a few percent and the droplet evaporation loss would be negligible (less than 1%). However,

due to the limitations of the available methodology these theoretical results could not be verified by field experiments in real crops. Latest studies (Uddin et al., 2013a & 2013b) showed that the advanced eddy covariance (ECV) technique can be used to measure the total evaporation during sprinkler irrigation and identification of the components of total evaporation is possible with some other additional measurements. Hence, in this study the additional evaporation during sprinkler irrigation was quantified.

Materials and Methods

The study was conducted over a cotton crop at the Agricultural Experimental Station situated at the University of Southern Queensland, Toowoomba, Australia. Eddy covariance system consisting of a 3D sonic anemometer and



FIGURE 1. Installed ECV and sap flow system at the centre of the field for continuous measurements

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infrared gas analyser (Figure and sensible heat flux (H)).

Net radiation (R_n) and soil heat flux were measured by a four component net radiometer and soil heat flux plates, respectively. The temperature and relative humidity were measured using two identical temperature and relative humidity probes placed at two locations on the periphery of the irrigated plot. The measurements were done every 0.1 sec and the 5 min averages were recorded. The sap flow measurements used six dynamometer sap flow sensors and a data logger (Figure 1). The sensors were installed on six randomly-selected plants of 10 to 13 mm stem diameter. The field was irrigated using a small movable sprinkler irrigation system with low angle and low pressure impact sprinklers. The irrigation system gave an irrigated circle of 50 m diameter. The irrigations were applied for 3 hours in the middle of the day (Figure 2).

The reference ET (ET_{ref}) was calculated from the weather data using the FAO Penman-Monteith method. The latent heat flux λE was deduced from the surface energy balance over the crop surface by measurement of all major terms of the energy balance. The latent heat flux was adjusted using the Bowen Ratio method as described by Twine et al., (2000) and then converted to ET in $mm\ hr^{-1}$ using appropriate conversion factors.

Results & Discussion

The ET, sap flow (F), soil heat flux (G) and calculated ET_{ref} on a particular day are presented in Figure (3). It shows that the values of ET during irrigation increased significantly due to the direct effect of irrigation. A significant reduction of transpiration was reflected in the measurements of sap flow.

The total volume of canopy evaporation during and immediately following irrigation is the summation of:

- additional evaporation during irrigation (A) which includes canopy evaporation from the wet canopy and droplet evaporation during flight,



FIGURE 2. Evapotranspiration being measured during irrigation with the ECV system

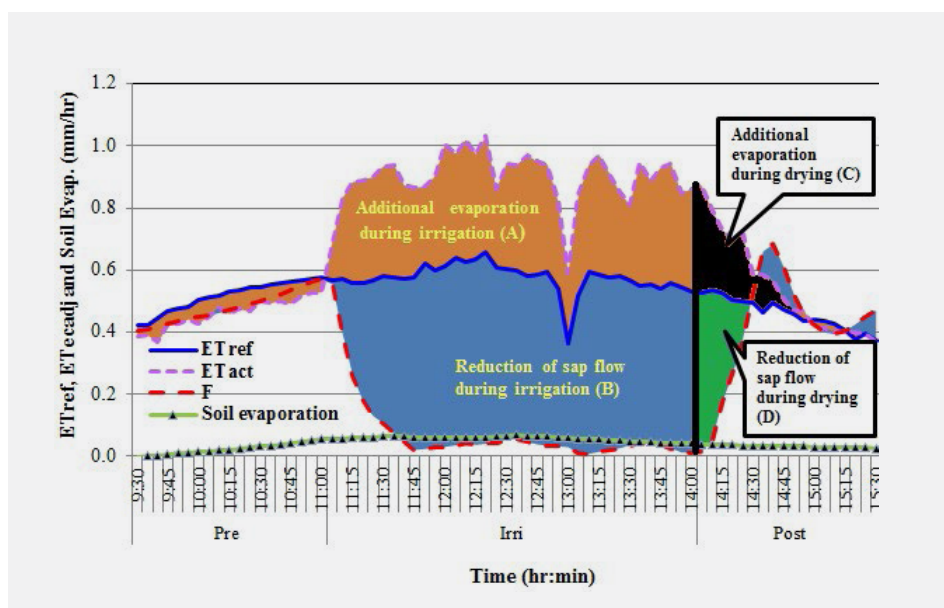


FIGURE 3. Components of total ET measured by ECV-sap flow method during sprinkler irrigation

- reduction of transpiration during irrigation in terms of sap flow (B) which would have occurred without irrigation,
- canopy interception capacity which includes the additional evaporation during irrigation (C) and reduction of transpiration in terms of sap flow during drying (D).

A negligible amount of soil evaporation was measured under closed canopy condition.

Total and additional evaporation

The total estimated depth of canopy evaporation ($A + B + C + D$) for the irrigation event on different days is presented in Table 1. The tabulated values show that total depth of canopy evaporation varied from 1.96 mm to 3.17 mm with an average 2.34 mm. On some days (e.g. DOY 102 & 104) the total evaporation was found to be significantly higher than the average due to the effect of advection during the

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irrigation. Assuming an application rate of 9 mm hr⁻¹ for the three hours irrigation, the canopy evaporation was typically about 8% of the total applied water. A slightly higher value (about 13% of applied water) was predicted by Thompson et al., (1997) while Yonts et al., 2007 measured 15% for corn. The depth of additional evaporation (A + C) in low angle impact type sprinkler irrigation was estimated to be about 1 mm which was about 4% of applied water.

Droplet evaporation

As evaporation during irrigation (Part A) includes wet canopy evaporation and droplet evaporation during irrigation, it was a strenuous task to separate these two components. However, to get an idea about the droplet evaporation during irrigation some measurements were taken over bare soil. Using the non-dimensional technique (ET_{ecadj}/ET_{ref}) to average the measurements on different days it was found that there was no discernible difference in nondimensional ET between the irrigation and post irrigation period (Figure 4) which indicates that the droplet evaporation was very small or negligible. Although the nondimensional ET was slightly lower during the pre-irrigation period, the higher nondimensional ET found during irrigation and post irrigation was most likely due to the evaporation of water from the wet soil in both periods.

Conclusions

The study shows that during the overhead sprinkler irrigation the total ET increased markedly and transpiration suppressed significantly. The total evaporation was found about 8% of the applied water. Considering the suppression of transpiration, the additional evaporation during sprinkler irrigation would only be about 4% of the applied water.

References

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DOY	Total applied water	Additional evap ⁿ during irrigation (A)	Reduction in trans ⁿ during irrigation (B)	Additional evap ⁿ during drying (C)	Reduction in trans ⁿ during drying (D)	Total evap ⁿ (A+B+C+D)	Additional evap ⁿ (A+C)
	mm	mm	mm	mm	mm	mm	mm
99	27 mm	0.76	0.93	0.08	0.21	1.52	0.59
102		1.43	1.10	0.14	0.20	1.98	0.84
103		0.88	1.10	0.11	0.20	2.98	1.59
104		1.65	1.09	0.19	0.20	2.50	0.99
105		0.95	0.91	0.11	0.19	3.17	1.88
114		0.58	1.09	0.08	0.21	2.33	1.23

TABLE 1. Total canopy evaporation (sum of part A, B, C, & D in figure 3)

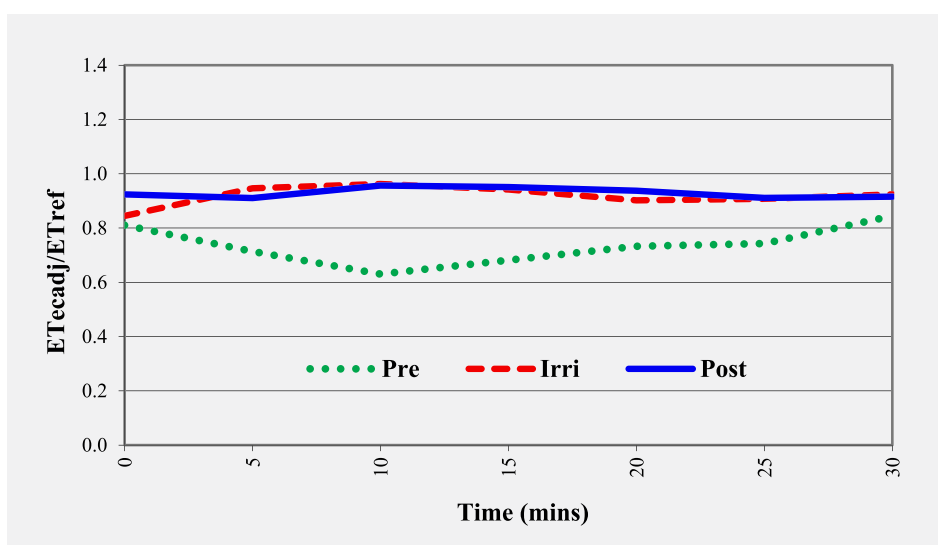


FIGURE 4. Nondimensionalised ET for bare soil before, during and after irrigation

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