Influence of Vapor Deposition on Wild Blueberry Water Requirements in a Humid Coastal Climate

G.C. Starr
USDA Agricultural Research Service
New England Plant, Soil, and Water Laboratory
Orono, ME 04469
USA

D.E. Yarborough
Cooperative Extension
University of Maine
Orono, ME 04469
USA

Keywords: Vaccinium augustifolium, evapotranspiration, water management, irrigation

Abstract

Growers need recommendations to improve both the timing and amount of irrigation water applied to wild blueberries (Vaccinium angustifolium) in the humid coastal region of Maine where direct vapor deposition may also supply water to the crop. This study was initiated to quantify the rates and timing of vapor deposition in relation to rates of evapotranspiration (ET). Weighing lysimeters were used to determine rates of net water vapor deposition (VD) or vapor uptake (VU) during hours when rainfall and drainage were not occurring. Vapor deposition occurred throughout the evening, night, and early morning during the fruit bearing year of a two year cropping cycle for the period June 11 to October 8, 2003. The mean values of daily VD, VU, and ET were 0.075 cm/d, 0.335 cm/d, and 0.27 cm/d with a coefficient of variability of 71%, 44%, and 71%, respectively. Thus, VD accounted for around 22% of total water taken up by the plants and amounted to 28% of ET. Under these conditions, classical approaches to irrigation scheduling based solely on rainfall measurements may result in over application of water by failing to account for vapor deposition.

INTRODUCTION

Wild blueberry (Vaccinium angustifolium) yields show a strong response to irrigation (Seymour et al., 2004), and, increasingly growers are adopting irrigation as a production practice in Maine. However, wild blueberry growers need technical support and recommendations for scheduling irrigation to improve their water use efficiency. A common grower irrigation scheduling practice is to supplement rainfall to ensure that roughly 2.5 cm per week of water reaches the plants during the growing season. Less irrigation water is thought to be required near the Atlantic coast where temperatures are cooler and dense fog and dew occur frequently. The fog is thought to relieve plant water stress even when there is no rainfall. More water is thought to be needed at inland locations where temperatures are higher and humidity lower.

The limited literature on the subject supports these grower beliefs and practices. Starr et al. (2004) showed that weighing lysimeters recorded nighttime increases in weight from water being deposited in the lysimeters, particularly at locations near the coast. Kosmas et al. (1998) showed that water vapor deposition on soil was a major contributor to water balance in a coastal Mediterranean climate. Kosmas et al. (2001) showed that up to 70% of water taken up by evapotranspiration was replenished by water vapor adsorption (deposition) during the dry season and linked this effect to diurnal fluctuations greater than 25% in relative humidity and temperature. The humid coastal region of Southeastern Maine where wild blueberry production is centered may also show significant vapor deposition in the absence of rainfall. Thus, classical approaches to irrigation scheduling based solely on rainfall measurements could result in the over application of water by failing to account for vapor deposition.

This study was initiated to quantify rates and governing processes of vapor deposition and uptake for wild blueberry production in Maine. Relevant soil and atmospheric parameters were measured in conjunction with weighing lysimeters. The measured parameters include: vapor deposition (VD), vapor uptake (VU),
evapotranspiration (ET), rainfall (R), drainage (D), relative humidity (RH), solar radiation (SR), air temperature (T), visibility (V), wind speed (W), and volumetric soil water content ($\theta_v$).

**MATERIALS AND METHODS**

This study was conducted at the blueberry hill research farm operated by the University of Maine and located near the Atlantic coast in Southeastern Maine. Wild blueberry plants had formed an organic mat or sod layer consisting primarily of roots, organic matter, and sand that was roughly 15 cm thick overlying a gravelly sandy loam (Sandy-skeletal, mixed, frigid Typic Haplorthods). Four weighing lysimeters (basal area = 0.21 m$^2$, soil depth = 39 cm) were constructed using the Storlie and Eck (1996) design (Fig. 1) as described in Starr et al. (2004). The design uses a set of springs between inner and outer chambers to balance a rectangular column of soil on a weighing load cell. An intact piece of sod (0.21 m$^2$) was extracted and installed in each lysimeter over reconstituted subsoil.

Changes in weight averaged over the four lysimeters on an hourly basis were used to determine vapor transfers. The VD (hourly increase in weight) or VU (hourly decrease in weight) were calculated for only those hours when $R = 0$, $D = 0$, and irrigation = 0. Daily evapotranspiration was calculated using three different definitions: (1) daily change in weight (expressed as equivalent water depth) on days where $R = 0$, $D = 0$, and irrigation = 0 (Storlie and Eck, 1996); (2) depth equivalent daily change in weight minus daily $R$ on days where $D = 0$ and irrigation = 0; (3) daily sum of VU minus sum of VD for all days.

Soil water content reflectometers (Kosmas et al., 1998) were installed to average $\theta_v$ over the top 15 cm (two probes inside and two outside of lysimeters). Hourly changes in $\theta_v$ were used as an indicator of changes in soil water storage in the root zone. A weather station obtained from Campbell Scientific Inc. (Logan, UT, USA) was used to measure RH, SR, R, and T. Data were collected from June 11 through October 8, 2003 during the fruit bearing year of the two year production cycle of wild blueberry. Irrigation was applied in 1.3 cm amounts whenever the soil water tension exceeded 20 kPa as measured by eight tensiometers from four inside and four outside of the lysimeters.

Linear and quadratic functions were fit to the data to determine which of these parameters would explain the observed variability in liquid-vapor transfer. Only polynomial models with significantly (i.e. with at least 95% confidence as determined by analysis of variance and F-values) better fits than the next lower order polynomial are shown. Data for each hour were combined over all days, thereby forming a composite to show the diurnal variation of parameters.

**RESULTS AND DISCUSSION**

The ET for the fruit bearing year in wild blueberries was first calculated as the water depth equivalent of daily changes in weight using definition 1. This parameter showed a significant quadratic trend when plotted against day of year over our study interval (Fig. 2). The trend line is very close to the constant 0.36 cm estimated water requirement for the first half of the study period, but it drops below the constant value around day 235 and approaches 0.1 cm by the end of the study period. Although the quadratic trend explained less than half ($R^2 = 0.38$) of the day to day variability in ET, a weekly assessment would average seven days of irrigation requirements thereby reducing scatter around the quadratic trend.

It was a concern that only 74 of the total 115 days could be used with definition (1) and this might inject bias into the ET measurement. The ET was also calculated using definition (2) for 103 days and definition (3) for all 115 days. Using definitions (1), (2), and (3), ET averaged 0.31 cm, 0.27 cm, and 0.26 cm with standard errors of 0.01, 0.02, and 0.02, respectively. Definition (1) gives a slightly higher average than definition (2) or (3), probably because by only using days with no rain, it represents a dry weather estimate for ET. Similar to, by eliminating all hours with rainfall and irrigation, definition (3) may
understate true evapotranspiration because it does not accurately quantify the rapid evaporation period immediately following wetting events.

Vapor deposition was a significant factor in the water balance for the study period as evidenced by the mean values of daily VD, VU, and ET (definition 2) which were 0.075 cm, 0.33 cm, and 0.27 cm with a coefficient of variability of 71%, 44%, and 71% in the daily data, respectively. Thus, vapor deposition accounted for around 23% of total water taken up by the crop and amounted to around 28% of ET. However, little of the day to day variation ($R^2 = 0.15$) in vapor deposition could be explained by the marginally significant seasonal quadratic trend model (Fig. 2).

The hourly composite data (Fig. 3) showed that VU was sharply peaked in mid afternoon and VD was the dominant transport process through most of the night. The VD was greatest in the morning hours between 7:00 and 9:00 a.m. Of the variables examined, the daily maximum $T$ (Fig. 4) and average SR (Fig. 5) during the uptake hours were best able to explain the variability in VU. These results should not be surprising because of the well documented effect of maximum $T$ and SR on ET. However, the correlation between VD and average SR (Fig. 5) was not expected and needs further explaining. The hourly data (data not shown) for the strongest deposition events indicated a daytime hour, usually in the mid to late morning, when RH dropped sharply from a high level and solar radiation increased dramatically. Evidently, some of the moisture loss from the air accumulated in the lysimeters during morning hours when air temperature increases rapidly, but the soil remains relatively cool. The VD showed a weak linear relationship ($R^2 = 0.27$) to soil water storage changes (Fig. 6), suggesting that when VD was occurring water was probably entering the soil and not merely occurring as dew deposition. Much of the scatter in Figure 6 is caused by error in measuring such small changes in water content.

CONCLUSIONS

Initial data from a study of soil water uptake and deposition indicate that vapor deposition accounts for about 22% of the total water uptake and 28% of ET. At this site, the supplemental irrigation to provide a constant weekly rate (2.5 cm/wk) matched measured water requirements through about day 235 after which ET fell rapidly and 2.5 cm/wk would be excessive. Given the high rates of water deposition in the absence of rainfall it is important to have further studies of these phenomena as it may confound traditional irrigation scheduling. The VD may have a profound influence on ET, both over time and spatially at varying distances from the coast. Daily composite data indicated net deposition was greatest between 7:00 and 9:00 a.m. Vapor deposition was weakly correlated with changes in soil water storage suggesting that deposition may be directed into the soil and not merely in the form of dew deposition on plants.

ACKNOWLEDGEMENTS

Maine Agricultural and Forestry Experiment Station Publication Number 2708.

Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

Literature Cited


**Figures**

**Fig. 1.** Installed weighing lysimeter.

![Installed weighing lysimeter](image)

![Graph](image)

**Fig. 2.** Daily evapotranspiration and deposition trends.
Fig. 3. Hourly composite of diurnal pattern of uptake and deposition.

Fig. 4. Relationship of daily uptake to maximum temperature during uptake hours.
Fig. 5. Relationship of daily uptake and deposition to average solar flux.

Fig. 6. Daily deposition as related to losses in soil water storage.