EFFECT OF PLANT DENSITY ON CROP WATER PRODUCTIVITY

K. DHAVU[1], H. ANYOJI[1], H. YASUDA[1], H. DEHGHANISANIJ[2]

Introduction

Crop water production is governed only by transpiration. As it is difficult to separate transpiration from evapotranspiration from the soil surface between the plants (which does not contribute directly to crop production), defining crop water productivity using evapotranspiration(ET) rather than transpiration makes practical sense at field and system level. In irrigated agriculture in saline areas, the leaching requirement, i.e. the amount of water that needs to percolate to maintain root zone salinity at a satisfactory level, should also be included together with evapotranspiration in the amount of water that is necessarily depleted during plant growth.

As with the numerator, the choice of the denominator (which drops to be included) should depend on the scale, the point of view and the focus. At basin level, the choice might be between water diverted from the source and the same minus water restored, whereas at field level one might consider useful rain, irrigation water and supplemental irrigation.

Reported data on water productivity with respect to evapotranspiration (WP_{ET}) show considerable variation, e.g. wheat 0.6-1.9 kg/m^3, maize 1.2-2.3 kg/m^3, rice 0.5-1.1 kg/m^3, forage sorghum 7-8 kg/m^3 and potato tubers 6.2-11.6 kg/m^3, with incidental outliers obtained under experimental conditions. Data on field-level water productivity per unit of water applied (WP_{irrig}), as reported in the literature, are lower than WP_{ET} and vary over an even wider range. For example, grain WP_{irrig} for rice varied from 0.05 to 0.6 kg/m^3, for sorghum from 0.05 to 0.3 kg/m^3 and for maize from 0.2 to 0.8 kg/m^3.

The objective of this study is to assess the effect of plant density on crop water productivity.

Methods and materials

Experiment

Sorghum was planted in a 154m^2 greenhouse at Arid Land Research Center, Tottori University, Japan (35^{0}32’N, 134^{0}13’E; 23m above sea level) from June 8th 2006. The soil type is Arenosol (silicious sand, typic Udipsamment) with 96% sand.

Three small evaporation pans were randomly located in two experimental plots of 35m^2. The pans were filled with the same water used for irrigating the crop. Water would be replaced everyday in order to maintain the same water level in the evaporation pan. On one of the plots (Plot A) the plant density was 7 plants/m^2 while it was 14 plants/m^2 on the other plot (Plot B). The pans were weighed daily at 0630hrs and 1830hrs. Daily evaporation was obtained from evaporation pan weight loss expressed in equivalent depth of water.

The grain weight was measured after harvest. This was at 12~15% moisture content.

Crop evapotranspiration computation

Evaporation measured from small evaporation pans (E_s) of 20cm diameter was converted to the conventional class A pan (E_A) using Agodzo et al.(1997) equation:

$$E_A = a E_s^b \qquad (1)$$

where a and b are fitting parameters and a = 0.58 and b = 1.3.
The E_A in equation (1) was converted to potential evapotranspiration (ETo) using Doorenbos and Pruitt (1977) equation:

$$ETo = Kpan\ E_A \qquad (2)$$

The Kpan is 0.8 and this value was obtained from Agodzo et al. (1997) for greenhouse condition using Doorenbos and Pruitt (1977) procedure.

The ETo from equation (2) was converted to crop evapotranspiration (Etc) using Doorenbos and Pruitt (1977) equation:

---

[1] Arid Land Research Center, Tottori University, Tottori 680-0001, Japan
[2] Agricultural Engineering Research Institute in Iran
Key words: Water productivity, plant density, evapotranspiration

$$Etc = Kc\ ETo \quad (3)$$

where Kc is crop coefficient and we used the Allen et al. (1998) published Kc values of 0.7, 1.1 and 0.55 for early growth stage, mid stage and late stage respectively.

Results and discussion

The crop yield varied only within 3% between the two plant densities though the plant density for plot B was twice as much as plot A. Consequently, there was no significant difference in water productivity for the two plant densities as shown in Table 1 below.

Table 1: Crop yield and water productivity

Plot	Density (plants/m2)	Crop yield (kg)	WP_{ET} (kg/m3)	WP_{IRRIG} (kg/m3)
A	7	6.8	1.15	0.31
B	14	7.0	1.18	0.32

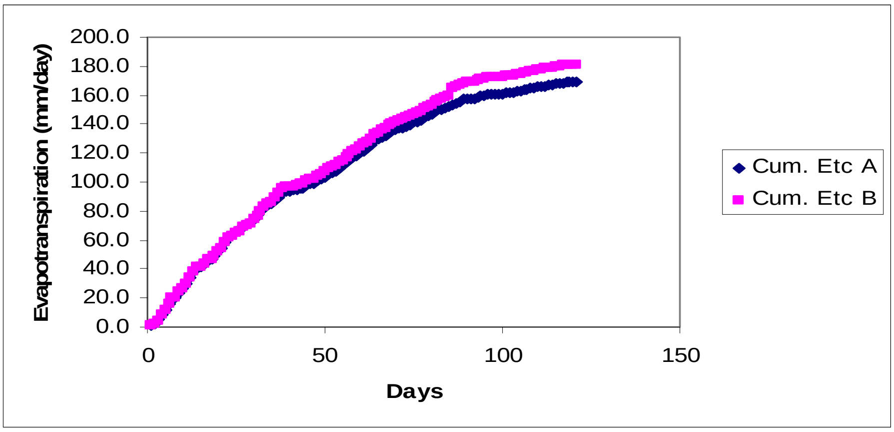

Fig. 1: Cumulative evapotranspiration for the two plant densities

Fig. 1 shows more water loss due to evapotranspiration for higher plant density than for the lower plant density. Water productivity is, however, higher in plot B. This means that the water loss is more due to transpiration than evaporation.

Conclusion

Increase in plant density has no significant effect on water productivity. Doubling plant density is, therefore, an unnecessary extra cost in land preparation and seeds.

References

Agodzo, S.K., Nishio, T., Yamamoto, T., 1997. Trickle irrigation of okra based on small pan evaporation schedule under glasshouse condition. Rural Environ. Eng. J. 33, 19-36.

Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998. Crop evapotranspiration. FAO Irrigation and Drainage Paper 56. FAO, Rome.

Doorenbos, J., Pruit, W.O., 1977. Crop water requirements. FAO Irrigation and Drainage Paper 24. FAO, Rome.