GROWTH AND YIELD RESPONSE OF FURROW-IRRIGATED BURLEY TOBACCO TO DEFICIT IRRIGATION

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Summary

A field experiment was conducted using furrow-irrigated Burley tobacco (cv. C104) to compare two deficit irrigation treatments with a full irrigation treatment (control). The deficit irrigation treatments received 50% of the crop evapotranspiration (ET_c) either to both sides of the row (DI_{50}) or to alternate rows (ARI_{50}). The ARI_{50} treatment consisted in wetting one-half of the root zone while the other half was maintained dry, with the wetted and dry root zone exchanged over two subsequent irrigations. Seedlings were transplanted at a 1.0 x 0.5 m distance on May 30 and fertilized with 120 kg ha^{-1} of nitrogen. All plants were topped at flowering, harvested 106 days after transplanting (DAT), and air-cured in ventilated rooms. The yield of cured leaves of DI_{50} and ARI_{50} treatments was 69 and 90% of that of the control, respectively. The dry matter at commercial harvest of DI_{50} and ARI_{50} was 54 and 76% of the control, respectively. The irrigation water use efficiency (IWUE) of DI_{50} and ARI_{50} treatments, expressed as kg of cured leaves ha^{-1} mm^{-1} of water applied, was 136 and 179% of the control, respectively. Results of the present experiment indicate that the ARI_{50} treatment is an interesting deficit irrigation strategy for Burley tobacco grown in semi-arid areas.

Introduction

Irrigation plays a key role in determining yield and quality of Burley tobacco and especially in semi-arid areas of Southern Italy, where water is the major limiting factor for growth and yield (Sifola and Postiglione, 2002; Sifola and Postiglione, 2003).
Several studies reported that deficit irrigation (DI), that is reducing the water applied at specific phenological stages, is a good strategy to save water since it increases irrigation water use without significant reduction in yield (Kirda et al., 1999; Kirda et al., 2004; Kirda et al., 2005). However, the implementation of deficit irrigation by growers requires an understanding of the crop response to water deficit. Recently, a new irrigation strategy was developed, whereby the rooting zone was alternatively exposed to dry and wet cycles (alternate row irrigation, ARI). This practice appeared to increase the irrigation water use efficiency and decrease the irrigation water requirements in several fruit and vegetable crops grown under field or greenhouse conditions (Kang et al 2000; Kang et al., 2001; Kang et al., 2002).
Despite the economic relevance of tobacco cultivation in areas with problems of water shortage, there is hardly any study on the comparison of DI or ARI strategies on growth and yield. The aim of the present work was to compare the effect of DI or ARI strategies of deficit irrigation on growth and yield of Burley tobacco.

Materials and methods

A field experiment was conducted in 2005 at the experimental farm of the University of Napoli (40° 37' N; 14° 58' E), using furrow-irrigated Burley tobacco cv. C104 grown in a sandy-clay-loam soil (47.1% sand, 25.6% silt, 27.2% clay, 10.1% lime, 7.1 pH, 1.3% organic matter, 0.09% Kjeldahl-N, 0.28 dS m^{-1} EC_e). Two deficit irrigation treatments (50% ET_c), imposed either using conventional deficit irrigation (DI_{50}) or alternate row irrigation (ARI_{50}), were compared with a full irrigation treatment (100% ET_c, control). In the DI_{50} treatment plants received half amount of water uniformly applied to both sides of the row; in the ARI_{50} treatment one-half of the root zone was wetted while the other half was maintained dry, with the wetted and dry root zone interchanged over two subsequent irrigations.
Seedlings were transplanted at a 1.0 x 0.5 m distance on May 30. One hundred and fifty kg ha^{-1} P_2O_5 and 120 kg ha^{-1} K_2O were added to the top of the soil at transplanting. One hundred and twenty kg ha^{-1} of nitrogen (N) was distributed as follows: 50% as ammonium sulphate (21% N) at transplanting, and 50% as ammonium nitrate (26% N) at side dressing. The latter was splitted into two applications: a) at seedling establishment (17 DAT); b) at the beginning of rapid stem elongation (31 DAT). Plants were furrow irrigated 11 times for a total volume of 246 and 124 mm in the control and in both DI_{50} and ARI_{50} treatments, respectively (Tab. 1).
Temperatures were greater than 30 °C in the second and third week of July. One hundred and ninety-four mm of rainfall were concentrated in May and August, with June and July dry (Tab. 1).
All plants were topped at flowering (first week of August), harvested on September 13 and air-cured in ventilated rooms. After curing was completed, the yield of entire leaves per each plot was determined at a standard moisture content of 19%. The number of leaves per unit land area and leaf mean weight were also determined. Broken leaves or those damaged during curing were excluded from the determination of yield. Irrigation water use efficiency was calculated as the ratio between the yield of cured leaves (kg ha^{-1}) and the seasonal irrigation water (mm) applied in different irrigation treatments.
For growth analysis, one plant per plot was destructively sampled at about two-week intervals starting from 32 DAT until harvest (46, 60, 85 e 106 DAT). The number of fully-expanded green and senescent leaves (yellow and dry) was measured. Dry weight of leaves and stems were determined by oven drying at 60 °C to constant weight.
The experimental design was a randomised complete with three replicate plots. Plot size was 36 m^2. Data on all parameters were processed by analysis of variance or standard error of mean.

Results and discussion

The yield in cured leaves of DI_{50} and ARI_{50} was 69 and 90% of that of the control (Fig. 1a). In particular, the yield of ARI_{50} was intermediate between those of DI_{50} and control treatments and not significantly different from that of the control (Fig. 1a). The IWUE (kg cured leaves ha^{-1} mm^{-1} water applied) of both DI_{50} and ARI_{50} was greater than that of the control (Fig. 1b). Interestingly, the IWUE of ARI_{50} was increased by 31% with respect to that of the DI_{50} treatment (Fig. 1b), indicating that using ARI_{50} strategy allowed to produce more cured leaves per unit of applied water.

The plant dry matter of DI_{50} and ARI_{50} was less than that of the control treatment starting from 60 DAT through commercial harvest (106 DAT), when dry matter accumulated by plants under DI_{50} and ARI_{50} regimes was 54 and 76% that of the control, respectively (Fig. 2).

The relationship between the dry matter accumulated in the leaf or stem and total above-ground DM is reported in figure 3. Data from all irrigation treatments were pooled together because there were no significant differences between irrigation treatments in the partitioning of above-ground biomass between leaves and stems. The slopes of the regression lines represent the partitioning coefficients for leaves and stems. Most above-ground DM was partitioned to leaves (Fig. 3). Partitioning coefficients of leaves and stems were 0.56 and 0.43, respectively. Even though not significantly, the ARI_{50} treatment determined greater dry matter partitioning to leaf than both DI_{50} and control treatments (0,60 *versus* 0.56 and 0.52, respectively).

This study showed that the ARI_{50} strategy allowed to save 50% irrigation water with only a marginal reduction in yield of cured leaves with respect to the full irrigation treatment. Interestingly, the ARI_{50} produced 32% more yield than the conventional DI_{50} despite the same amount of applied water. Similar results were obtained for greenhouse-grown tomato by Kirda et al. (2004) who found that the ARI treatment produced 27% more yield than the conventional DI. By contrast, Kirda et al. (2005) reported no differences in grain yield of field-grown maize between ARI and DI strategies but they also found that the ARI strategy determined a 24% greater N recovery that was also associated with less mineral N residue in the soil with respect to conventional DI.

Considering the differences in total dry matter and yield of cured leaves between conventional DI_{50} and ARI_{50}, results of the present work showed that the better response of the latter treatment was probably due to the greater both amount of biomass partitioned to leaves and IWUE.

In conclusion, the results here reported indicate that the ARI_{50} can be advantageous for Burley tobacco in conditions of water shortage, and represent an improvement with respect to conventional DI_{50} strategy.

Aknowledgements

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Table 1. Monthly distribution of the number of irrigations, irrigation volumes and rainfall in 2005. The irrigation at transplanting (15 mm) is not included.

	No. of irrigations	Volume (mm)		Rainfall (mm)
		Full irrigation 100% ET_c	DI or ARI (50% ET_c)	
May	-	-	-	29.8
June	1	15	8	-
July	5	83	42	-
August	4	124	62	29.1
September	1	24	12	135.1

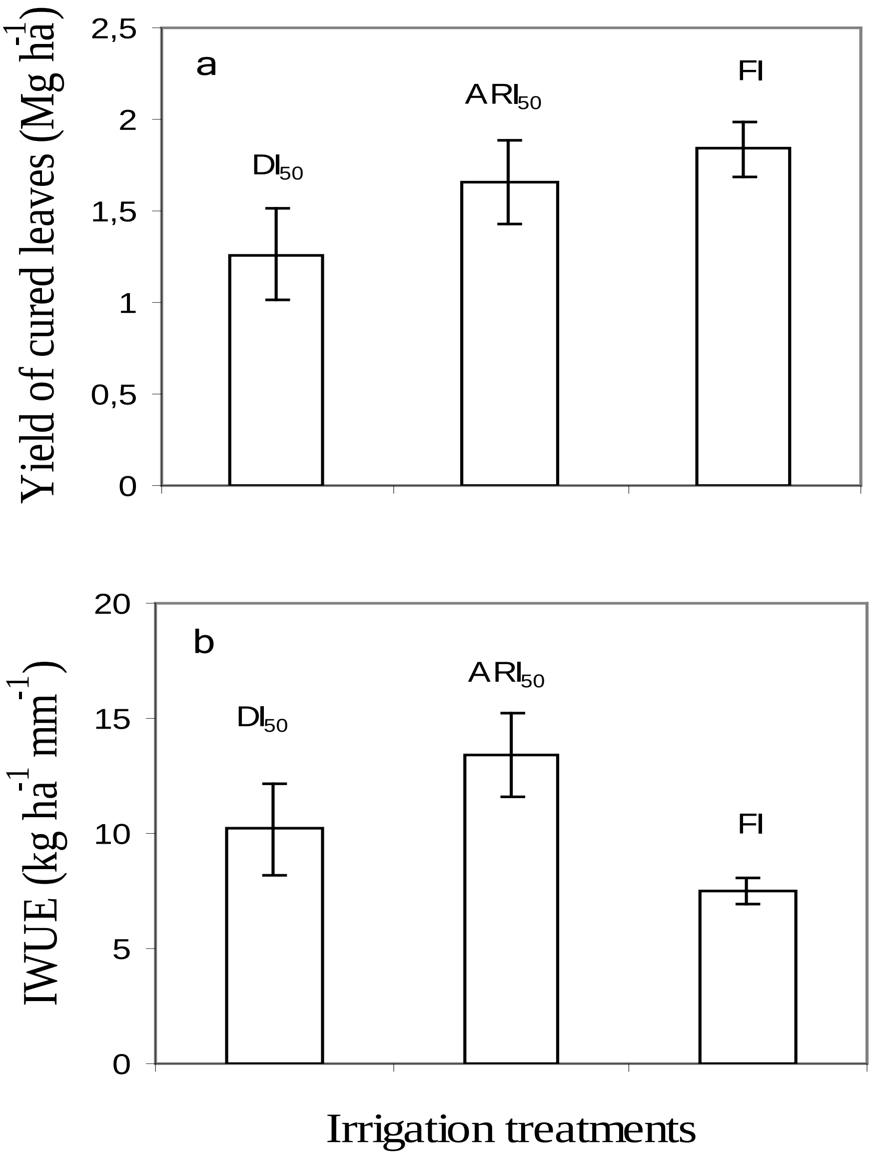

Figure 1. The effect of irrigation treatments on the yield of cured leaves (a) and the irrigation water use efficiency (IWUE, b). Bars indicate standard errors of the mean of three replicates. Legend: DI_{50}, conventional deficit irrigation (50% ET_c); ARI_{50}, alternate row irrigation (50% ET_c); FI, full irrigation (100% ET_c).

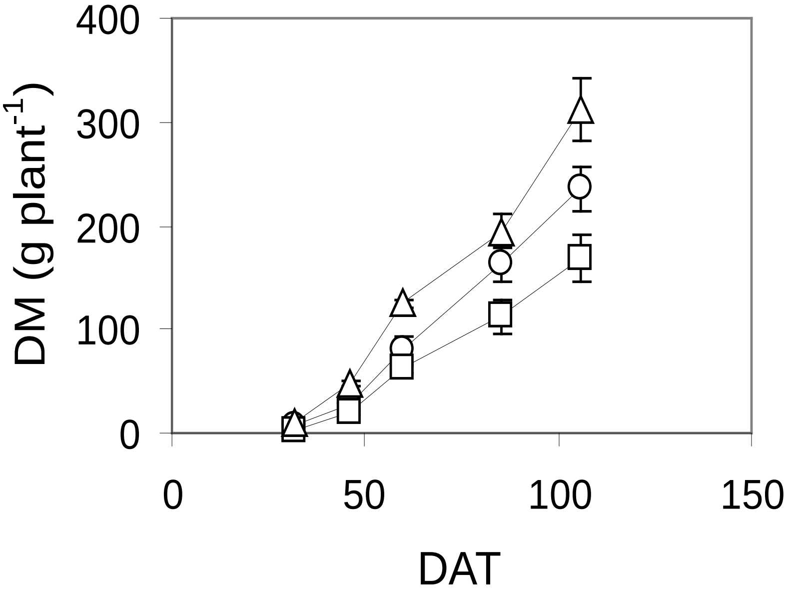

Figure 2. The effect of irrigation treatments on dry matter (DM) accumulation. Bars indicate standard errors of the mean of three replicates. Legend: (❑) DI_{50}, conventional deficit irrigation (50% ET_c); (❍) ARI_{50}, alternate row irrigation (50% ET_c); (Δ) FI, full irrigation (100% ET_c); DAT, days after transplanting.

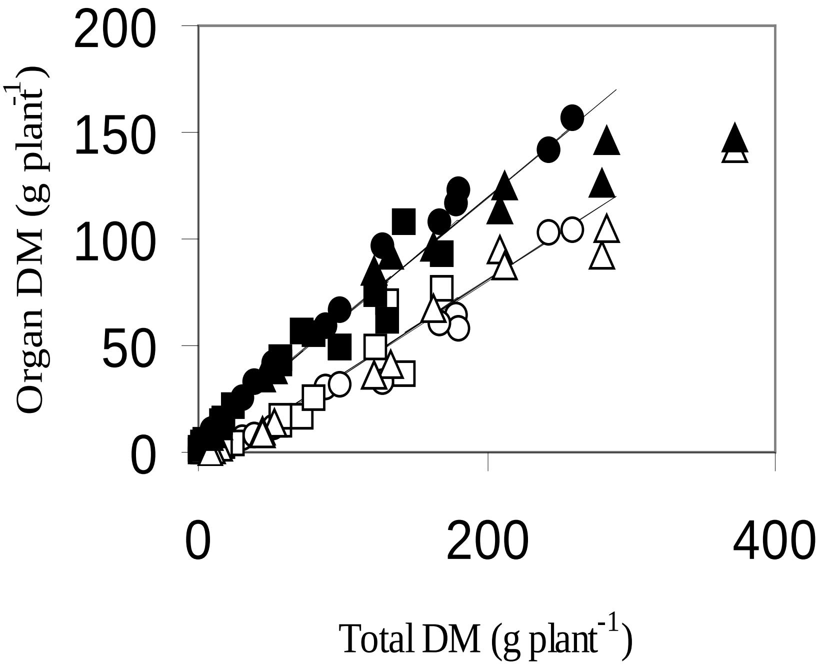

Figure 3. Leaves (filled symbols) and stem (open symbols) dry matter (DM) *versus* total plant above-ground DM. Data of all irrigation treatments were pooled together. Legend: (□) DI_{50}, conventional deficit irrigation (50% ET_c); (❍) ARI_{50}, alternate row irrigation (50% ET_c); (Δ) FI, full irrigation (100% ET_c). Equations: DM_{leaves} = 0.56 Total DM +7.02, r = 0.985**; DM_{stem} = 0.43 Total DM – 7.03, r = 0.976**; asterisks indicate significance at $P < 0.01$