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The response of autumn and spring sown sugar beet (*Beta vulgaris* L.) to irrigation in Southern Italy: Water and radiation use efficiency

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Abstract

The Apulia region in Southern Italy is an important area for sugar beet cultivation. It is characterised by clay soils and a hot-arid and winter-temperate climate. The capability of sugar beet to exploit solar radiation, water use and irrigation supply in root yield, total dry matter and sucrose production was studied and analysed in relation to two experimental factors: sowing date – autumn (October–December) and spring (March) – and irrigation regime – optimal and reduced (respectively with 100 and 60% of actual evapotranspiration). Data sets from three experiments of spring sowing and three of autumn sowing were used to calculate: (1) water use efficiency in the conversion in dry matter (WUE_{dm}, plant dry matter at harvest versus seasonal water use ratio), in sucrose (WUE_{suc}, sucrose yield versus seasonal water use ratio); (2) irrigation water use efficiency in the conversion in dry matter ($IRRWUE_{dm}$), in sucrose ($IRRWUE_{suc}$) and fresh root yield ($IRRWUE_{fr}$); and (3) radiation use efficiency (RUE, plant dry matter during the crop cycle and at harvest versus intercepted solar radiation ratio).

Autumnal beet was more productive than spring for fresh root, plant total dry matter, sucrose yield and concentration; also WUE_{suc} and $IRRWUE_s$ were higher in the autumnal sugar beet, but no difference was observed in WUE_{dm} (on average, 2.83 g of dry matter kg^{-1} of water used). An average saving of about 26% of seasonal irrigation supply (equivalent to about 100 mm) was measured in the three years with the earliest sowing time. The optimal irrigation regime produced higher root yield, plant total dry matter and sucrose yield than the reduced one; on the contrary the $IRRWUE_{fr}$ and $IRRWUE_{dm}$ were higher in the reduced irrigation strategy. WUE_s and $IRRUWE_s$ correlated positively with the length of crop cycle, expressed in growth degree days and, in particular, to the length of the period from full soil cover canopy to crop harvest, the period when plant photosynthetic activity and sucrose accumulation are at maximum rates. Seasonal RUE was higher in the spring than in the autumn sowing (1.14 $\mu g\ J^{-1}$ versus 1.00 $\mu g\ J^{-1}$). The RUE values during the crop cycle reached the maximum in the period around complete canopy soil cover. The results showed the importance for better use of water and radiation resources of autumnal sowing time and of reduced irrigation regime in sugar beet cropped in a Mediterranean environment.

Keywords: *Beta vulgaris* L.; Use efficiency; Water; Radiation; Sowing time; Irrigation regime; Dry matter; Sucrose

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1. Introduction

The sustainability of cropping systems can be achieved through the choice of certain field crops which are better able than others to exploit natural resources, like solar radiation – which is a no-cost resource – and water – which is becoming more and more expensive. One of these crops is the sugar beet (*Beta vulgaris* L.), a crop cultivated for the production of sucrose and, potentially, for the production of energy (bio-ethanol). Both radiation and water can limit the productivity of beet: radiation in Northern European environments (Scott and Jaggard, 1978), water in Southern Europe (Rizzo et al., 1983; D'Amato and Giordano, 1985).

In the literature, sugar beet is considered a crop with a high efficiency value of transformation of solar radiation into dry matter; higher than durum wheat, but lower than maize and sorghum (Tanner and Sinclair, 1983). In the literature very variable values of radiation use efficiency (RUE, expressed in $\mu g\ J^{-1}$ of intercepted solar radiation) are reported. Damay and Le Gouis (1993) reported values ranging from 2.96 to 3.76 $\mu g\ J^{-1}$, Milford et al. (1980) reported values ranging from 3.16 to 4.12 $\mu g\ J^{-1}$, Biscoe and Gallagher (1977) obtained 3.5 $\mu g\ J^{-1}$. Lower values were obtained by Scott et al. (1973) 1.93 $\mu g\ J^{-1}$, Brown et al. (1987) 1.44 $\mu g\ J^{-1}$ in unirrigated and 1.66 $\mu g\ J^{-1}$ in irrigated beet, Werker and Jaggard (1998) in UK with 12 years of data and Wright et al. (1997) in different locations in Northern Europe, from 1.3 to 1.6 $\mu g\ J^{-1}$. However, all of these studies were conducted with spring-sown crops.

Sowing times affect plant canopy development (growth, number, size and age of green leaves) in relation to global and intercepted solar radiation throughout the crop season. RUE is assumed as constant (Sinclair, 1986) in many studies on crop models, but other authors reported that it varied widely during the plant growth cycle. In pea, Lecoeur and Ney (2003), reported a change in RUE during crop growth, and in particular a small decrease during the vegetative phase. Werker and Jaggard (1998) suggested also for sugar beet a decrease of RUE during the crop cycle and this decrease was faster in the rainfed crop.

As for water, in the beet sown in the spring, more commonly studied in Northern Europe and America, efficiency values for conversion in dry matter (WUE_{dm}) are reported to be between 4.6 and 5.6 $g\ kg^{-1}$ of used water (Brown et al., 1987). Dunham (1993) reviewed WUE_{dm} values ranging from 2.1 to 10.0 $g\ kg^{-1}$ in several environments; in experimental areas with seasonal water use close to Southern Italy conditions (600–900 mm), the values ranged from 2.3 to 5.8 $g\ kg^{-1}$. This suggests that sugar beet, a C_3 species, is an efficient user of water, even comparable to maize, a C_4 species (Tanner and Sinclair, 1983).

Water use efficiency for sucrose production (WUE_{suc}), showed a linear increase with water irrigation amount, ranging from 0.7 to 1.6 $g\ kg^{-1}$ in spring sown beet (Cassel and Bauer, 1976). Davidoff and Hanks (1989) concluded that sugar beet yield was related to root yield and not to sucrose content, and that sucrose content was not affected by irrigation treatments and water levels: reported values of WUE_{suc} were from 0.8 to 1.7 $g\ kg^{-1}$. Also Dunham (1993) reported values for WUE_{suc} from 1.1 to 2.5 $g\ kg^{-1}$ in the locations with 600–900 mm of seasonal water use. Ehlig and LeMert (1979) in autumnal sugar beet in USA reported WUE_{suc} values of 1.4–2.0 $g\ kg^{-1}$, inversely related to seasonal water use.

In the cropping areas from 38°N to 60°N beet is usually sown in spring (March–April) and harvested in autumn. In the southern areas of Spain, Italy and Greece (at varying latitudes according to the climatic zones, between 35°N and 45°N), the beet is sown in autumn, using lines resistant to bolting, with several advantages that can be summarized as:

- extension of growing period;
- early harvest (end of July);
- reduction of the irrigation requirements;
- reduced risks of a low root sugar content.

The autumn seeding allows the beet to exploit the winter rainfall and to avoid the period of maximum water demand (July–August) (Caliandro et al., 1996).

This study was proposed to evaluate the effects of two sowing times – autumn and spring – and two different levels of irrigation water application – optimal and reduced – on the efficiency of the sugar beet in using the water and radiation resources in fresh root, dry matter and sucrose production.