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Analysis of intercepted radiation and dry matter accumulation in rose flower shoots

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Abstract

The relationship between intercepted photosynthetic active radiation, PAR and dry weight of single flower shoots of a rose (*Rosa hybrida* cv. Dallas) canopy managed with the arching technique was investigated through three growth cycles (summer, autumn and spring) under Mediterranean greenhouse conditions (Valencia, southern Spain). Non-destructive measurements were carried out at eight phenological growth stages and the evolution with thermal time of the in situ shoot dry weight, W_s, was estimated for each growth cycle. Intercepted PAR by the shoot, $R_{p,int}$, was estimated at a daily scale from a simplified single shoot interception model. The relationship between W_s and $R_{p,int}$ was analysed using a radiation use efficiency (RUE)-based approach that considered three main periods throughout the shoot growth cycle: (i) from the stage the axillary bud had reached a length of about 1 cm (AB stage) till the visible bud (VB) stage, with a high *apparent* value of RUE due to the supply of assimilates from the plant reserves, (ii) from the VB stage to the stage of last leaf unfolded (LLF stage), when the shoot became self-supporting for assimilates, with the *true* value of RUE and (iii) from LLF stage till the stage of harvest (Y stage), when the shoots slowed down their growth and more assimilates were available for translocation to the basal part of the plant, with a low *apparent* value of RUE. This approach allowed the estimation of the imported and exported amounts of dry matter by the growing shoot. The reserves imported till the VB stage ranged from 5% (spring and summer shoots) to 25% (autumn shoots) of the shoot dry weight at harvest. The relative contribution of the shoot during the export phase was small (<5%) for the autumn and summer shoots, but reached up to 30% of its final dry weight for the spring shoots. A computational scheme was proposed to derive the dynamics of the import rate of assimilates from the plant reserves (roots, parent shoots, bent shoots and old foliage). It was found that the maximum translocation rate occurred near the 3LF stage (third unfolded leaf) and that the bud became self-supporting for assimilates at the VB stage.

Keywords: Growth; Dry biomass; Phenological stage; Thermal unit; Extinction coefficient; Intercepted radiation; Assimilates translocation

1. Introduction

Classical analysis of crop growth is currently assessed through empirical relationships or growth functions, relating changes in biomass to chronological or thermal time. However, such a description does not explicitly account for the effects on plant growth of environmental factors (such as solar radiation) and plant architecture (leaf area and structure). The methodology first introduced by Monteith (1972, 1977), distinguishing between the plant function in absorbing solar radiation (resource capture) and that in using this energy

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into the processes of biomass production (resource transformation), allows to account for these effects. The efficiency of resource transformation is characterized by the radiation use efficiency, RUE, defined as the ratio between the biomass production and the amount of radiation intercepted over a given period. The utility and appropriateness of this approach for analysing biomass production at canopy scale are supported by numerous experimental and modelling studies available in the literature (Warren-Wilson et al., 1992; Sinclair and Shiraiwa, 1993; Wheeler et al., 1993; Ruimy et al., 1994; Hanan et al., 1995; Sinclair and Muchow, 1999). The linkage between classical growth analysis and the RUE approach was clearly assessed since the sound-based theoretical analysis proposed by Goudriaan and Monteith (1990), later revised by Monteith (2000) and Yuan and Bland (2004), who proposed the "expolinear" growth function as a means for relating the growth parameters to light resource capture.

Whereas most RUE studies dealt with whole canopies at field scale, few were devoted to the analysis of RUE of single plant units, such as fruit bearing stems or, in the case of this study, rose flower shoots. In what refers to rose plant growth and production, the interest in applying the RUE approach at this scale is to determine at what extent a single rose flower shoot participates in resource capture and transformation, as both processes are of special relevance when dealing with flower shoot quality and vase life. Besides, other useful aspects of the RUE approach can be underlined. On one hand, it may serve as a performance criterion in the evaluation of the effects of crop management (e.g. pruning, de-budding and pinching). On the other hand, it may yield information about the role played by the plant reserves of assimilates in sustaining the shoot growth during the initial stages of its development, when light capture by the shoot cannot occur (no leaves) or is very small. Therefore, the analysis of the "*apparent*" radiation use efficiency, exhibited by the flower shoot during the early stages, with respect to the "*true*" radiation use efficiency characterizing the shoot in the adult stage, could supply valuable information about the intensity and duration of the translocation process.

The main aims of this article were: (i) to analyse and estimate the RUE pattern of single rose flower shoots along a growth cycle, (ii) to evaluate to what extent the RUE approach is a suitable method for predicting the flower shoot growth and (iii) to provide a better insight into shoot dry matter acquisition during the early stages of growth, when the young shoot mainly depends on the plant reserves and translocation of assimilates.

2. Materials and methods

2.1. Greenhouse and crop management

The experiments were carried out in a plastic greenhouse, located in southern Spain (Valencia, 39°30′N, 0°24′E). The greenhouse was E–W oriented, and was naturally ventilated by means of a continuous roof opening located on the southern side. Ventilation was provided automatically when inside air temperature exceeded 25 °C. During spring and summer, a mist system was operating whenever air relative humidity was lower than 60%. The greenhouse was heated to 14 °C during the night. In summer (from July to September), whitening was applied to greenhouse roof and walls leading to a reduction of about 35% of the greenhouse transmission coefficient for solar radiation.

The rose plants (*Rosa hybrida* cv. Dallas) were grafted on *Rosa manetti* root-stocks. The crop was planted in 1997 on February 3 in containers made of polypropylene (12 m × 0.40 m × 0.30 m) filled with an artificial substrate (perlite). The plantation rows were E–W oriented, row path width was 1.1 m and plant density was 6 plants m^{-2} ground surface. The first harvest occurred on 23 May of the same year and continuous harvesting was since then practiced. Along the first months after plantation, the plants were structured following the arching technique (Kool and Lenssen, 1997; de Hoog et al., 2001; Lieth and Kim, 2001). Plants were irrigated by means of a drip system, and water supply scheduling was based on the estimation of the evapotranspiration rate from solar radiation and crop coefficient. The nutrient solution contained: 11 mmol l^{-1} NO_3^-, 1.5 mmol l^{-1} NH_4^+, 1.25 mmol l^{-1} $H_2PO_4^-$, 1.2 mmol l^{-1} SO_4^{2+}, 4.5 mmol l^{-1} K^+, 3.3 mmol l^{-1} Ca^{2+} and 1.1 mmol l^{-1} Mg^{2+} (Sonneveld and Vooght, 1997). The nutrient solution pH was adjusted to 5.5–6.0 and its electrical conductivity was maintained between 1.5 and 2 mS cm^{-1}.

2.2. Microclimatic data

Solar radiation incident on the canopy was measured by a solarimeter LI-200SZ (LICOR, Lincoln, NE, USA) located at a height of 2.3 m. Dry and wet bulb temperatures were measured at the same height by an aspirated shielded psychrometer (mod. 1.1130, Thies Clima, Germany). The signals of the sensors were sampled at 1 min interval by means of a data logger (Delta-T Devices, Cambridge, UK) and mean values were calculated and stored every 30 min.