EFFECTS OF INCREASING R/FR RATIO ON LEAF SENESCENCE IN A COMMERCIAL DENSITY SUNFLOWER (*Helianthus annuus L.*) FIELD CROP.

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Abstract

In high population density sunflower crops, leaf senescence (LS) of lower leaves begins before anthesis. Experiments using isolated field-grown sunflower plants demonstrated that pre-anthesis LS is controlled by both photosynthetically active radiation (PAR) and the red/far-red ratio (R/FR) perceived by individual leaves. We tested the hypothesis that increasing the R/FR perceived by basal leaves delays LS in sunflower canopies. Plants were sown on 23-Dec-94 and 6 Oct. 1995 at high density (4.76 plants m^{-2}). R/FR on the abaxial surface of north oriented 8th leaves was increased by red light emitting diode (LED) panels. Green LED panels (PAR photon flux slightly greater than to red LED treatment; GREEN) and unlit LED panels (UNLIT) were used as controls.

Additional R provided by red LEDs significantly ($P<0.05$) modified R/FR perceived by the abaxial surface with respect to controls treatments and significantly ($P<0.01$) delayed LS. Leaf duration, as time between full expansion and 70% diminution of chlorophyll content, was 3 days longer for RED compared with controls. However, the light quality effect also depended on daily PAR receipt. Red light enrichment caused a delay in the loss of photosynthetic capacity. Twenty days after light treatment started RED maximum photosynthetic rate was 66 % larger than the rate for GREEN and UNLIT ($P<0.07$). We conclude that increases in the R/FR ratio delays LS in high density crops.

Keywords: leaf senescence, light quality, R/FR ratio, sunflower

Introduction

Senescence is complex process that begins as a response to internal (reproduction, growth regulators) and environmental (light

environment, water stress, mineral deficiencies, pathogens) signals. In monocarpic plants fruit growth is accompanied by plant senescence (*monocarpic senescence*) and this internal factor studied in greater detail.

Where environmental signals are concerned, there are several indications that fluence rate and/or the spectral composition of the light environment can influence the onset of basal leaf senescence in crop canopies (Biswal and Biswal 1984). Ottman and Welch (1988) have demonstrated that increasing the photosynthetic active radiation (PAR) incident on basal leaves of a maize canopy can delay the onset of senescence, and Cock et al (1979) showed that there was a relation between leaf duration (LD) and the percentage of solar radiation incident on cassava leaves. However, not only the PAR affected LD. Rousseaux et al. (1995) observed a diminution of LD when supplying individual leaves with far-red radiation, and shewed that this effect depended on the fraction of PAR received.

The R/FR ratio and fraction of PAR received by individual leaves decrease as the leaf area index (LAI) increases in sunflower canopies of different plant population densities (Rousseaux et al 1995), and that decrease is accompanied by a decrease in LD. The objective of this work was to demonstrate that increasing the R/FR of individual leaves of plants growing in a high population density canopy, where other variables that change with LAI (for example, temperature, water vapor pressure, CO_2 partial pressure) are not altered, delays leaf senescence. To test that hypothesis we supplied leaves of the 8^{th} node with red light (modifying PAR and R/FR) or green light (modifying PAR).

Materials and Methods

Growth conditions

Sunflower seeds (cv G100, Dekalb, Argentina) were sown on 23 Dec. 1994 (Exp. 1) and 6 Oct. 1995 (Exp. 2) in the experimental field of the Facultad de Agronomía UBA (latitude 34° 35'S, 58° 29'W) at a density of 48 seeds m^{-2}. Final density (4.76 plant m^{-2}, in rows 0.7 m apart and 0.3 m between plants in the row) was established by thinning 14 and 20 days after sowing respectively (two fully expanded leaves). Rows were oriented N-S. A randomized complete block design with four (Exp. 1) and six (Exp. 2) replications was used, and all plots received

25 kg N ha^{-1} (calcium nitrate) at sowing and 100 kg N ha^{-1} (urea) in two doses 17 and 25 days after sowing. Soil water content was maintained near field capacity during the experiment.

Light environment manipulation

We modified the R/FR ratio perceived by N-oriented (midrib in a direction within 30° from north) leaves at node 8 (node 0= cotyledon) supplying the abaxial surface with light from red LED panels (RED). As controls we used green LED panels (GREEN) and unlit LED panels (UNLIT). All the panels were turned on at sunrise and turned off at sunset. The PAR irradiances generated by the LED panels were 8.33 μmol m^{-2} s^{-1} for the red panels and 10.56 μmol m^{-2} s^{-1} for green panels, to compensate the lower photosynthetic efficiency of green light (Mc Cree 1972). We measured the panel irradiances in the laboratory with a 1 m linear sensor (LI 191S, LI-COR, NE, USA) placed 2 cm above the diodes. Unlit panels were used with two objectives: a) to mimic the effect of the reflection of light from the LED and b) to determine if the PAR irradiance from the LED panels were affecting LD.

Characterization of the light environment

The dynamics of the light environment and of the onset of senescence were studied for each treated leaf. Measurements were made on the adaxial and the abaxial leaf surfaces, at three fixed positions per leaf (the center of each half-lamina and the apex) to reduce the variability caused by the use of point sensors. The three data per leaf were averaged and constituted a single value per plant. Determination of the irradiance above the canopy (sensor surface in horizontal position) accompanied measurements at each target leaf.

The light environment of the treated leaves and its diurnal variation were measured on 4 (Exp 1) and 10 (Exp. 2) occasions at intervals of approximately 7 days (Exp. 1) and 2 days (Exp. 2) between achievement of maximum area of the target leaf and anthesis. Photosynthetic photon flux was measured using PAR sensor (LI 190, LICOR, NE, USA) and R and FR irradiances using a R-FR radiometer (SKR110, SKYE, UK). Measurements were made on three occasions (8 h 30, 12 h, 15 h 30; Exp. 1) and five occasions (7 h, 9 h 30, 12 h, 14 h 30, 17 h; Exp. 2) per day.

Incident and treated leaf PAR, R and FR irradiances were plotted against time for each measurement day, and curves fitted by hand to the data points. Graphical integration was used to estimate integrated daily values for each variable. Fractional PAR irradiance (I/Io, where Io is the irradiance above the canopy) was calculated as the ratio between total daily PAR received by the leaf and the corresponding value at the top of the canopy. Mean daily R/FR for each leaf was calculated as the ratio between total daily integral for R and FR.

Leaf duration

During the expansion phase of the target leaves, leaf area was determined every two days using measurements of maximum leaf width. Leaf chlorophyll content was determined with a non-destructive chlorophyllmeter (SPAD-502, Minolta, Plainfield, IL) every two days, and leaf duration (LD) was taken as the time (in days) from end of expansion (Rawson and Dunstone 1986) to senescence. A leaf was categorized as senescent when SPAD readings felt below 30% of its initial value. For the calibration of the chlorophyllmeter the chlorophyll content of leaf disks was extracted with NN-dimethylformamide (Inskeep and Bloom, 1985) after the reading with the chlorophyllmeter.

Photosynthesis

In all treatments measurements of maximum leaf photosynthesis were performed at noon on leaves at node 8 every 2-5 days with a portable photosynthesis meter (Li-Cor 6200, Li-Cor Inc., NE, USA). The leaves were exposed to maximum irradiance for at least 15 min before the determination, and the measurements were made by inserting the apical third of the leaf into a one liter chamber. The average PAR irradiance on leaves during the measurements was 1500 μmol m^{-2} s^{-1}.

Results and Discussion

LD of basal leaves of a sunflower plants, growing at a high population density, was prolonged 3 days ($P<0.05$) more than the corresponding controls (GREEN and UNLIT) when supplied with red light. This delay in the onset of leaf senescence was not explained by an increase in photosynthesis related with the light supply. LD of GREEN supply did not differed from UNLIT although the first

received an extra 10.56 μmol m^{-2} s^{-1} of PAR. Because PAR has been shown to affect LD, the effects of the manipulation of R/FR were analyzed using an analysis of covariance (ANCOVA), using the fraction of radiation (I/Io) received by leaves 7 (Exp. 1) and 12 (Exp. 2) days after treatment application as the covariable (Fig. 1). These dates were selected as both occurred before leaves started to senesce and the P value for the treatment effect in the ANCOVA were the lower. This result is consistent with previous findings of PAR-R/FR interaction on LD of individual leaves of isolated sunflower plants supplied with far-red light (Rousseaux et al. 1995). In both studies the effect of light quality on LD depended on the PAR received by the considered leaf.

Enrichment with red light caused a delay in the loss of photosynthetic capacity (Fig. 2). Twenty days after light treatment started RED maximum photosynthetic rate was % larger than the rate for GREEN and UNLIT ($P<0.07$).

We conclude that the decrease in chlorophyll content and maximum photosynthetic rate during leaf senescence were delayed when leaves were supplied with red light. These results support the hypothesis that phytochrome is involved in the control of theonset of leaf senescence.

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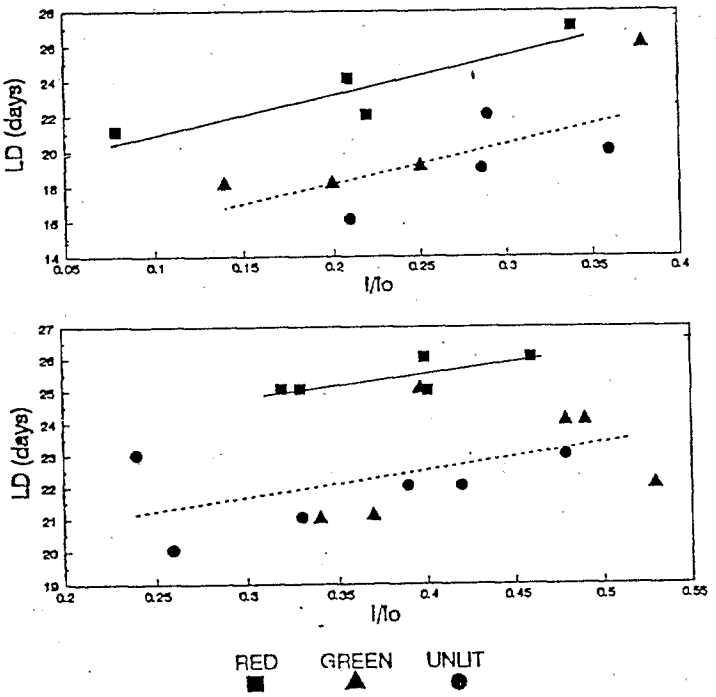

Fig. 1: Leaf duration (time between maximum leaf size and chlorophyll content less than 30% of the initial value) as a function of I/Io 7 days (Exp. 1, a) and 12 days (Exp. 2, b) after treatment application. Lines represent the regression equation for RED (___) and GREEN + UNLIT (....).

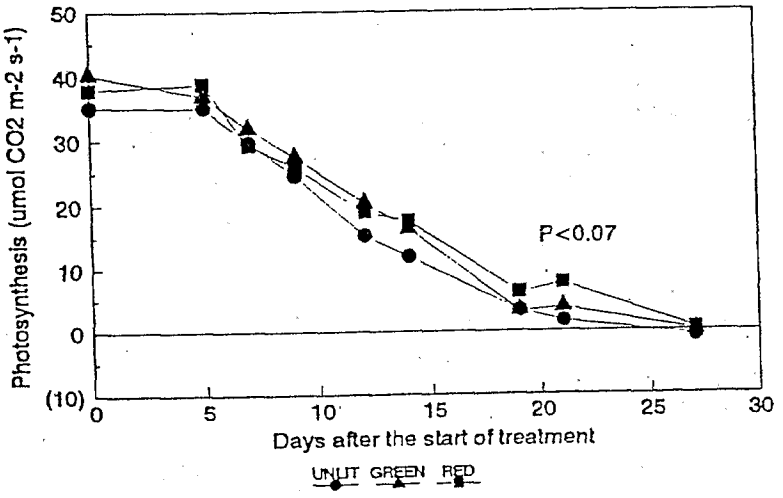

Fig. 2: Maximum leaf photosynthesis as function of time from treatment application. Measurements were performed at noon.