

EFFECTS OF SHADING ON DRY MATTER PARTITIONING AND YIELD OF FIELD-GROWN SUNFLOWER

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SUMMARY

Crop simulation models require quantitative descriptions of the effects of irradiance on dry matter partition and yield. The objective of this work was to quantify the effects of reduced radiation intensity during different phenological stages on sunflower (*Helianthus annuus*, L.) dry matter partitioning and yield. A field experiment was carried out in 1990 with seven radiation treatments (using a shade-cloth that reduced incoming PAR to 50%) which were applied at various phenological stages. Grain number was affected by shading, with the greatest effect occurring when shading was applied prior to anthesis. Shading reduced assimilate partitioning to the heads, final biomass, and yield, increased dry matter partitioning to stems and had no effect on the partitioning to leaves.

INTRODUCTION

Modelling crop growth requires knowledge on how environment influences dry matter partitioning and yield. Experimental work to study carbon partition priorities must be based on manipulating C supply, either by varying plant population or by changing radiation intensity through shading. Information regarding dry matter partitioning in sunflower under different radiation levels, which is necessary for crop growth modelling, is lacking.

The period of reduced irradiance may also play an important role in dry matter partition and yield. The conditions during flower initiation affect potential seed number in the sunflower (Steer et al., 1984). The effects of shading during different periods could help understanding seed number determination in the sunflower.

The objectives of this study were a) to quantify the partition coefficients for the various organs in sunflower under different radiation environments and b) to study the effect of shading during different periods on seed number.

#### MATERIALS AND METHODS

Sunflower hybrid 'Sungro-380' was sown on 28 March, 1990 at the Agriculture Research Center in Cordoba, Spain (38°N 4°W). The soil is a deep sandy-loam. Plant population was 7.1 plants/m<sup>2</sup>, with rows at 0.7 m. Incoming PAR was reduced to 50% by shading, using black shade netting. Plots (3.5 x 3.5 m) were arranged in three blocks which included six treatments consisting of periods when radiation was reduced and an unshaded control (Table 1). Fertilizer was applied on 29 March (150 kg N/ha and 100 kg K<sub>2</sub>O/ha) and on 29 May (150 kg N/ha). The plots were furrow-irrigated up to field capacity every ten days. The time to flower initiation (FI) was estimated from final leaf number and progress of leaf appearance as proposed by Sadras and Villalobos (submitted).

Biomass was determined six times between emergence and anthesis. Plants were separated into leaves, stems and heads, oven-dried at 70°C and weighted. Partition coefficients for leaves, stem and head were calculated as the slopes of linear regressions of organ weights on shoot biomass, for the six samplings. At harvest (6 August), leaves, stem, head and seeds of three plants per plot were separated and dried to constant weight. Total seed weight and the weight of one hundred seeds were also determined.

Air temperature, solar radiation and rainfall were measured at an automated weather station located 600 m away from the experimental plot.

#### RESULTS AND DISCUSSION

The relationship between leaf weight and shoot weight was linear for all treatments, although the slopes decreased at similar shoot weights (around 26 g/plant) for all treatments (Fig. 1). All linear relations were then recalculated by forcing the change of slope at 26 g, to allow treatment comparisons. There were no significant differences among treatments in the partition coefficient to leaves (PCL). Average PCL for all treatments was 0.47 for shoot weights below 26 g/plant, and 0.22 for values

above. It is not known why the PCL is reduced above a given shoot weight. The fact that it occurs at the same weight suggests that this reduction is not associated with ontogeny or plant leaf area.

Stem partition coefficient (SPC) increased for all shaded treatments, ranging from 0.54 to 0.63, as compared to 0.47 of unshaded plants. This response was associated with an increase in stem height which varied from 174 cm for control plants to 193-241 cm for the different shaded treatments ( $P < 0.07$ ). Surprisingly, maximum stem length occurred in treatment S23 (241 cm), while S123 plants were only 190 cm tall. Shading during the FI-RHG period had the largest impact on stem height. Height increases for shaded sunflower plants have also been reported by Rawson and Hindmarsh (1983).

Dry matter distribution to the head was negatively affected by shading. Head partition coefficient (HPC) was reduced to values between 0.15 and 0.25 in shaded plants versus 0.39 in the control. HPC was affected even when shading occurred before the start of rapid head growth (treatments S1 and S12) which implies that HPC in sunflower is partly determined in very early developmental stages. The amount of carbohydrates available around flower initiation may affect the initiation process and thus, potential head size. Later restrictions of carbon supply reduce even more carbon partitioning to the head. While this type of response would confer an adaptive advantage for plant survival by improving the carbon supply/demand ratio after anthesis, it is puzzling that reproductive growth apparently loses priority in carbon allocation when C-supply is diminished by shading.

Grain number was affected by shading treatments (Table 2). Control plants produced more than 1500 seeds/head while seed numbers ranged from 800 to 950 in shaded plants if shading occurred during the start of rapid head growth-anthesis period (S3, S23 and S123) and between 1200 to 1400 seeds/head, otherwise (S1, S2 and S12). It has been proposed that floret number in sunflower is determined by the end of flower initiation (Steer et al., 1984). In our experiment major effects were induced by shading only during the period previous to anthesis (treatment S3). Charles-Edwards et al. (1986) suggested that assimilation rate around anthesis is responsible for grain number determination in grain crops. Regression analysis of grain number

on shoot growth rates before anthesis had  $r^2=0.42$  suggesting that other important factors not related to C supply may also affect grain number determination. Rawson (1988) suggested that temperature may also be involved in controlling grain number, as it affects the duration of the FI-anthesis period. Field experiments including shading treatments under different temperature environments would be helpful to test Rawson's (1988) hypothesis.

Single seed weights were around 45 mg/seed for five of the seven treatments, while S1 and S12 had lower and higher seed weights, respectively, despite no differences in seed number.

Grain yield was affected in parallel to grain number, ranging from 36.9 (S123) to 71.6 g/plant (Control). Harvest index (HI) ranged from 0.24 to 0.33, with the lowest values corresponding to treatments that were shaded during the RPG-anthesis period. The reduction in seed number in that period was most important (Table 2) without any important reduction in biomass. Treatment S3 had 50 and 80% of seed number and biomass of the control, respectively. The linear regression of grain weight on shoot weight at harvest of single plants yielded an intercept  $a=-14.62$  (SE=4.27) and slope  $b=0.359$  (SE=0.0217) with  $n=21$  and  $P<0.0001$ . The negative intercept suggests that HI will increase with plant size and that a minimum plant size is required to produce yield (in our experiment, 40.7 g/plant).

#### CONCLUSIONS

Dry matter distribution in the above-ground parts of the sunflower plant is drastically affected by shading at various times during canopy development. Stem partition coefficient increased while the C-distribution to the developing head was negatively affected by shading. Also, the latitude exhibited by the sunflower in grain number adjustments during head development in response to declining C-supply probably represents an adaptive advantage for a species which evolved in an arid environment where post-anthesis C-supply is severely curtailed by drought.

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Table 1. Description of shading treatments and weather conditions during the experiment. Cordoba, Spain, 1990.

Treatment	Low radiation period Dates <sup>4</sup>	Stage	TMAX <sup>1</sup>	TMIN <sup>2</sup>	SOLRAD <sup>3</sup>
S1	101 - 131	(E <sup>5</sup> - FI <sup>6</sup> )	23.6	8.9	23.0
S2	131 - 156	(FI - RHG <sup>7</sup> )	28.9	12.6	24.2
S3	156 - 180	(RHG - A <sup>8</sup> )	30.6	13.9	27.2
S12	101 - 156	(E - RHG)			
S23	131 - 180	(FI - A)			
S123	101 - 180	(E - A)			
Control	-				

<sup>1</sup> Average maximum temperature (°C)

<sup>2</sup> Average minimum temperature (°C)

<sup>3</sup> Average shortwave solar radiation (MJ m<sup>-2</sup> day<sup>-1</sup>)

<sup>4</sup> Day of year

<sup>5</sup> Emergence

<sup>6</sup> Flower initiation

<sup>7</sup> Start of rapid head growth

<sup>8</sup> Anthesis

Table 2. Yield components and total biomass at harvest of sunflower cv. 'Sungro-380' grown at Cordoba under different shading treatments. Standard errors are shown in parenthesis.

Treatment	Seeds per head	Seed weight (mg/seed)	Shoot biomass (g/plant)
S1	1228 ( 80)	35.2 (4.1)	159.7 (15.0)
S2	1394 (144)	46.8 (2.8)	208.5 (31.0)
S3	896 ( 67)	47.1 (8.6)	173.3 (24.8)
S12	1249 ( 76)	56.4 (4.1)	218.6 (15.9)
S23	947 ( 75)	46.3 (2.1)	167.2 (15.7)
S123	836 ( 69)	43.3 (2.1)	146.1 (10.3)
Control	1541 (195)	43.8 (5.1)	216.6 (51.6)

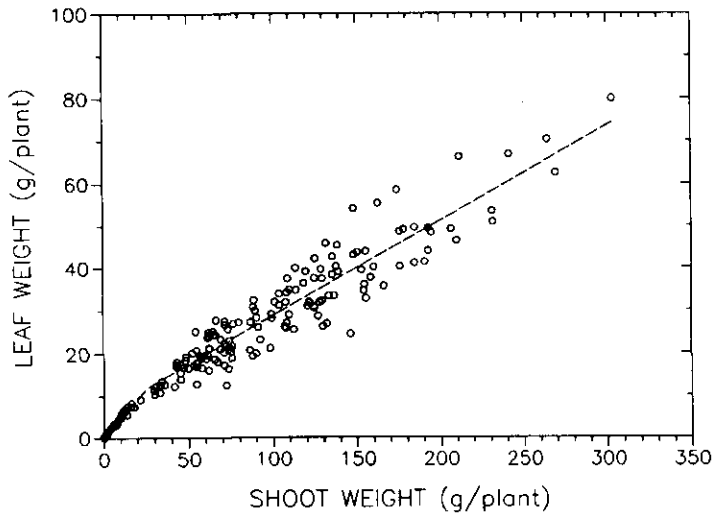


Figure 1. Leaf weight versus shoot weight of sunflower cv. 'Sungro-380'. Data include all shading treatments and the control. The two linear functions correspond to a least-square fit with the slope changing at 26 g shoot/plant from 0.47 to 0.22. The slope of each line represents the leaf partition coefficient for that interval.

#### REFERENCES

- Charles-Edwards, D.A., Doley, D. and Rimmington, G.M. 1986. Modelling plant growth and development. Academic Press, Australia. North Ryde, NSW. 235 p.
- Rawson, H.M. 1988. Can productivity in sunflower be increased by changed plant development?. In: Sinha, S.K., Sane, P.V., Bhargaba, S.C., and Agrawal, P.K. (Eds.). Proc. Int. Congress of Plant Physiol. New Delhi, India. Feb. 15-20, 1988. pp. 361-372.
- Rawson H.M. and Hindmarsh, J.H. 1983. Light, leaf expansion and seed yield in sunflower. Aust. J. Plant Physiol. 10:25-30.
- Steer, B.T., Hocking, P.J., Lortt, A.A. and Roxburgh, C.M. 1984. Nitrogen nutrition of sunflower (*Helianthus annuus* L.): Yield components, the timing of their establishment and seed characteristics in response to nitrogen supply. Field Crops Res. 9: 219-236.