

## A PHYSIOLOGICAL ANALYSIS OF THE GROWTH AND YIELD OF TWO SUNFLOWER CULTIVARS.

N. Trapani, V.O. Sadras, F. Vilella and A.J. Hall.

Depto. Ecología, Facultad de Agronomía (UBA), Av. San Martín 4453, 1417 Buenos Aires, ARGENTINA.

### SUMMARY

The physiological determinants of the growth of crops of Contiflor 3 (C3) and Contiflor 8 (C8), two Argentine hybrids, were examined in a comparative study of the ways in which yield in these cultivars is achieved under non-limiting water and nutrient conditions. Crops (population density 37,500 pl./ha) of the two cultivars were grown on a Typic Hapludoll with irrigation and fertilization at Junín, Prov. of Buenos Aires during the 1985-86 season. During the growth cycle periodic observations and measurements were made of development, grain filling, above-ground biomass accumulation, leaf area index and intercepted photosynthetically active radiation (PAR). C8 had a higher proportion of oil in the seeds, and biomass values were corrected for oil synthesis costs when comparing the cultivars and in comparing pre- and post-anthesis biomass accumulation. Duration of the total growth cycle (emergence-maximum grain weight) was the same (91 days) for both cultivars, but C3 flowered six days later than C8. Grain number and rate of grain growth were greater and duration of grain growth shorter in C3. Leaf area index of young crops, duration of the pre-anthesis period, biomass at anthesis and at harvest and yield were significantly ( $P = 0.05$ ) higher in C3. The dynamics of efficiency of PAR conversion to biomass ( $\epsilon$ ) could be described by three straight lines, corresponding to the establishment (0-30 days from emergence [DDE]), pre-anthesis (30 DDE to anthesis) and post-anthesis (anthesis-maximum grain weight) periods. Maximum values of  $\epsilon$  for C3 (2.82 g dwt./MJ) and C8 (2.56 g dwt./MJ) were attained during the pre-anthesis period. Biomass partitioning to lamina during early growth was the same in both cultivars, thus the greater leaf area index of C3 was due to its greater specific leaf area. Hence, greater interception of PAR early in the season and a longer pre-anthesis period must have contributed to the greater pre-anthesis biomass of this cultivar. The putative advantage of a longer grain-filling period in C8 was offset by lower values for grain number, rate of grain growth and  $\epsilon$  during the post-anthesis period. We conclude that yield in these cultivars was achieved via different combinations of attributes linked to PAR interception, duration of developmental phases and carbon partitioning. We further hypothesize that other more appropriate combinations of these attributes should be achievable and lead to greater yields.

### INTRODUCTION

Analysis of the physiological determinants of growth and yield has been proposed as a tool to understand the ways in which yield is achieved by crops. This approach, developed by Charles-Edwards (1962) and Charles-Edwards et al. (1986) has its antecedents in the 70's (Warren Wilson, 1971; Monteith, 1977). Within this framework, the main determinants of crop production are taken to be: 1) the amount of photosynthetically active radiation (PAR) intercepted by the canopy, 2) the efficiency of PAR conversion to biomass ( $\epsilon$ ), 3) the proportions of dry matter partitioned to the different plant organs ( $\eta$ ), 4) the rate of dry matter loss ( $V$ ), and the duration of growth of plants or plant parts ( $L$ ).

To improve our understanding of the ways in which the yield of different cultivars is achieved, some of these physiological determinants were measured in crops of two Argentine hybrids grown under non-limiting water and nutrient conditions and are reported in this paper.

### MATERIALS AND METHODS

The experiment was conducted at Junín, Prov. of Buenos Aires (34°33' S. Lat.) during the 1985-86 season. Crops of two non-related hybrids (A. Vazquez, personal communication) Contiflor 3 (C3) and Contiflor 8 (C8) were grown on a Typic Hapludoll on plots which were maintained near field capacity by complementary irrigations. Plots were 9 x 33.6 m; rows were spaced at 0.70 m; row orientation was NW-SE. Crops were sown on 20 November 1985 and plants emerged on 27 November. Population density of 35700 plants ha<sup>-1</sup> was achieved by thinning when the plants had one pair of leaves. Crops were fertilized at sowing (63 kg N ha<sup>-1</sup>) and at 50 days from emergence (DDE) (20 kg N ha<sup>-1</sup>) with urea. Weeds were controlled chemically at pre-sowing and manually during crops growth. The experiment was laid out as complete blocks with two replicates.

Biomass accumulation - total biomass during the first 30 DDE and aerial biomass from 30 DDE to maturity - was determined by weekly harvests of plants growing in perfect competition (3 plants per plot and cultivar). Roots biomass accumulation was obtained from harvests of plants which had been sown in PVC cylinders (0.16 m in diameter and 0.30 or 0.60 m deep) placed in the soil within the crop. After harvesting the tops of the plants, the

cylinders were taken from the soil and the root system washed out. Cylinders had no effect on the aerial biomass of plants until 30 DDE ; it was therefore assumed that cylinders did not affect root biomass before that date. Dry weight of plant organs was determined after drying at 70 ° during 72 hours.

Leaf area index (LAI) was determined from weekly measurements of maximum leaf width (Pereyra *et al.*, 1982). Proportion of intercepted PAR was determined once a week from 31 DDE until maturity. Measurements were made in the early morning, at noon and before sunset on clear days using a 1-m quantum sensor (Li-Cor 191s) placed parallel to the row as proposed by Charles-Edwards and Lawn (1984). Interception values at 0.10 m intervals across the width of the row were graphically integrated to obtain daily crop interception values.

Evolution of grain growth was followed by harvesting samples from the periphery (excluding the outer two files of grain) of the inflorescence (2-3 times a week, three replicates of 20 grains per cultivar) from post-anthesis to achievement of maximum weight. Seed oil content was determined by nuclear magnetic resonance.

Incident radiation was calculated according to Penman (1948) using sunshine duration data from a station 7 km from the site. PAR was taken to be 0.5 incident radiation.

## RESULTS

The hybrids C3 and C8 completed their growth cycle (emergence - maximum grain weight) in 91 days. Duration of pre-anthesis period was shorter for C8 (Table 1); consequently grain growth took place over a longer period in C3.

TABLE 1. Pre-anthesis leaf attributes and biomass at anthesis.

	CONTIFLOR 3	CONTIFLOR 8
Leaf Area (cm <sup>2</sup> plant <sup>-1</sup> )		
DDE = 31	3993 a *	2967 b
DDE = 38	8139 a	6438 b
ANTHESIS	16632 a	14954 a
Specific leaf area (cm <sup>2</sup> .g <sup>-1</sup> )		
DDE = 22	301.2 a	246.1 b
DDE = 31	260.5 a	167.8 b
DDE = 38	226.5 a	184.7 a
Aerial biomass at anthesis (g. plant <sup>-1</sup> )	296.00 a	241.59 b
Duration emergence-anthesis period (days)	63	57

\* Values followed by different letters are significantly different (P=0.05).

Table 2. Yield and yield-linked attributes of the hybrids.

	CONTIFLOR 3	CONTIFLOR 8
AERIAL BIOMASS (g.plant <sup>-1</sup> )	405.6 a *	312.6 b
GRAIN YIELD (g. plant <sup>-1</sup> )	113.9 a	88.9 a
GRAIN NUMBER (grains.plant <sup>-1</sup> )	2370 a	2116 b
CORRECTED GRAIN YIELD (g.plant <sup>-1</sup> )	178.0 a	144.9 a
CORRECTED HARVEST INDEX	0.38 a	0.39 a
OIL CONTENT IN GRAINS (%)	42.3 a	45.9 b
NON-GRAIN AERIAL BIOMASS VARIATION DURING POST-ANTHESIS (g. plant <sup>-1</sup> )	-4.4 a	-11.7 b

\* Values followed by different letters are significantly different (P=0.05).

Aerial biomass accumulation at anthesis (Table 1), at maturity, and yield were significantly higher in C3; C8 had a higher proportion of oil in the grains (Table 2). Given the higher synthesis cost of lipids, post-anthesis biomass and yield values were corrected on the assumption that carbohydrates were accumulated instead of lipids using the appropriate factor (Penning de Vries et al., 1983). Corrected yields of C3 and C8 were statistically different at  $P=0.10$ . Corrected harvest indices were, however, similar in both hybrids (Table 2).

Aerial biomass accumulation after anthesis was restricted to the reproductive organs in both cultivars; non-grain aerial organs in C8 lost a significantly greater amount of biomass during this period (Table 2).

Growth of grain as from eight days after anthesis could be described by two straight lines (Figure 1); rate of grain growth was higher and duration of grain growth was shorter in C3 (20 and 32 days for C3 and C8 respectively). At physiological maturity average grain weight was similar in both cultivars ( $0.475$  and  $0.457$  g.grain<sup>-1</sup> for C3 and C8 respectively), but grain number was significantly greater in C3 (Table 2).

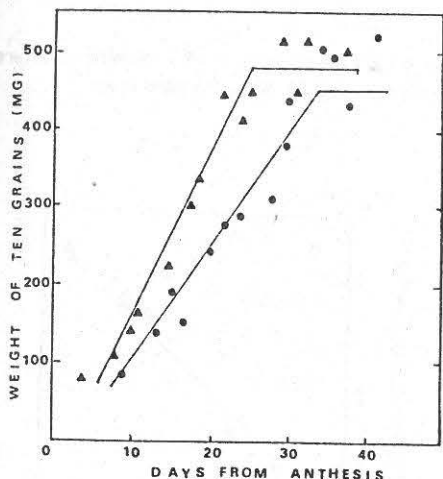


Figure 1. Dynamics of grain weight of Contiflor 3 ( $\Delta$ ) and Contiflor 8 ( $\bullet$ ). Filled lines are :  
 Contiflor 3:  $Y \text{ (mg)} = -61 + 22.2 \text{ (DFA)}$ ;  
 $R^2 = 0.95$ ,  $n=8$ .  
 Contiflor 8:  $Y \text{ (mg)} = -37 + 13.9 \text{ (DFA)}$ ;  
 $R^2 = 0.96$ ,  $n=9$ .

Leaf area index of C3 was consistently greater during the growth cycle (Figure 2 A) though differences were not always statistically significant. Partitioning of aerial biomass to lamina was similar in both cultivars during the first month from emergence (Figure 3 A) but specific leaf area was significantly different during the same period (Table 1). The partitioning coefficient aerial biomass/total biomass was also similar in both cultivars up to 30 DDE (Figure 3 B).

The dynamics of PAR interception differed little between hybrids (Figure 2 B); the proportion of PAR intercepted (Q) reached its maximum value for a LAI of between 2 to 3 (Figure 4). The Q/LAI relationships observed in pre and post anthesis did not differ (Figure 4). Values of Q during the early part of the growth cycle (0-25 DDE) were estimated using the relationships showed in figures 2A and 4. These estimated values were used for calculating  $\epsilon$  (g dwt. MJ<sup>-1</sup>) during the establishment period of the crops. Values for biomass in the post-anthesis period were corrected for higher lipid synthesis costs.

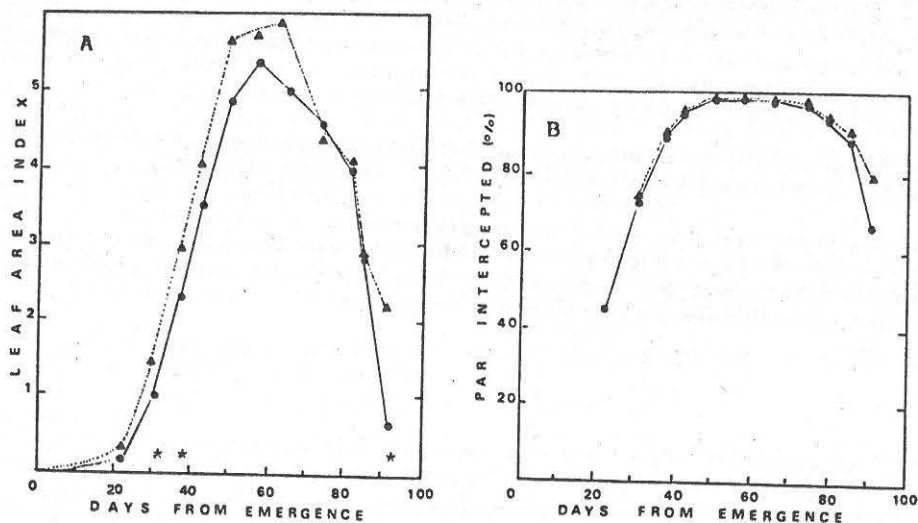


Figure 2. A) Dynamics of leaf area index in crops of Contiflor 3 (▲) and Contiflor 8 (●). Significant difference (P=0.05) are indicated by asterisks. B) Proportion of intercepted radiation (Q, %) by the same crops.

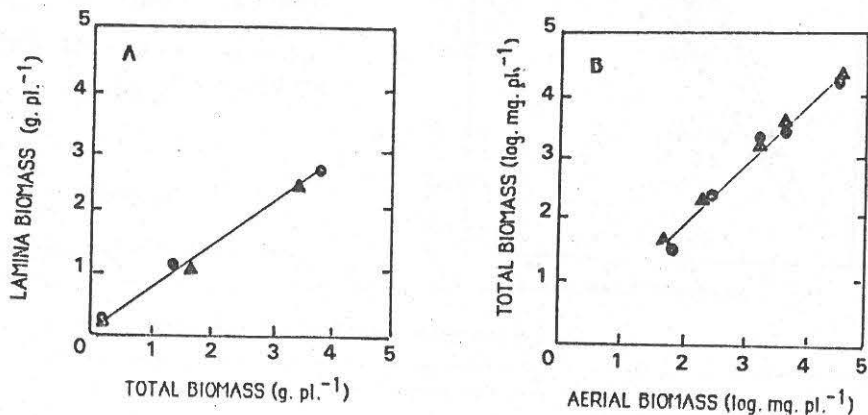


Figure 3. A) Lamina biomass/ Aerial biomass relationships in the 0-22 DDE period. B) Aerial biomass/Total biomass relationships in the 0-30 DDE period.

Dynamics of  $\mathcal{E}$  could be described by three straight lines corresponding to the establishment (0-30 DDE), pre-anthesis (30 DDE to anthesis) and post-anthesis (anthesis-maximum grain weight) periods (Figure 5). Estimated values for the establishment period were markedly lower than the pre and post-anthesis ones. Including root biomass in the calculation of  $\mathcal{E}$  for the establishment phase increased its value by 25% in both hybrids, but this was not

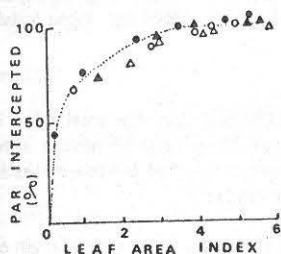


Figure 4. Leaf area index and proportion of intercepted radiation (PAR) of Contiflor 3 ( $\blacktriangle, \triangle$ ) and Contiflor 8 ( $\bullet, \circ$ ) crops. Closed symbols correspond to pre-anthesis and open symbols to post-anthesis periods respectively.

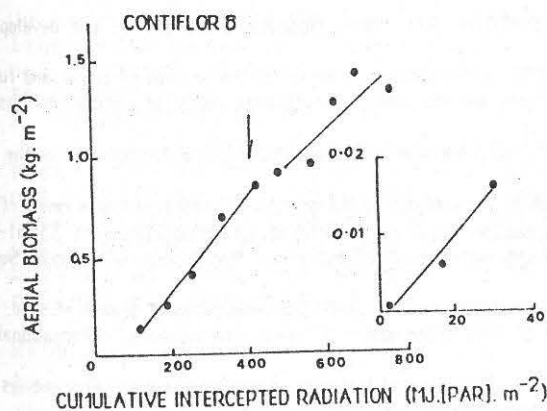
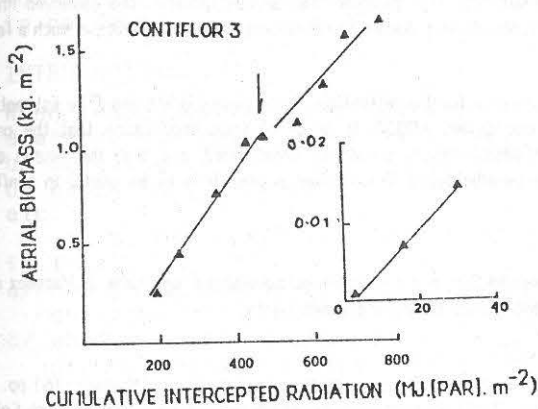


Figure 5. Seasonal aerial biomass production and cumulated intercepted radiation (PAR) for Contiflor 3 ( $\blacktriangle$ ) and Contiflor 8 ( $\bullet$ ) crops. Insets show values for establishment period (0-30 DDE). Arrows indicate anthesis of crops. Values of  $\mathcal{E}$  (slopes of fitted lines) are (in g.dwt/MJ PAR): Establishment 0.39 (C3) and 0.41 (C8); Pre-anthesis 2.82 (C3) and 2.56 (C8); Post-anthesis 2.47 (C3) and 1.77 (C8).

sufficient to remove the difference with later phases. Maximum values of  $\epsilon$  for C3 (2.82 g dwt. MJ<sup>-1</sup>) and C8 (2.56 g dwt. MJ<sup>-1</sup>) were attained during the pre-anthesis period, and were significantly greater ( $P=0.05$ ) than those achieved in the remaining phases. Values for  $\epsilon$  within periods were not statistically different between cultivars, but values of C3 were consistently higher than those of C8 over the last two periods. Changes in  $\epsilon$  with ontogeny have also been recorded in sweet and forage sorghum (Ferraris and Charles-Edwards, 1986) and *Vigna trilobata* crops (Muchow and Charles-Edwards, 1982).

## DISCUSSION

Biomass partitioning to lamina during early growth was the same in both cultivars, thus the greater leaf area index of C3 in the early part of the season was due to its greater specific leaf area. The greater biomass at anthesis of C3 must be attributed to greater interception resulting from this and the longer duration of the pre-anthesis period of this hybrid. The greater grain number of this hybrid may be linked to these attributes.

The putative advantage of a longer grain filling period in C8 was partially offset by a lower rate of grain growth; at the same time C8 had a higher percentage of oil in grain and a greater apparent translocation of dry matter from vegetative aerial organs to grains. C3 had the greater grain number and grain growth rate but a shorter filling period.

This analysis indicates that yield linked attributes differed between cultivars and neither cultivar exhibited a consistent advantage for all the determinants examined. The question that arises is: are the observed linkages between characteristics fixed? If they are not, it should be possible to recombine these attributes in such a fashion as to increase potential crop yields.

The changes in the value of  $\epsilon$  with development deserve further attention. Some crop models use  $\epsilon$  to estimate dry matter production (e.g. CERES-Wheat, Ritchie and Otter, 1983). It is of obvious importance that the precise developmental stage which fixes the end of the establishment period be determined, and that the causes of the changes in value of this variable with ontogeny be elucidated if a similar approach is to be useful in sunflower modelling.

## ACKNOWLEDGEMENTS

Financial support by CONICET and Compañía Continental S.A. are gratefully acknowledged. We thank A. Vazquez and A. Bertero de Romano for much encouragement and assistance during the experiments.

## REFERENCES

- CHARLES-EDWARDS, D.A., 1982. Physiological determinants of crop growth. Academic Press, Sydney. 161 pp.
- CHARLES-EDWARDS, D.A. and LAWN, R.J., 1984. Light interception by grain legume row crops. *Plant Cell and Environment* 7: 247-251.
- CHARLES-EDWARDS, D.A., DOLEY, D. and RIMMINGTON, G.M., 1986. Modelling plant growth and development. Academic Press, Sydney. 235 pp.
- FERRARIS, R. and CHARLES-EDWARDS, D.A., 1986. A comparative analysis of the growth of sweet and forage sorghum crops. I: Dry matter production, phenology and morphology. *Australian Journal of Agricultural Research* 37: 495-512.
- MONTEITH, J.L., 1977. Climate and efficiency of crop production in Britain. *Philosophical Transactions of the Royal Society, Series B* 281: 277-294.
- MUCHOW, R.C. and CHARLES-EDWARDS, D.A., 1982. An analysis of the growth of mung beans at a range of plant densities in Tropical Australia. I. Dry matter production. *Australian Journal of Agricultural Research* 33: 41-51.
- PENMAN, H.L., 1948. Natural evaporation from open water, bare soil and grass. *Proceedings of the Royal Society, Series A* 193: 120-145.
- PENNING DE VRIES, F.W.T., VAN LAAR, H.H. and CHARDON, M.C.M., 1983. Bioenergetics of growth of seed, fruits and storage organs. In: Potential productivity of field crops under different environments. International Rice Research Institute, Los Baños. pp. 37-60.
- PEREYRA, V.R., FARIZO, C. and CARDINALI, F., 1982. Estimation of leaf area on sunflower plants. *Proceedings 10th. International Sunflower Conference, Surfers Paradise, Australia*. pp. 21-23.
- RITCHIE, J.T. and OTTER, S., 1983. Description and performance of CERES-Wheat: A user-oriented wheat yield model. USDA-ARS Grassland, Soil and Water Laboratory, Temple, Texas. 37 pp.
- WARREN WILSON, J., 1971. Maximum yield potential. In: Transition from extensive to intensive agriculture with fertilizers. *Proceedings of the 7th. Colloquium International Potash Institute. IPI, Berne*. pp 34-56.