EFFECT OF INTERCEPTED SOLAR RADIATION DURING THE FRUIT FILLING PERIOD ON SUNFLOWER OIL YIELD.

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Summary:

The expression of oil yield components in sunflower could depend on environmental conditions of plants during the fruit filling period. The objective of this work was to investigate the effect of intercepted PAR during the fruit filling period on oil yield components in two sunflower hybrids, one with high oil percentage potential and black hull (G-100), and other with low oil percentage potential and stripped hull (NKT). Three experiments were carried out in three years under good water and nutrient conditions. Intercepted PAR was modified by shading, thinning or their combination. Oil yield was increased when intercepted PAR increased. Greater intercepted PAR increased non empty fruit number and weight. Fruit growth rate was also increased by the effect of intercepted PAR. Oil percentage in G-100 increased with higher intercepted PAR, because of longer duration of the accumulation period. Oil percentage in NKT remained unaffected although the thinned treatments intercepted up to 7.5 times the amount of radiation per plant that the shaded ones did. About 84% (G-100), and 80% (NKT) of the variability among treatments and experiments in weight per fruit were accounted for by the PAR intercepted during the fruit filling period. Oil percentage variability in G-100, was also related to intercepted solar radiation (r^2=0.93). It is concluded that intercepted PAR during fruit filling period plays a main role in determining oil production in sunflower. Genotypic differences were found. It may be important to consider them to accurate simulation models of crop growth and yield.

Keywords: Sunflower; Intercepted PAR; Fruit number; Fruit weight; Oil percentage.

INTRODUCTION

Oil yield per plant in sunflower is the result of number of filled fruits per capitulum, weight per fruit (fruit weight)and oil percentage. These three components are determined by genetic factors (see revisions of Merrien, 1992; Sadras and Villalobos, 1994; Connor and Hall, 1997), but they can be highly modified by environmental factors and growth conditions (Hall et al., 1985; Steer et al., 1984; Andrade and Ferreiro, 1996).

Incident and intercepted PAR during the fruit filling period may affect the three oil yield components. Fruit number was reduced when shading was applied between 16 days before and 20 days after 50% of first anthesis (Chimenti and Hall, 1992). Daily mean intercepted PAR from 30 days before to 20 days after flowering was a good predictor of fruit number (Cantagallo et al., 1997). Moreover, fruit number, fruit weight and oil percentage were affected in a hybrid with black hull by shading and thinning plants at the beginning of fruit filling (Andrade and Ferreiro, 1996). However, no relationships between fruit number, fruit weight or oil percentage and intercepted PAR during the fruit filling period have been established in previous works.

Hybrids with black hull fruits are potentially able to reach high oil percentage (48% or more), whereas hybrids with stripped hull fruits typically reach low oil percentage (44% or less). There are no data about the effect of intercepted PAR during fruit filling on oil yield and its components in sunflower hybrids with low oil percentage potential (stripped hull) and about the relationships in both types of hybrids between oil yield components and intercepted PAR accumulated during the fruit filling period. These relationships could be useful for simulation purposes, and could eventually be incorporated in growth models (Texier, 1992; Steer et al., 1993; Villalobos et al., 1996).

The objective of this work was to study the effect of intercepted PAR during the fruit filling period on the oil yield and its components in two sunflower hybrids, one with high oil percentage potential and black hull (G-100), and other with low oil percentage potential and stripped hull (NKT).

MATERIALS AND METHODS

Three experiments (A, B and C) were carried out under good water and mineral conditions for three years (1994, 1996 and 1995, respectively) at Balcarce, Argentina (37°45’ S, 58°18’ W). Two hybrids were used, ‘Dekalb G-100’ (G-100, black hull, oil percentage from 48 to 54%), and ‘Northrup King Tordillo’ (NKT, stripped hull, oil percentage from 38 to 44%). The experiments were split-plot designs with four (Experiment A) and three (Experiments B and C) replicates. The hybrids were assigned to main plots and the radiation treatments to subplots.

Intercepted PAR was modified (except for the control plot) after fecundation by 50 % uniform shading (neutral mesh cloth), thinning (to 25 %, experiments A and C, or 50 % experiment B, of original density), and their combination (shading+thinning). Daily intercepted PAR was calculated as the product of global daily incident radiation (sensor LI-COR, Lincoln, NE, USA) and daily percent interception by the crop (according to Gallo and Daughtry, 1986). Capitulum temperature was measured in G-100, in experiments A and B, with small transistors (LM35 DH, Sener Electrónica, Mar del Plata, BA, Argentina), located in the fruit insertion zone. Samples of 3 to 5 capitulum were taken periodically (each 2 to 8 days) during the fruit filling period. Non empty fruits (kernel occupying at least 20% of total space in fruit) were separated, counted and weighted. Oil percentage was measured by nuclear magnetic resonance (NMR, Analyzer Magnet Type 10, Newport Oxford Instruments, Buckinghamshire, England).

Conditional models where used to determine the rate and the duration of fruit weight and oil percentage increasing linear phases. Data of fruit number, fruit weight, oil percentage and oil yield, were processed by analysis of variance procedures (SAS Institute Inc., 1988). Means comparisons were evaluated by the Tukey test ($p < 0.05$). Data adjustments were made with Sigma Plot Scientific Graphing System, version. 4.10 (Jaendel Corporation).

RESULTS AND DISCUSSION

Daily mean air temperature (°C) of the period that goes from treatment application to physiological maturity of the control was 20.9 ± 2.8, 19.4 ± 3.2 and 16.6 ± 3.1 for experiments A, B and C, respectively. Daily mean incident radiation (MJ m^{-2} d^{-1}) of the same period was 19.4 ± 3.0, 22.0 ± 4.9 and 12.0 ± 4.2 for experiments A, B and C, respectively. Intercepted PAR was affected by treatments (Table 1). Thinned treatment had always the highest value, and shaded the lowest. The control and shaded+thinned treatments showed intermediate values of this variable. Capitulum mean daily temperature during the treatment application-physiological maturity period of shading treatment (measured only in G-100) was between 0.4 and 0.9 °C higher in non-shading treatments (control, thinned), than in shaded ones (shaded, shaded+thinned).

Table 1: Cumulative intercepted PAR (MJ $plant^{-1}$) for the period from treatment application to physiological maturity of each treatment. Hybrids G-100 and NKT, experiments A, B and C.

Hybrid	Experiment	Shaded	Control	Shaded + Thinned	Thinned
G-100	A	12.3 ± 0.3	22.9 ± 0.7	34.2 ± 1.1	74.3 ± 4.3
	B	29.7 ± 1.6	67.5 ± 4.8	61.9 ± 2.4	107.0 ± 8.3
	C	10.1 ± 0.2	20.9 ± 1.5	28.5 ± 4.7	61.2 ± 4.2
NKT	A	14.1 ± 0.2	27.3 ± 0.4	34.0 ± 4.4	78.8 ± 10.0
	B	37.6 ± 1.2	68.9 ± 7.6	61.6 ± 5.0	102.4 ± 7.3
	C	11.8 ± 0.4	25.6 ± 1.1	40.5 ± 1.9	88.5 ± 6.7

Oil yield per plant increased when intercepted PAR was higher (Fig. 1). In experiments A and C, hybrid NKT reported higher values than hybrid G-100. In experiment B, where intercepted PAR showed higher values than the other experiments, oil yield in NKT did not differ significantly among treatments. Also in this case, G-100 control, shaded+thinned and thinned treatments had higher oil yield than similar treatments in NKT. These results suggest a great oil yield stability in the hybrid with stripped hull and low oil percentage potential in response to changes in intercepted PAR during fruit filling, and a high oil yield potential but a low stability to variation in intercepted PAR in the hybrid with black hull and high oil percentage potential.

Intercepted PAR during fruit filling period affected oil yield by modifying its components (non empty fruit number, non empty fruit weight and oil percentage). Number of non empty fruit slightly decreased in response to a lower intercepted PAR per plant (Table 2). This response was expectable since our treatments were applied close to the end of the period during which Villalobos et al. (1996) consider that filled fruit number is set. In Experiment B, in which was intercepted the greatest quantity of PAR, both hybrids had a higher number of non empty fruit than in experiments A and C.

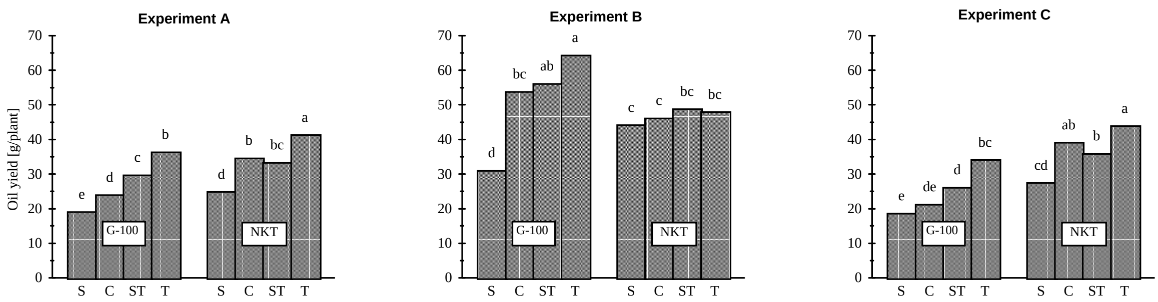

Figure 1: Oil yield per plant for shaded (S), control (C), shaded and thinned (ST) and thinned (T) treatments. Hybrids G-100 and NKT, experiments A, B and C. For each experiment, bars with the same letter have values not significantly different (Tukey, $p<0.05$).

Mean fruit weight was always higher in treatment thinning and lower in shading (Table 2). Treatments control and shading+thinning had intermediate values. Intercepted PAR affected oil percentage in G-100, but did not in NKT (Table 2). In NKT, the effect was not observed even though intercepted PAR per plant increased up to 7.5 times (experiment C). Hybrid G-100 showed maximum oil percentage values higher than NKT in all experiments. However, in experiment A oil percentage values of shading treatment were lower in G-100 than in NKT because in the former it was affected by intercepted PAR.

Table 2: Oil yield components. Hybrids G-100 and NKT, experiments A, B and C.

	Non empty fruit per plant		Fruit weight		Oil percentage	
	G-100	NKT	G-100	NKT	G-100	NKT
Experiment/Treatment			mg		%	
A						
Shading	1337 bc	1110 d	36.3 e	51.7 bc	41.3 d	43.4 c
Control	1360 abc	1350 bc	39.4 e	59.1 ab	43.7 c	43.2 c
Shading+Thinning	1515 ab	1278 cd	41.5 de	59.6 a	46.3 b	43.7 c
Thinning	1573 a	1501 ab	47.0 cd	63.3 a	49.5 a	43.3 c
B						
Shading	1494 c	1536 c	45.4 c	66.9 a	45.5 c	43.0 d
Control	1899 ab	1564 bc	55.9 b	67.9 a	51.3 a	43.6 d
Shading+Thinning	2094 a	1619 bc	54.5 b	69.3 a	49.2 b	42.7 d
Thinning	2129 a	1619 bc	59.8 b	70.1 a	50.0 ab	42.2 d
C						
Shading	1210 cd	1273 bcd	35.9 e	52.7 cd	42.0 cd	40.8 de
Control	1135 d	1549 ab	41.2 e	62.5 ab	45.1 b	39.3 e
Shading+Thinning	1491 abc	1493 abc	38.2 e	60.0 bc	44.0 bc	41.3 de
Thinning	1488 abc	1650 a	47.4 d	66.7 a	48.6 a	39.9 de

For each variable and experiment, values followed by the same letter do not differ significantly (Tukey, $p<0.05$).

Intercepted PAR modified fruit weight and oil percentage by affecting rate and/or duration of their evolution along time. The adjustment of results of both evolution to a lineal+plateau function presented in all cases determination coefficients (r^2) higher than 0.95. Fruit growth rate was affected by intercepted PAR. Highest values were found in thinned (1.5 and 1.8 mg d^{-1}, G-100 and NKT, respectively), and lowest values corresponded to shaded (1.1 and 1.5 mg d^{-1}, G-100 and NKT, respectively). Duration in hybrid G-100 was up to 6 days longer in treatment thinned than in shaded, while NKT was not affected. Andrade and Ferreiro (1996), also founded differences in growth rate applying similars treatments to hybrid G-100. Differences in oil percentage among treatments showed in G-100 were the result of a longer period of accumulation with the same rate (up to 4 days longer in thinning than in shading treatments). Hybrid NKT did not vary neither in rate, nor in duration.

Fruit weight was well related to intercepted PAR accumulated during the whole period treatment application-physiological maturity (r^2 = 0.84 and 0.80 for G-100, Fig 2 A, and NKT, Fig. 2 B, respectively). Difference between hybrids became smaller at higher values of intercepted PAR (values of intercepted PAR beyond 60 MJ per plant increased fruit weight in G-100, but did not in NKT, Fig. 2 A and B). These results suggest that when intercepted PAR is reduced, the supply of assimilates to the fruit decreases, causing a decrease in fruit weight. Fruit weight response to intercepted PAR is not the same for both genotypes. Hybrid NKT, which showed a greater fruit weight than G-100 at lower intercepted PAR, reached the maximum fruit weight with low values of intercepted PAR. Fruit weight in it was similar in plants that differed 62% in intercepted PAR (difference between treatments thinned and shaded, experiment B). This suggests that, in this hybrid, physical or chemical capacity to accumulate dry matter in fruit tissues was saturated in the plants that intercepted high quantities of PAR.

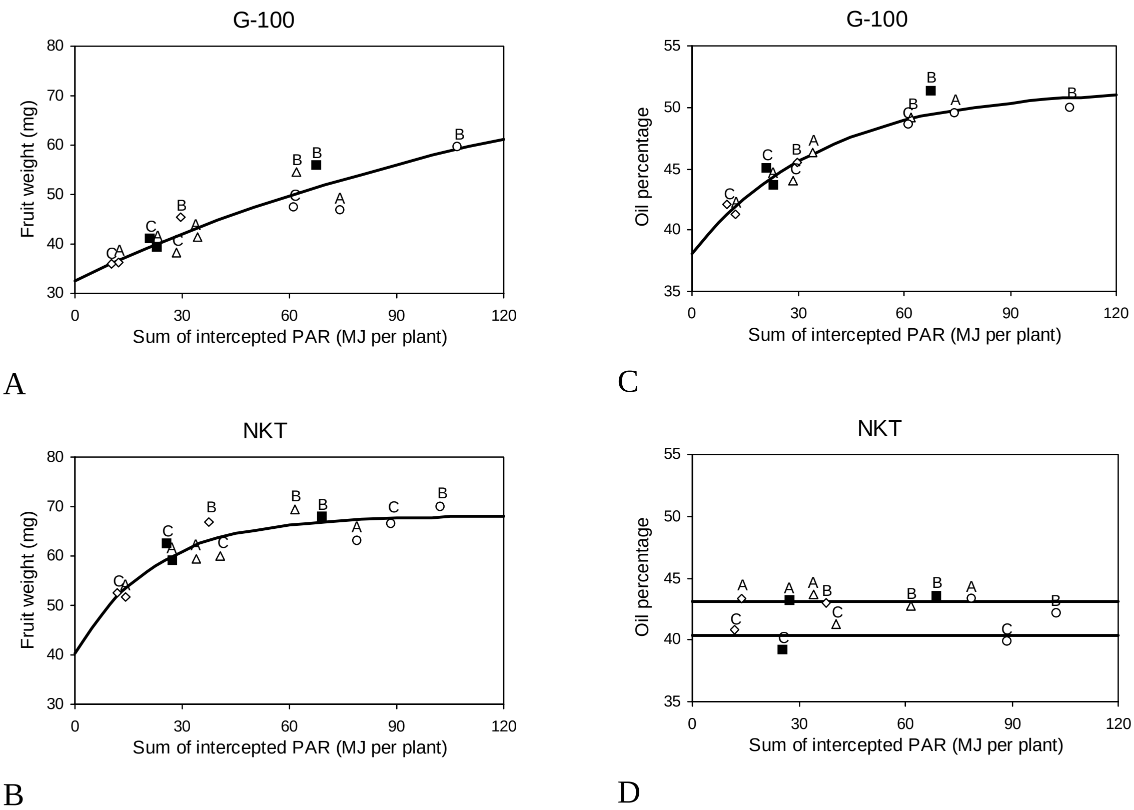

Figure 2. Fruit weight and oil percentage ,vs. intercepted PAR . Hybrids G-100, NKT, Exp. A, B and C. Treatments: shaded (rhombs), thinned (circles), shaded+thinned (triangles) and control (solid squares).

Oil percentage in G-100 was also related to intercepted PAR accumulated during the fruit filling period ($r^2 = 0.93$). Oil percentage increased up to 60 MJ of intercepted PAR per plant. Beyond this point the response was smaller and oil percentage tended to a plateau (Fig. 2 C). Surprisingly, oil percentage in NKT did not change in response to intercepted PAR. Oil percentage values of experiments A and B in this hybrid, did not differ significantly, and their average value (43.1 ± 0.5) was higher than the average of experiment C (40.3 ± 0.9%, Fig 2 D).

CONCLUSION

Intercepted PAR during the fruit filling period affected sunflower oil yield by modifying non empty fruit number and fruit weight in both hybrids tested, with high and low oil percentage potential and black and stripped hull (G-100 and NKT, respectively), and oil percentage only in G-100. Intercepted PAR during the fruit filling period affect both rate and duration of fruit filling period in G-100, and only the rate in NKT. Intercepted PAR during fruit filling period affected duration of oil percentage increase period in G-100. Fruit weight in both hybrids and oil percentage in G-100 were well related to intercepted PAR accumulated in fruit filling period. Genotypic differences in the response of these components to intercepted PAR were shown. It may be important to incorporate them in simulation models of crop growth and yield.

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