INTRASPECIFIC VARIABILITY OF SUNFLOWER RESPONSES TO CROP DENSITY

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Abstract

The aim of this work was to explore the intraspecific variability exhibited by commercial Argentine hybrids for traits that might contribute to tolerance to high population density. Two types of experiments were conducted. In Experiment 1, the hybrid Contiflor 9 was grown during the 2002-2003 season using a range of crop densities (2.0 to 14.3 plants per square meter). Length (IL) and dry weight of the fourth (from the base) internode, plant height at anthesis, stem angle with respect to the vertical and total number of seeds per plant were measured. In Experiment 2, 12 hybrids were grown under high, intermediate and low crop population densities at six sites within the central sunflower cropping area of Argentina. Most of the variables measured in Experiment 1 were also measured in Experiment 2. In Experiment 1, plant height at bud visible and total seed number per plant were significantly associated with IL, and both IL and fourth internode weight increased in response to population density. Stem inclination also increased with plant population density. Data from Experiment 2 showed that relative sensitivity of IL varied across hybrids, and that there are also strong G*E interactions for this variable. Hybrid harvest index corrected for oil synthesis costs and yield exhibited three categories of response to plant population: decreasing, increasing and curvilinear. We conclude that these variable (between hybrid) responses to plant population density justify further work on tolerance to this factor as a means to increase sunflower yield potential.

Introduction

Yield in sunflower crops protected from disease and lodging increases with plant population density up to densities (i.e., 14 plants per square meter) far in excess of the commercial norm (i.e., 5 plants per square meter) in Argentina (López Pereira et al., 2003). Libenson et al. (2002) have shown the existence of intraspecific variability in sunflower responses to crop population density and in the controls of biomass partitioning in the seed. These findings suggest that it would be useful to explore possible sources of tolerance to high population densities (HPD). This type of approach has been used with success over the last 20 years in maize (Tollenaar and Wu, 1999; Tollenaar and Lee, 2002) but no similar systematic work has been conducted in sunflower. Very little is known about possible sources of tolerance to HPD and their connection with yield determination. Even in maize, which has received much greater attention; causal links are only now beginning to emerge. This paper deals with our attempts to make progress in this area. Our overall approach has been to examine the responses of a set of Argentine commercial hybrids to HPD. Two important features of our approach have been: i) to examine hybrid relative (to low population density) responses to HPD; and ii) to focus on particular attributes which may be linked to yield determination. We assume that the linkages between these attributes and yield may only be partial, so that if material tolerant to HPD can be identified, breeding may be required to combine the sources of tolerance with yield potential. The traits we focused on were: a) harvest index (HI), which often tends to fall at HPD; b) fourth internode length (IL) and weight responses to HPD; and stem bending (SB). The interest in HI as a determinant of yield requires no comment; the rationale for examining IL responses is that increased stem elongation under HPD may reduce photoassimilate available for inflorescence growth around initiation; and SB has been observed to be a variable (among cultivars) but frequent response to HPD. SB could have positive (e.g., better light interception) or negative consequences (e.g., increased susceptibility to lodging) for yield under HPD.

Materials and Methods

Two types of experiments were conducted. In Experiment 1 at the experimental field of the Facultad de Agronomía, Universidad de Buenos Aires (FAUBA) (34º 35´ S.), hybrid Contiflor 9 (C9) was grown during the 2002-2003 season under a range of crop densities (2, 5.1, 6.8, 10.2 and 14.3 pl m sq). The experimental field area was 0.1 ha and the crop rows were oriented north-south. The distance between rows was 0.70 m (the commercial norm in Argentina). The plots were fertilized (60 kg N/ha) and irrigated. Diseases, insects and lodging were controlled. Crops were over-sown and desired crop densities were established by removing plants at the two-leaf stage. Treatments were laid out in a randomized complete block design with six replications. Phenological development, length and dry weight of the fourth internode (counting from the base of the plant), plant height at bud visible and anthesis, stem angle with respect to the vertical and total number of seeds per plant were measured. A preliminary experiment had previously shown that the fourth internode was particularly sensitive to HPD in the early stages of crop growth.

In Experiment 2, the sunflower crops were grown in six sites within the central sunflower cropping area of Argentina. Twelve commercial Argentine hybrids were laid out in a factorial design with two factors (crop density and hybrid) and three replications. Each plot had 4 6-m long rows spaced at 0.70 m between rows. The crop densities were 2.5,6, 5, 8.6 plants m sq. The early responses to crop population density registered in Experiment 1 were used to select the variables to be measured in Experiment 2 to characterize the intraspecific variability of the 12 hybrids used in the different environments of the network. Plant height at bud visible, and at anthesis were measured, and length of the fourth internode and basal stem diameter were measured at anthesis. At physiological maturity, aerial biomass, seed oil concentration and seed yield were determined. Corrected (oil synthesis cost) harvest index was calculated. The incidence of diseases and lodging was also registered.

In Experiment 2, indications of intraspecific variability to HPD were often sought using within-hybrid comparisons (change in a variable relative to value measured in the same hybrid at low population density) (see example in Figure 1).

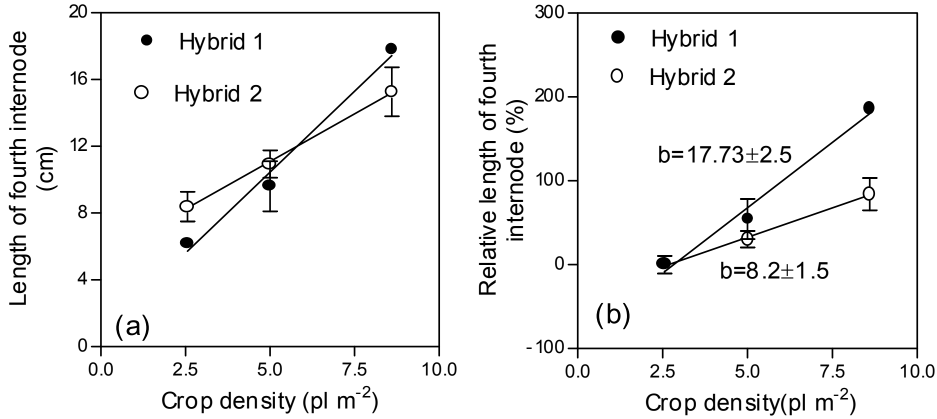

Figure 1. Length of the fourth internode (IL, cm) as a function of sunflower crop density (a). In (b) changes in IL are expressed in relative terms using the lower crop density as a standard (Experiment 2). The slope of the relationship in (b) indicates the relative variation in IL as crop density increases in one unit.

Results

Experiment 1. The plants under high crop density (14.3 plants per square meter) reached, at bud visible, a height at least 50 % higher than the height corresponding to the lowest crop density (two plants per square meter), while at anthesis these differences had largely disappeared (Table 1). At bud visible, the length of the fourth internode (IL) was positively and significantly ($p>0.05$, $R2=0.87$) associated to plant height. The internodes were larger and heavier as crop density increased but the increment in length was more than proportional to the increment in internode weight (Table 1). At the bud visible stage plants in the denser stands were already bent towards the interrow, alternatively to east and west of the row axis. The angle of inclination increased with crop density ($p<0.0001$; $b= 0.64\pm0.11$ degrees per unit population density, $R2=0.70$) and the stem inclination was detected earlier in the denser treatments. The values of the cited variables for the highest and lowest crop densities are given in Table 1.

Total seed number per plant was significantly ($p<0.05$) associated to the IL of plants grown at different densities (Figure 2), providing at least partial support for the notion that stem and inflorescence may compete for assimilates during floret initiation.

Experiment 2. At most sites and for most of the hybrids used in the experimental network, plant heights at anthesis were not modified in response to variations in crop population density (data not shown). By contrast, IL proved very sensitive to CPD, as illustrated in Figure 2a, and significant ($P <0.01$) differences among hybrids in relative sensitivity of IL to CPD were also found (see Figure 2b). An analysis of hybrid ranking for IL relative sensitivity to CPD showed important variations in relative sensitivity and hybrid rankings, indicating strong G x E effects (Figure 3). It is possible that water availability in early stages of crop growth could have been a factor here, as Junin and Daireaux had better water supplies than Balcarce and Miramar.

Table 1. Length of the fourth internode, angle of stem inclination with respect to the vertical, plant heights at bud visible and anthesis, and total seed number per plant at extreme densities (14.3 and 2 plants per square meter). Relative variation of these variables between the extreme densities is also shown. Values are means (n=9) ± one standard error. Experiment 1.

Variable	Densities (plants per square meter)		Probability value of differences between stands	Variation (%)
	14.3	2		
Length of the fourth internode (mm)	148±23.29	47.3±11.7	P<0.001	68.1
Weight of the fourth internode (g)	5.14±0.38	4.28±0.44	P<0.12	21
Angle of stem inclination (degrees)	6.47±1.43	0	P<0.0001	100
Plant height at bud visible (m)	0.82±0.05	0.54±0.03	P<0.015	34.2
Plant height at anthesis (m)	1.62±0.15	1.75±0.15	P>0.41	-8
Total seed number per plant	1093±109	1777±205	P<0.004	-62.6

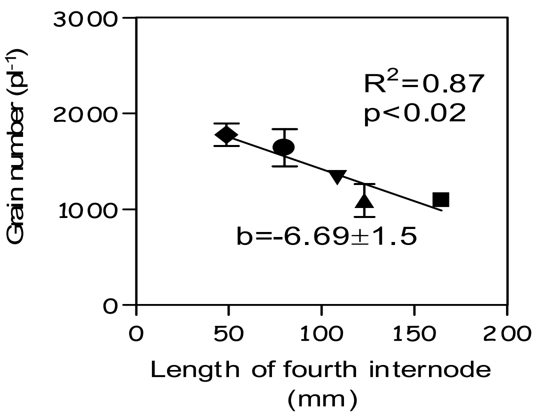

Figure 2. Relationship between total seed number per plant and length of the fourth internode of sunflower plants growing under nonlimiting conditions, protected from disease and lodging (Experiment 1). The symbols identify the different density treatments: closed rhombus (2pl m sq.); closed circle (5.1 pl m sq.); inverted closed triangle (6.8 pl m sq.); closed triangle (10.2 pl m sq.); closed square (14.3 pl m sq.). Bars on symbols indicate ± standard error of the mean, n=9.

Harvest index corrected for oil synthesis costs (HIcvp) was used as an indicator of biomass partitioning for seed grain response to HPD. Three basic patterns of response emerged: decreasing, increasing and curvilinear, and these varied among hybrids. Yield responses to HPD tended to follow those of HIcpv as illustrated for crops at Venado Tuerto (Figure 4). The three basic responses the HIcpv to HPD and the association of grain yield and HIcpv were repeated in other sites, but hybrid rankings varied across sites (data not shown).

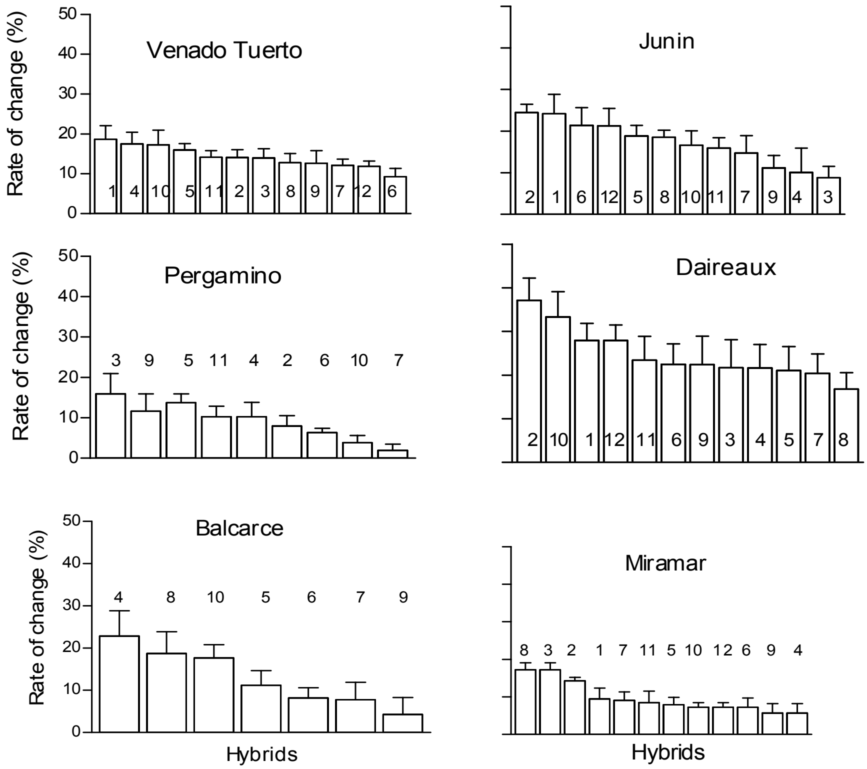

Figure 3. Relative rate of change of the length of the fourth internode with sunflower crop density (slope of lines in Figures 1b) of hybrids growing in six sites of the Argentine sunflower cropping area (Experiment 2). The numbers identify the different hybrids: (1) MG2, (2) MG50, (3) ACA 884, (4) ACA 885, (5) DK 3900, (6) DK3920, (7) DK4050, (8) Paraiso 20, (9) Paraiso 30, (10)Aguara, (11) CF 17, and (12) Zenith.

Discussion

Although very preliminary, these results show that intraspecific variability for responses of some traits to HPD exist, albeit their expression may be subject to important G x E effects. We conclude there is some scope for the pursuit of the objective of raising sunflower yield potential through selection for tolerance to HPD. Future work will focus on the understanding of the connections between the responses to HPD of variables such as IL, SB and HIcpv and yield determination.

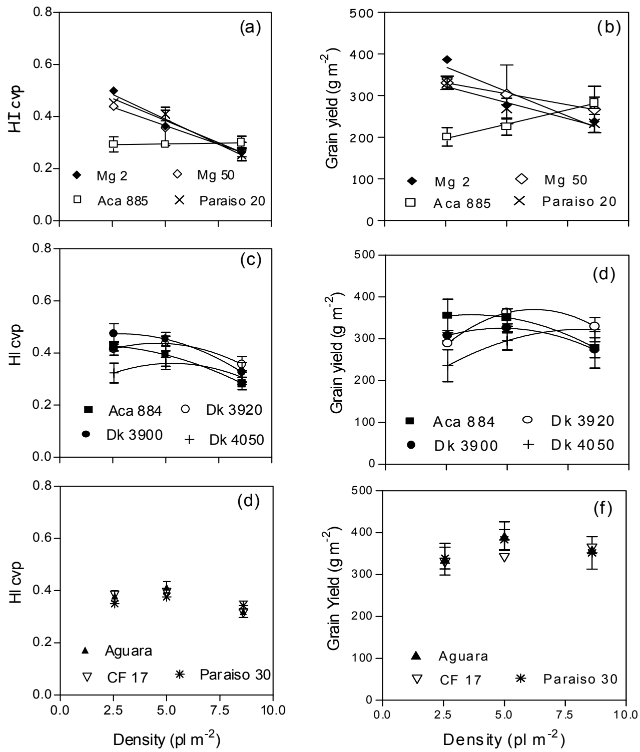

Figure 4. Harvest index corrected by oil synthesis cost (HIcvp) (Figures a, c, e) and grain yield (Figures b, d, f) as a function of sunflower crop density (Experiment 2). The 12 Argentine hybrids were classified according to the HI response obtained at the Venado Tuerto site.

Acknowledgments

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