Hybrid maturity and plant population density to improve sunflower performance in Entre Ríos, Argentina.

Oscar Valentinuz[1], Leonardo Coll[1], Jonathan Ojeda[2]
[1]INTA EEA Paraná, Ruta 11 km 12.5, Oro Verde (3101), Argentina, ovalenti@parana.inta.gov.
[2]UNER Facultad de Ciencias Agropecuaria, Ruta 11 km 10.5, Oro Verde (3101), Argentina.

ABSTRACT

- Sunflower yield is sensitive to rain magnitude and distributions during the growing season. Adverse effects of drought or excess of water might be avoided or alleviated by using a specific sunflower hybrid and plant population density. This study was conducted to compare agronomic performance of early and late maturity sunflower hybrids growing at different plant population density (PPD).
- Field experiments were carried out at Paraná (Entre Ríos, Argentina) during two growing seasons (2009-10 and 2010-11). Two sunflower hybrids, DOW MG60 (early maturity) and DOW MG2 (late maturity), were sown at three PPD (3, 6, and 9 plant m^{-2}).
- Rain between crop emergency and first anthesis was 69% greater in 2009-10 than in 2010-11 (266 vs. 158 mm) accounting for greater leaf area index ($p<0.0001$). On the other hand, excess of rain and less radiation around flowering could be related to lower harvest index (HI) in 2009-10 ($p= 0.0026$). Grain yield was 48% greater in 2010-11 in respect to 2009-10 and, for both years, showed an optimal value when hybrids were grown at 6 plant m^{-2}. Even though dry matter at flowering increased with hybrid maturity and PPD, comparable grain yield for hybrids and a grain yield reduction at high PPD (associated to lower HI; $p<0.0004$) highlight the role of both favorable post-flowering weather conditions and maintenance of functional canopy for sunflower yield determination. Hybrids responded in a different way to yearly weather conditions (year x hybrid interaction; $p=0.0185$). In spite of grain yield differences between hybrids (19% for 2009-10 and 10% for 2010-11), lack of significance does not allow to identify a specific combination between hybrid maturity and the weather condition of a specific year.
- Results suggest that exist an optimum PPD for sunflower growing at Entre Ríos and indicate that hybrid maturity do not alter sunflower agronomic performance.
- In order to increase yield potential, breeding should improve post-flowering partitioning and high PPD tolerance in late maturity hybrids.

Key words: sunflower - hybrid – plant population density – grain yield

INTRODUCTION

Potential yield of sunflower (*Helianthus annuus* L.), depends on environment conditions during cycle of the crop. Proper combination between plant population density (PPD) and maturity of hybrids (i.e., early and late hybrids) could be useful to match environment limitations, mainly water constrain. In addition, both management practices are essential when practices as double cropping or intercropping are considered (Echarte et al., 2011).

The cropping zone of Entre Ríos sunflower crops are often subjected to drought or excess of water due to rain variability during spring and early summer. Water stress at vegetative stages reduces leaf area index (LAI) and limits light capture. However, the regulation of LAI in response to water stress is the main mechanism by which sunflower achieves an effective regulation of crop transpiration (Connor and Sadras, 1992). Maximum LAI are not related to grain yield (Bange et al., 1997). Excess of water at flowering and reproductive stages reduces leaf photosynthesis and anticipates crop senescence (Grassini et al., 2007).

In general, farmers admit that final grain yield is poorly related to visual aspect of the crop at flowering and often they argue that the lack of certainty is the main reason discouraging them for planting the crop. Sunflower crops showing a reduced LAI by the time of flowering may reach high grain yields if high incident radiation occurs prior to anthesis (Villalobos et al., 1994) and early grain filling period. In contrast, healthy crops (i.e., high and green LAI) may progress to low grain yield crop when functionality of canopy declines for excess of rain or water stress during the grain filling period (Grassini et al., 2007; Whitfield et al., 1989).

Plant population density constitutes the most common management practice under farmer decision. Sunflower grain yield is less responsive to PPD than other crops such maize (Vega and Andrade, 2002). Valentinuz (1996) found out comparable grain yields when commercial density in sunflower (5.5 plant m^{-2}) was doubled (11 plant m^{-2}). However, Robinson et al. (1980) reported grain yield increases when PPD rises from 1.7 to 6.2 plant m^{-2}. A specific PPD also can be chosen according to the rate or rain. Up to 8 plant m^{-2} are recommended in areas with more than 500 mm $year^{-1}$ and a top limit of 4 plant m^{-2} area recommended with rain is between 300 and 400 mm $year^{-1}$ (Diepenbrock, 1988). Rain during sunflower growing season in Entre Ríos shows variations ranging from 300 and 1000 mm according to the year and time to hybrid maturity. By examining both PPD and hybrid maturity through different growing season, an optimal combination PPD x HM for high grain yield could be found out and more precise recommendation could be made with the help of forecast model. This study was conducted to compare agronomic performance of early and late maturity sunflower hybrids growing at different plant population density.

MATERIALS AND METHODS

The experiments were conducted at INTA Research Station, Paraná, Entre Ríos (31º50´ S, 60º31´ W, 110 m above sea level) in 2009/10 and 2010/11 growing seasons. Two sunflower hybrids from DOW breeding program (MG60, y MG2), differing at time to anthesis and physiological maturity, were assessed at three PPD (3, 6 y 9 plants m^{-2}). Experiments were established on a silty clay loam soil (Class I, Aquic Argiudolls, USDA taxonomy). Daily mean air temperature, rainfall and incident global radiation were obtained by a weather station situated 400 m from the experimental site. Experimental design was a randomized complete block in a split-plot arrangement with three replicates. PPD was assigned to the main plot with and sunflower hybrids to subplots (six rows spaced 0.52 m apart and 10 m in length). For the remainder of the paper, MG60 will be referred as early maturing hybrid (EM) and MG2 as late maturing hybrid (LM). The experiments were hand planted on 12/09/09 and 20/09/2010. Plots were kept free of weed and pest and fertilized with nitrogen (14 g m^{-2}) 20 days after emergence. Crop ontogeny was weekly recorded according to Schneither and Miller (1981). Leaf Area Index (LAI) was measured by using a LICOR 3100 planimeter (LI-COR, Lincoln, NE, USA). Total and partitioned aerial dry matter (DM) was estimated from sampling five plants per plot at flowering (DMR5.5) and physiological maturity (DMR9). Grain yield (GY) was determined from 5.2 m^2. Data were analyzed by means of ANOVA procedures and means were compared by LSD test.

RESULTS

Growth conditions

Weather conditions differed markedly between growing seasons. Although experimental sites showed a comparable amount of accumulated rain during the fallow, approximately between April and September of 2009 and 2010 (Table 1), both growing seasons differed in the magnitude of total accumulated rainfall. Rainfall during 2009-10 was more than twice that during 2010-11. Rainfalls between emergence and R5 and between R5 and maturity were around 90% and 130% greater in 2009-10 in respect to 2010-11.

Grain yield

Grain yield was 48% greater in 2010-11 in respect to 2009-10 (Table 2) and, for both growing seasons, showed an optimal value when hybrids were grown at 6 plant m^{-2}. Grain yield at 6 plant m^{-2} was 22% greater ($p<0.05$) than other PPD.

Although there was no differences between hybrids in both growing seasons, a significant ($p<0.05$) interaction growing season x hybrid was observed (Table 2). In respect to late maturity hybrid, grain yield for MG60 was greater (19%) in 2009-10 and lower (11%) 2010-2011.

Hybrids trended ($P=0.08$) to respond in different manner with changes in PPD. Both hybrids showed the greatest value of GY when grown at 6 plant m^{-2}. Nevertheless, when grown at 3 plant m^{-2}, GY of MG60 was approximately 21% greater than MG2. When grown a 9 plant m^{-2}, both hybrids had comparable GY.

Table 1. Accumulated rainfall for fallow, crop growing season and two sub-periods within sunflower growing season.

Accumulated rainfall	**2009-2010**	**2010-2011**	**1934-2008**
Fallow (April-September)	276.0	242.4	309.8
Growing season (October-January)	641.3	295.7	449.2
○ Emergence-R5	165.1	85.4	-
○ R5-Maturity	478.2	210.3	-

Leaf Area Index

There were significant differences in LAI between growing seasons and hybrids. LAI in 2009-2010 was 95% greater than that in 2010-11 (Table 2). Averaged through growing seasons and PPD, LAI for MG2 was around 30% greater than for MG60. There was a significant interaction growing season x PPD ($p<0.05$). During 2010-11, LAI increased steadily from 3 to 9 plant m^{-2} and, during 2009-10, LAI increased only from 3 to 6 plant m^{-2}. For this growing season, LAI did not differ between 6 and 9 plant m^{-2} (5.5 vs. 5.6).

Dry Matter

Total dry matter from planting to R5.5 varied with PPD and hybrids ($p<0.0001$). Analysis of variance did not reveal significant two or three way interactions. DMR5 at PPD of 6 plant m^{-2} was 48% greater and 11% lower than those showed by PPD of 3 and 9 plant m^{-2}, respectively. Averaged through growing seasons and PPD, DMR5 was 36% greater in the late maturity hybrid in respect to early maturity hybrid.

Total dry matter accumulated at maturity was similar for both growing seasons (c. 1000 g m^{-2}). Averaged through growing seasons and PPD, DMR9 was 20% greater in the late maturity hybrid in respect to early maturity hybrid.

Harvest Index

Harvest index was altered by growing seasons, PPD and hybrids. There were not significant two or three way interactions for this variable. When averaged across PPD and hybrids, HI was 0.25 at 2010-11 and 0.20 at 2009-10. When averaged across growing season and hybrids, PPD of 3 and 6 plant m^{-2} had 25% greater HI than did the 9 plant m^{-2}. HI for early maturity hybrid was 25% greater than that observed for late maturity hybrid.

Table 2. Analysis of variance for total dry matter at flowering (DMR5.5) and maturity (DMR9), leaf area index (LAI), grain yield (GY) and harvest index (HI) for two sunflowers hybrids (HYB) grown at three plant population densities (PPD) during two growing seasons (GS).

GS	PPD	HYB	DMR5.5	LAI	DMR9	GY	HI
2009-10	3	MG 2	762,5	4,29	923,4	1426,7	0,15
		MG 60	524,7	2,85	782,5	1965,5	0,26
	6	MG 2	1167,9	5,99	1218,1	2151,5	0,18
		MG 60	927,1	4,94	970,4	2641,2	0,27
	9	MG 2	1271,2	6,11	1312,0	1976,4	0,15
		MG 60	955,8	4,99	1202,7	2007,4	0,17
2010-11	3	MG 2	757,6	2,27	1041,2	2772,6	0,23
		MG 60	616,4	1,87	914,6	3131,1	0,30
	6	MG 2	1079,2	2,76	1214,4	3669,4	0,27
		MG 60	771,2	2,33	1044,0	2932,6	0,26
	9	MG 2	1339,8	3,36	1347,0	3011,4	0,20
		MG 60	897,0	2,30	982,2	2462,1	0,23
Anova					**p-value**		
Model			<0,0001	<0,0001	0,1807	<0,0001	0,0036
Growing season (GS)			0,6139	<0,0001	0,7872	<0,0001	0,0026
Plant population density (PPD)			<0,0001	<0,0001	0,0221	0,0051	0,0100
Hybrid (HYB)			<0,0001	0,0002	0,0269	0,8682	0,0037
GS*PPD			0,3565	0,0235	0,5603	0,2843	0,9267
GS*HYB			0,7378	0,1856	0,7420	0,0185	0,1804
PPD*HYB			0,2933	0,7919	0,8687	0,0848	0,1976
GS*PPD*HYB			0,6236	0,6365	0,6830	0,2775	0,3327

DISCUSSION

This study compared agronomic performance of two sunflower hybrids growing under a commercial range of plant population density during two growing seasons. Both growing season differed markedly in terms of rainfall. Sunflower hybrids showed the greatest grain yield during 2010-11, a dry growing season that totaled 350 and 150 mm below the 2009-10 and the mean (1934-2008). Better agronomic performance of sunflower during dry growing season has been reviewed by Magrín (2010).

Although grain yield differences between hybrids were lower than 40 g m^{-2}, hybrids differed in the ranking. In fact, meanwhile early maturity hybrid was first at wet growing season, the opposite happened at dry growing season. Nevertheless, the difference in time to anthesis and maturity between hybrids was around a week. Since both hybrids belong to the same breeding program, that difference could be not the maximum difference between the earliest and the latest hybrid in the domestic seed market.

Interestingly, the response of sunflower to PPD showed an optimal value of grain yield when crops was grown at 6 plant m^{-2}. Decline in HI was associated with grain yield decrease at 9 plant m^{-2}. A greater dry matter accumulated in stem at R9 (not shown), also would be an indication of grain number adjustment during head growing in response to declining assimilate supply (Villalobos et al., 1994), usually referred as sink limitation.

Collectively, grain yield was associated with total dry matter accumulated at maturity (r^2= 0.33, p<0.05), harvest index (r^2=0.56, p<0.0001) and leaf area index (r^2=-0.40, p<0.02).

This study confirms, considering a regional environment, that sunflower performs better with dry weather. Adjustment in LAI and HI seem be the adaptive advantage for this species which evolved in an arid environment where post-anthesis assimilate supply can be severely curtailed by drought (Villalobos et al., 1994).

Intermediate plant population density averaged 22% higher grain yield when compared with low and high PPD. This response was consistent in spite of marked differences between both growing seasons and was not related with hybrid maturity. Nevertheless, hybrids trend to perform different according to growing season. Thus, while late maturity hybrids could perform better at high yield growing season, early maturity hybrids would do it at less favorable growing seasons for high grain yield. Nevertheless, this should be corroborated by doing a more detailed comparison of hybrids in terms of disease incidence.

The data from this study suggest that maturity of sunflower hybrids does not interact with plant population density regardless of growing conditions. However, future studies should test a broader range of hybrid maturities. In order to obtain better agronomic performance, sowing sunflower at intermediate plant population density, and choosing late maturity hybrids when dry season are forecasted could be two valuable helps for sunflower farmers.

ACKNOWLEDGMENTS

Authors thank Exequiel Scandolo and Nicolás Cabello for their help at the field experiment and Dow Agroscience for providing the seed.

REFERENCES

Bange, M.P., G.L. Hammer, and K.G. Rickert. 1997. Environmental control of potential yield of sunflower in the subtropics. Aust. J. Agric. Res. 48:231-240.

Connor, D.J., and V.O. Sadras. 1992. Physiology of yield expression in sunflower. Fiel Crop Res. 30:333-389.

Diepenbrock, W. 1988. Yield development in the sunflower - A survey. Plant Res. Devel., 27, 38-58.

Echarte, L., A. Della Maggiora, D. Cerrudo, V.H. Gonzalez, P. Abbate, A. Cerrudo, V.O. Sadras And P. Calviño. 2011. Yield response to plant density of maize and sunflower intercropped with soybean. Field Crops Res. 121:423-429.

Grassini, P., G. Indaco, M. Lopez Pereira, A. Hall, and N. Trapani. 2007. Responses to short-term waterlogging during grain filling in sunflower. Field Crop Res. 101: 352-363.

Magrín, G. 2010. El Niño 2009/10 y la Niña 2008/09: efectos sobre la agricultura argentina. p. 13-52. In 5to Congreso Argentino de Girasol. Asagir 2010: con la mirada en la competitividad. Buenos Aires, Argentina.

Robinson, R.G.; J.H. Ford, W.E. Lueschen, D.J. Rabas, L.J. Smith, D.D. Warnes, J.V. Wiersma. 1980. Response of sunflower to plant population density. Agron. J. 72:869-871.

Schneiter, A.A., and J.F. Miller. 1981. Description of sunflower growth stage. Crop Sci. 21: 901-903.

Valentinuz, O.R. 1996. Crecimiento y rendimiento comparados de girasol, maíz y soja ante cambios en la densidad de plantas. M. of Sc. Thesis. Universidad de Mar del Plata, Mar del Plata, Argentina.

Vega, C.R., and F.H. Andrade. 2000. Densidad de plantas y espaciamiento entre hileras. p. 97-133. In: F.H. Andrade and V.O. Sadras (ed.), Bases para el Manejo del Maíz, el Girasol y la Soja. Editorial Médica Panamericana, Buenos Aires, Argentina.

Villalobos, F.J., V.O. Sadras, A. Soriano, and E. Federes. 1994. Planting density effects on dry matter partitioning and productivity of sunflower hybrids. Field Crops. Res. 36:1-11.

Whithfield, D.M., D.J. Connor, and A.J. Hall. 1989. Carbon dioxide balance of sunflower (Helianthus annuus) subjected to water stress during grain-filling. Field Crops Res. 20:65-80.