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Spurred Anoda (*Anoda cristata*) Competition in Narrow- and Wide-Row Soybean (*Glycine max*)[1]

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Abstract: The effect of spurred anoda competition in narrow- (35 cm) and wide-row (70 cm) soybean was studied in field experiments for 2 yr. Vigorous early soybean growth in narrow- compared with wide-row soybean resulted in lower radiation transmitted through the canopy, which can partially account for greater competitiveness of narrow-row than wide-row soybean. Soybean plant height was not significantly influenced by the row spacing. Relative yield total (RYT), which is the relationship between yield in mixtures and in monocultures of the crop or the weed and indicates resource complementarity, was equal to 1 with 12 spurred anoda/m^2 in the year with less precipitation. Regardless of the row spacing, spurred anoda gave resource use complementarity with the crop (RYT $>$ 1) in all other treatments; therefore, partial avoidance of competition in mixed species was evident. Soybean aggressivity, which takes into account the effect of competition on both the crop and the weed and indicates competitive ability, decreased with weed density in both row spacings. Soybean yield loss at harvest was linearly related to relative dry weight 40 d after planting. Weed-free narrow- and wide-row soybean produced similar yields. In the presence of the spurred anoda, soybean yield was greater in narrow-row compared with wide-row soybean only in the most humid year. A management system that uses quick canopy closure with narrow-row soybean can provide excellent soybean yield and suppression of low spurred anoda densities.

Nomenclature: Soybean, *Glycine max* (L.) Merr.; spurred anoda, *Anoda cristata* (L.) Schlecht. #[3] ANVCR.

Additional index words: Aggressivity, competition, crop and weed biomass, row spacing, weed density.

Abbreviations: DAP, days after planting; PPF, photosynthetic photon flux; RDW, relative dry weights; RYT, relative yield total.

INTRODUCTION

Soybean is the major oilseed crop in Argentina (Vitta et al. 2000), and spurred anoda is one of the most serious weed problems in the central area of the country (Leguizamón et al. 1994; Leiva and Ianone 1994; Mattioli 1984). There is a trend toward reducing crop row width as a means of increasing crop competition to suppress weeds (Johnson et al. 1997). In Argentina, soybean is usually planted in wide rows, but the adoption of a narrower and more dense row spacing is increasing. Earlier results in narrow-row soybean show that this technique can provide adequate weed control and soybean yield (Buhler et al. 1993; Defelice et al. 1989; Johnson et al. 1997; Prostko and Meade 1993; Steckel et al. 1990).

Weed competition studies are based on binary mixtures, and different indices are used to evaluate competition. Some of these indices are relative yield total (RYT) (De Wit 1960), which consists of the addition of crop and weed relative yields and indicates resource complementarity, and aggressivity (McGilchrist and Trenbath 1971), which takes into account the effect of competition on both the crop and the weed and indicates competitive ability.

The success of weed competition with soybean has been attributed to various aspects of growth characteristics (Shaw et al. 1997) and spatial arrangement of the crop (Spitters and Van der Bergh 1982). Light is a primary resource for which weeds compete in dense crop stands. Traits critical to competition from light include rate of growth and height (Lindquist et al. 1998). Differences in these traits between spurred anoda and soy-

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

bean may explain competition in contrasting row spacings. There is a lack of information about competition between weeds and soybean in narrow and wide rows. There are no reports about the effect of weed density on resource complementarity and competitive ability. Soybean yield reduction must also be considered in evaluating spurred anoda as an economically important weed.

The objective of this research was to evaluate the effect of spurred anoda biomass, density, and height on resource complementarity, competitive ability, and soybean yield in narrow- and wide-row soybean.

MATERIALS AND METHODS

Field experiments were conducted in 1997 and 1998 at the University of Rosario Experimental Farm at Zavalla (33°01′S, 60°53′W), Argentina. The soil is a vertic argiudol with 3% organic matter, pH of 5.8, 5% sand, 70% silt, and 25% clay. Crops that have been grown during the previous 15 yr are wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and soybean. Mean monthly precipitation data during soybean growth were recorded near the experimental area. There was sufficient moisture each year for planting soybean in a normal date, and crop emergence occurred 7 d after planting (DAP). Rainfall was 753 mm from November 1997 to February 1998.

Experiments were established as a split-plot design with three replicates, and plot size was 7 m^2. The main plots consisted of two different soybean row spacings (narrow and wide) and absence of soybean; the subplots in the two different row spacings consisted of five weed densities (0, 2, 4, 7, and 12 spurred anoda/m^2), and in the absence of soybean, the subplot consisted of four weed densities (2, 4, 7, and 12 spurred anoda/m^2) to obtain weed monocultures. To establish the different densities of spurred anoda, a naturally occurring seedling population was thinned, selecting uniform plants at approximately 15 DAP.

Before planting, the field was harrow disked at a depth of 12 cm. Soybean was planted in narrow rows (35 cm) and in wide rows (70 cm). Soybean cv. 'Asgrow RR 640/600' was planted on December 4, 1997 and cv. 'Asgrow RR 6401' was planted on November 23, 1998 and harvested in May every year. Soybean was planted in narrow rows with a Gherardi G100[4] grain drill and in wide rows with a Gherardi G95[4] planter. Density was 371,800 plants/ha in narrow rows and 280,000 plants/ha in wide rows. A 30% increase in planting rate in narrow-row soybean is recommended for producers in Argentina. The soil was not fertilized, and there was no interrow cultivation. Grass weeds were controlled with haloxyfop at 0.36 kg ae/ha, and broadleaf weeds other than spurred anoda were hand weeded.

In 1998, photosynthetic photon flux (PPF) penetrating through the soybean canopy was measured at midday, eight times during soybean growing season, every 5 to 35 d using a bar and a LI-COR line quantum sensor (400 to 700 nm) placed across the center plot rows within narrow- and wide-row soybean monocultures. Percent light interception was calculated by dividing the measurement made below the soybean canopy (0 and 30 cm from the soil) by ambient unshaded light.

In 1997 and 1998, crop and weed top biomass was harvested from randomly selected 1-m^2 quadrats, dried at 80 C, and weighed. To determine crop and weed biomass dynamics, dry weights were assessed in both row spacings at approximately 40, 84, 126, and 147 DAP in plots containing 2 and 12 spurred anoda/m^2.

Relative yield total (de Wit 1960) was established for 2, 4, 7, and 12 spurred anoda/m^2 in both row spacings at 147 DAP and was calculated as:

$$\mathrm{RYT} = (B_{cw}/B_c) + (B_{wc}/B_w)$$

where B_{cw} and B_{wc} are the biomass per unit area of the crop and weed, respectively, when grown in mixtures and B_c and B_w are their biomass in monoculture. The overall plant density in weed–crop mixtures was equal to the sum of the density of crop and weeds in monocultures, a fully additive design according to Snaydon (1991). The RYT values were displayed in bivariate diagrams (Snaydon and Satorre 1989) by plotting the relative biomass of soybean against that of the weed. For an additive experiment, an RYT value of 1 means full competition between species, and an RYT value of 2 means no competition. Any value of RYT between 1 and 2 means that competition is partial, i.e., that there is some resource complementarity between species.

Aggressivity (Snaydon and Satorre 1989) was established for 2, 4, 7, and 12 spurred anoda/m^2 in both row spacings 147 DAP and was calculated as:

$$\mathrm{Aggressivity} = (B_{cw}/B_c) - (B_{wc}/B_w)$$

where B_{cw} and B_{wc} are the biomass per unit area of the crop and weed, respectively, when grown in mixtures and B_c and B_w are their biomass in monoculture.

Crop and weed height were determined in 1998 in 10 crop plants and in all weed plants present in 1-m^2 quad-

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Table 1. Biomass of narrow- (35 cm) and wide-row (70 cm) soybean growing with 2 and 12 plants/m² of spurred anoda during the crop growing season.

	1997				1998			
	2 spurred anoda/m²		12 spurred anoda/m²		2 spurred anoda/m²		12 spurred anoda/m²	
DAP[a]	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide
	g/m²							
40	97*[b]	63	103*	76	115*	83	107*	89
84	643	503	336*	157	289	323	218*	156
126	978	956	750*	620	603	612	575*	378
147	1,033	1,055	860*	681	681	697	602*	423

[a] Abbreviation: DAP, days after planting.

[b] For each DAP and weed density, means followed by * are significantly greater than the corresponding mean within row spacing based on a *t* test at P = 0.05.

Table 2. Biomass of 2 and 12 plants/m² of spurred anoda growing in narrow- (35 cm) and wide-row (70 cm) soybean during the crop growing season.

	1997				1998			
	2 spurred anoda/m²		12 spurred anoda/m²		2 spurred anoda/m²		12 spurred anoda/m²	
DAP[a]	Narrow	Wide	Narrow	Wide	Narrow	Wide	Narrow	Wide
	g/m²							
40	2	4	9	8	0.8	0.5	8	9
84	9	24*[b]	15	41*	21	19	39	62*
126	23	42*	55	82*	38	37	65	142*
147	23	45*	55	86*	37	38	69	144*

[a] Abbreviation: DAP, days after planting.

[b] For each DAP and weed density, means followed by * are significantly greater than the corresponding mean within row spacing based on a *t* test at P = 0.05.

rats for 12 spurred anoda/m² in both row spacings at 40, 84, 126, and 147 DAP.

Relative dry weights (RDW) were calculated as weed dry weight/dry weight (crop + weed) for 0, 4, 7, and 12 spurred anoda/m² in both row spacings 40 DAP.

Soybean grain yield was determined from 2-m² quadrats for 0, 4, 7, and 12 spurred anoda/m² in both row spacings 147 DAP, and samples were processed through a static thresher and seed cleaner to determine yield, and weights were adjusted to 12% moisture.

Number of soybean pods per plant was determined at harvest in 1998 in 10 plants per plot in both row spacings for 0, 2, 4, 7, and 12 spurred anoda/m².

Before analysis, dry weights were transformed into logarithm (log (x + 1)) values to homogenize variance and improve normality. For soybean and spurred anoda biomass, an ANOVA (P = 0.05) was used to test the effect of year, row spacing, weed density, and all possible interactions. For each DAP and weed density, biomass between row spacings was compared using a *t* test at P = 0.05. Relative yield total values from all mixture treatments were subjected to ANOVA (P = 0.05), and LSD (P = 0.05) was calculated to compare mean values against an RYT of 1. Aggressivity values from all mixture treatments were subjected to ANOVA (P = 0.05). For each spurred anoda density, means were compared between row spacings using a *t* test at P = 0.05. Photosynthetic photon flux, and crop and weed heights were compared between row spacings by a *t* test (P = 0.05). Data of grain yield in percentage relative to control without weeds were subjected to ANOVA (P = 0.05) to determine the significance of any interactions among main effects. The quality of the regression models was estimated from the percent variance accounted for by the model. Parameters of the equations were compared by a *t* test (P = 0.05).

RESULTS AND DISCUSSION

In both 1997 and 1998, soybean biomass at early developmental stages (40 DAP) was greater in narrow- than in wide-row soybean and can account for the greater competitive ability of narrow-row soybean (Table 1). A year by treatment interaction was significant at all sampling dates; therefore, data for each year were analyzed separately. Row spacing × weed density interaction was also significant, and data for each density were analyzed separately. Greater crop biomass at early stages resulted in a greater competitive advantage in other studies with broadleaf weeds (Paolini et al. 1998). During both years between 84 DAP to the end of the growing season, in the presence of 12 spurred anoda/m², crop biomass was greater in narrow- than in wide-row soybean. However, row spacing had no effect on crop biomass in the presence of 2 spurred anoda/m².

No differences in spurred anoda biomass were observed between row spacings 40 DAP. However, at the end of the growing season, spurred anoda biomass was lower in narrow- than in wide-row soybean in the presence of 12 spurred anoda/m² (Table 2). With 2 spurred anoda/m², biomass was greater in wide- than in narrow-row soybean only in 1997.

Soybean planted in narrow compared with wide rows was able to obtain more limiting resources than spurred anoda. Vigorous early soybean growth led to higher radiation interception for narrow- compared with wide-row soybean during the whole growing season when measured 30 cm from the soil surface and until 94 DAP when measured 0 cm from the soil surface in 1998 (Figure 1). The lower radiation transmitted through the canopy in narrow- compared with wide-row soybean can partially account for the greater competitiveness of the narrow-row soybean with spurred anoda. Senescence of

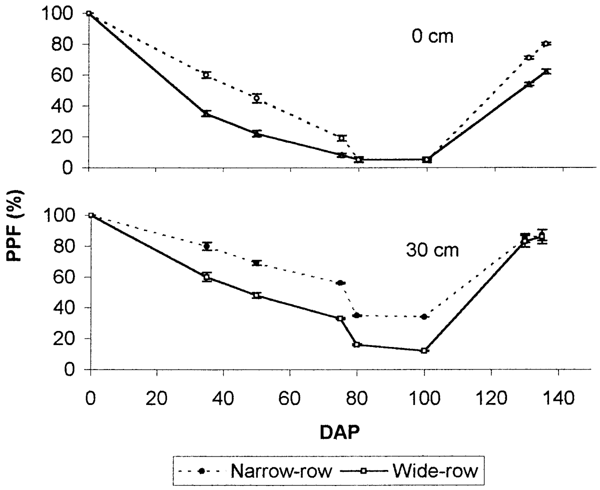

Figure 1. Percent interception of photosynthetic photon flux (PPF) in relation to days after planting in 1998 in narrow- and wide-row soybean measured 0 and 30 cm from the soil surface. Vertical bars pertaining to PPF are standard errors of the mean of three replications.

soybean began between 130 and 140 DAP, and at that time, a rapid increase in radiation was observed in both planting spacings. The increase in radiation due to crop senescence in both planting spacings had no effect on spurred anoda growth because the weed had already completed its growth by this time.

For RYT data, a year × treatment interaction was significant, and data for each year were analyzed separately. Soybean gave resource complementarity with the weed in most treatments (RYT > 1), regardless of the row spacing (Figure 2). The exception was the mixture of 12 spurred anoda/m^2 with soybean in 1998 when RYT equals 1. Therefore, partial avoidance of competition in mixed species was evident. Relative yield total values greater than one were determined in other studies with broadleaf species in soybean (Crotser and Witt 2000; Vitta and Satorre 1999). During both years, spurred anoda growing season was completed about 130 DAP, whereas soybean growth continued until about 150 DAP; therefore, the shorter life cycle of the weed relative to the crop may explain the tendency to give resource complementarity as was reported for *Sinapis arvensis* L. (Paolini et al. 1999). In 1997, precipitation was high, and RYT was greater than 1, regardless of the weed density. In 1998, a year with less precipitation, RYT was greater than 1 with 2, 4, and 7 spurred anoda/m^2, but with 12 weeds/m^2, productivity was equal in monoculture and mixed species (RYT = 1). This indicates that the tolerance of soybean to spurred anoda competition was greater with low weed density and with adequate levels of soil moisture. Differences between years in spurred anoda biomass response to competition with soybean

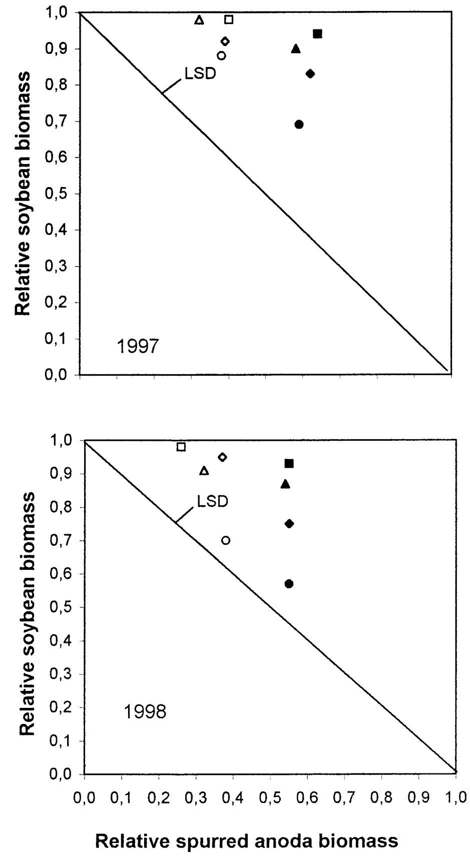

Figure 2. Bivariate diagram based on the relative biomass of spurred anoda in 1997 and 1998 in competition with soybean. The diagonal line indicates conditions of RYT = 1. The bars indicate an LSD (P = 0.05) from 1. Narrow-row (35 cm): 2 spurred anoda/m^2 (□), 4 spurred anoda/m^2 (△), 7 spurred anoda/m^2 (◇), 12 spurred anoda/m^2 (○). Wide-row (70 cm): 2 spurred anoda/m^2 (■), 4 spurred anoda/m^2 (▲), 7 spurred anoda/m^2 (◆), 12 spurred anoda/m^2 (●).

may be caused by environmental factors as has been observed with other weed species (Deibert 1989; Hamill et al. 1994). Planting with adequate soil moisture ensures rapid soybean establishment and encourages soybean rather than spurred anoda.

For aggressivity, a year × treatment interaction was significant; therefore, data for each year were analyzed separately. Planting pattern × weed density interaction was also significant, and data for each density were analyzed separately. During both years, soybean aggressivity decreased with the increase in weed density in both row spacings and was greater in narrow- than in wide-row spacing (Table 3). Therefore, competitive ability of soybean toward spurred anoda is influenced by weed density and crop row spacing.

Plant height of soybean and spurred anoda during the crop growing season in 1998 is shown in Table 4. Soybean plant height was not significantly influenced by row spacing. Row spacing had little influence on weed height

Table 3. Effect of spurred anoda density on aggressivity at the end of the crop growing season in narrow- (35 cm) and wide-row (70 cm) soybean.

	1997		1998	
Weed density	Narrow	Wide	Narrow	Wide
plants/m²	aggressivity values[a,b]			
2	0.61 a*	0.31 a	0.74 a*	0.40 a
4	0.68 a*	0.32 a	0.60 b*	0.33 a
7	0.55 b*	0.22 b	0.56 c*	0.20 b
12	0.51 b*	0.10 c	0.33 d*	0.02 c

[a] Within row spacings, means followed by different letters differ significantly, based on LSD at P = 0.05.

[b] For each spurred anoda density, means followed by * are significantly greater than the corresponding mean within row spacing based on a *t* test at P = 0.05.

Table 5. Pods per soybean plant at crop harvest of narrow- (35 cm) and wide-row (70 cm) soybean in monoculture and growing with 2, 4, 7, and 12 plants of spurred anoda/m².

Weed density	Narrow	Wide
plants/m²	pods/plant	
0	30	35*[a]
2	25	29*
4	23	29*
7	26	34*
12	17	20*

[a] For each spurred anoda density, means followed by * are significantly greater than the corresponding mean within row spacing based on *t* test at P = 0.05.

before 126 DAP, but the reduced height of spurred anoda plants in narrow- than in wide-row soybean after 126 DAP is consistent with the reduced competitiveness of the weed in the narrower row spacing.

Soybean grain yield in monocultures (0 spurred anoda/m²) was not different between row spacings and averaged 4,030 kg/ha in 1997 and 2,880 kg/ha in 1998. Soybean yield in monocultures was also equal in narrow- and wide-row soybean in previous research (Wells 1993). In narrow- compared with wide-row soybean, a higher number of pods per plant in wide rows in 1998 was compensated for by a lower number of plants per area (Table 5). This compensation can partially account for the absence of yield differences in both row spacings.

In the presence of spurred anoda, soybean yield improved in narrow- compared with wide-row soybean only in the most humid year, this was also observed for other annual broadleaf weeds (Bauer et al. 1991; Elmore 1987). Furthermore, the early shading by soybean may account for the greater grain yields in narrow-row compared with wide-row soybean (Wax et al. 1997).

The relationship between RDW and yield in 1997 and 1998 is shown in Figure 3. The ANOVA revealed a significant year by treatment interaction between narrow and wide rows. As a result, regression analyses between grain yield and relative dry weights were conducted separately for each year and were based on linear models. In the presence of a single weed species, RDW can be used to predict yield losses in crops (Lutman et al. 1996). Yield loss in relation to weed density varies because of differences in the period between crop and weed emergence (Kropff and Lotz 1993), but the RDW yield loss model accounts for the effect of weed densities, the period between crop and weed emergence, and different flushes of weeds. The relationship between weed dry weight and and crop yield loss has been described by various models, including linear, quadratic, sigmoidal, and a rectangular hyperbola (Swanton 1999). Linear

Table 4. Height of soybean and spurred anoda (12 plants/m²) growing in mixtures in narrow- (35 cm) and wide-row (70 cm) soybean during the crop growing season.

	Soybean		Spurred anoda	
DAP[a]	Narrow	Wide	Narrow	Wide
	cm[b]			
40	14	11	12	14
84	71	83	48	49
126	85	84	52	77*
147	95	97	62	94*

[a] Abbreviation: DAP, days after planting.

[b] For each DAP and species, means followed by * are significantly greater than the corresponding mean within row spacing based on a *t* test at P = 0.05.

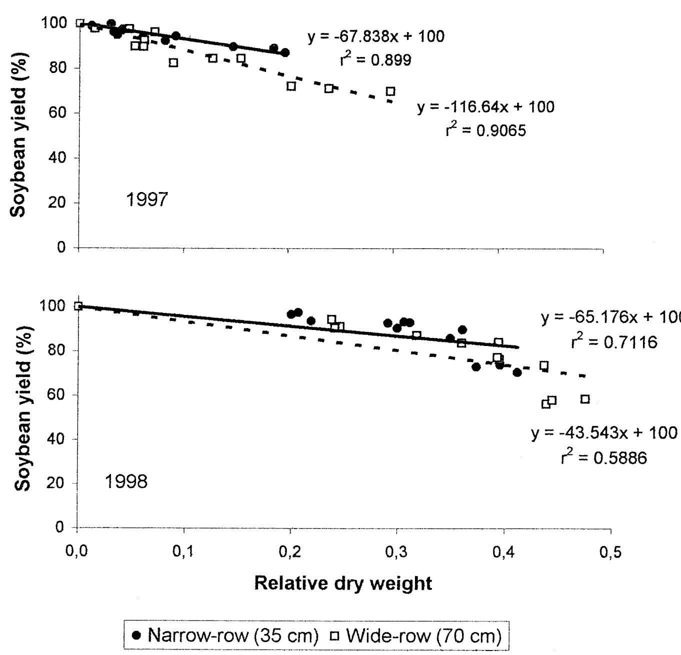

Figure 3. Linear regression and predicted values of soybean grain yield in 1997 and 1998 in percentage relative to control without weeds in relation to relative dry weights (RDW) in narrow- (●) and wide- (□) row soybean and symbols represent observed values.

equations were used with low weed densities (Bauer et al. 1991). In this study, a linear function related best the soybean yield loss at harvest to RDW 40 DAP, probably because the highest weed density observed in the field during the study was only 12 spurred anoda/m^2. The low crop yield reduction by the lower spurred anoda densities can also account for the high lack of fit of rectangular hyperbola models.

A management system that uses quick canopy closure by planting narrow-row soybean can provide excellent soybean yield and spurred anoda suppression with low weed densities. However, in the presence of high weed densities, the reduction in weed biomass by crop competition may enhance the effect of alternative control practices such as the use of postemergence herbicides.

LITERATURE CITED

Bauer, T. A., D. A. Mortensen, G. A. Wicks, T. A. Hayden, and R. A. Martin. 1991. Environmental variability associated with economic thresholds for soybeans. Weed Sci. 39:564–569.

Buhler, D. D., J. L. Gunsolus, and D. F. Ralston. 1993. Common cocklebur (*Xanthium strumarium*) control in soybeans (*Glycine max*) with reduced bentazon rates and cultivation. Weed Sci. 41:447–453.

Crotser, M. P. and W. W. Witt. 2000. Effect of *Glycine max* canopy characteristics, *G. max* interference, and weed-free period on *Solanum ptycanthum* growth. Weed Sci. 48:20–26.

Defelice, M. S., W. B. Brown, R. J. Aldrich, B. D. Sims, D. T. Judy, and D. R. Guethle. 1989. Weed control in soybeans (*Glycine max*) with below-label rates of postemergence herbicides. Weed Sci. 37:365–374.

Deibert, E. J. 1989. Soybean cultivar response to reduced tillage systems in northern dryland areas. Agron. J. 81:672–676.

Elmore, R. W. 1987. Soybean cultivar response to tillage systems. Agron. J. 77:459–465.

Hamill, A. S., J. Zhang, and C. Swanton. 1994. Reducing herbicide use for weed control in soybean (*Glycine max*) grown in two soil types in southwestern Ontario. Can. J. Plant Sci. 75:283–292.

Johnson, G. A., T. H. Hoverstad, and R. E. Greenwald. 1997. Integrated weed management using narrow row crop spacing, herbicides and cultivation. Agron. J. 90:40–46.

Kropff, M. J. and L.A.P. Lotz. 1993. Empirical models for crop-weed competition. *In* M. J. Kropff and H. H. van Larr, eds. Modelling Crop-Weed Interactions. U.K.: CAB International. Pp. 9–24.

Leguizamón, E., D. Faccini, L. Nisensohn, et al. 1994. Funciones de daño y cálculos de pérdidas por malezas en el cultivo de soja. Informe técnico No. 296. INTA Pergamino. Ed. R. Parisi. R. 19 p.

Leiva, P. and N. Ianone. 1994. Soja: El problema de las malezas y su control. Segunda parte: Presencia y evolución de las principales especies. Carpeta de Producción Vegetal. Area de Agronomía. EEA Pergamino. ISSN 0326-2354. Información No. 119. Pp. 1–4.

Lindquist, J. L., D. A. Mortensen, and B. E. Johnson. 1998. Mechanisms of corn tolerance and velvetleaf suppressive ability. Agron. J. 90:787–792.

Lutman, P.J.W., R. Risiott, and H. P. Ostermann. 1996. Investigations into alternative methods to predict the competitive effect of weeds on crop yields. Weed Sci. 44:290–297.

Mattioli, A. J. 1984. Control de malezas en el cultivo de soja. Actas de la X reunión Argentina sobre la maleza y su control. Tucumán. Argentina 1: C-53–C-70.

McGilchrist, C. A. and B. R. Trenbath. 1971. A revised analysis of plant competition experiments. Biometrics 27:659–671.

Paolini, R., S. Del Puglia, M. Principi, O. Barcelona, and E. Riccardi. 1998. Competition between safflower and weeds as influenced by crop genotype and sowing date. Weed Res. 38:247–255.

Paolini, R., M. Principi, R. J. Froud-Williams, S. Del Puglia, and E. Biancardi. 1999. Competition between sugarbeet and *Sinapis arvensis* and *Chenopodium album*, as affected by timing of nitrogen fertilization. Weed Res. 39:425–440.

Prostko, E. P. and J. A. Meade. 1993. Reduced rates of postemergence herbicides in conventional soybean (*Glycine max*). Weed Sci. 38:541–545.

Shaw, D. R., A. Rankins Jr., and J. T. Ruscoe. 1997. Sicklepod (*Senna obtusifolia*) interference with soybean (*Glycine max*) cultivars following herbicide treatments. Weed Technol. 11:510–514.

Snaydon, R. W. 1991. Replacement or additive designs for competition studies? J. Appl. Ecol. 28:930–946.

Snaydon, R. W. and E. H. Satorre. 1989. Bivariate diagrams for plant competition data: modifications and interpretations. J. Appl. Ecol. 26:1043–1057.

Spitters, C.J.T. and J. P. Van der Bergh. 1982. Competition between crop and weeds: a system approach. *In* M. Holzner and W. Numata, eds. Biology and Ecology of Weeds. The Hague: Junk Publishers. Pp. 137–148.

Steckel, L. E., M. S. Defelice, and B. D. Sims. 1990. Integrating reduced rates of postemergence herbicides and cultivation for broadleaf weed control in soybeans (*Glycine max*). Weed Sci. 38:541–545.

Swanton, C. J., S. Weaver, P. Cowan, R. Van Acker, W. Deen, and A. Shreshta. 1999. Weed thresholds: theory and applicability. J. Crop Prod. 2:9–29.

Vitta, J. I. and E. Satorre. 1999. Validation of a weed: crop competition model. Weed Res. 39:259–269.

Vitta, J., D. Tuesca, E. Puricelli, L. Nisensohn, D. Faccini, y G. Ferrari. 2000. Consideraciones acerca del manejo de malezas en cultivares de soja resistentes a glifosato. UNR Editora. 15 p.

Wax, L. M., W. R. Nave, and R. L. Cooper. 1997. Weed control in narrow and wide row soybeans (*Glycine max*). Weed Technol. 7:365–369.

Wells, R. 1993. Dynamics of soybean growth in variable row spacings. Agron. J. 85:44–48.

Wit, C. T. de. 1960. On competition. Verslagen van Landbouwkundige Onderzoekingen, 66:1–82.