Effect of Sowing Spacing on Vegetative Growth, Dry Matter Production, and Peanut Pod Yield

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ABSTRACT

Peanut growth and pod yield are influenced by sowing spacing and plant density. Production and distribution of dry matter on peanut cultivars sown in different spacings and densities and their relationships with pod and kernel yields were assessed. The factors evaluated were two cultivars (Florman INTA, virginia-type "runner" and Colorado Irradiado, valencia-type erect), three interrow spacings (IRS) (0.70, 0.50, and 0.30 m) and two interplant spacings (IS) (0.06 and 0.12 m). The 12 treatments were disposed in a factorial arrangement of 2x3x2 and a randomized block design with three replications. Weeds were controlled with Imazetapir (100 g ai/ha) and also hand weeded while leaf spot control was done with Fluzilasole (60 g ai/ha). Sowing spacings did not affect phenologic stage duration, but the differences observed were due to the cultivar. Vegetative growth was sensitive to spacings effect. At an individual plant level, dry matter and leaf area decreased significantly because of the greater intraspecific competition produced by the shortening of distances between rows (from 0.70 to 0.30 m) and between plants (from 0.12 to 0.06 m) and the corresponding density increase from 12 to 56 plants/m^2. However, at a population level, most compact spacings produced more dry matter per surface and leaf area index. This also is related to the lesser time required for plants at these spacings to achieve a radiation interception higher than 90%. Dry matter distribution did not vary with sowing spacings. The number of branches per plant was reduced with the increase of density. The effect was greater in the late maturing cultivar. The most compact sowing spacings (0.30x0.06, 0.50x0.06 and 0.30x0.12 m) produced higher pod and kernel yield/ha than those less dense. This response is based upon the significant correlations between the dry matter and number of branches per surface area, and leaf area index and pod yield.

Key Words: Plant competition, plant growth, row spacing.

Crop yield is determined by the efficiency with which plant population uses available environmental resources for growth. This efficiency depends largely on the spatial and temporal occupational pattern of the genotype. Peanut (*Arachis hypogaea* L.) cultivars vary in the duration of plant growth and maturity, growth habits, and branching patterns that range from the erect and sequential types of *A. hypogaea* subsp. *fastigiata* to the semi-erect and runner types with alternated branching in *A. hypogaea* subsp. *hypogaea* (Gibbons *et al.*, 1972).

Understanding the effects of different sowing patterns and densities on the morphological characters and peanut yield is essential for the design and adjustment of management practices that allow improvement and stabilization of yield. Yayock (1979) used cultivars with different growth habits and found less primary and secondary branching and dry matter per plant, and a greater proportion of dry weight in the stems during the final growth stages with an increase of density from 43,000 to 271,000 plants/ha. However, increased plant density had the opposite effect on dry matter accumulation. Leaf area index (LAI) increased with sowing density varying among cultivars and locations. These results are similar to those obtained previously by Cahaner and Ashiri (1974), with different densities and distances between rows for virginia-type peanuts with different growth habits. Later, Giri and Saran (1986) studied virginia and spanish type cultivars and found that yields were significantly greater for high densities while individual growth, measured upon the basis of dry matter per plant, was lower and corresponded to fewer pods per plant.

By working with equal densities and different spacings, Auma (1985) and Gardner and Auma (1989) found a greater solar radiation interception during the initial growth stages in almost square spacings (0.35x0.30 m) as opposed to rectangular ones (0.70x0.15 m and 1.05x0.10 m). Total dry matter, LAI, relative growth rate, and pod and kernel yield in square spacings were also greater for Florunner and Pronto, which are runner and erect habit cultivars, respectively. Jaafar and Gardner (1988) used genotypes of different growth habits and found that canopy closure, LAI, light interception, cultivar growth rate, dry matter as well as yield were greater in smaller interrow spacings (0.46x0.15 m) and also in twin rows [(0.69-0.23)x0.15 m] than in those conventional row plantings (0.91x0.08 m).

In the peanut production area in Argentina, plants from erect and runner cultivars sown in high densities (0.30x0.06 m) produced less dry matter (leaves and stems) and pods than at the recommended densities (0.70x0.08 or 0.70x0.12 m), whereas pod and kernel yields were greater (Giayetto *et al.*, 1993, 1994).

Mozingo and Wright (1995) found a highly significant effect on yield when using diamond-shaped seeding configuration and different cultivars. High density sowings (0.152x0.152 m) had a greater yield than the most spaced configurations (0.457x0.457 m). The interaction between sowing spacing and cultivar was significant for pod yield.

The objective of this work was to evaluate the production and distribution of dry matter on peanut cultivars sown in different spacings and sowing densities and their relationship with pod and kernel yields.

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Material and Methods

This study was performed at the Facultad of Agronomía y Veterinaria, Universidad Nacional de Río Cuarto, Province of Córdoba, Argentina (34 S, 64 W) during 1994/95 and 1995/96 on a typical Hapludol soil. The factors evaluated were two cultivars (Florman INTA, virginia-type "runner" and Colorado Irradiado, valencia-type erect), three interrow spacings (IRS) (0.70, 0.50, and 0.30 m), and two interplant spacings (IS) (0.06 and 0.12 m). The 12 treatments were planted in a factorial arrangement of 2x3x2 and a randomized block design with three replications. Each plot had eight 5-m long rows. Plant densities for each spacing are shown in Table 1.

Table 1. Plant densities for each sowing spacing.

Sowing spacing	Plants
m	per m^2
0.70 × 0.12	12
0.50 × 0.12	18
0.70 × 0.06	24
0.30 × 0.12	28
0.50 × 0.06	33
0.30 × 0.06	56

Sowing was performed in 25 Nov. 1994 and 17 Nov. 1995 and plants were harvested at maturity (R8) on 13 April 1995 and 20 March 1996 for cv. Colorado and 2 May 1996 for cv. Florman, respectively. Weeds were controlled with Imazetapir (100 g ai/ha) during both years and also hand weeded while leaf spot control was done with Fluzilasole (60 g ai/ha). Phenological stages were evaluated according to Boote (1982). Dry matter production and distribution were estimated by sampling three plants per plot and separating the plant parts (except for roots). Drying was with a forced air circulation heater at 80 C until a constant weight was reached. A LICOR Model Li-3000 automatic area meter was used to measure the leaf area per plant, and the LAI corresponding to each treatment was calculated. Canopy closure was estimated every 10 d by taking photographs from a 2.5-m height. A digital processing also was used to estimate canopy closure when a cover greater than 90% was reached. The number of branches per plant and the yield of pods and kernels per ha starting from the sampling of 10 plants per treatment and replication were evaluated during the R8 stage. All data were submitted to ANOVA and Tukey's test (SAS Institute, 1990) was used to compare treatment means. The correlation between morphological characters, dry matter production, and pod and kernel yield were calculated.

Results

Weather Conditions Prevailing During the Growth Season. Figure 1 shows mean temperature values and monthly rainfall for both growth seasons. For the first season data were obtained by pan evaporation, while potential evapotranspiration (ET) following Thornthwaite's methodology was used when measuring the second season. Figures obtained by both methods were used as estimators of the atmospheric demands. Rainfall between sowing and harvest for cv. Florman was 380 mm in the first year and 498 mm in the second year; for cv. Colorado the values were 378 and 381 mm, respectively. Distribution was more stable during the second year. Comparing rainfall to evaporation, hydrological shortages occurred during the months of Dec. 1994, Feb., March, and April of 1995; while for the second growing season, these conditions occurred only in Dec. 1995 and March 1996.

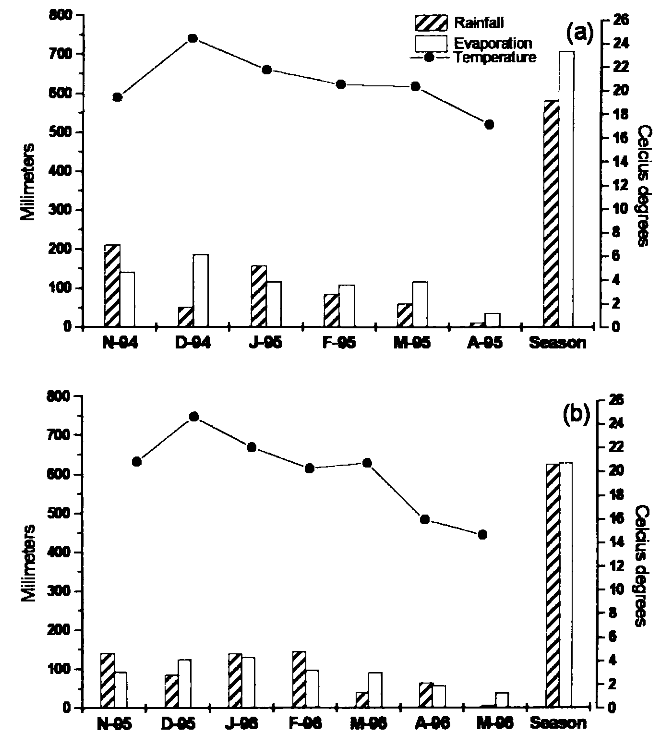

Fig. 1. Weather conditions recorded during peanut cycles for both growing seasons (a) 1994/95 and (b) 1995/96.

Monthly mean temperatures were similar in both years. The high temperature value obtained in December was noticeably greater than the historical average (22.0 C). Florman was affected at its final growth stage by an early frost on 21 April 1995.

Phenology. Sowing spacings did not affect phenologic stages duration (Table 2). The differences observed were due to the cultivar, particularly during stages VE-R1 and R1-R8 for the longer duration cv. Florman for both years. The shorter duration of cycle VE-R8 of

Table 2. Duration of the phenological stages of both cultivars for each year.

Phenological stage[a]	Colorado Irradiado 1994/95	Colorado Irradiado 1995/96	Florman INTA 1994/95	Florman INTA 1995/96
	-------- d --------		-------- d --------	
S[b]-VE	10	8	10	14
VE-R1	25	25	36	34
R1-R5	42	33	41	40
R1-F8	94	91	104	119
S-R8	129	124	150	167

[a]Boote (1982).
[b]Sowing.

this cultivar during the first year was due to the frost that occurred on 21 April which interrupted the growth by plant death.

Dry Matter Production. Colorado dry matter production followed a similar pattern for both growing seasons (Fig. 2). Dry matter accumulation was different for the spatial arrangements 40 d after sowing (DAS) with 0.70×0.12 m having maximum values and 0.30×0.06 m having minimum values. Spacings between the two extremes also had intermediate dry matter accumulations. At the final stages of growth, the tendencies were maintained, but changed in the treatments with the intermediate values. Spacing 0.50×0.12 m was similar to treatment 0.70×0.12 m while the other three were similar to spacing 0.30×0.06 m. Comparing the dry matter maximum values per plant between growing seasons, favorable weather conditions during the second season also resulted in more plant growth.

Cultivar growth of the runner-type cv. Florman was similar to Colorado (erect growth habit) with slight differences observed between years (Fig. 3). In 1994/95, the greatest values were for spacings 0.70×0.12 m and 0.50×0.12 m while the other four spacings had the lowest values. For 1995/96, spacing 0.50×0.12 m was similar to those spacings with the highest plant density. These tendencies began to differentiate at 50-60 DAS and were

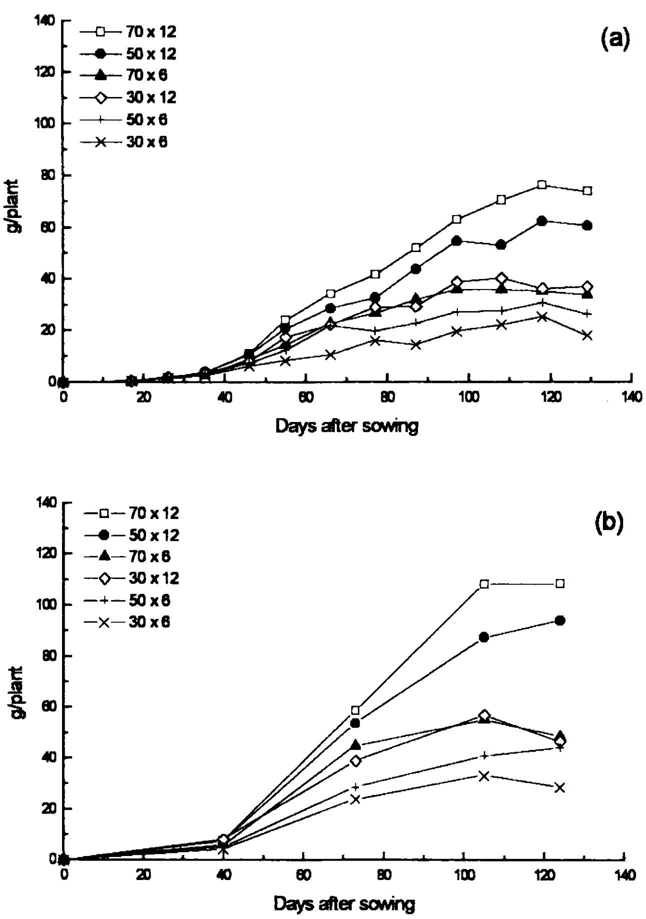

Fig. 2. Dry matter per plant for the different sowing spacings as a function of the days after sowing, cv. Colorado Irradiado: (a) 1994/95 and (b) 1995/96.

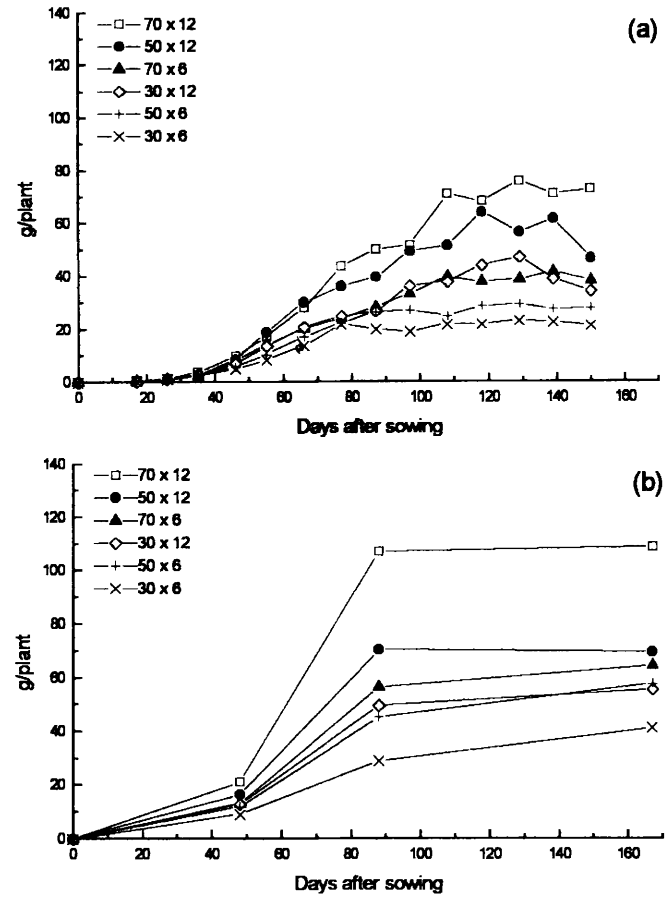

Fig. 3. Dry matter per plant for the different sowing spacings as a function of the days after sowing, cv. Florman INTA: (a) 1994/95 and (b) 1995/96.

maintained until pod maturity.

Table 3 shows the average data of dry matter per plant for each growing season. Due to the lack of significant interactions, data are presented as the aggregate per factor. During both growing seasons the late cultivar

Table 3. Average value of dry matter for three factors studied during two growing seasons.

	Cultivar		Interrow spacing (m)			Interplant spacing (m)	
Stage[a]	Colorado	Florman	0.70	0.50	0.30	0.12	0.06
	---- g/plant ----		--------- g/plant ---------			---- g/plant ----	
				1994/95[b]			
R1	3.4 b	7.5 a	6.1 a	5.7 a	4.3 b	6.1 a	4.8 b
R5	28.3 a	31.9 a	37.7 a	29.7 b	23.0 c	37.3 a	22.9 b
R8	44.5 a	41.7 a	55.6 a	44.1 b	29.6 c	57.8 a	28.4 b
				1995/96[b]			
R1	6.5 b	14.1 a	12.0 a	10.3 a	8.6 a	12.3 a	8.3 b
R5	41.5 b	60.2 a	66.7 a	50.6ab	35.4 b	63.8 a	37.9 b
R8	63.5 a	67.3 a	85.5 a	63.9 b	46.8 c	81.5 a	49.2 b

[a]Boote (1982).

[b]According to Tukey's test (P = 0.05), equal letters do not differ significantly among them for each factor.

(Florman) accumulated more dry matter than Colorado. These differences extended up to the R5 stage in the second season, while in the first season the differences were only maintained up to R1 stage because of the drought both cultivars suffered after that stage. Florman was most affected by this drought due to its longer maturing cycle. IS significantly affected the growth of peanut through all cycles during both seasons. Dry matter was greater at 0.12 m IS. Differences due to IRS manifested before and after R1 in 1994/95 and 1995/96, repectively, and remained differentiated up to R8. The plants sown in the 0.7-m row spacing produced a dry matter after R1 greater than those sown at 0.50 and 0.30 m. The latter differed significantly from the other row spacings during the first season and only in R8 in the second growing season.

Dry Matter Distribution. Dry matter distribution was not affected by the sowing spacings. There were differences only among cultivars in the first season due to the lesser reproductive growth of cv. Florman caused by limited water during pod-filling period. Colorado partitioned 50% of the total dry weight to pods and Florman partitioned 43%. In the second season, the mean value for partition to pods was 50% for both cultivars.

Leaf Area and Leaf Area Index. Leaf area per plant for both cultivars was related to dry matter production per plant in the two seasons (Figs. 4 and 5). Both cultivars had a similar response. The maximum value of leaf area per plant occurred about 100 DAS independently of cultivar and season, and corresponded to the spacings 0.70x0.12 and 0.50x0.12 m, varying between 2500-2800 cm^2/plant for the first season and 3800-6000 cm^2/plant for the second one. The lowest values were for spacings 0.50x0.06 and 0.30x0.06 m with 1000-1200 cm^2/plant in 1994/95 and 1400-2500 cm^2/plant in 1995/96. The other spacings (0.70x0.06 and 0.30x0.12 m) had intermediate values. LAI also varied with plant spacings and the cultivar. For cv. Colorado, the greatest values were for the spacing 0.30x0.06 m and the lowest for 0.70x0.12 m; for cv. Florman the maximum was also for 0.30x0.06 m while the minimum corresponded to both 0.70x0.12 and 0.50x0.12 m. The other designs showed intermediate values in both seasons (Figs. 6 and 7). When comparing the cultivars independently of the spacings, Florman surpassed Colorado in both the LAI maximum values and in the leaf area duration, particularly in the most compact spacings of 0.50x0.06 and 0.30x0.06 m.

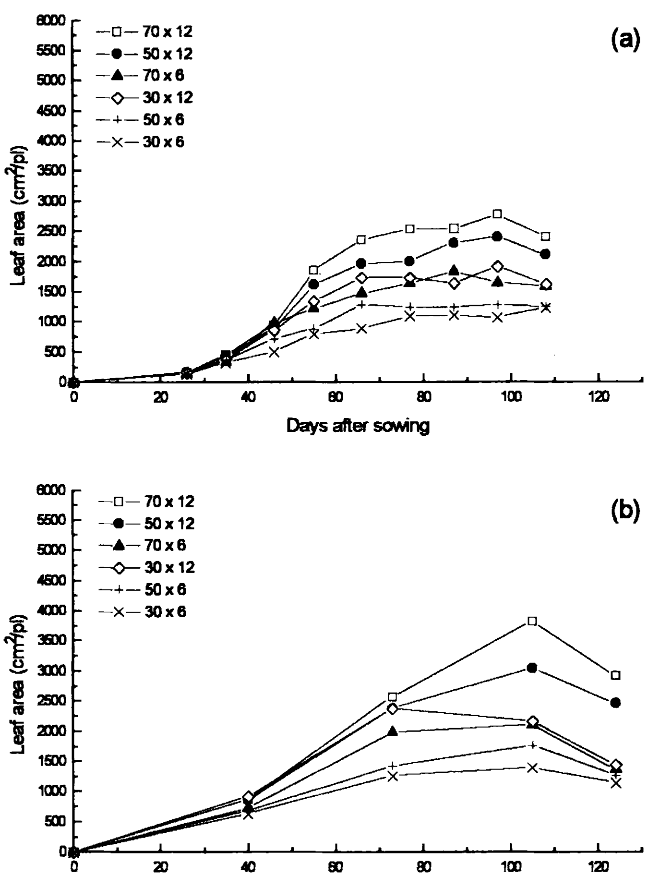

Fig. 4. Leaf area (cm²/plant) during ontogeny of crop, cv. Colorado Irradiado: (a) 1994/95 and (b) 1995/96.

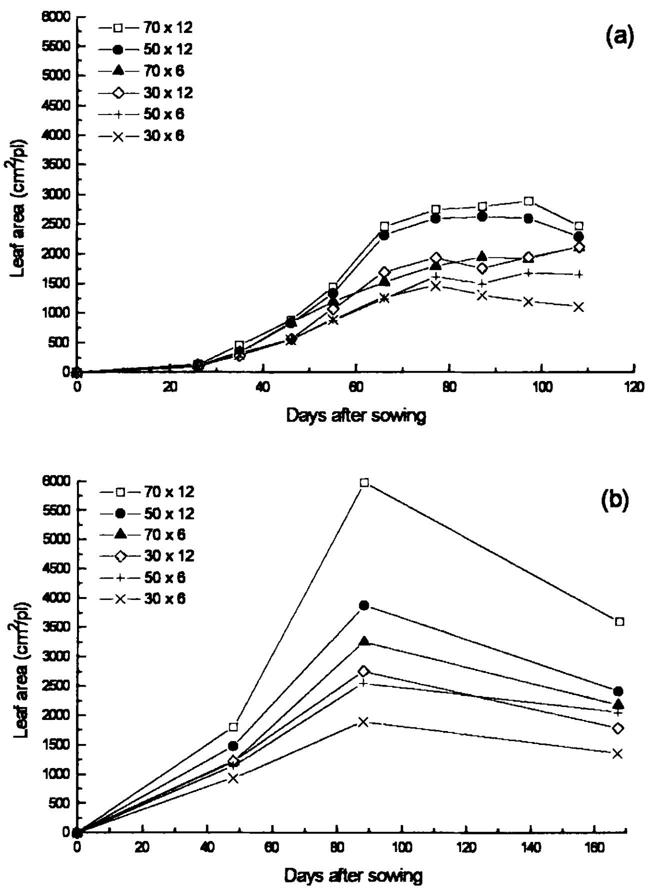

Fig. 5. Leaf area (cm²/plant) during ontogeny of crop, cv. Florman INTA: (a) 1994/95 and (b) 1995/96.

Number of Branches. The number of branches per plant responded to the combined effect of cultivar and plant spacing (Fig. 8). Florman had more marked reductions than Colorado due to its greater branching potential (up to tertiary) and runner habit.

Canopy Closure. The time required for each cultivar to achieve a ground cover greater than 90% ranged with IRS for both seasons. Planting at 0.30 and 0.50 m

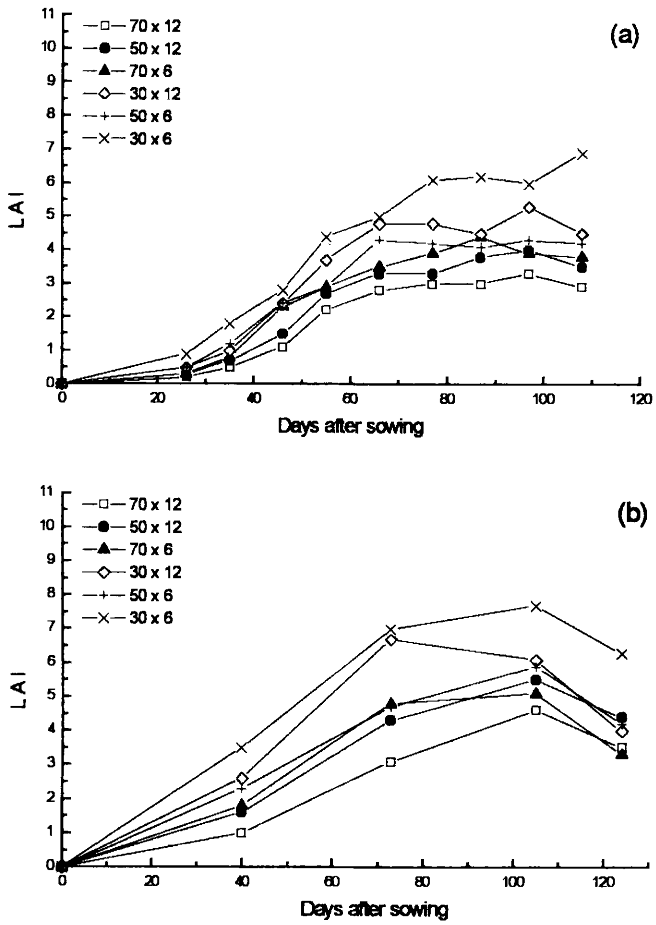

Fig. 6. Leaf area index (LAI) during ontogeny of crop, cv. Colorado Irradiado: (a) 1994/95 and (b) 1995/96.

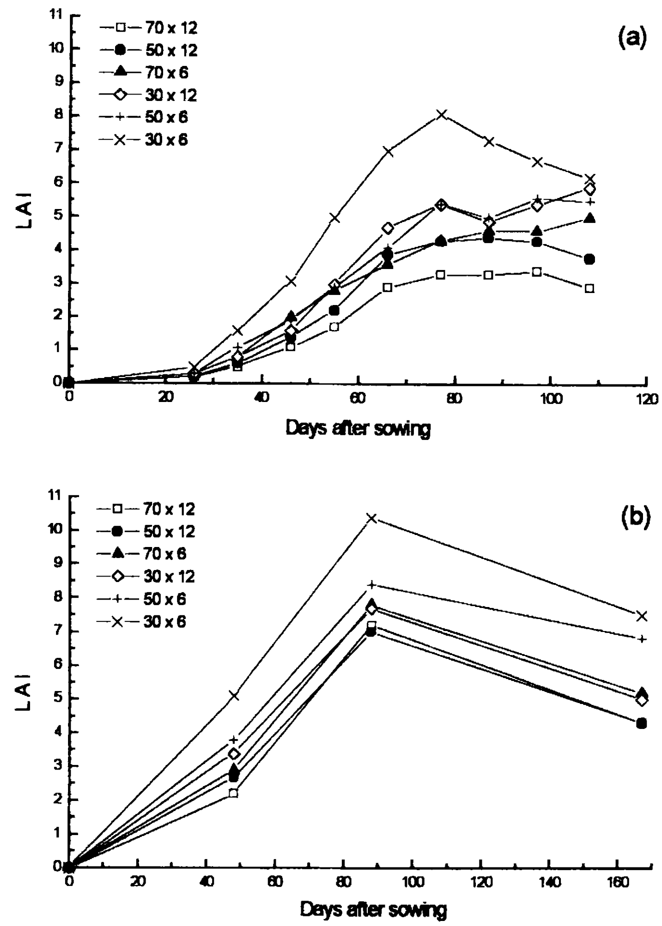

Fig. 7. Leaf area index (LAI) during ontogeny of crop, cv. Florman INTA: (a) 1994/95 and (b) 1995/96.

between rows reached this value in stages R2 and R3 (46 and 60 DAS), respectively, with no differences among cultivar while sowing in rows at 0.70 m needed 66 and 87 d for Florman and Colorado, respectively. No differences referred to IS were observed in either case.

Pod and Kernel Yields. Pod and kernel yields per ha for each sowing density and cultivar, respectively, are shown in Fig. 9. The lack of an IRS × IS interaction indicates that the spacings did not affect peanut yield. This increased significantly with plant density and adjusted to a second order polinomic equation with significant determination coefficients ($P \leq 0.01$). The increasing rate was more pronounced up to 30-35 plants/m^2 density showing a proportionally lower increase at greater plant densities. As the values reached by the respective curves show (Fig. 9), the season effect was greater during 1995/96. Regarding cultivars, Florman had significantly more pods than Colorado in the year with better hydrological conditions (1995/96), while significant differences were not observed during the dry year.

Vegetative Growth and Yield Correlations. Correlation coefficients between the vegetative characters at an individual level (dry matter and number of branches) and at a population level (dry matter and LAI) and pod yield are indicated in Table 4. In the first case, the relationships were negative and significant in both seasons for cv. Florman, whereas they were negative and significant for cv. Colorado only in the second season. On the other hand, at a population level, the relationships were positive and significant among LAI and pod yield for both cultivars and seasons, and between dry matter/ha and pod yield for both cultivars only in the first season.

Discussion

These results confirm different sowing spacings and densities affect vegetative growth (dry matter and leaf area) and peanut pod yield. The responses vary according to cultivar and growing season. The lack of response of the phenological stage duration of the sowing spacings and densities here studied agrees with reports by Giayetto *et al.* (1993, 1994). Differences among cultivars are due to genotypical characteristics. Differences in flowering time between seasons were due to December temperatures which were above the historic mean value and resulted in increased growth rate during the first year.

Vegetative growth (dry matter and leaf area) was sensitive to spacing effects as it was previously pointed out by other investigators. At an individual plant level, dry matter and leaf area decreased significantly because of the greater intraspecific competition produced by the shortening of distances between rows (from 0.70 to 0.30 m) and between plants (from 0.12 to 0.06 m) and the

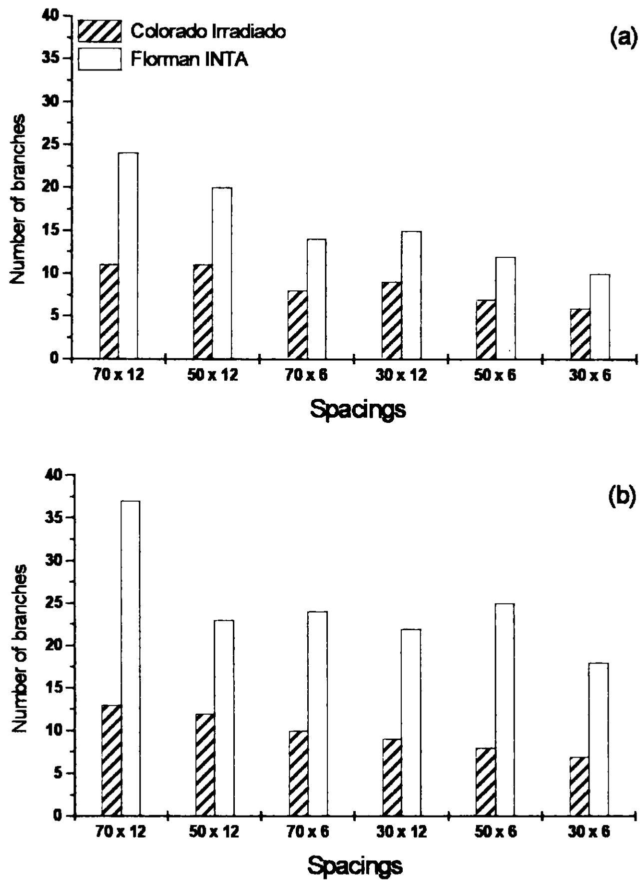

Fig. 8. Number of branches per plant for both cultivars (Colorado Irradiado and Florman INTA) according to the different spacings: (a) 1994/95 and (b) 1995/96.

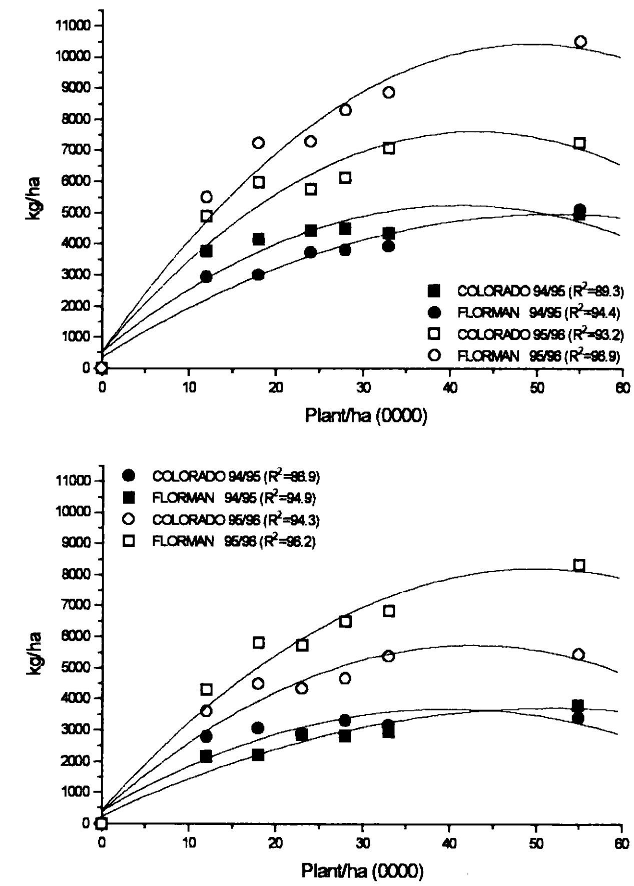

Fig. 9. Pod (a) and kernel (b) yield for both cultivars for each sowing density and season.

corresponding density increase (from 12 to 56 plants/m^2). Similar results were observed by Cahaner and Ashri (1974) for the virginia cv. Yayock (1979), Giri and Saran (1986) with virginia and spanish cultivars, Jaafar and Gardner (1988) with different spacings and equal density, and by Giayetto *et al.* (1993, 1994) under conditions similar to the ones in this study. However, at a population level, the most compact spacings produced more dry matter per surface area and LAI. This also was observed by Yayock (1979). The increased dry matter accumulation is related to the lesser time required for plants in high density spacings to achieve a solar radiation interception higher than 90%.

In opposition to results obtained by Yayock (1979), dry matter distribution did not vary with sowing spacings in this study. Only differences among cultivars were observed during the first season due to the concurrent effect of cycle duration and drought at the end of growth season, resulting in cv. Florman distributing the highest relative amount of dry matter to stems and leaves after the R5 stage.

The number of branches per plant was reduced with the increase of density as reported by Cahaner and Ashri (1974) and Yayock (1979). The effect was greater in the late maturing cultivar due to its greater branching potentiality (up to tertiary) and runner habit.

Due to the greatest amount of dry matter, number of branches per surface, LAI, and more rapid canopy closure, the most compact sowing spacings (0.30×0.06, 0.50×0.06, and 0.30×0.12 m) produced higher pod and kernel yield per ha than those less dense. Similar observations were reported by Cahaner and Ashri (1974), Giri and Saran (1986), Giayetto *et al.* (1993, 1994), and Mozingo and Wright (1995). This response is based upon the close and significant correlations between these variables and pod yield. When hydrologic balance during the growth season is positive, particularly during the reproductive phase, these correlations are more pronounced.

The effect of a negative hydrologic balance, as the one recorded at the end of growth season in 1994/95, is

Table 4. Correlation coefficients between vegetative characters and pod yield.

Vegetative characters	Pod yield (kg/ha) 1994/95 Colorado	1994/95 Florman	1995/96 Colorado	1995/96 Florman
Dry matter (g/plant)	-0.75	-0.90*	-0.90*	-0.93**
No. branches/plant	-0.73	-0.89*	-0.93**	-0.86*
Dry matter (kg/ha)	0.89*	0.92**	0.66	0.77
LAI	0.93**	0.92**	0.86*	0.88*

*,**Significant correlation coefficients (P = 0.05 and 0.01, respectively).

different among cultivars. During that year, cv. Colorado yielded more pods and kernels than cv. Florman because it completed its reproductive cycle before drought occurred, whereas the drought coincided with pod filling period in Florman. The absence of those weather limitations in the second year enhanced reproductive development for cv. Florman. Yields were significantly greater than cv. Colorado.

Squareness (IS/IRS) of plant densities involved in this study varied within a narrow range (0.1 to 0.4). The results in this study differ from reports by Auma (1985), Jaafar and Gardner (1988), and Gardner and Auma (1989). We observed peanut growth and yield was greatly influenced by density. No evident relationship was detected between cultivar and sowing spacing, and variation observed was due to genotypic responses of the two cultivars.

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