Peanut response to plant densities and planting patterns: light interception, growth analysis and yield

Respostas do amendoim a população de plantas e configuração de plantio: interceptação da radiação solar, análise de crescimento e produção

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ABSTRACT

This study examined the relationships among plant density and leaf area index (L), light interception (LI), crop growth rate (C), plant dry matter (W) and yield in peanut (*Arachis hypogaea* L.). Narrow-row (40 cm) and wide-row (80 cm) treatments had greater leaf area and plant dry matter as the growth cycle progressed and plant density increased from 62,500 to 200,000 plants/ha. In the narrow-row, the L did not reach saturation as plant density increased. The wide-row allowed maximum dry matter yield at a density of 170,000 plants/ha, while dry matter saturation was not reached for the narrow-row. $L_{95\%}$ was higher and was reached earlier for narrow-row. Wide-row combined with lower density did not reach full light interception. Number and weight of pods/plant increased as plant density decreased. However, these increments were slower with decreasing plant density in the narrow-row. The optimum plant densitys for pod yield were 190,000 and 150,000 plants/ha for the narrow and wide-row width, respectively. The data suggest a positive effect of narrow-row planting pattern on peanut crop performance in Northeast of Brazil.

Index terms: *Arachis hypogaea* L., leaf area index, crop growth rate.

RESUMO

Foram examinadas as relações entre a densidade de plantio e o índice de área foliar (L), a interceptação da luz solar (LI), a taxa de crescimento da cultura (C), a matéria seca da planta (W) e a produção, em amendoim (*Arachis hypogaea* L.). Tanto a fileira estreita (40 cm) como a larga (80 cm) apresentaram maiores áreas foliares e matéria seca com a evolução do ciclo da cultura, e a densidade populacional aumentava de 62.500 a 200.000 plantas/ha. Na fileira estreita, o L não alcançou a saturação com o aumento da população. A fileira larga proporcionou uma saturação na produção de matéria seca (W) no nível populacional de 170,000 plantas/ha, enquanto esta não foi atingida na fileira estreita. Nesta última, o L_{95} foi atingido mais cedo e apresentou valores maiores. A fileira larga, combinada com baixas densidades populacionais, não alcançaram uma completa interceptação de luz. O número e o peso de vagem/planta aumentaram com a redução da população. Entretanto, estes aumentos foram mais lentos no plantio em fileiras estreitas. A população ótima foi atingida com 190.000 e 150.000 plantas/ha para fileiras estreitas e largas, respectivamente. Os dados sugerem um efeito positivo do plantio em fileira estreita na produtividade do amendoim no Nordeste do Brasil.

Termos para indexação: *Arachis hypogaea*, índice de área foliar, taxa de crescimento.

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Introduction

Peanut (*Arachis hypogaea* L.) commercial crops are found predominantly in tropical and to a lesser extent in sub-tropical environments at a range of altitudes. The plant is adapted to a wide variety of climate conditions and is widespread in both humid and semi-arid regions. Peanut acreage in Northeast Brazil is still small. However, the crop has a high potential due to a great adaptability to different water regimes as well as to low soil fertility, that characterize large areas available for cultivation (Távora and Melo, 1991).

Plant density is a very important factor affecting peanut yield by directly influencing the yield components (Nakagawa et al., 1994). Several authors have reported yield increase in different crops as a response to narrow row spacings (Board et al., 1996 and Bullock et al., 1998 in soybean; Jost and Cothren, 2000 in cotton; Staggenborg et al., 1999 in sorghum).

Planting configuration affects the distribution of the plants in the field, enabling more even distribution when sown in narrower row spacing (Flenet et al., 1996). In soybean (Board et al., 1992), an increase in light interception has been reported, when the row spacing was reduced, at the same density. An increase in light interception has often determined yield increases (Parvez et al.., 1989). Most authors report that peanut yield increases in response to higher plant density. They also indicate that the narrow row pattern improves water use efficiency (Stone et al., 1985; Erickson et al., 1986), increases solar radiation interception (Jaaffar and Gardner, 1988; Simmonds and Azam-Ali, 1989;) and promotes yield increase (Wehtje et al, 1984; Martins and Pitelli, 1994). The accumulation of dry matter in the shoots was highly correlated with the solar radiation intercepted in peanut (Bell et al. 1993). It should be emphasized, however, that the ideal planting configuration and spacing depend on soil characteristics and climatic conditions as well as to the crop itself. Studies on this subject have to be carried out for a particular crop in a specific environment. There are just a few experiments with peanut pursuing these objectives in Northeast of Brazil (Lima et al., 1981).

The objectives of this study were to determine the effect of plant density and planting configuration on (i) light interception (ii) growth parameters (iii) yield and yield components of peanut grown under irrigation conditions in Northeast of Brazil.

Materials and Methods

A field experiment was conducted in 1996 on a silt loam soil, at the Federal University of Ceará in Pentecoste, Ceará, Brazil (3° 45' S, 39° 15' W, and 47 m above sea level). Conventional tillage was used. The seedbed was prepared by plow and harrow disking the experimental area. Furrows to provide irrigation were spaced 80 cm apart. The crop was irrigated weekly in order to reestablish the field capacity. Weeds were controlled by hand hoeing. Soil analysis revealed high levels of P, K, Ca and Mg, and pH 6.9, indicating that fertility was adequate for peanut production. *Aphis gossypii* was controlled by the application of Diazinon (l ml/l) 60 days after planting (DAP) and Stegasta bosquella was controlled by application of Parathion methyl (l ml/l) 76 DAP. Cultivar PI-165317 that belongs to the Spanish group was used. The pods were harvested 95 DAP.

The experimental design was a randomized complete block with eight treatments and four replications. The treatments were the combinations of two planting arrangements (40 cm and 80 cm between rows) and four plant densities (62,500, 83,300, 125,000 and 200,000 plants/ha).

The plots were 5 m long, and the row number varied as a function of the planting arrangement. The 0.8 m row configuration (wide row), had plots (12 m^2) with four rows. The 0.4 m row configuration (narrow row) had plots (10 m^2) with five rows. The two or three guard rows, depending on the row width, in each plot, were harvested.

Leaf area index (L) and dry weight (W) were determined at 40, 55 and 70 DAP. The grid method, described by Távora et al. (1982), was used to determine the L. At each harvest a sample of 3 plants was cut at ground level and the leaf area measured by placing the leaflets under a glass grid marked with 2 x 2 cm squares. The number of intersections covering the leaflets enabled the calculation of leaf area. The leaflets, petioles, stems, pegs and fruits of the sampled plants were dried at 70°C in a forced drier to constant weight, to determine the dry matter (W). The specific leaf weight was obtained and the leaf area was determined. The L was calculated based on the land area sampled.

Average crop growth rate (C) was calculated in the intervals 40 to 55 and 55 to 70 DAP using the following equation:

$$C = \frac{W_2 - W_1}{t_2 - t_1}$$

where w_2 and w_1 are the

dry matter in the harvested dates and t_2 and t_1 are the number of DAP at the harvesting dates.

A sample of three plants was cut at ground level 95 DAP and the leaves, stems, pegs and pods were dried at 70°C in a forced air drier to constant weight.

Light interception was measured between 11h00 and 13h00, on sunny days, using a radiometer Licor model LI-170. The solar radiation determinations (mE/m²/s) were obtained at 40, 55 and 70 DAP. Solar radiation was estimated at ground level and above the plant canopy. Three and five measurements in each replication were made for the 40 cm and 80 cm row width treatments, respectively. The points where the solar radiation was measured within the plant canopy were spaced 20 cm and distributed over a line perpendicular to the row, with the center of the line even with the row. The position within the plots where the measurements were taken were chosen at random. In each replication the sensor was positioned above the plant canopy to allow the measurement of the income solar radiation. Light interception was calculated as follows: Light interception = $1-(I/I_0)]$ 100, where I= the solar radiation at the ground level and I_0 = the solar radiation above the canopy.

Analysis of variance was performed in the data and the treatment means were compared using the Tukey test at the 0,05 level of significance.

The effects of plant density, planting arrangement and stage of growth upon leaf area index, % light interception, number and pod weight per plant and pod yield were examined by comparing fitted regression functions.

Results and Discussion

Leaf area index (L) increased from 40 to 70 DAP in all plant density and both width treatments (Fig. 1). Plant density had a strong positive effect on L, at the three sampling dates. The fitted polynomial curves relating plant densities and L showed a different behavior for both planting patterns. In the wide-row pattern, the curves showed saturation at levels below the maximum plant densities studied, in all three sampled dates. On the other hand, in the narrow-row arrangement, the L did not reach saturation at any sampled dates, even at the higher plant densities. In both planting arrangements the value of L almost doubled between the highest and the lowest plant densities (62,500 and 200,000 plants/ha) at 55 and 70 DAP. At 40 DAP, in the narrow-row, the L values showed a 3:1 proportion, indicating a better performance in the early stage of growth for the combination of high plant density and narrow row configuration. A close relationship was also detected between L and W based on the high correlation coefficient obtained throughout the plant cycle (r =0,95**). Jaaffar and Gardner (1988) found similar results in peanut, where L for the narrow row pattern was greater than that for the conventional row pattern up to about 80 DAP.

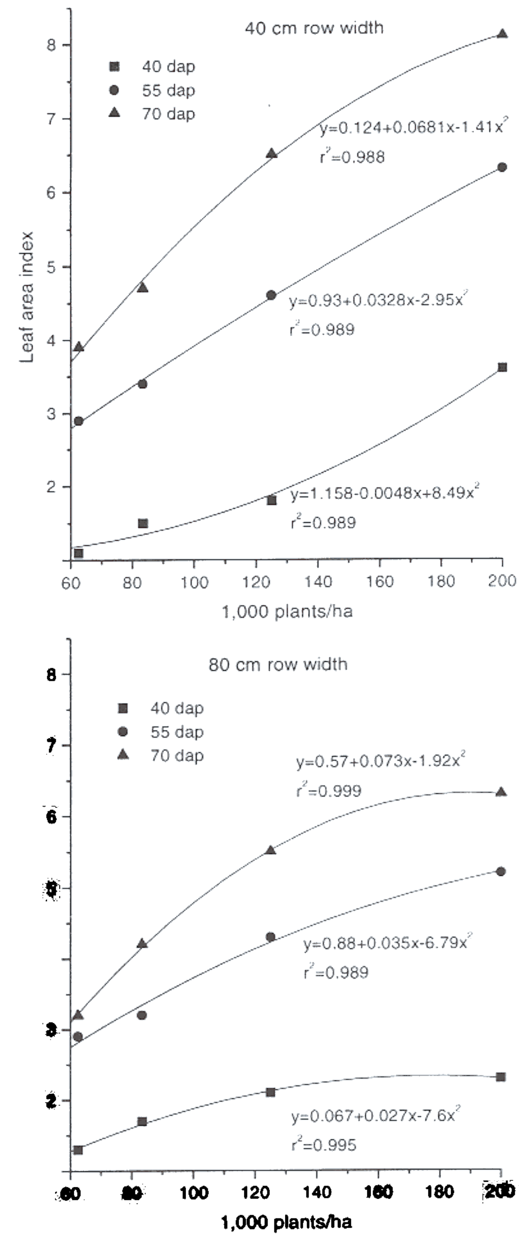

Figure 1 - Leaf area index *versus* plant density of peanut grown at 40, 55 and 70 DAP, in narrow (40 cm) and wide (80 cm) row width.

At the same planting densities and sampling dates, the narrow-row width pattern yielded higher L values compared to the wide-row. At 70 DAP, L was highest (8,1) in the combination of 200,000 plants/ha and narrow-row. At the same plant density, L reached the maximum value of 6,3 in the wide-row. Duncan et al. (1978) reported maximum values for L close to the ones obtained in our study (7,0) at equidistant spacing (30 x 25 cm). They emphasized, however, that solar radiation interception was completed (95%) when the crop reached an L above 3,0. Jaaffar and Gardner (1988), reported maximum L values of 6,0 for all cultivars in the narrow row configuration. Ball et al (2000) reported that losses due to delays in leaf area development and slow growth of soybean could be minimized by using high plant density in narrow rows.

Differences in light interception were evident for planting pattern. At early stages and plant densities varying from 83,300 to 125,000 plants/ha narrow row configuration provided the higher light interception values for each density except 60,000 plants/ha 40 DAP (Fig. 2). This difference disappeared at 70 DAP. Light interception increased with plant density at the early stages of growth. A longer period of time was necessary for light interception to reach maximal levels in the wide-row.

The increased light interception with narrow rows was previously observed by Board and Harville (1996) in soybean, and correlated with a higher C during the vegetative period.

A curvilinear relationship of the hyperbolic type described by the equation $y = a - \frac{b}{(1+cx)^{1/d}}$ was evident between percent light interception (y) and L (x) in both planting configurations (Fig. 3). According to the fitted curves, leaf area index that corresponded to complete canopy closure ($L_{95\%}$) were 4,84 and 5,45 for the narrow and wide-row, respectively. Based on adjusted lines of L versus DAP, the narrow-row configuration reached canopy closure at approximately 47, 59, 71 and 79 DAP, corresponding to 200,000 125,000 83,300 and 65.500 plants/ha, while wide-row configuration reached canopy closure at 62, 68, and 84 DAP corresponding to the three highest plant densities, respectively. The 95% light interception (canopy closure) at the lowest plant density -65,500 plants/ha- in the wide-row was not attained at harvesting time (95 DAP). The peanut cultivars studied by Duncan et al. (1978) attained more than 95% light interception by the 55[th] DAP in narrow row planting arrangement. Similar results were reported by Jaaffar and Gardner (1988) where the narrow row planting achieved a critical L at about 5 days earlier and intercepted more light than the conventional row pattern.

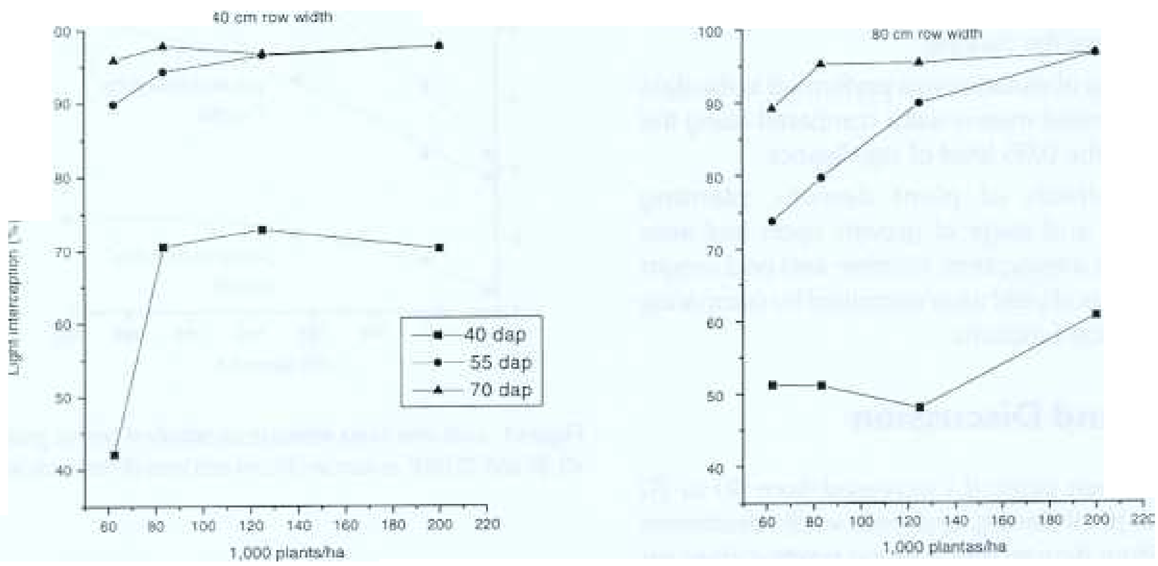

Figure 2 - Light interpection (%) of peanut grown at four plant density combined with two row width.

The C values increased linearly and significantly as plant densities increased (Fig. 4). The rate of increase was highest in the narrow row pattern at the early reproductive stage. However, there was no significant differences in C between planting

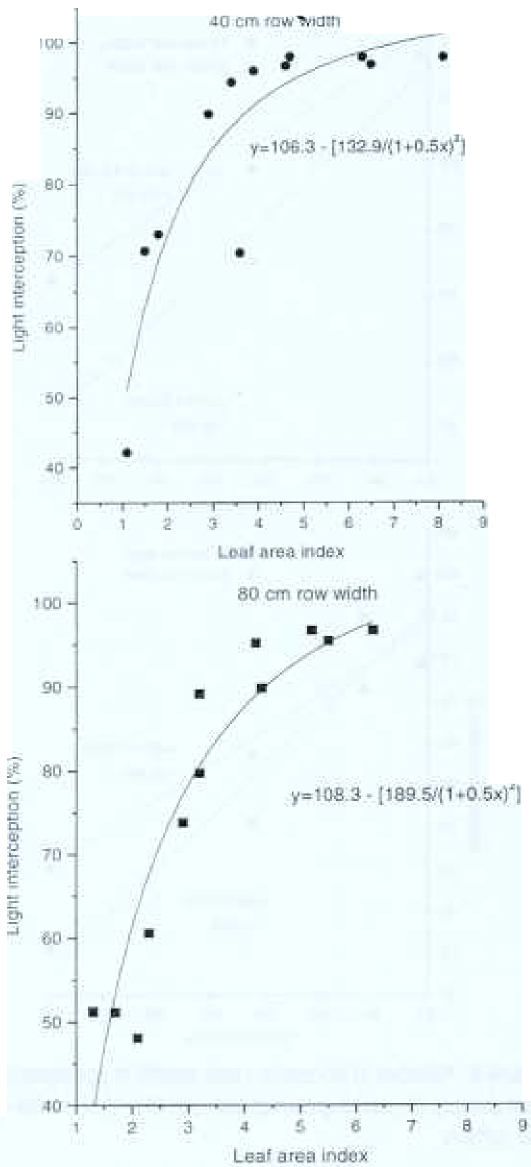

Figure 3 - Percentage of light interception versus leaf area index of peanut grown from 40 to 70 DAP in narrow (40 cm) and wide row (80 cm) planting pattern.

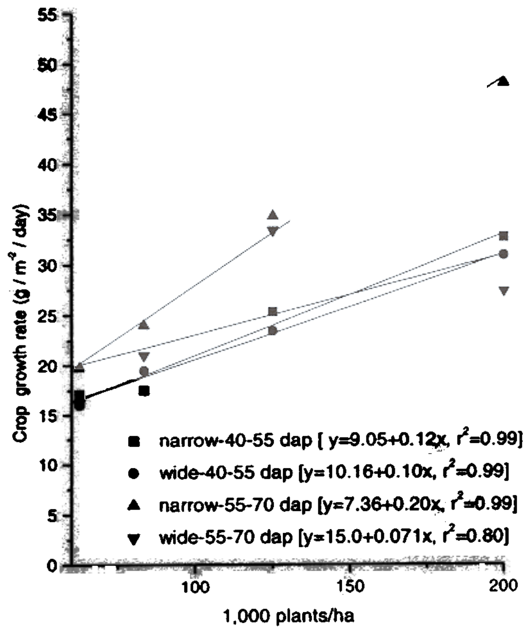

Figure 4 - Crop Growth Rate (C) versus plant density of peanut grown at narrow (40 cm) and wide (80 cm) row width.

arrangement at both stages of growth. Jaaffar and Gardner (1988) reported maximum C values in peanut at 78 and 92 DAP in the narrow row arrangement. The authors concluded that maximum growth rates would be expected with closed canopy and total light interception.

Dry matter yield (kg/ha) responded positively to increasing plant densities in both planting configurations (Table 1); although the effect of plant densities was more effective in the narrow row spacing. Figure 5 shows a curvilinear relationship between plant density and dry matter yield. The wide-row pattern reached maximum dry matter production at a density of 170,000 plants/ha, while the maximum

Table 1 - Dry matter, number of pods/plant, weigh of pods/plant and pod yield of peanut plants grown at four plant densities combined with two row width[1].

Plants/ha	Dry matter (kg/ha)		Number of pods/plant		Weight pods/plant(g)		Pod yield (kg/ha)	
	40 cm	80 cm	40 cm	80 cm	40 cm	80 cm	40 cm	80 cm
62,500	876d	1,005cd	96a	99a	74.4abc	84.8a	3,524c	3,811bc
83,300	1,217bcd	1,147bcd	100a	82ab	80.0ab	71.5abc	4,471ab	3,943bc
125,000	1,435b	1,299bc	79ab	65bc	63.7bcd	55.6cde	4,437ab	4,271ab
200,000	1,793a	1,334bc	62bc	44c	50.1de	40.5e	4,869a	4,144bc
Mean	1,330A	1,196B	84A	73B	67.1A	63.1A	4,325A	4,042B

Means of combinations of plant density and row spacing treatments followed by the same small letters did not differ statistically at p< 0,05; means of row width treatments followed by the same capital letter did not differ statistically at p<0,05.

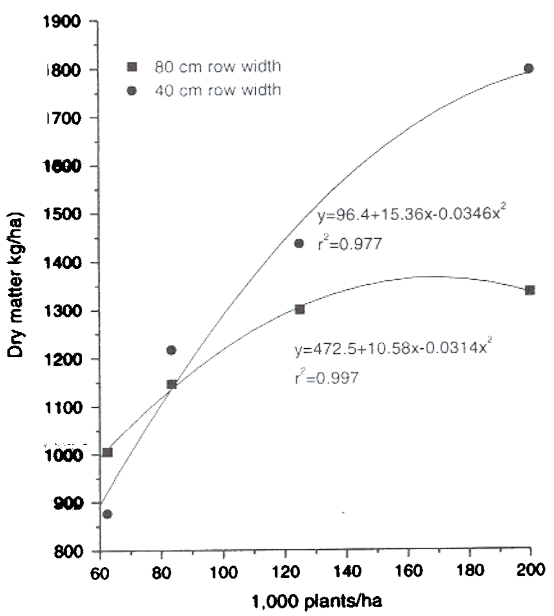

Figure 5 - Dry matter versus plant density of peanut grown at narrow (40 cm) and wide (80 cm) row pattern.

dry weight was not reached for the narrow-row configuration. The advantage of the narrow over the wide-row pattern started from about 100,000 plants/ ha. Cahaner and Ashri (1974) also found an increase in vegetative growth of peanuts, but the yields of mature pods were the same in the three density densities studied. In the higher densities (125,000 and 200,000 plants/ha), the use of narrow rows appeared to be more advantageous over the wide row arrangement. On the other hand, in lower densities the planting configuration had no effects on dry matter yield. Optimum planting densities were obtained at 160 and 200 thousand plants/ha for 80 and 40 cm row width, respectively. The highest dry matter production was reached when the highest densities were combined with the narrow row configuration.

The number of fruits per plant was significantly affected by plant density (Table 1). The narrow-row width showed higher values when compared to the wide-row. There was a negative linear relationship between number of pods per plant and plant densities in both planting arrangements (Figure 6). The decrease in number of pods per plant was slower with increasing plant density in the narrow-row as compared with the wide-row planting pattern. This result suggests a better performance of the individual plant in the narrow-row pattern as density increased. The reduction in number of pods/plant, as the density increased, has been reported for peanuts (Nakagawa et al.,1994; Martins and Pitelli, 1994).

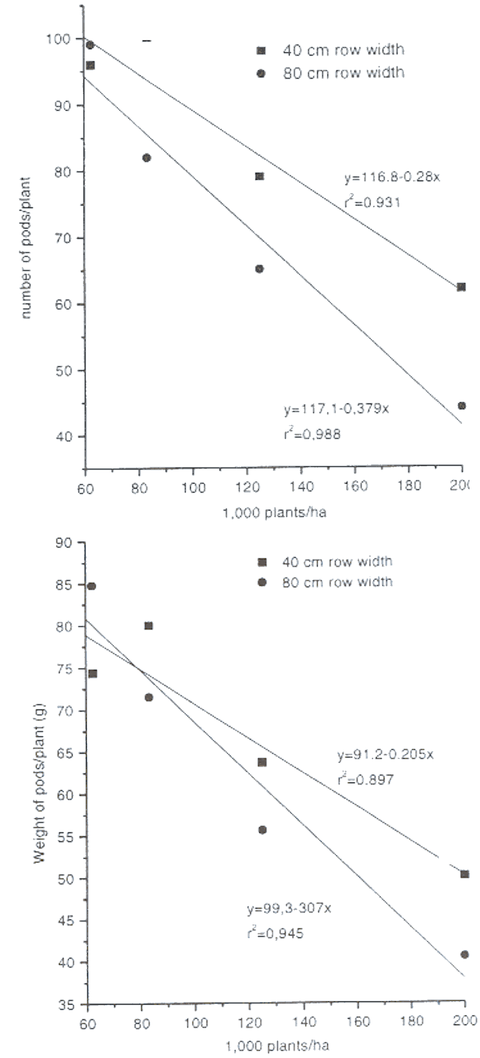

Figure 6 - Number of pods/plant and weight of pods/plant versus plant density of peanut grown at narrow (40 cm) and wide (80 cm) row pattern.

Planting pattern did not significantly affect pod weight per plant and the increasing of yield was the result of more pods per plant (Table 1). This variable showed a linear negative relationship to plant density in both planting arrangements (Fig. 6). The reduction in the pod weight per plant with increasing plant density was slower in the narrow-row than in the wide-row planting pattern. This response was probably a result of a lower competition among the individual plants for the limiting factors that affect crop growth and yield under lower densities and more equidistant planting arrangement. Similar results were reported by Langford (1977) and Martins and Pitelli (1994). This behavior reflected the differences in the way solar radiation is intercepted among the different plant densities and planting arrangements.

Pod yield increased with plant density in both planting arrangements (Table 1). Pod yield and plant density were fitted to a curvilinear function as shown in (Fig. 7). According to this figure, the optimum plant densities were approximately 190.000 and 150.000 plants/ha for the planting arrangement of narrow and wide-row, respectively. At lower plant densities there was no difference between the two planting patterns. However, as plant density increased (starting from 80 thousand plants/ha) the narrow-row out-yielded the wide-row pattern. Gerakis and Tsangarakis (1969), reported that an increase in planting density from 40,000 to 80,000 plants/ha led to an increase in peanut yield. Plant densities above 80,000 plants/ha did not cause any further yield increase. The narrow-row width produces higher yield than the wide-row as the plant density increased. This response is comparable to the ones reported by Martins and Pitelli (1994).

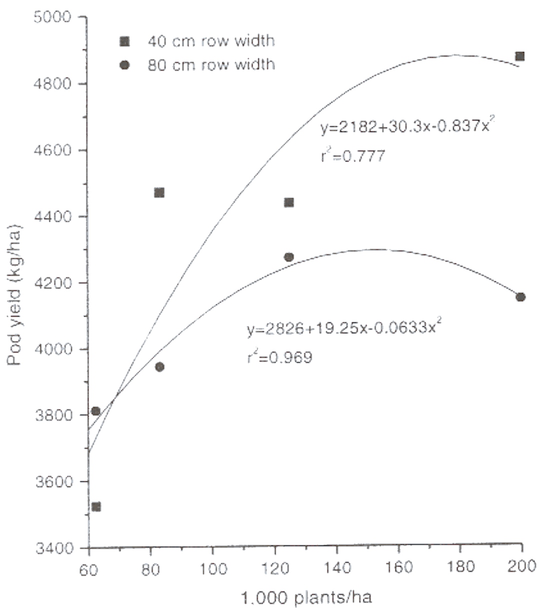

Figure 7 - Pod yield versus plant density of peanut grown at narrow (40 cm) and wide (80 cm) row pattern.

Conclusions

At early stages and intermediary plant densities, narrow-row provided higher light interception than wide rows. L95% was higher for narrow-row than for wide-row width, and was reached earlier for the narrow-row pattern.

In the narrow-row arrangement, L did not reach saturation at any sampled date as plant density increased.

The wide-row configuration had a maximum dry matter yield at a density of 170,000 plants/ha, while the maximum was not reached for the narrow-row configuration.

There was a negative linear relationship between number and pod weight per plant and plant density in both planting arrangements. However, the decrease in the number and pod weight per plant was slower with increasing plant density in the narrow-rows compared to the wide-rows, indicating a better performance of the individual plants in the narrow-rows pattern with increasing density.

The optimum plant densities were approximately 190.000 and 150.000 plants/ha for the planting arrangement of narrow and wide-row, respectively. At lower plant density there was no difference between the two planting arrangement. The narrow-row treatments started to out-yield the wide-row ones at about 80,000 plants/ha;

The C values increased linearly and significantly with plant density. The rate of increase was the highest in the narrow row pattern at the early reproductive stage. However, there was no significant differences in C between planting arrangement at both stages of growth.

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