ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.20, n.11, p.960-964, 2016
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v20n11p960-964

Spatial arrangements and fertilizer doses on soybean yield and its components

Tiago C. Duarte[1], Simério C. S. Cruz[1], Guilherme F. Soares[1], Darly G. de Sena Júnior[1] & Carla G. Machado[1]

[1] Universidade Federal de Goiás/Regional Jataí/Programa de Pós-graduação em Agronomia. Jataí, GO. E-mail: tiagocamiloduarte@gmail.com (Corresponding author); simerio_cruz@yahoo.com.br; guilhermefs_agro@outlook.com.br; darly.sena@gmail.com; carlagomesmachado@gmail.com

Key words:
Glycine max (L.)
twin rows
spacing
phosphorus
potassium

ABSTRACT

The aim with this study was to evaluate the effects of single- and twin-row spatial arrangements associated with different doses of fertilization on soybean yield and its components. The experiment was carried out at Federal University of Goiás, Campus of Jataí, in a split-plot randomized block design with 10 treatments and four replicates. Each plot corresponded to a dose of P and K fertilization (0, 50, 100, 200 and 400% of the recommended dose) and the subplots to two types of spatial arrangements: single and twin rows. The yield components evaluated were plant final population, number of pods and seeds per plant, number of seeds per pod, weight of a thousand grains and yield. The increase in fertilization dose, even at doses two and four times higher than recommendation, results in increased soybean grain yield for both studied arrangements. The single-row arrangement provides greater soybean yield, regardless of the dose of fertilization, although most of the production components were not negatively affected, except the population.

Palavras-chave:
Glycine max (L.)
fileira dupla
espaçamento
fósforo
potássio

Arranjos espaciais e doses de adubação na produtividade da cultura da soja e seus componentes

RESUMO

O objetivo com este trabalho foi avaliar o efeito de arranjos espaciais, simples e fileira dupla, associados a diferentes doses de adubação sobre os componentes de produção e a produtividade da cultura da soja. O experimento foi conduzido na Universidade Federal de Goiás, Regional Jataí, com delineamento experimental constituído de 10 tratamentos estabelecidos em blocos casualizados com parcelas subdivididas, em quatro repetições. Cada parcela correspondeu a uma dose de adubação com P e K (0, 50, 100, 200 e 400% da dose recomendada) e as subparcelas a dois tipos de arranjos espaciais: simples e fileira dupla. Foram avaliados os seguintes componentes: população final de plantas, número de vagens e de grãos por planta, número de grãos por vagem, peso de mil grãos e produtividade. O aumento na dose de adubação, mesmo com doses duas e quatro vezes maiores que o recomendado, resulta em incremento de produtividade de grãos de soja para os dois arranjos estudados. O arranjo simples proporciona maior produtividade de grãos, independente da dose de adubação, apesar da maior parte dos componentes de produção não ser afetada negativamente, exceto a população.

Ref. 175-2015 – Received 8 Dec, 2015 • Accepted 2 Sept, 2016 • Published 29 Sept, 2016

Introduction

Soybean (*Glycine max* (L.) Merrill) has been widely cultivated in Brazil and in the world due to its food and economic importance, which drives several agro-industrial complexes. Nowadays this crop has achieved yield increase that is a result of studies that aimed to identify the factors that contribute to crop yield maximization, linking the interactions between yield level, the cultivar, environmental conditions and management practices. According to Mauad et al. (2010), among these management practices, sowing time, choice of cultivar and spacing are factors that modify soybean yield and its production components.

New soybean seeding systems are being tested in Brazil and abroad in order to obtain higher yields. A system worth mentioning is sowing in twin rows, where there may be better penetration of light and agrochemicals in the canopy, enhancing the photosynthetic rate and the permanency of the lower third of the plant leaves, which can maximize yield (Bruns, 2011).

Fertilization management is another factor that significantly contributes to higher yields. It is possible to observe in the literature different soybean responses to fertilization, where, for the most part, the doses established in the recommendation manuals do not guarantee high yields (Araújo et al., 2005; Foloni & Rosolem, 2008; Bernardi et al., 2009; Guareschi et al., 2011). Thus, there is the need to search new management practices that maximize the use of available environmental factors.

Given the above, and considering the study of Carvalho (2014) in southwest Goiás, with 5 soybean varieties grown in twin and single row, in which no difference was observed in yield for most varieties, but there was a reduction of the weight of a thousand grains when soybean plants were grown in the twin row, set up the hypothesis that the increased levels of fertilization offset the reduction in mass of thousand grains, providing greater increase in yield of soybean grown in twin rows compared with the single-row arrangement.

The aim with this study was to evaluate the effects of single- and twin-row spatial arrangements associated with different doses of fertilization on soybean yield and its components.

Material and Methods

The experiment was carried in the city of Jataí, GO, Brazil, during the 2014/2015 growing season (spring and summer), in the experimental area of the Federal University of Goiás, Campus of Jataí, at the geographic coordinates 17° 55' 32" S and 51° 42' 32" W and 685 m altitude.

The soil of the area is classified as dystroferric Red Latosol (Brazilian Soil Classification System) with clay texture. The climate in the region is Aw, typical of the savanna with two distinct seasons: a dry and cold (fall and winter) and another hot and humid (spring and summer), according to Köppen's classification.

The meteorological data measured during the experiment are shown in Figure 1.

For soil amendment and determination of the fertilization doses to be used in soybean crop, as well as chemical and textural characterization of the experimental area soil, samples were collected in the layers of 0-20 and 20-40 cm (Table 1).

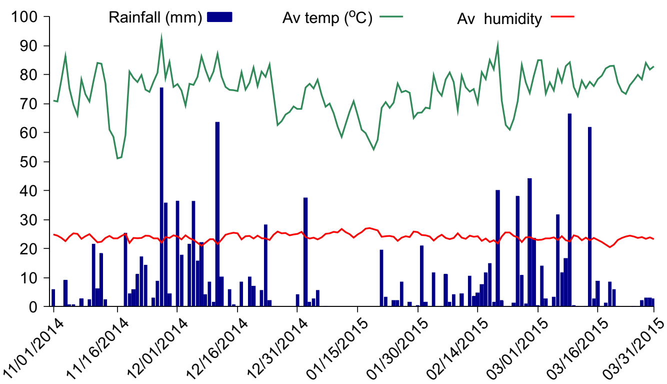
The experiment consisted of 10 treatments established in split-plot randomized block design, with four replicates, and area of 21.6 m^2 (3.6 x 6.0 m) in each subplot.

Each plot corresponded to a P and K fertilization dose (0, 50, 100, 200 and 400% of the recommended dose), based on the results of soil analysis, following the recommendations described in Sousa & Lobato (2004). The subplots were composed of two types of spatial arrangements: single (spacing of 0.45 m between rows) and twin rows (two rows spaced by 0.25 m and 0.65 m spacing between twin rows).

Soil correction was performed with 3.0 Mg ha^{-1} of dolomitic limestone, distributed on soil surface and subsequently incorporated with moldboard plow. A second application of 1.5 Mg ha^{-1} of filler limestone, distributed on soil surface and subsequently incorporated with disc harrow, during September month.

The soybean crop P and K recommended doses, according to Sousa & Lobato (2004) were 80 kg ha^{-1} P_2O_5 and K_2O. The sources were single superphosphate and potassium chloride, manually distributed in each plot and incorporated with disc harrows before seeding (approximately 0.10 m depth).

The maximum potassium dose incorporated before sowing was 80 kg ha^{-1} of K_2O (100% of the recommended dose). Thus, for the dose of 200% potassium fertilization, half dose were applied before sowing and a side dress application done on the phenological stage V1. For the amount of 400%, in addition to the pre-planting fertilizer, two coverage applications were done



Source: INMET (2015)

Figure 1. Rainfall (mm) and average air temperature (°C) obtained in the experimental area from November (2014) to March (2015)

Table 1. Soil chemical and textural characterization at depths of 0-20 and 20-40 cm, before the experiment

Prof. (cm)	pH $CaCl_2$	OM (g kg^{-1})	P (mel.) (mg dm^{-3})	K	Ca	Mg	Al	H + Al	CEC	V%	Al sat. (%)	S	Fe	Mn	Zn	Cu	Na	Texture (g dm^{-3})		
				(cmol$_c$ dm^{-3})								(mg dm^{-3})						Clay	Sand	Silt
0-20	5.2	45.2	8.5	0.16	2.26	1.37	0.10	5.1	8.9	42.6		13.8	28.0	29.5	3.4	6.6	2.7	585	240	175
20-40	5.3	36.1	4.3	0.13	1.75	0.95	0.07	4.3	7.1	39.9		30.6	40.0	25.0	7.7	7.3	0.9			

in the growth stages V1 and V3. Phosphorus was distributed as a single dose in all treatments before sowing.

The soybean sowing, cultivar Anta 82 (medium cycle and semi-determinate growth habit), was held on November 18, 2014, using a one-line seeder for micro tractor, distributing 22 seeds per meter. Soybean seeds were treated with Carbendazim + Thiram (30 + 70 g 100 kg^{-1} of seeds), Imidacloprid (45 g 100 kg^{-1} of seeds), Fipronil (30 g 100 kg^{-1} of seeds) and inoculant (100 mL ha^{-1}).

With soybean plants at the R8 stage, the following components were evaluated: final population of plants, obtained by counting the plants of the useful area extrapolating to hectare; number of pods and seeds per plant, determined in 10 plants randomly chosen in useful area; number of seeds per pod obtained by the ratio of the number of seeds and number of pods per plant; thousand grain weight, as in Brasil (2009), and grain yield per hectare, corrected to 13% moisture.

All cultivation practices and plant protection products used followed the technical recommendations for soybean in the region.

Data were subjected to variance analysis at 0.05 and 0.01 probability levels by F test. Data related to fertilization doses were submitted to regression analysis calculated for linear and quadratic equations and accepted when significant at 0.05 probability level by F test.

Results and Discussion

The analysis of variance summary is presented in Table 2, noting that there was no significant interaction between treatments for yield and its evaluated components for the soybean crop.

The production components means, separately evaluating the spatial arrangement variation factor, are presented in Table 3. It can be seen that the single-row arrangement was greater than the twin-row arrangement for final plant population and grain yield. These results demonstrate that the plant final population was the only factor contributing to the higher yield of the single-row arrangement, even using the same populations on both arrangements at sowing time (488,889 plants ha^{-1}), since, for the other production components evaluated, significant differences between the arrangements were not observed.

It is possible that during sowing time, using the one-line seeder attached to the micro tractor, the largest treading of sowing lines in the double-row arrangement promoted less emergence of soybean plants.

The observed yields, although above the state average, fell short of desired due to low rainfall during flowering and grain filling (period between late December 2014 and early February 2015, Figure 1), periods of maximum water requirement (7-8 mm d^{-1}). This causes physiological changes in the plant, leading to premature leaf fall and yield reduction (EMBRAPA, 2013) and may have limited the magnitude of crop response to spatial arrangements.

Procópio et al. (2014), working with the cultivar BRS 294 RR, concluded that seeding in twin rows promotes grain yield similar to that of the traditional arrangement used in the crop. On the other hand, Vitorino (2013) worked with twin- and single-row arrangements and observed a significant yield increase of 7.6% using twin rows.

Regarding the effect of row spacing, there are conflicting results in the literature, showing that the response is dependent on cultivar and growing environment (Rambo et al., 2003; Heiffig et al., 2006; Procópio et al., 2014).

Janovicek et al. (2005) reported that twin-row arrangements in direct planting systems often increased yields over those obtained with single 76-cm rows, with yields that were similar to those obtained with sowing in 38- or 19-cm rows.

A study conducted by Bowers et al. (1999), with row spacing ranging from 25 to 100 cm, reported that narrow lines, less than or equal to 40 cm, should be used to optimize the yields of crops.

Table 2. Analysis of variance summary: blocks, fertilizer dose (FD), spatial arrangements (SA) and their interactions for final plant population (Population), pods per plant, seeds per plant, seeds per pod, thousand-grain weight (1000 g) and yield

Sources of variation	Population	Pods $plant^{-1}$	Seeds $plant^{-1}$	Seeds pod^{-1}	1000 g	Yield
Blocks	1.24^{ns}	0.92^{ns}	0.84^{ns}	0.38^{ns}	16.33^{**}	5.20^{*}
FD	6.05^{--}	1.73^{--}	3.47^{--}	1.65^{--}	1.23^{--}	2.53^{--}
SA	6.40^{*}	0.01^{ns}	0.01^{ns}	0.01^{ns}	0.57^{ns}	9.08^{**}
FD x SA	0.67^{ns}	0.52^{ns}	0.85^{ns}	1.58^{ns}	0.53^{ns}	0.69^{ns}
Polynomial Regression						
Linear equation	5.74^{*}	1.99^{ns}	6.84^{*}	5.56^{*}	1.27^{ns}	8.80^{*}
Quadratic equation	17.10^{**}	3.39^{ns}	4.99^{*}	0.16^{ns}	1.50^{ns}	0.01^{ns}

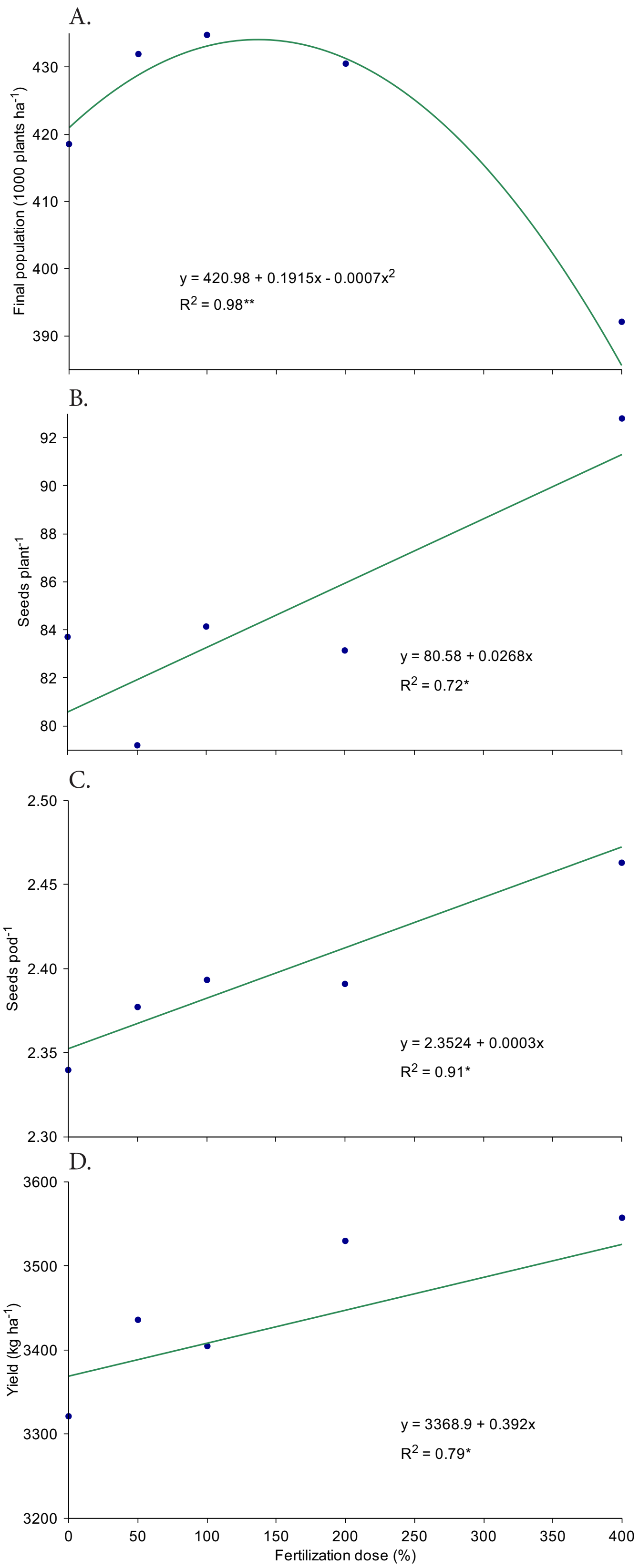
--Treatments are quantitative; **Significant at 0.01 probability level ($p < 0.01$); *Significant at 0.05 probability level ($0.01 \le p < 0.05$); nsNon-significant ($p \ge 0.05$)

Table 3. Means of final plant population (population), pods $plant^{-1}$, seeds $plant^{-1}$, seeds pod^{-1}, thousand-grain weight (1000 g) and yield of soybean grown in two spatial arrangements, single and twin rows, evaluating separately the spatial arrangement variation factor

Treatment	Population (plants ha^{-1})	Pods $plant^{-1}$	Seeds $plant^{-1}$	Seeds pod^{-1}	1000 g (g)	Yield (kg ha^{-1})
Single Rows	428,703.70 a	35.31 a	84.55 a	2.39 a	113.04 a	3,535.67 a
Twin Rows	414,444.40 b	35.39 a	84.65 a	2.39 a	113.86 a	3,363.80 b
LSD	12,000.44	3.29	8.21	0.05	2.31	121.41
VC %	4.23	13.82	14.42	3.16	3.03	5.23

Means followed by the same letter are not statistically different by Tukey test at 0.05 probability level

The thousand-grain weight was not affected by the evaluated treatments, corroborating results found in the literature (Procópio et al., 2013; 2014), where Bruns (2011) concluded that the row type (twin or single row) or seeding rate does not affect seed weight, since this characteristic is influenced in a greater degree by genotype compared with environmental conditions (Rambo et al., 2004).



**; *Significant at 0.01 and 0.05 probability levels, respectively

Figure 2. Final plant population (A), number of seeds per plant (B), number of seeds per pod (C) and yield (D) as a function of fertilization dose in soybean, cultivar Anta 82

Balbinot Júnior et al. (2015), working with row spacing, densities and seeding system for the cultivar BRS 294 RR, state that the number of seeds per pod and thousand-grain weight from the stems and branches were not affected by the treatments.

According to Ferreira Júnior et al. (2010), the number of pods per plant is influenced by genotype, as well as by the change in space for each plant, which could not be observed in this research. Rambo et al. (2002) stated that the type of branches where the pods are located and the number of branches per plant directly influence this yield component.

It was possible to fit linear or quadratic regression equations for the variables evaluated, except for the number of pods and thousand-grain weight (Figure 2). Only for final plant population, a quadratic effect with increasing fertilization dose was observed, obtaining the maximum population using 138.71% of P_2O_5 and K_2O recommended dose (Figure 2A), demonstrating that increases in soil solution concentration (high salt concentration) can cause problems in germination and initial root development, negatively influencing the population and plant development (Sangoi et al., 2009).

The number of seeds per plant (Figure 2B), seeds per pod (Figure 2C) and yield (Figure 2D) increased linearly with the increase in fertilization doses, obtaining response even with doses two and four times greater than the recommended one.

According to Lana et al. (2003), there is a direct relationship between soil fertility and plant yield, which is directly dependent on the concentration of P and K in the soil solution.

According to Thomas et al. (1998), low levels of soil fertility negatively affect soybean yield, but an increase in soil phosphorus availability promotes higher grain yield, regardless of the row spacing used.

Conclusions

1. The increase in the fertilization dose, even at doses two and four times higher than the recommended, results in increased soybean grain yield for both arrangements studied.

2. The single-row arrangement promotes greater soybean yield, regardless of the dose of fertilization, although most of the production components were not negatively affected, except the population.

Literature Cited

Araújo, W. F.; Sampaio, R. A.; Medeiros, R. D. de. Resposta de cultivares de soja à adubação fosfatada. Revista Ciência Agronômica, v.36, p.129-134, 2005.

Balbinot Júnior, A. A.; Procópio, S. de O.; Debiasi, H.; Franchini, J. C.; Panison, F. Semeadura cruzada em cultivares de soja com tipo de crescimento determinado. Semina: Ciências Agrárias, v.36, p.1215-1226, 2015. http://dx.doi.org/10.5433/1679-0359.2015v36n3p1215

Bernardi, A. C. de C.; Oliveira Júnior, J. P. de; Leandro, W. M.; Mesquita, T. G. da S.; Freitas, P. L. de; Carvalho, M. da C. S. Doses e formas de aplicação da adubação potássica na rotação soja, milheto, e algodão em sistema plantio direto. Pesquisa Agropecuária Tropical, v.39, p.158-167, 2009.

Bowers, G. R.; Rabb, J. L.; Ashlock, L. O.; Santini, J. B. Row spacing in the early soybean production system. Agronomy Journal, v.92, p.524-531, 1999. http://dx.doi.org/10.2134/agronj2000.923524x

Brasil. Ministério da Agricultura, Pecuária e Abastecimento/ Secretaria de Defesa Agropecuária. Regras para análise de sementes. 1.ed. Brasília: MAPA/ACS, 2009. 399p.

Bruns, H. A. Comparisons of single-row and twin-row soybean production in the Mid-South. Agronomy Journal, v.103, p.702-708, 2011. http://dx.doi.org/10.2134/agronj2010.0475

Carvalho, B. V. Soja cultivada em arranjo espacial convencional e fileira dupla. Jataí: UFG, 2014. 30p. Trabalho Conclusão Curso

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Tecnologias de produção de soja - Região central do Brasil 2014. 21.ed. Londrina: Embrapa Soja, 2013. 268p.

Ferreira Júnior, J. A.; Espindola, S. M. C. G.; Gonçalves, D. A. R.; Lopes, E. W. Avaliação de genótipos de soja em diferentes épocas de plantio e densidade de semeadura no município de Uberaba-MG. FAZU, n.7, p.13-21, 2010.

Foloni, J. S. S.; Rosolem, C. A. Produtividade e acúmulo de potássio na soja em função da antecipação da adubação potássica no sistema plantio direto. Revista Brasileira de Ciência do Solo, v.32, p.1549-1561, 2008. http://dx.doi.org/10.1590/S0100-06832008000400019

Guareschi, R. F.; Gazolla, P. R.; Perin, A.; Santini, J. M. K. Adubação antecipada na cultura da soja com superfosfato triplo e cloreto de potássio revestidos por polímeros. Ciência e Agrotecnologia, v.35, p.643-648, 2011. http://dx.doi.org/10.1590/S1413-70542011000400001

Heiffig, L. S.; Câmara, G. M. de S.; Marques, L. A.; Pedroso, D. B.; Piedade, S. M. de S. Fechamento e índice de área foliar da cultura da soja em diferentes arranjos espaciais. Bragantia, v.65, p.285-295, 2006. http://dx.doi.org/10.1590/S0006-87052006000200010

INMET - Instituto Nacional de Meteorologia. Estação meteorológica de observação de superfície automática. <http://www.inmet.gov.br/portal/index.php?r=estacoes/estacoesautomaticas>. 31 Mar. 2015.

Janovicek, K. J.; Deen, W.; Vyn, T. J. Soybean response to zone tillage, twin-row planting, and row spacing. Agronomy Journal, v.96, p.800-807, 2005.

Lana, R. M. Q.; Vilela Filho, C. E.; Zanão Júnior, L. A.; Pereira, H. S.; Lana, A. M. Q. Adubação superficial com fósforo e potássio para a soja em diferentes épocas em pré-semeadura na instalação do sistema de plantio direto. Scientia Agraria, v.4, p.53-60, 2003. http://dx.doi.org/10.5380/rsa.v4i1.1066

Mauad, M.; Silva, T. L. B.; Almeida Neto, A. I.; Abreu, V. G. Influência da densidade de semeadura sobre características agronômicas na cultura da soja. Agrarian, v.3, p.175-181, 2010.

Procópio, S. de O.; Balbinot Júnior, A. A.; Debiasi, H.; Franchini, J. C.; Panison, F. Plantio cruzado na cultura da soja utilizando uma cultivar de hábito de crescimento indeterminado. Revista de Ciências Agrárias, v.56, p.319-325, 2013. http://dx.doi.org/10.4322/rca.2013.048

Procópio, S. de O.; Balbinot Júnior, A. A.; Debiasi, H.; Franchini, J. C.; Panison, F. Semeadura em fileira dupla e espaçamento reduzido na cultura da soja. Revista Agroambiente, v.8, p.212-221, 2014.

Rambo, L.; Costa, J. A.; Pires, J. L. F.; Parcianello, G.; Ferreira, F. G. Rendimento de grãos da soja e seus componentes por estrato do dossel em função do arranjo de plantas e regime hídrico. Scientia Agraria, v.3, p.79-85, 2002. http://dx.doi.org/10.5380/rsa.v3i1.1034

Rambo, L.; Costa, J. A.; Pires, J. L. F.; Parcianello, G.; Ferreira, F. G. Rendimento de grãos da soja em função do arranjo de plantas. Ciência Rural, v.33, p.405-411, 2003. http://dx.doi.org/10.1590/S0103-84782003000300003

Rambo, L.; Costa, J. A.; Pires, J. L. F.; Parcianello, G.; Ferreira, F. G. Estimativa do potencial de rendimento por estrato do dossel da soja, em diferentes arranjos de plantas. Ciência Rural, v.34, p.33-40, 2004. http://dx.doi.org/10.1590/S0103-84782004000100006

Sangoi, L.; Ernani, P. R.; Bianchet, P.; Vargas, V. P.; Picoli, G. J. Efeito de doses de cloreto de potássio sobre a germinação e o crescimento inicial do milho, em solos com texturas contrastantes. Revista Brasileira de Milho e Sorgo, v.8, p.187-197, 2009. http://dx.doi.org/10.18512/1980-6477/rbms.v8n2p187-197

Sousa, D. M. G.; Lobato, E. Calagem e adubação para culturas anuais e semiperenes. In: Sousa, D. M. G.; Lobato, E. (ed.). Cerrado: Correção do solo e adubação. Brasília: Embrapa Informação Tecnológica, 2004. 2.ed, Cap.12, p.283-315.

Thomas, A. L.; Costa, J. A.; Pires, J. L. Rendimento de grãos de soja afetado pelo espaçamento entre linhas e fertilidade do solo. Ciência Rural, v.28, p.543-546, 1998. http://dx.doi.org/10.1590/S0103-84781998000400002

Vitorino, H. S. Interferência da comunidade de plantas daninhas na cultura da soja em função do espaçamento de semeadura. Botucatu: UNESP. 2013. 79p. Tese Doutorado