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SOYBEAN YIELD IN SUCCESSION TO SINGLE AND INTERCROPPING CORN AND BRACHIARIA AND SUBMITTED TO DIFFERENTS IRRIGATION INTERVALS

Neriane de Souza Padilha*[1], Gessí Ceccon[2], Valdecir Batista Alves[3], Antonio Luiz Neto Neto[1], Juslei Figueiredo da Silva[4] & Priscila Akemi Makino[1]

1 - Federal University of Grande Dourados, Course of Agronomy, Faculty of Agricultural Sciences, Dourados, MS, Brazil

2 - Brazilian Agricultural Research Corporation, Embrapa Western Agriculture, Dourados, MS, Brazil

3 - City Hall of Terenos, Secretary of Economic Development, Agrarian, Tourism and Environment, Terenos, MS, Brazil

4 - Fasipe University Center, Course of Agronomy, Sinop, MT, Brazil

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Glycine max L.
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Brachiaria ruziziensis
Straw
Water deficit and excess

ABSTRACT

The experiment was performed at a non-acclimatized protected screened environment. The objective of the study was to evaluate the influence predecessor crops of single and intercropping corn and brachiaria on soybean yield submitted to irrigation intervals. The experimental design adopted was in a split split-plot randomized block design with four repetitions. Two soil classes (dystroferric Red Latosol and dystrophic Red Latosol) were evaluated in the plots, three intervals between irrigations were used during the soybean flowering (each one day, two days and three days) in the subplots and three types straw in the crops autumn-winter (single corn, single brachiaria, intercropping corn and brachiaria) in the sub-subplots. The two soybean plants cultivated in polyethylene pots containing 20 liters of dystroferric Red Latosol or dystrophic Red Latosol corresponded to each repetition, according to the treatment. The irrigation intervals of three and two days, in dystroferric Red Latosol and dystrophic Red Latosol, respectively, with single brachiaria at the previous crop provided greater number and weight of pods, higher number of grains and higher soybean yield. Irrigation every three days with single corn at the previous crop in dystroferric Red Latosol and dystrophic Red Latosol, resulted in the lower soybean performance.

Palavras-chave:
Glycine max L.
Zea mays L.
Brachiaria ruziziensis
Palha
Déficit e excesso de água

PRODUTIVIDADE DA SOJA EM SUCESSÃO A MILHO E BRAQUIÁRIA SOLTEIROS E EM CONSÓRCIO E SUBMETIDA A INTERVALOS DE IRRIGAÇÃO

RESUMO

O experimento foi desenvolvido em ambiente protegido telado não climatizado, com o objetivo de avaliar o efeito do cultivo antecessor de milho e braquiária solteiros e em consórcio sobre a produtividade da soja submetida a intervalos de irrigação. O delineamento experimental adotado foi o de blocos casualizados, em esquema de parcelas sub-subdivididas com quatro repetições. Sendo as classes de solos (Latossolo Vermelho distroférrico e Latossolo Vermelho distrófico) nas parcelas, os intervalos de irrigação aplicados durante o florescimento da soja (a cada um, dois e três dias) nas subparcelas e as palhas de culturas de outono-inverno (milho solteiro, braquiária solteira e consórcio milho-braquiária) nas sub-subparcelas. Cada repetição correspondeu a duas plantas de soja, cultivadas em um vaso de polietileno contendo vinte litros de Latossolo Vermelho distroférrico ou Latossolo Vermelho distrófico, de acordo com o tratamento. Os intervalos de irrigação de três e dois dias, em Latossolo Vermelho distroférrico e Latossolo Vermelho distrófico, respectivamente, tendo a braquiária solteira como cultura antecessora proporcionaram maior número e peso de vagens, número de grãos e produtividade da soja. A irrigação a cada três dias com o milho solteiro como cultura antecessora em Latossolo Vermelho distroférrico e Latossolo Vermelho distrófico, resultou no menor desempenho da soja.

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Email (corresponding author)*: nerianepadilha@hotmail.com

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Michael Silveira Thebaldi

INTRODUCTION

Water is one of the most indispensable factors for agricultural production. Its use must be controlled, since its lack or excess significantly affects the development and production of crops (SILVA *et al*., 2011). Therefore, the rational management of this resource is necessary for the adequate supply to the cultures (PAIVA *et al*., 2005; OLIVEIRA *et al*., 2011).

Defining the timing of irrigation and the appropriate amount of water for the crops is of fundamental importance to properly manage irrigated systems. Thus, knowing the water needs of the plants is important, as well as the phase of greatest water demand from them; such information being indispensable for the success of the enterprise (PAIVA *et al*., 2005; MAROUELLI *et al*., 2008 ; VIEIRA *et al*., 2008).

The need for water in the soybean crop increases with the development of the plant, reaching the maximum during flowering-filling of grains, decreasing after this period. Expressive water deficits, during flowering and grain filling, cause physiological changes in the plant, such as stomatal closure and leaf curl. As a consequence, it causes premature leaf and flower fall and pod miscarriage, resulting in finally, a reduction in grain yield (EMBRAPA, 2013). The excess of water, on the other hand, causes abortion of flowers and pods (SIONIT; KRAMER, 1977; NEUMAIER *et al*., 2000), consequently reducing productivity.

Adequate soil cover by straw-forming species alters the soil-water-plant ratio, reducing evaporation and the evapotranspiration rate of crops, especially in stages where their canopy does not fully cover the soil. This cover provides a reduction in frequency of irrigation and savings in operating costs of the irrigation system (STONE *et al*., 2006). In addition, the straw present on the soil surface reduces soil temperature variations, protects against erosion during periods of excess water, retains more water, reduces runoff, increasing the infiltration rate and promoting higher agricultural crops yields (BRAGAGNOLO; MIELNICZUCK, 1990).

The species of the *Brachiaria* genus are excellent alternatives for soil cover, due to their high dry mass production, vigorous and deep root system and high tolerance to water deficiency. In addition, they absorb nutrients in deeper layers of the soil, developing under unfavorable environmental conditions for most grain-producing crops and species used for ground cover (BARDUCCI *et al*., 2009).

The corn crop has favorable characteristics for intercropping, such as high plant size and ear insertion height, allowing the harvest to occur without interference from forage plants (ALVARENGA *et al*., 2006). Thus, corn cultivation intercropped with brachiaria allows corn to be maintained as an economic yield crop and brachiaria with the production of straw to cover the soil (CECCON, 2007), without affecting the production of corn grains (CECCON *et al*., 2005; JAKELAITIS *et al*., 2005; COSTA *et al*., 2012).

The objective of this study was to evaluate the effect of the predecessor cultivation of single and intercropping corn and brachiaria on the yield of soybeans submitted to different irrigation intervals.

MATERIAL AND METHODS

The experiment was performed in a non-acclimatized protected screened environment, belonging to Embrapa Agropecuária Oeste, Dourados-MS, Brazil, located at the coordinates of 22 ° 13 'South and 54 ° 48' West, at 400 m altitude.

The soils used, classified as dystroferric Red Latosol (dfRL) and dystrophic Red Latosol (dRL), were collected in the experimental area of Embrapa Agropecuária Oeste in Dourados - MS and in Fátima do Sul - MS, respectively. The soils were collected in the layer 0 to 15 cm deep, submitted to drying in the open air and sieved in a 4 mm sieve (5 mesh). A sub-sample was submitted to grinding in a Willey mill followed by sieving in a 2 mm (10 mesh) sieve, for chemical (Table 1) and physical (Table 2) characterization at the Soil Fertility and Physics laboratory at Embrapa Agropecuária Oeste, according to the methodology described by Embrapa (1997). The following determinations were performed: pH in water, by potentiometry; potential acidity, aluminum and organic matter, by titration; phosphorus, by molecular absorption emission spectrometry; potassium, by flame emission spectrophotometry; and calcium, magnesium, copper, iron, manganese and zinc, by atomic absorption spectrophotometry.

The physical-hydric characterization of the soils was performed using four twenty-liter pots containing dystroferric Red Latosol and dystrophic Red Latosol. Undisturbed samples were collected in the 25 cm deep layer from the pots using volumetric rings. The soil density (Table 2) and the water retention curve (Figure 1) of these samples were determined by the Richards method, at the respective pressures 0.1; 0.33; 1; 3; 9 and 15 bar, according to the methodology described by Embrapa (1997). The analyses were performed at the Soil Fertility and Physics laboratory at Embrapa Agropecuária Oeste.

A mixture of correctives was applied ($CaCO_3$ and

Table 1. Chemical characterization[1] of the soil used in the experiment

Soil	pH H_2O	Al	Ca	Mg	K	CTC	P	V	M.O.	Cu	Fe	Mn	Zn
		- - - - - - - - - - cmol$_c$ dm^{-3} - - - - - - - - - -					mg dm^{-3}	%	g kg^{-1}	- - - - - - - - mg dm^{-3} - - - - - - - -			
dfRL*	5.8	0.1	4.0	1.2	0.63	11.7	37.5	50	29.7	11.0	30.7	51.3	4.6
dRL**	6.1	0.0	3.3	0.8	0.29	7.0	15.8	63	15.4	8.9	12.7	86.1	7.6

[1] Al^{3+}, Ca^{2+} and Mg^{2+} extracted by KCl 1 mol L^{-1}; P, K, Cu, Fe, Mn e Zn extracted by HCl 0.05 mol L^{-1} + H_2SO_4 0.0125 mol L^{-1} and organic carbon by oxidation with potassium dichromate
* dystroferric Red Latosol (dfRL), collected in Dourados, MS
** dystrophic Red Latosol (dRL), collected in Fátima do Sul, MS

Table 2. Physical characterization of the soil used in the experiment

Soil	Total Sand	Silt	Clay	Density
	---------- g kg^{-1} ----------			----g cm^{-3} ----
dfRL*	100	118	782	1.12
dRL**	684	67	249	1.41

* dystroferric Red Latosol (dfRL), collected in Dourados, MS
** dystrophic Red Latosol (dRL), collected in Fátima do Sul, MS

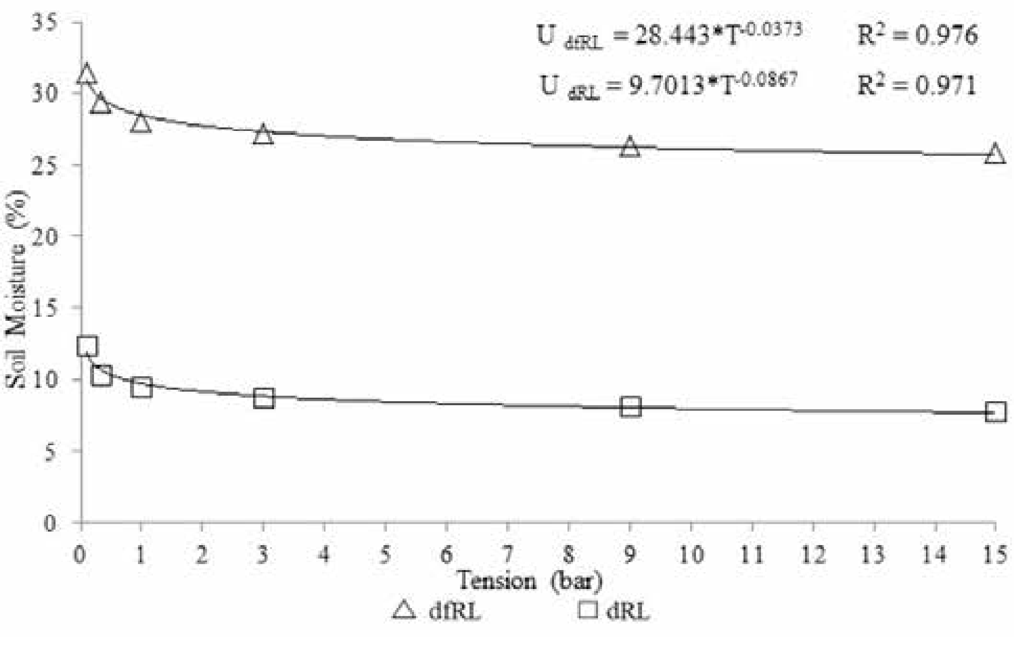

Figure 1. dfRL and dRL water retention curve, 25 cm deep

$MgCO_3$, in a 4:1 molar ratio), aiming at increasing the saturation by dystroferric Red Latosol bases from 50% to 60%. After adding acidity correctives, the soil contained in the pots was kept in incubation for a period of 15 days. During this period, all pots containing twenty liters of dystroferric Red Latosol and dystrophic Red Latosol were maintained at 80% of field capacity.

Autumn-winter crops

In the sowing of autumn-winter crops (BRS 1010 corn hybrid, *Brachiaria ruziziensis* and intercropping corn-brachiaria) performed in March 2012 and 2013, four corn seeds and eight brachiaria seeds were sown in the pots, according to each treatment. Thinning was performed 7 days after emergence, leaving one corn plant and four brachiaria plants per pot. Fertilizations were performed only at sowing, with a dose of 4 g per pot and 2 g per pot in dystroferric Red Latosol and dystrophic Red Latosol, respectively, of the formula 08-20-20 (N-P_2O_5-K_2O), in both years. The seeds were treated with the insecticide Thiodicarb, at a dose of 20 mL kg^{-1} of seed.

After sowing the autumn-winter species, the pots were irrigated daily by drip, in order to maintain soil moisture at 70% of the field capacity (Table 3), since the field capacity was provided by the water retention curve (Figure 1).

The irrigation system used was a drip irrigation hose with an internal filter in each dripper. The distance between the drippers was 20 cm, with two drippers per plant, with a flow rate of 10.9 mL min^{-1} each. The moment of irrigation was given by the water tensions in the soil, from puncture tensiometers installed in the pots at a depth of 20 cm. The readings of the tensiometers were performed daily with a digital needle tensiometer “Soil Moisture Sensor” (Blumat).

The corn completed its productive cycle and its straw was left in the pot. The brachiaria was desiccated 14 days before soybean sowing, using glyphosate herbicide at a dose of 1.08 kg ha^{-1} of acid equivalent, with 200 L ha^{-1} of syrup.

The amount of straw in each pot in the treatment of single corn and single brachiaria was 50 g and 60 g, respectively. The amount of intercropping corn straw and brachiaria straw was 80 g per pot (40 g of corn and 40 g brachiaria).

Experimental Design

The randomized blocks design in a split-split plot scheme with four repetitions was adopted. The soil classes (dystroferric Red Latosol and dystrophic Red Latosol) were evaluated in the plots, the irrigation intervals applied during soybean flowering (each day, two days and three days) were evaluated in the subplots and the autumn-winter crop straws (single corn, single brachiaria and intercropping corn-brachiaria) were evaluated in the sub-subplots.

Soybean Cultivation

Six seeds of the BRS 284 soybean cultivar were sown in October 2012 and 2013 on single corn straw, single brachiaria and intercropping corn-brachiaria that were grown in autumn-winter. The amount of straw in each pot in the single corn and single brachiaria treatment was 50 g and 60 g, respectively. The amount of intercropping corn straw and brachiaria straw was 80 g per pot (40 g of corn and 40 g of brachiaria). Fertilizations were performed only at sowing, with a dose of 4 g per pot and 2 g per pot in dystroferric Red Latosol and dystrophic Red Latosol, respectively, of the formula 00-20-20 (N-P_2O_5-K_2O), in both years. The soybean seeds were inoculated at the time of sowing with *Bradirhizobium japonicum*. Thinning was performed 7 days after emergence, leaving four soybean plants per pot and at 20 days after emergence, leaving two plants per pot until the end of the experiment.

During the vegetative stage of soybeans, soil moisture was maintained at 70% of field capacity (Table 3). From flowering to harvest, the soybean plants were subjected to irrigation intervals: each one day, two days and three days. The soil water tension was monitored by puncture tensiometers and reading was performed by digital needle tensiometer, always leaving the soil with 80% of the field capacity (Table 4).

Assessments

In the maturation of soybeans, the number and weight of pods, number of grains and yield per plant were evaluated.

Data analysis

The data were subjected to analysis of variance and to the Tukey test for comparison between the means at 5% probability, using the SISVAR software, version 5.6 (FERREIRA, 2008). The treatments were coded according to the soil class, the irrigation interval and the straw of predecessor crops (Table 5) for a better interpretation of the data.

Table 3. Soil water tension and soil moisture corresponding to 70% of the field capacity in dfRL and dRL

Soil	Tension (bar)	Tension (KPa)	Soil Moisture (%)	Soil Moisture (mm)
dfRL*	0.28	28	29.80	5867
dRL**	0.23	23	10.99	2737

* dystroferric Red Latosol (dfRL), collected in Dourados, MS
** dystrophic Red Latosol (dRL), collected in Fátima do Sul, MS

Table 4. Soil water tension and soil moisture corresponding to 80% of the field capacity in dfRL and dRL

Soil	Tension (bar)	Tension (KPa)	Soil Moisture (%)	Soil Moisture (mm)
dfRL*	0.17	17	30.36	5976
dRL**	0.14	14	11.45	2850

* dystroferric Red Latosol (dfRL), collected in Dourados, MS
** dystrophic Red Latosol (dRL), collected in Fátima do Sul, MS

Table 5. Coding of treatments according to soil class, irrigation interval and straw from predecessor crops

Soil Class	Irrigation interval	Straws from predecessor crops	Coding
dystroferric Red Latosol	every 1 day	single corn	Df1C
dystroferric Red Latosol	every 1 day	single brachiaria	Df1B
dystroferric Red Latosol	every 1 day	intercropping corn-brachiaria	Df1I
dystroferric Red Latosol	every 2 days	single corn	Df2C
dystroferric Red Latosol	every 2 days	single brachiaria	Df2B
dystroferric Red Latosol	every 2 days	intercropping corn-brachiaria	Df2I
dystroferric Red Latosol	every 3 days	single corn	Df3C
dystroferric Red Latosol	every 3 days	single brachiaria	Df3B
dystroferric Red Latosol	every 3 days	intercropping corn-brachiaria	Df3I
dystrophic Red Latosol	every 1 day	single corn	D1C
dystrophic Red Latosol	every 1 day	single brachiaria	D1B
dystrophic Red Latosol	every 1 day	intercropping corn-brachiaria	D1I
dystrophic Red Latosol	every 2 days	single corn	D2C
dystrophic Red Latosol	every 2 days	single brachiaria	D2B
dystrophic Red Latosol	every 2 days	intercropping corn-brachiaria	D2I
dystrophic Red Latosol	every 3 days	single corn	D3C
dystrophic Red Latosol	every 3 days	single brachiaria	D3B
dystrophic Red Latosol	every 3 days	intercropping corn-brachiaria	D3I

RESULTS AND DISCUSSION

In the experiments performed in the years 2012 and 2013, in a dystroferric Red Latosol, the number of pods per soybean plant showed the highest value in Df1B treatment. In the Df2C, Df2B and Df2I treatments no statistical difference on this variable was observed. In Df3C, Df3B and Df3I treatments a significant difference was observed on the number of pods, being that Df3B presented the highest number of pods and Df3C the lowest. Comparing corn as predecessor crop straw and the three irrigation intervals, Df1C, Df2C and Df3C differed statistically. The Df2C treatment provided the highest number of pods and Df3C, the smallest. Comparing the brachiaria as a predecessor crop straw and the three irrigation intervals, Df1B, Df2B and Df3B also differed statistically. The Df3B had the highest number of pods and Df1B, the lowest. Comparing the intercropping as a predecessor crop straw and the irrigation intervals, Df2I and Df3I provided the largest number of soybean pods (Table 6).

In both years, in a dystroferric Red Latosol, the lowest number of pods per soybean plant was obtained in Df3C. The highest number of pods was

Table 6. Number of pods per soybean plant after predecessor crops and submitted to irrigation intervals in two soil classes in 2012 and 2013

Irrigation Intervals (days)	Predecessor crops (2012)												Mean
	Corn				Brachiaria				Intercropping				
	dystroferric Red Latosol												
1	55	b	B	*A*	59	c	A	*A*	56	b	B	*a*	57
2	63	a	A	*A*	64	b	A	*A*	64	a	A	*a*	64
3	45	c	C	*A*	70	a	A	*A*	64	a	B	*a*	60
Mean	55				68				65				60
	dystrophic Red Latosol												
1	24	a	C	*B*	32	b	B	*B*	35	b	A	*b*	30
2	22	a	C	*B*	44	a	A	*B*	41	a	B	*b*	36
3	17	b	C	*B*	30	c	A	*B*	28	c	B	*b*	25
Mean	21				35				35				30
C.V.$_{Plot}$(%)	3.07												
C.V.$_{Subplot}$(%)	3.42												
C.V.$_{Sub-subplot}$(%)	2.54												
Irrigation Intervals (days)	Predecessor crops (2013)												Mean
	Corn				Brachiaria				Intercropping				
	dystroferric Red Latosol												
1	53	b	B	*A*	59	c	A	*A*	57	b	A	*A*	56
2	68	a	A	*A*	68	b	A	*A*	68	a	A	*A*	68
3	45	c	C	*A*	76	a	A	*A*	70	a	B	*A*	64
Mean	54				64				61				63
	dystrophic Red Latosol												
1	29	a	B	*B*	35	b	A	*B*	37	a	A	*b*	34
2	29	a	B	*B*	41	a	A	*B*	38	a	A	*b*	36
3	22	b	B	*B*	35	b	A	*B*	33	b	A	*b*	30
Mean	27				37				36				33
C.V.$_{Plot}$(%)	3.44												
C.V.$_{Subplot}$(%)	2.99												
C.V.$_{Sub-subplot}$(%)	3.16												

Means followed by the same letter, lower case in the columns, upper case in the lines and lower case italics between soil classes, do not differ by the Tukey test at 5% probability obtained in Df3B, being 36% and 41% higher, in 2012 and 2013, respectively, when compared to the Df3C treatment (Table 6).

In the 2012 experiment, in a dystrophic Red Latosol, the treatments D1C, D1B and D1I caused a significant effect on the number of pods per soybean plant. The D2B treatment showed the highest number of pods and the D3C, the lowest. Comparing corn as a predecessor crop straw and irrigation intervals, D1C and D2C provided the largest number of soybean pods. The D2B and D2I treatments had the highest number of pods, but intervals of three days provided the lowest value for this variable (Table 6).

In dystroferric Red Latosol, in 2013, the number of pods per plant showed the highest value in D1B, D2B, D3B, D1I, D2I, D3I. Comparing corn as straw of predecessor crop and the irrigation intervals, D1C and D2C obtained the highest number of pods. Comparing the intercropping as straw of predecessor crop and the irrigation intervals, D1I and D2I obtained the highest number of pods. Comparing brachiaria and the irrigation intervals, D2B provided the highest number of pods (Table 6).

In the two years of cultivation in a dystroferric Red Latosol, the lowest number of pods per soybean plant was obtained in the D3C treatment. The highest number of pods was obtained in D2B, being 61% and 46% higher, in 2012 and 2013, respectively, when compared to the D3C treatment (Table 6).

Souza *et al*. (2012) observed that the soybean in succession to the intercropping corn-brachiaria had 54 pods per plant, being significantly higher to the other systems, which presented an average of 35 pods per plant. Pereira (2013) found no significant effect between the predecessor cultivation of single corn and intercropping corn-brachiaria on the number of soybean pods, where single corn and intercropping provided 68 and 73 pods per soybean plant, respectively. Brandt *et al*. (2006) evaluated the agronomic performance in soybean cultivars over predecessor crops, and found a number of 35 pods per plant. The authors claim that these values are considered normal for the good development of the crop. According to Peixoto *et al*. (2002), this characteristic is not enough to guarantee that the productivity potential is reached, since it depends on the plant's capacity to fill the pods with grains.

In the experiment in 2012, in dystroferric Red Latosol, no statistical difference in Df1C, Df1B and Df1I treatments was observed for the weight of pods per soybean plant. A significant effect between the three predecessor crops on the weight of pods was observed. The Df3B and Df2I treatments provided the highest weight of pods, and Df2C and Df3C, the lowest value for this variable. Comparing corn as straw of predecessor crop and the irrigation intervals, Df2C treatment provided greater weight of pods than Df1C and Df3C treatments. Comparing the brachiaria as straw of predecessor culture and the three irrigation intervals, the Df1B, Df2B and Df3B treatments differed statistically. The Df3B treatment had the highest weight of pods and Df1B, the lowest. Comparing between the intercropping and the irrigation intervals, we could observe that Df2I and Df3I treatments presented the highest weight of soybean pods (Table 7).

In dystroferric Red Latosol, in 2013, the Df1B and Df3B treatments presented the highest values for the weight of pods per soybean plant and Df1C and Df3C, the lowest. The Df3B and Df3I treatments had the highest weight of pods, whereas the Df1C, Df3C, Df1B and Df1I treatments provided the lowest value for this variable (Table 7).

In the two years of experiment in a dystroferric Red Latosol, the lowest weight of pods per soybean plant occurred in the Df1C and Df3C treatments. In 2012, the highest weight of pods was obtained with the Df3B treatment, with 50% and 52% higher when compared to the Df1C and Df3C treatments, respectively. In 2013, the highest weight of pods was obtained with the Df3B treatment, with 40% and 42% higher when compared to the Df1C and Df3C treatments, respectively (Table 7).

In the experiment in the year 2012, in a dystrophic Red Latosol, the weight of pods per soybean plant showed the highest value in the D2B and D2I treatments. Comparing corn as straw of predecessor crop and the three irrigation intervals, the D1C and D2C treatments obtained the highest weight of pods. Comparing the predecessor brachiaria culture with the irrigation intervals, the D2B treatment provided greater value for

Table 7. Weight of soybean pods (g per plant) after predecessor crops and subjected to irrigation intervals in two soil classes in 2012 and 2013

Irrigation Intervals (days)	Predecessor crops (2012)												Mean
	Corn				Brachiaria				Intercropping				
	dystroferric Red Latosol												
1	11.57	b	A	*a*	12.42	C	A	*A*	11.63	b	A	*a*	11.87
2	15.68	a	C	*a*	16.71	B	B	*A*	21.02	a	A	*a*	17.80
3	10.92	b	C	*a*	22.95	A	A	*A*	21.14	a	B	*a*	18.34
Mean	13				17				18				16.00
	dystrophic Red Latosol												
1	3.24	a	B	*b*	3.93	B	B	*B*	5.27	b	A	*b*	4.15
2	3.20	a	B	*b*	8.94	A	A	*B*	8.20	a	A	*b*	6.78
3	1.48	b	B	*b*	3.83	B	A	*B*	3.23	c	A	*b*	2.85
Mean	2.64				5.57				5.57				4.59
C.V.$_{Plot}$(%)	5.28												
C.V.$_{Subplot}$(%)	7.84												
C.V.$_{Sub-subplot}$(%)	5.74												
Irrigation Intervals (days)	Predecessor crops (2012)												Mean
	Corn				Brachiaria				Intercropping				
	dystroferric Red Latosol												
1	15.00	b	C	*a*	18.21	C	A	*a*	16.50	c	B	*a*	16.57
2	18.74	a	B	*a*	19.44	B	AB	*a*	20.16	b	A	*a*	19.45
3	14.50	b	C	*a*	24.93	A	A	*a*	23.58	a	B	*a*	21.00
Mean	16.08				20.86				20.08				19.01
	dystrophic Red Latosol												
1	6.40	a	B	*b*	12.31	B	A	*b*	12.71	a	A	*b*	10.47
2	5.01	b	C	*b*	13.80	A	A	*b*	12.70	a	B	*b*	10.50
3	4.66	b	C	*b*	10.47	C	A	*B*	9.36	b	B	*b*	8.16
Mean	5.36				12.19				11.59				9.71
C.V.$_{Plot}$(%)	7.58												
C.V.$_{Subplot}$(%)	3.87												
C.V.$_{Sub-subplot}$(%)	3.73												

Means followed by the same letter, lower case in the columns, upper case in the lines and lower case italics between soil classes, do not differ by the Tukey test at 5% probability

this variable than D1B and D3B treatments. The intercropping corn-brachiaria presented a significant difference between the three irrigation intervals. The D2I treatment had the highest weight of pods and D3I, the lowest (Table 7).

In dystrophic Red Latosol in 2013, the weight of pods per soybean plant showed the highest value in the D2B treatment and the lowest values in the D2I and D3I treatments. Comparing single corn as a predecessor crop and the irrigation intervals, the D1C treatment obtained the highest weight of pods. The single brachiaria predecessor crop differed significantly between the three irrigation intervals. The D2B treatment had the highest weight of pods and D3B the smallest. However, the intercropping corn-brachiaria combined with the irrigation intervals, provided the highest value for this variable in the D1I and D2I treatments (Table 7).

In 2012, in a dystrophic Red Latosol, the lowest weight of pods per soybean plant was obtained with the D3C treatment. The highest weight of pods was obtained in the D2B and D2I treatments, being 83% and 82%, respectively higher when compared to the D3C treatment. In 2013, in a dystrophic Red Latosol, the lowest weight of pods per soybean plant was obtained in the D2C and D3C treatments. The highest weight of pods was obtained in D2B, being 64% and 66% higher when compared to the D2C and D3C treatments, respectively (Table 7).

In the experiment performed in 2012 in a dystroferric Red Latosol, the Df3B treatment provided the largest number of grains and Df3C, the smallest. Comparing only the single corn straw as a predecessor crop and the three irrigation intervals, the Df2C treatment provided the largest number of grains and the Df3C the smallest. Comparing only the single brachiaria predecessor crop and the irrigation intervals, the Df3C treatment presented the largest number of grains and Df1B the smallest. However, the comparison of the intercropping as a predecessor crop and the irrigation intervals, the Df2I and Df3I treatment provided a greater number of soybeans (Table 8).

In dystroferric Red Latosol, in 2013, in the irrigation intervals of one and three days, a significant effect of the three predecessor crops

Table 8. Number of grains per soybean plant after predecessor crops and submitted to irrigation intervals in two soil classes in 2012 and 2013

Irrigation Intervals (days)	Predecessor crops (2012)			Mean
	Corn	Brachiaria	Intercropping	
	dystroferric Red Latosol			
1	105 b C *a*	111 C A *A*	109 B B *A*	108
2	137 a B *a*	139 B B *A*	142 A A *A*	139
3	96 C C *a*	160 A A *A*	143 A B *a*	133
Mean	113	137	131	127
	dystrophic Red Latosol			
1	37 A C *b*	46 B B *B*	62 B A *b*	48
2	27 B C *b*	88 A A *B*	82 A B *b*	66
3	20 C B *b*	41 C A *B*	39 C A *b*	33
Mean	28	58	61	49
C.V.$_{Plot}$(%)	3.63			
C.V.$_{Subplot}$(%)	1.80			
C.V.$_{Sub-subplot}$(%)	1.42			
Irrigation Intervals (days)	Predecessor crops (2013)			Mean
	Corn	Brachiaria	Intercropping	
	dystroferric Red Latosol			
1	132 b C *a*	141 c A *A*	135 C B *a*	136
2	145 a B *a*	147 b AB *A*	150 b A *a*	147
3	109 c C *a*	168 a A *A*	158 a B *a*	145
Mean	129	152	148	143
	dystrophic Red Latosol			
1	58 a C *b*	85 b B *B*	90 a A *b*	78
2	45 b C *b*	96 a A *B*	91 a B *b*	77
3	43 b C *b*	84 b A *B*	75 b B *b*	67
Mean	49	88	85	74
C.V.$_{Plot}$(%)	1.23			
C.V.$_{Subplot}$(%)	1.22			
C.V.$_{Sub-subplot}$(%)	1.38			

Means followed by the same letter, lower case in the columns, upper case in the lines and lower case italics between soil classes, do not differ by the Tukey test at 5% probability on the number of grains per soybean plant was observed, where the Df3B treatment provided the highest number of grains and the Df3C, the smallest. Comparing only single corn as a predecessor crop and the three irrigation intervals, the Df2C treatment provided the largest number of grains and the Df3C, the smallest. Comparing the single brachiaria predecessor crop with the three irrigation intervals and the intercropping as a predecessor crop with the irrigation intervals, the Df3B and Df3I treatments had the highest number of grains and Df1B and Df1I, the smallest (Table 8).

In both years in a dystroferric Red Latosol, the lowest number of grains per soybean plant was obtained in the Df3C treatment. The highest number of grains was obtained in the Df3B treatment, being 40% and 35% higher, in 2012 and 2013, respectively, when compared to the Df3C treatment (Table 8).

In the experiment performed in 2012 in a dystrophic Red Latosol, comparing the one-day irrigation interval, a significant effect of the three predecessor crops on the number of grains per soybean plant was observed, where the D2I treatment provided the largest number of grains and the D2C treatment, the smallest. Comparing only the two-day interval and the three predecessor crops, a significant effect of the three predecessor crops on the number of grains was also verified. The D2B treatment had the highest value of this variable, and D2C, the lowest. The comparison of the three-day irrigation interval with the predecessor crops, the D3B and D3I treatments provided the highest value for this variable. Comparing only single corn as a predecessor crop with the three irrigation intervals, the D1C treatment provided the largest number of grains and the D3C, the smallest. The predecessor brachiaria single culture compared with the irrigation intervals and the intercropping corn-brachiaria compared with the irrigation intervals, differed statistically between the three irrigation intervals. The D2B and D2I treatments presented the highest number of grains and the D3B and D3I, the smallest (Table 8).

In dystrophic Red Latosol, in 2013, comparing the one-day irrigation interval with the three predecessor crops on the number of grains per soybean plant, the D1I treatment provided the largest number of grains, and the D1C the smallest. Comparing only the two-day irrigation interval with the predecessor crops and the three-day irrigation interval with the predecessor crops, a significant effect of the three predecessor crops on the number of grains was observed. The single brachiaria had the highest value while the single corn had the smallest value for the variable number of grains. Comparing the predecessor cultivation of the intercropping corn-brachiaria with the irrigation intervals, the D1I and D2I treatments promoted the highest number of soybeans (Table 8).

In 2012, in a dystrophic Red Latosol, the lowest number of grains per soybean plant occurred in the D3C treatment. The highest number of grains was obtained in the D2B treatment, being 77% higher when compared to the D3C treatment. In 2013, in a dystrophic Red Latosol, the lowest number of grains per soybean plant occurred in the D2C and D3C treatments. The highest number of grains was obtained in the treatment D2B, being 53% and 55% higher when compared to the D2C and D3C treatments (Table 8).

Santos *et al*. (2013) working on a dystrophic Red Latosol, reported that the predecessor crops such as wheat, black oats and triticale provided an average of 57 grains per soybean plant in succession. In research on dystrophic Red Latosol, Santos *et al*. (2014), observed that the cultivation of soybean in succession to white oats, pastures, alfalfa provided an average of 72 grains per soybean plant. These results were similar to that found in this present work in a dystrophic Red Latosol in 2013, with an average of 74 grains per soybean plant (Table 8).

In the two years of experiment in a dystroferric Red Latosol, the lowest yield per soybean plant occurred in the Df1C and Df3C treatments. The highest yield was obtained in the Df3B treatment, with 56% and 53% (in 2012) and 44% and 46% (in 2013) higher when compared to the Df1C and Df3C treatments, respectively (Table 9).

Table 9. Soybeans yield (g per plant) after predecessor crops and subjected to irrigation intervals in two soil classes in 2012 and 2013

Irrigation Intervals (days)	Predecessor crops (2012)												Mean
	Corn				Brachiaria				Intercropping				
	dystroferric Red Latosol												
1	7.42	b	C	*a*	9.40	C	A	*A*	8.34	c	B	*A*	8.39
2	11.77	a	B	*a*	11.73	B	B	*A*	12.86	b	A	*A*	12.12
3	7.99	b	C	*a*	17.02	A	A	*A*	14.49	a	B	*A*	13.17
Mean	9.06				12.72				11.90				11.22
	dystrophic Red Latosol												
1	1.44	a	A	*b*	1.71	B	A	*B*	2.24	b	A	*B*	1.80
2	1.34	a	B	*b*	4.81	A	A	*B*	4.58	a	A	*B*	3.58
3	0.41	b	B	*b*	1.51	B	A	*B*	1.43	c	A	*B*	1.12
Mean	1.06				2.68				2.75				2.16
C.V.$_{Plot}$(%)	7.01												
C.V.$_{Subplot}$(%)	10.05												
C.V.$_{Sub-subplot}$(%)	7.01												
Irrigation Intervals (days)	**Predecessor crops (2012)**												**Mean**
	Corn				Brachiaria				Intercropping				
	dystroferric Red Latosol												
1	10.53	b	C	*a*	13.11	B	A	*A*	11.61	c	B	*A*	11.75
2	13.46	a	B	*a*	13.48	B	B	*A*	14.63	b	A	*A*	13.86
3	10.16	b	C	*a*	18.89	A	A	*A*	17.07	a	B	*A*	15.37
Mean	11.38				15.16				14.44				13.66
	dystrophic Red Latosol												
1	2.93	a	B	*b*	3.80	B	A	*B*	3.91	b	A	*B*	3.55
2	2.89	a	B	*b*	5.90	A	A	*B*	5.76	a	A	*B*	4.85
3	1.56	b	B	*b*	3.79	B	A	*B*	3.42	b	A	*B*	2.92
Mean	2.46				4.50				4.36				3.77
C.V.$_{Plot}$(%)	4.60												
C.V.$_{Subplot}$(%)	7.98												
C.V.$_{Sub-subplot}$(%)	5.46												

Means followed by the same letter, lower case in the columns, upper case in the lines and lower case italics between soil classes, do not differ by the Tukey test at 5% probability

In experiments in dystrophic Red Latosol in the years 2012 and 2013, comparing corn as a predecessor crop and the irrigation intervals, the D1C and D2C treatments obtained the highest productivities. Comparing the predecessor cultivation of single brachiaria with the irrigation intervals and the intercropping corn-brachiaria with the irrigation intervals, it was observed that the D2B and D2I treatments ensured higher soybean yield (Table 9).

In the two years of experiment in a dystrophic Red Latosol, the lowest yield per soybean plant occurred in the D3C treatment. The highest productivities were obtained in the D2B and D2I treatments, 74% and 73% (in 2013), respectively, being higher when compared to the D3C treatment. In 2012, the productivity of soybeans in D2B and D2I treatments were 91% higher when compared to the D3C treatment (Table 9).

Borges *et al*. (2015), in an eutrophic Red Latosol in Votuporanga-SP, Brazil, did not observe a significant effect of single corn and single brachiaria on soybean productivity in succession. However soybean anticipated by brachiaria showed higher productivity. Correia *et al*. (2013) worked with intercropping cultivation of corn with

B. ruziziensis and single corn preceding soybean and observed that the intercropping guaranteed greater production of soybeans than single corn. Mendonça *et al*. (2014), reported that in a dystrophic Red Latosol, the intercropping corn-brachiaria did not increase soybean productivity compared to the single corn area. In an experiment in Dourados-MS, Brazil, in dystroferric Red Latosol, Ceccon *et al*. (2006), did not find a significant effect of single corn, single brachiaria and intercropping corn-brachiaria on soybean productivity in succession. However, soybean in succession to the intercropping showed higher productivity than soybean in succession to single corn and single brachiaria.

The lower performance of soybean in dystroferric Red Latosol and dystrophic Red Latosol with single corn as the predecessor crop and the need for a shorter interval between irrigations in soybean in succession (Tables 6, 7, 8 and 9), can be explained by the low percentage of soil covered by the straw produced by corn (CECCON, 2007; FRANCHINI *et al*., 2009). As a result, an increase of the losses of water by evaporation of soil occur during the soybean cycle (FRANCHINI *et al*., 2009).

Straw reduces evaporation of water from the soil, by reflecting part of the solar energy (STONE; MOREIRA, 2000). Consequently, the temperature fluctuations reduce, increasing the conservation of soil moisture.

B. ruziziensis as a predecessor crop provided a better performance of the soybean crop, with a longer interval between irrigations than the single corn as a predecessor crop (Tables 6, 7, 8 and 9). Therefore, *B. ruziziensis* provided greater water savings in both the soils than single corn. This result is probably due to the adequate and persistent coverage provided by the brachiaria straw.

According to Oliveira *et al*. (2015), brachiariae and other forage species that have a deep, bulky, branched and aggressive root system, are able to penetrate the compacted layers. Therefore, when they die and decompose, they leave channels (biopores) through which the roots of subsequent crops can explore to deepen the root system, increasing the absorption of water and nutrients. These channels are also important for the infiltration of water and for the movement of fertilizers and correction materials applied on the surface. Franchini *et al*. (2009) showed that the predecessor cultivation with *B. ruziziensis* reflected in a greater development of the soybean root system. This result indicates that the volume of soil explored by the soybean roots, in search of water and nutrients, was higher in production systems that include tropical forages, which gave the soybean crop a greater tolerance to periods of water deficiency.

The benefits of cover crops can also be complemented with the maintenance of high rates of water infiltration by the combined effect of the root system and straw and also by the large and continuous supply of vegetal mass to the soil. Thus, it can be possible to maintain, or even increase the organic matter content, promote nutrient recycling, improve soil aggregation, reduce thermal amplitude, decrease evaporation and increase water conservation in the soil (SALTON, 2000; CAPECHE *et al*., 2008; CHIODEROLI, 2010) .

Despite the smaller contribution of the intercropping corn-brachiaria, the straw of these predecessor crops showed better results for soybean than single corn as a previous crop (Tables 6, 7, 8 and 9). The results indicate that the intercropping is an alternative interesting for the off-season, without the need to remove corn from the production system. According to Ceccon, (2007), Broch and Ceccon (2008), intercropping off-season corn and brachiaria is a technology that allows corn to be maintained as an economic yield crop, and brachiaria with the production of straw to cover the soil in the period between the corn harvest and the sowing of the next crop, in general the soybean.

Regarding the irrigation intervals, the best results for soybean cultivation in dystroferric Red Latosol and dystrophic Red Latosol were with irrigation intervals of three and two days, respectively (Tables 6, 7, 8 and 9). According to Cardoso (2001) and Moline *et al*. (2013), the amount of water to be applied to the crop depends directly on the type of soil that exists, since the moisture retention capacity in a sandy soil is less than in a clayey soil, requiring shorter intervals between irrigations.

In general, sandy soils have a higher amount of macropores, which determines higher rates of infiltration compared to more clayey soils, which have a higher amount of micropores (BERTONI; LOMBARDI NETO, 2012). According to Lima and Lima (1996) and Resende *et al*. (2007), macropores are responsible for aeration, water movement and root penetration, and micropores for water retention in the soil.

In relation to soil classes, the dystrophic Red Latosol provided the lowest performances in all analyzed variables (Tables 6, 7, 8 and 9) when compared to the dystroferric Red Latosol, probably due to the low organic matter content and low CTC (Table 1) contained in the dystrophic Red Latosol.

According to Silva *et al*. (2006), soils with higher CTC, allow greater retention of nutrients, increasing their availability for plants, causing greater growth for plants. However, soils with low organic matter content and, consequently, low CTC, retain only small amounts of cations, and are therefore more susceptible to nutrient losses by leaching (MEURER, 2012). Furthermore, the low levels of organic matter combined with the low levels of clay and the structure, with a large volume of macropores, determine low water retention (SANTOS; ALBUQUERQUE FILHO, 2007), which restricts the growth of plants.

According to Stone and Silveira (2001), the maintenance of straw is essential in soils with sandy texture, since the contribution of straw over the soil, in the medium and long term, can increase the content of organic matter, which is the main responsible for CTC sandy soils.

CONCLUSION

- Soybean showed higher yield after cultivation with brachiaria, lower yield after corn and intermediate yield after the intercropping.
- The irrigation interval of two days and three days after brachiaria in dystroferric Red Latosol and dystrophic Red Latosol, respectively, resulted in the best soybean performance.

AUTHORSHIP CONTRIBUTION STATEMENT

PADILHA, N.S.: conception of the research, acquisition of data, analysis and interpretation of data, drafting and reviewing the work. CECCON, G.: guidance, conception of the research, reviewing the work. ALVES, V.B: acquisition and analysis of data, reviewing the work. NETO-NETO, A.L.; SILVA, J.F.; MAKINO, P.A.: acquisition of data, reviewing the work.

DECLARATION OF INTERESTS

The authors declare that they have no knowledge of a conflict of interest that could have appeared to influence the work reported in this paper.

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