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Soybean growth and nitrogen accumulation by soybeans in response to desiccation times of *Urochloa brizantha* pasture and nitrogen fertilization

Crescimento e acúmulo de nitrogênio pela soja em função de épocas de dessecação de pastagem de *Urochloa brizantha* e adubação nitrogenada

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Highlights

Early desiccation of *U. brizantha* favors the establishment of soybean in succession.
The soybean yield was not influenced by the desiccation time.
N fertilization at sowing promote soybean growth but there were no effects on yield.

Abstract

The desiccation time of high-biomass pasture and nitrogen (N) fertilization of pasture and soybean can influence the soybean sowing, establishment and growth. The objective of this study was to evaluate how the time of desiccation of the preceding pasture of *Urochloa brizantha* cv. BRS Piatã, cultivated at three levels of N, and by the soybean N fertilization affect soybean growth and N accumulation. Three N rates (0; 150 and 300 kg ha^{-1}), broadcast as urea on the *U. brizantha* pasture were evaluated separately in each N level, every one considered as one experiment. In each experiment, five times of pasture desiccation were evaluated (60; 45; 30; 15, and 1 day before soybean sowing) and two levels of soybean N fertilization: 30 kg ha^{-1} (urea) broadcast at sowing or without N fertilization. A randomized complete block design with five replications was used. Early desiccation of *U. brizantha* pasture favors the establishment of soybean and promotes an increase in biomass and N accumulation in the vegetative stages, however these differences are not observed during the grain filling, regardless the soybean N fertilization. The soybean yield was not influenced by the desiccation time. N fertilization with 30 kg ha^{-1} at sowing intensifies soybean growth at the vegetative phase, but after full flowering, there were no effects on biomass and grain yield, independently of the desiccation time.

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Key words: *Glycine max* L. Integrated Crop-Livestock System. Nitrogen. Plant biomass. *Urochloa brizantha* cv. BRS Piatã.

Resumo

A época da dessecação da pastagem de braquiária com alta quantidade de biomassa e a adubação nitrogenada na pastagem e na soja podem influenciar a qualidade da semeadura e as condições para o estabelecimento e o crescimento das plantas de soja. O objetivo do trabalho foi avaliar o efeito de épocas de dessecação de pastagem de *Urochloa brizantha* cv. BRS Piatã, cultivada em três doses de nitrogênio, e da adubação nitrogenada na soja, sobre o crescimento e acúmulo de N pela cultura. Foram estudadas três doses de N na pastagem de *U. brizantha* cv. BRS Piatã: 0; 150 e 300 kg ha^{-1} de N, aplicados na forma de ureia, a lanço, constituindo três experimentos, que foram analisados separadamente. Em cada experimento foram avaliadas cinco épocas de dessecação da pastagem: 60; 45; 30; 15 e 1 dias antes da semeadura da soja e dois níveis de adubação nitrogenada na soja, com 30 kg N ha^{-1} aplicados a lanço no dia da semeadura (ureia) e sem adubação nitrogenada. Foi utilizado o delineamento de blocos completos casualizados, com cinco repetições. Os resultados evidenciaram que a dessecação antecipada da *Urochloa brizantha* cv. BRS Piatã favoreceu o estabelecimento de plantas de soja e promoveu incremento na massa seca e acúmulo de N nos estádios vegetativos da cultura, entretanto essas diferenças não são observadas no enchimento e na produtividade de grãos, independentemente da adubação nitrogenada na soja. A produtividade de grãos não é influenciada pelas épocas de dessecação. A adubação nitrogenada na implantação da soja com 30 kg ha^{-1} de N proporciona maior crescimento das plantas de soja na fase vegetativa, mas, após o pleno florescimento, não interfere na biomassa e na produtividade de grãos, independentemente da época de dessecação.

Palavras-chave: Biomassa vegetal. *Glycine max* L. Integração lavoura-pecuária. Nitrogênio. *Urochloa brizantha* cv. BRS Piatã.

Introduction

Over the last two decades, the Integrated Crop-Livestock System (ICLS) with diversification of production systems have become an advantageous option to optimize resources and reduce costs. ICLS provides economic and environmental advantages over single production systems mainly because of the improvements in soil and water quality, and can mitigate greenhouse gases, increase biodiversity, and diversify rural property income (Balbinot et al., 2009; F. C. Santos et al., 2014).

Some *Brachiaria* (syn. *Urochloa*) species have been widely used in ICLS in Brazil (Castoldi et al., 2014; Janegitz et al., 2016), mainly due to its high adaptability to different soil types, high biomass production, and ease of seed acquisition (Costa et al., 2016). The desiccation management of *Brachiaria* plants with herbicides prior to soybean sowing is fundamental for the success of the system (Nascente et al., 2013). In general, a longer period between pasture desiccation and sowing of the grain crop facilitates the operation, improves plant establishment, and increases initial growth, although an additional desiccation may become necessary, in case of pasture regrowth or weed emergence (Ricce et al., 2011). On the other hand, when soybean is sown immediately after pasture desiccation (drying/planting system), sowing may be hampered and the soybean plantlets can be shaded by residual pasture biomass (Nascente & Crusciol, 2012; Nepomuceno et al., 2012).

Another important feature that can affect plant growth is the level of nitrogen (N) supply. During the cycle of soybean development, the requirement for N is around 80 kg per ton of grain (Van Roekel & Purcell, 2014). Despite the high requirement, studies confirm that biological N fixation (BNF), in addition to N from the soil solution, can meet the entire plant demand for this nutrient, dismissing supplemental mineral N (Campo et al., 2009). Several studies in various production environments and yield expectations have shown that mineral N fertilization of soybean is unnecessary in Brazil, as long as inoculation is done as recommended (Hungria & Mendes, 2015; Moretti et al., 2018). However, large amounts of residues with high C/N ratio, as in the case of *Urochloa* spp. pastures, temporary immobilization of N may occur, making it unavailable for soybean (Calonego et al., 2012). For this reason, some questions have been raised about the response of soybean to mineral N applied at sowing. Possibly, this response could vary according to the history of N fertilization of the pasture. In other words, if *Urochloa* spp. pasture does not receive N fertilization, soybean in ICLS might respond to N fertilization.

The objective of this study was to evaluate the effects of desiccation times of *Urochloa brizantha* pasture, cultivated at three levels of N, and the effects of N fertilization of soybean at sowing, on its growth and N accumulation.

Material and Methods

The study was carried out from March 2016 to March 2018, in Londrina, Paraná (23°11’S, 51°11’W, at 620 m a.s.l.). The soil was classified as LATOSSOLO Vermelho distroférrico (H. G. Santos et al., 2018), with a very clayey texture, which had been managed in a no-tillage system for 15 years, with soybean in the summer and wheat or black oat in the winter.

In March 2016, *Urochloa brizantha* cv. BRS Piatã was sown in rows spaced 20 cm apart, intercropped with maize in the second season, using 5 kg ha^{-1} of pure and healthy seeds of brachiaria. After maize harvest, in July 2016, the experimental area was divided into three paddocks of 1.2 ha, constituting three experiments. In the first paddock, no N fertilization was applied to the pasture, while in the second and third paddocks, the pasture was fertilized with 150 and 300 kg ha^{-1} of N (urea, 45% of N), which was broadcast, half the rate in September and the other half in November 2016. The soil had the following properties (0 - 20 cm layer): 27.9 g dm^{-3} organic C; pH ($CaCl_2$) 4.8; 15.5 mg dm^{-3} of available P (Mehlich^{-1}); 0.53 $cmol_c$ dm-3 of exchangeable K; 3.2 $cmol_c$ dm^{-3} exchangeable Ca; 1.4 $cmol_c$ dm^{-3} exchangeable Mg; 15.3 mg dm^{-3} of SO_4^{2-} and 49% base saturation.

From October 2016 to July 2017, a variable stocking rate of male cattle (live weight 350 - 550 kg) was left to graze continuously in the area, to maintain the same plant height (30 cm) in the three paddocks. During the grazing period, the stocking rate was two to five animal units ha^{-1}, depending on the level of N fertilization and time of the year. Thereafter, the animals were removed from the area until August 2017, when an experiment in randomized complete blocks design with five replications was installed in each paddock, in a 5 x 2 factorial arrangement. The treatments consisted of five desiccation times (60; 45; 30; 15; and 1 day before soybean sowing) and two levels of nitrogen fertilization (30 kg ha-1 of N broadcast at soybean sowing as urea or no N fertilization). The soybean cultivar BRS 1010 IPRO was used, which has an indeterminate growth type and belongs to the relative maturity group 6.1. Pasture was desiccated with glyphosate, at a rate of 1,500 g a.i. ha^{-1}, sprayed with flat-fan nozzles on a tractor, at a spray volume of 200 L ha^{-1}. At all desiccation times, the atmospheric and soil moisture conditions were adequate for maximized herbicide efficiency.

Soybean sowing was carried out on November 03, 2017 and the seeds were treated with Carboxin (30 mL a.i. 50 kg^{-1} seeds) and Tiram (30 mL a.i. 50 kg^{-1} seeds), and inoculated with *Bradyrhizobium elkanii* at a concentration of 5 x 10^9 CFU mL^{-1} (100 ml 50 kg^{-1} of seeds). A seeder-fertilizer equipped with a furrow-cutting mechanism for fertilizer placement and offset double discs for the seeds was used. Fertilization at sowing consisted of 350 kg ha^{-1} of 0-20-20 N-P-K fertilizer. In the 5 x 8 m plots (total evaluated area 40 m^2), the seeder was adjusted to an inter-row spacing of 0.45 m.

Diseases, pest insects, and weeds were controlled as recommended by the technical indications for soybean cultivation (Empresa Brasileira de Pesquisa Agropecuária [Embrapa], 2013). The meteorological data were measured at the agrometeorological station of the Brazilian Agricultural Research Corporation [Embrapa] Soybean, installed at a distance of 700 m from the experimental site. The sequential climatological water balance (SCWB) of Thornthwaite and Mather (1955) was calculated during the field experiments (Figure 1). The reference evapotranspiration (ETo) was computed during the 10 days of the experiment by the Penman-Monteith equation and transformed into soybean crop evapotranspiration (ETc = ETo x Kc), according to the recommendation of the crop coefficient (Kc) by FAO (Allen et al., 1998). The available water content (AWC) used to calculate the SCWB was 75 mm (Farias et al., 2001).

The evaluated variables were initial and final plant density (thousand plants ha^{-1}), leaf area index (LAI), SPAD index, plant biomass (kg ha^{-1}), shoot N concentration (%), and shoot N accumulation (kg ha^{-1}) evaluated at five soybean developmental stages (V3, V6, R2, R4, and R5.4).

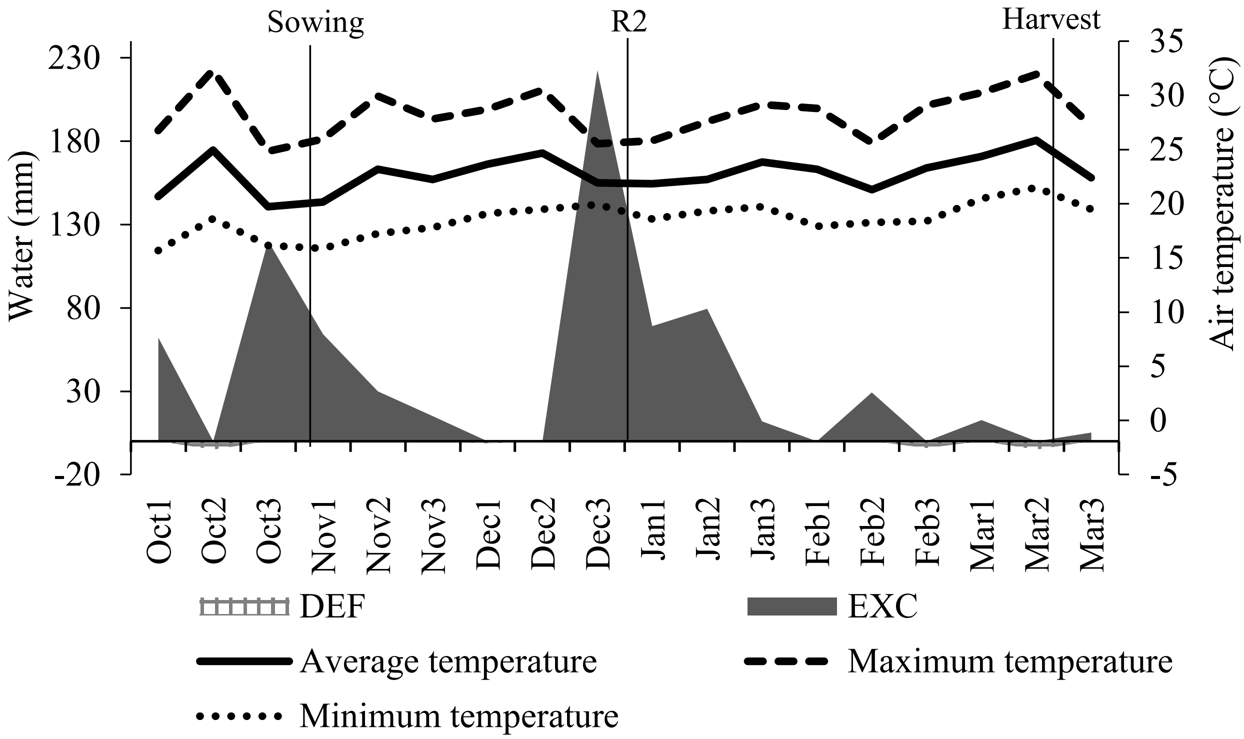

Figure 1. Extract of sequential climatological water balance with available water content of 75 mm and maximum, average, and minimum temperature means (°C) during the experimental periods in the growing season 2017/18. Londrina, PR.

Initial plant density was determined by counting all plants in a total area of 3 m^2 per plot at V2 stage. To easily and accurately measure the leaf area index (LAI) by a non-destructive method, a LI-COR® LAI-2200 plant canopy analyzer with a fisheye sensor to capture light was used. The SPAD index of 10 leaves per plot was determined with a SPAD-502 Plus (Konica Minolta®) chlorophyll meter, using the third trefoil from the apex (diagnostic leaf). The SPAD index was always measured in the central leaflet of the diagnostic trefoil.

To measure biomass, all plants growing within 1 m per row plot were cut close to the ground, placed in paper bags and oven-dried at 65 °C to constant biomass. After drying, the total shoot biomass was determined on an analytical scale (precision 0.1 g). After weighing, plants were ground in a mill and taken to the laboratory to determine the N concentration after sulfuric digestion by the Kjeldhal method (Association of Official Analytical Chemists [AOAC], 1995). N accumulation in the plant shoots (kg ha^{-1}) was obtained by multiplying the N concentration (%) by the dry plant biomass (kg ha^{-1}). The final plant density was determined at stage R7 at the same point where the initial plant density was evaluated, in 3 m^2 per plot. The yield, expressed in kg ha^{-1}, was determined by weighing the grains harvested with the Classic harvester Wintersteiger® in the useful area (15 m^2) of each plot, with moisture standardized to 13%.

The data were analyzed for normality and homoscedasticity by the Shapiro-Wilk and Hartley tests, respectively, which indicated that data transformation was not necessary. Then, data were submitted to analysis of variance with F test for each experiment separately. The means for soybean N fertilization were compared by the F test. For desiccation levels, a polynomial regression analysis was performed up to the second degree. All analyses, at an error probability of 5%, were carried out using the software System for Analysis of Variance - SISVAR (Ferreira, 2011).

Results and Discussion

The climate conditions during the experiments were adequate for soybean (Figure 1). There was no interaction between desiccation times of pasture and N fertilization of the subsequent soybean for any variable. There was effect of desiccation times on initial plant density in the experiment without N fertilization (Table 1) and in with 300 kg ha^{-1} of N (Table 3), since early desiccation increased initial density. In the pasture treated with 150 kg ha^{-1} of N, the initial soybean density was not affected by desiccation times (Table 2). In an evaluation of *U. ruziziensis* desiccation between 0 and 30 days before soybean sowing, Nepomuceno et al. (2012) found no differences in the initial soybean stand. According to Franchini et al. (2014) an increasing interval from 8 to 35 days between desiccation and soybean sowing increased the initial plant density. In the experiment without N application, final plant density was not affected by desiccation times. For the experiments treated with N fertilizer in the pasture, there was effect of desiccation times in which earlier desiccation increased the final plant stand (Tables 2 and 3).

Table 1

SPAD Index, Leaf area index (LAI), plant biomass (kg ha^{-1}), shoot nitrogen concentration (%) and nitrogen accumulation (kg ha^{-1}) at different soybean development stages, initial and final plant density (thousand plants ha^{-1}) and grain yield (kg ha^{-1}) in response to intervals between the desiccation of *Urochloa brizantha* cv. BRS Piatã pasture and soybean sowing, without pasture fertilization (0 kg ha^{-1} of N) (averages with and without N in soybean). Londrina, PR, 2017/18 growing season

Variables	Intervals between pasture desiccation and soybean sowing (days)					Fitted equations	R^2	CV (%)
	1	15	30	45	60			
Init. dens. (× 1000 ha^{-1})	453	457	458	471	481	$\hat{Y}$ = 449.68** + 0.48**x		
Fin. dens. (× 1000 ha^{-1})	422	434	421	443	438	ns		6.4
Grain yield (kg ha^{-1})	4862	4947	5005	4838	4910	ns		7.0
			Stage V3					
SPAD	29.1	30.6	27.8	30.4	31.8	ns		10.4
LAI	0.97	1.3	1.07	1.2	1.24	ns		18.3
SDM (kg ha^{-1})	238	259.3	265.5	305.3	299.8	$\hat{Y}$ = 239.0** + 1.145**x	0.89	19.0
N concentration (%)	3.23	3.32	3.29	3.35	3.3	ns		8.2
N accumulation (kg ha^{-1})	7.69	8.63	8.77	10.27	9.89	$\hat{Y}$ = 7.819** + 0.0407**x	0.85	21.4

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			Stage V6					
SPAD	32.4	34.9	34.6	35.7	34.7	Ŷ = 33.37** + 0.036*x	0.47	6.2
LAI	2.05	2.2	1.98	2.16	2.46	ns		18.9
SDM (kg ha^{-1})	886	1033	890	1050	1271	Ŷ = 865.2** + 5.32** x	0.63	17.0
N concentration (%)	3.15	3.18	3.17	3.36	3.17	ns		6.3
N accumulation (kg ha^{-1})	27.97	32.85	28.73	35.35	40.35	Ŷ = 27.48** + 0.1843** x	0.72	19.1
			Stage R2					
SPAD	38.9	39.2	40.3	39.3	38.3	ns		4.9
LAI	5.8	6.2	6.4	6.2	6.7	Ŷ = 5.894** + 0.012** x	0.74	9.3
SDM (kg ha^{-1})	3477	3700	3535	3920	4050	ns		16.2
N concentration (%)	2.5	2.65	2.65	2.76	2.62	ns		12.8
N accumulation (kg ha^{-1})	87	99.5	94.4	109.7	106.1	ns		23.3
			Stage R4					
SPAD	44.6	44.4	45	43.8	45.2	ns		4.4
LAI	7	7.1	7.1	7.3	7.5	ns		5.5
SDM (kg ha^{-1})	5803	6004	5840	6127	6565	ns		13.6
N concentration (%)	2.94	2.98	3.09	2.92	3.22	ns		13.2
N accumulation (kg ha^{-1})	170	181	180	178	212	ns		21.6
			Stage R5.4					
SPAD	48.1	49	49.4	48.4	48.9	ns		3.3
LAI	6.3	6.5	6.5	6.2	6.4	ns		6.3
SDM (kg ha^{-1})	8248	8634	8311	7987	9141	ns		14.3
N concentration (%)	2.72	2.75	2.65	2.73	2.81	ns		13.8
N accumulation (kg ha^{-1})	225.2	219.6	220.4	220.9	257.2	ns		26.9

ns, not significant, ** and *, significant at 1% and 5% probability, respectively, by the F test. Init. dens.: initial density (×1000 plants ha-1); Fin. dens.: final density (thousand plants ha-1); SPAD: Soil Plant Analysis Development; LAI: Leaf area index; SDM: Shoot dry matter (kg ha-1); Shoot nitrogen concentration (%); Accumulation of Nitrogen (kg ha-1).

Table 2

SPAD Index, Leaf area index (LAI), plant biomass (kg ha^{-1}), shoot nitrogen concentration (%) and nitrogen accumulation (kg ha^{-1}) at different soybean development stages, initial and final plant density (1000 plants ha^{-1}) and grain yield (kg ha^{-1}) in response to intervals between the desiccation of *Urochloa brizantha* cv. BRS Piatã pasture and soybean sowing, with 150 kg ha^{-1} of N in the pasture (averages with and without N in soybean). Londrina, PR, 2017/18 growing season

Variables	Intervals between pasture desiccation and soybean sowing (days)					Fitted equations	R^2	CV (%)
	1	15	30	45	60			
Init. dens. (× 1000 ha^{-1})	429	458	472	468	472	ns		8.0
Fin. dens. (× 1000 ha^{-1})	384	426	442	433	422	Ŷ = 383.42** + 3.19* x - 0.043**x^2	0.96	7.7

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Grain yield (kg ha^{-1})	4868	4784	4768	4792	4763	ns		4.5
Stage V3								
SPAD	28.7	29.4	29.8	30.7	30.7	ns		8.5
LAI	0.93	0.85	0.89	0.93	1.02	ns		20.1
SDM (kg ha^{-1})	279.3	336.2	311.8	316.9	354.2	ns		17.8
N concentration (%)	3.15	3.28	3.26	3.27	3.32	ns		8.1
N accumulation (kg ha^{-1})	8.84	11.13	10.16	9.5	11.74	$\hat{Y}$ = 9.43** + 0.0279*x	0.31	20.4
Stage V6								
SPAD	34.9	34.5	34.3	35.3	35.4	ns		5.0
LAI	2.1	2.4	2.6	2.8	3	$\hat{Y}$ = 2.1317** + 0.0148**x	0.99	19.3
SDM (kg ha^{-1})	859	1091	946	1044	1198	$\hat{Y}$ = 899.45** + 4.2434** x	0.58	20.6
N concentration (%)	2.79	2.96	2.94	2.94	2.93	ns		8.7
N accumulation (kg ha^{-1})	24.1	32.4	27.8	30.7	35	$\hat{Y}$ = 25.925** + 0.1349** x	0.56	24.3
Stage R2								
SPAD	40.1	40	40.8	40.8	40.7	ns		3.7
LAI	5.5	6.1	6	6.4	6.6	$\hat{Y}$ = 5.611** + 0.0168** x	0.88	8.6
SDM (kg ha^{-1})	3227	4148	4027	3874	4323	$\hat{Y}$ = 3532.8** + 12.816* x	0.52	19.8
N concentration (%)	2.78	3.03	2.76	2.74	2.95	ns		14.8
N accumulation (kg ha^{-1})	90	124.1	109.8	107	128.1	$\hat{Y}$ = 99.88** + 0.3947* x	0.38	22.1
Stage R4								
SPAD	44	44.5	44.3	45.1	44.4	ns		3.7
LAI	7.2	7.6	7.4	7.4	7.6	ns		5.7
SDM (kg ha^{-1})	5396	5846	5408	5549	6033	ns		14.8
N concentration (%)	2.97	2.99	3.02	2.84	2.99	ns		13.3
N accumulation (kg ha^{-1})	159.9	176.9	162.5	155.8	180.7	ns		18.7
Stage R5.4								
SPAD	48.6	48.1	47	48.6	48	ns		4.9
LAI	5.7	5.8	5.7	5.6	5.8	ns		8.0
SDM (kg ha^{-1})	7436	8788	8380	8984	8911	ns		13.3
N concentration (%)	2.85	2.65	2.64	2.84	2.56	ns		11.3
N accumulation (kg ha^{-1})	213.5	233.6	220.7	257.5	228.1	ns		17.5

ns, not significant, ** and *, significant at 1% and 5% probability, respectively, by the F test. Init. dens.: initial density (×1000 plants ha^{-1}); Fin. dens.: final density (thousand plants ha^{-1}); SPAD: Soil Plant Analysis Development; LAI: Leaf area index; SDM: Shoot dry matter (kg ha^{-1}); Shoot nitrogen concentration (%); Accumulation of Nitrogen (kg ha^{-1}).

Table 3

SPAD Index, Leaf area index (LAI), plant biomass (kg ha^{-1}), shoot nitrogen concentration (%) and nitrogen accumulation (kg ha^{-1}) at different soybean development stages, initial and final plant density (thousand plants ha^{-1}) and grain yield (kg ha^{-1}) in response to intervals between the desiccation of *Urochloa brizantha* cv. BRS Piatã pasture and soybean sowing, with 300 kg ha^{-1} of N in the pasture (averages with and without N in soybean). Londrina, PR, 2017/18 growing season

Variables	Intervals between pasture desiccation and soybean sowing (days)					Fitted equations	R^2	CV (%)
	1	15	30	45	60			
Init. dens. (× 1000 ha^{-1})	409	452	474	490	474	$\hat{Y}$ = 425.76** +1.127** x	0.71	7.3
Fin. dens. (× 1000 ha^{-1})	376	405	435	451	439	$\hat{Y}$ = 386.26** + 1.157** x	0.79	7.6
Grain yield (kg ha^{-1})	4702	4793	4712	4755	4657	ns		5.8
Stage V3								
SPAD	30	30.1	31.2	29.8	31.7	ns		7.7
LAI	0.92	0.87	1.01	1.05	0.98	ns		20.0
SDM (kg ha^{-1})	236	279	342	330	343	$\hat{Y}$ = 252.17** + 1.78**x	0.79	17.4
N concentration (%)	3.34	3.11	3.27	3.12	3.29	Ns		10.0
N accumulation (kg ha^{-1})	7.97	8.7	11.1	10.4	11.3	$\hat{Y}$ = 8.19** + 0.056**x	0.79	20.4
Stage V6								
SPAD	35.1	34.4	35.3	34.2	34.1	ns		4.1
LAI	2.28	2.55	2.91	3.56	3.1	$\hat{Y}$ = 2.340** + 0.0179**x	0.72	15.0
SDM (kg ha^{-1})	847	1078	1223	1160	1115	$\hat{Y}$ = 835.75** + 19.54* x - 0.252** x2	0.97	18.2
N concentration (%)	2.91	2.86	2.9	2.97	2.99	ns		7.9
N accumulation (kg ha^{-1})	25	30.9	35.8	34.4	33	$\hat{Y}$ = 27.882** + 0.1304** x	0.54	18.6
Stage R2								
SPAD	40.3	40.5	39.4	40.5	40.2	ns		3.9
LAI	5.2	5.6	6.1	6.2	6.1	$\hat{Y}$ = 5.352** +0.016** x	0.83	6.6
SDM (kg ha^{-1})	3635	3702	4044	3971	4027	ns		14.6
N concentration (%)	2.89	2.79	2.86	2.75	2.85	ns		13.7
N accumulation (kg ha^{-1})	106.1	103.5	114.8	109.1	114.9	ns		20.9
Stage R4								
SPAD	44.8	44.7	44.3	44.8	43.2	ns		3.6
LAI	6.69	6.85	7.03	7.08	7.22	$\hat{Y}$ = 6.71** + 0.0087** x	0.98	5.6
SDM (kg ha^{-1})	5347	5861	6061	6145	6120	$\hat{Y}$ = 5536.1** + 12.27* x	0.76	13.5
N concentration (%)	3.13	2.84	2.77	3.27	3	ns		15.2
N accumulation (kg ha^{-1})	165.5	167.2	168.3	199.6	183.4	ns		18.2

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Stage R5.4							
SPAD	48	48.6	47	48	45.3	ns	4.3
LAI	6.4	6.35	6.16	6.09	6.13	ns	7.5
SDM (kg ha^{-1})	8738	8853	8777	8472	8662	ns	14.6
N concentration (%)	2.64	2.61	2.63	2.58	2.49	ns	14.6
N accumulation (kg ha^{-1})	229.9	231	231.6	224.9	215.8	ns	20.6

ns, not significant, ** and *, significant at 1% and 5% probability, respectively, by the F test. Init. dens.: initial density (×1000 plants ha^{-1}); Fin. dens.: final density (thousand plants ha^{-1}); SPAD: Soil Plant Analysis Development; LAI: Leaf area index; SDM: Shoot dry matter (kg ha^{-1}); Shoot nitrogen concentration (%); Accumulation of Nitrogen (kg ha^{-1}).

In a study of Monquero et al. (2010), desiccation of *Urochloa ruziziensis, Pennisetum americanum* and *Brachiaria brizantha* at 14, 21, and 28 days before soybean sowing (DBS) resulted in higher soybean plant density than at 2 and 7 DBS. This shows that cover crops that are not completely desiccated can negatively affect soybean germination and emergence. In addition, if pasture is desiccated less than 10 days before soybean sowing, it may be difficult to cut the straw, and, consequently, the contact of the seeds with the soil is impaired by the residues (Ricce et al., 2011; Franchini et al., 2014). Early desiccation was more adequate for deposition of seeds and fertilizer, favoring plant emergence, as also confirmed by Balbinot et al. (2016a).

In the experiment without N application to pasture, desiccation times affected plant biomass and N accumulation in soybean shoots at stages V3 and V6 (Table 1). The desiccation of pasture as close as soybean sowing reduced plant biomass and, consequently, N accumulation in shoots. According to Franchini et al. (2015a), the desiccation of *U. ruziziensis* between 8 and 35 days before soybean also had no effect on soybean shoot N concentration. This was probably due to the effect of N dilution in the biomass, i.e., the increase in N availability can increase biomass production without increasing the tissue concentration of this nutrient (Foloni et al., 2016).

In the experiment in which pasture received 150 kg ha^{-1} of N, desiccation times affected N accumulation in soybean shoots at stages V3 and V6 (Table 2). There was also effect of pasture desiccation on LAI and plant biomass at V6. These variables were also increased with the early pasture desiccation. Probably, a longer interval between pasture desiccation and soybean sowing may have enabled greater nutrient release from straw mineralization during early soybean stages, resulting in increased plant growth (Franchini et al., 2014).

For the experiment fertilized with 300 kg ha^{-1} of N, desiccation times affected plant dry mass and N accumulation in soybean shoots at stages V3 and V6 and LAI only at stage V6 (Table 3). In the other two experiments (Tables 1 and 2), earlier desiccation increased plant shoot biomass, N accumulation and

LAI. In a study of Balbinot et al. (2016a), earlier desiccation of *U. ruziziensis* increased soybean shoot biomass and N accumulation up to 30 days after plant emergence, whereas the shoot N concentration did not change at 12 and 30 days after emergence. However, greater N accumulation was observed after earlier desiccation, due to greater biomass accumulation at the beginning of the crop cycle.

At R2 stage in the experiments without N fertilization, and fertilized with 300 kg ha^{-1} of N, only LAI differed statistically in response to desiccation times, when earlier desiccation increased LAI compared with desiccations closer to sowing. For the experiment with 150 kg ha^{-1} of N, there was effect of desiccation time at R2 stage on LAI, plant biomass, and shoot N accumulation, in which earlier desiccation of pasture increased these variables. However, under late desiccation the values of LAI at R2 stage (>5.2) were enough to reach high grain yields (Tagliapietra et al., 2018). Under similar conditions to this study, Balbinot et al. (2016a) observed that earlier desiccation of *U. ruziziensis* pasture intensified soybean growth at the early developmental stages, but did not influence soybean biomass, shoot N concentration, and N accumulation at 60 days after emergence. Evaluating desiccation intervals of *U. ruziziensis* between 8 and 35 days before soybean sowing, Franchini et al. (2015a) observed greater soybean biomass accumulation at 12 and 30 days after emergence with larger intervals between desiccation and soybean sowing, indicating better conditions for initial plant growth. From 59 days after soybean emergence onwards, however, desiccation times had no effect on soybean growth.

In all experiments, there was no effect of desiccation time on the SPAD Index, LAI, plant biomass, N concentration, and shoot N accumulation at R5.4 stage. The same was observed at R4 in the experiment without N application and with 150 kg ha^{-1} of N. For the experiment treated with 300 kg ha^{-1} of N, there was effect of desiccation times on LAI and plant dry mass at R4, when earlier desiccation before sowing increased these variables. Thus, these effects on soybean growth and N accumulation disappeared with later on the crop cycle, corroborating previous results from Franchini et al. (2015a), Balbinot et al. (2016b).

Although early desiccation promotes better plant establishment than desiccation closer to soybean sowing, there was no effect on grain yield (Tables 1, 2 and 3). Soybean grain yield was probably not affected by the high phenotypic plasticity of the soybean crop (Balbinot et al., 2018). For *U. brizantha,* Nascente and Crusciol (2012) observed that larger periods between desiccation and soybean sowing increased soybean yield. According to Debiasi and Franchini (2012), desiccation intervals shorter than 44 days decreased soybean yield if the residual biomass of *U. brizantha* exceeded 9 t ha^{-1}. In addition, Balbinot et al. (2016a) found no effects on soybean grain yield among desiccation times of *U. ruziziensis* at 35, 28, 20, and 8 days before soybean sowing, with or without supplemental 30 kg ha^{-1} of N at soybean sowing.

There was no effect of soybean N fertilization on initial and final plant density in the three experiments (Tables 4, 5 and 6). Effect of soybean N fertilization in the experiment without N application in the pasture was observed on SPAD index and LAI at V3, and on soybean shoot N concentration at V6, with increase due to N application (Table 4). In the experiment in which pasture received 150 kg ha^{-1} of N, soybean N fertilization increased LAI, plant biomass, and N accumulation in soybean shoots at stages V3 and V6, as N application favored plant growth (Table 5). In the experiment with 300 kg ha^{-1} in the pasture, N fertilization increased SPAD index and LAI at stages V3 and V6 (Table 6). According to Werner et al. (2016), application of 45 kg ha^{-1} of N also increased leaf and total shoot dry mass at V5, whereas the SPAD index at R5.3 was not affected.

Table 4

SPAD Index, Leaf area index (LAI), plant biomass (kg ha^{-1}), shoot nitrogen concentration (%) and nitrogen accumulation (kg ha^{-1}) at different soybean developmental stages, initial and final plant density (thousand plants ha^{-1}) and grain yield (kg ha^{-1}) in response to two levels of nitrogen fertilization (0 or 30 kg ha^{-1}), without N applied to the *Urochloa brizantha* pasture (averages of five intervals between pasture desiccation and soybean sowing). Londrina, PR, 2017/18 growing season

Variables	Nitrogen fertilization		CV (%)
	0 kg ha^{-1}	30 kg ha^{-1}	
Initial density (× 1000 plants ha^{-1})	462 a[1]	466 a	4.8
Final density (× 1000 plants ha^{-1})	427 a	436 a	6.4
Grain yield (kg ha^{-1})	5043 a	4782 a	7.0
	Stage V3		
SPAD	28.7 b	31.1 a	10.4
LAI	1.05 b	1.26 a	18.3
Dry matter (kg ha^{-1})	259.8 a	287.4 a	19.0
Shoot N concentration (%)	3.3 a	3.3 a	8.2
N accumulation (kg ha^{-1})	8.6 a	9.5 a	21.4
	Stage V6		
SPAD	34.3 a	34.6 a	6.2
LAI	2.06 a	2.28 a	18.9
Drymatter (kg ha^{-1})	1002 a	1050 a	17.0
Shoot N concentration (%)	3.1 b	3.3 a	6.3
N accumulation (kg ha^{-1})	31.6 a	34.5 a	19.1
	Stage R2		
SPAD	38.9 a	39.5 a	4.9
LAI	6.2 a	6.4 a	9.3
Dry matter (kg ha^{-1})	3594 a	3879 a	16.2
Shoot N concentration (%)	2.6 a	2.6 a	12.8
N accumulation (kg ha^{-1})	95.8 a	102.8 a	23.3

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continuation...

	Stage R4		
SPAD	44.3 a	44.9 a	4.4
LAI	7.2 a	7.2 a	5.5
Dry matter (kg ha^{-1})	5890 a	6246 a	13.6
Shoot N concentration (%)	3.1 a	3.0 a	13.2
N accumulation (kg ha^{-1})	182.0 a	187.0 a	21.6
	Stage R5.4		
SPAD	48.5 a	49.0 a	3.3
LAI	6.3 a	6.4 a	6.3
Dry matter (kg ha^{-1})	8119 a	8809 a	14.3
Shoot N concentration (%)	2.7 a	2.8 a	13.8
N accumulation (kg ha^{-1})	220.3 a	237.0 a	26.9

[1] Means sharing the same lowercase letter in the line are statistically equal by the F test.

Table 5

SPAD Index, Leaf area index (LAI), plant biomass (kg ha^{-1}), shoot nitrogen concentration (%) and nitrogen accumulation (kg ha^{-1}) at different soybean development stages, initial and final plant density (thousand plants ha^{-1}) and grain yield (kg ha^{-1}) in response to two levels of nitrogen fertilization, with 150 kg ha^{-1} of N applied to the *Urochloa brizantha* pasture (averages of five intervals between pasture desiccation and soybean sowing). Londrina, PR, 2017/18 growing season

Variables	Nitrogen fertilization		CV (%)
	0 kg ha^{-1}	30 kg ha^{-1}	
Initial density (× 1000 plants ha^{-1})	452 a[1]	468 a	8.0
Final density (× 1000 plants ha^{-1})	420 a	423 a	7.7
Grain yield (kg ha^{-1})	4862 a	4728 a	4.5
	Stage V3		
SPAD	29.3 a	30.4 a	8.5
LAI	0.87 b	0.99 a	20.1
Dry matter (kg ha^{-1})	294.8 b	344.5 a	17.8
Shoot N concentration (%)	3.2 a	3.3 a	8.1
N accumulation (kg ha^{-1})	9.4 b	11.2 a	20.4
	Stage V6		
SPAD	34.7 a	35.0 a	5.0
LAI	2.41 b	2.73 a	19.3
Drymatter (kg ha^{-1})	963.9 b	1091.5 a	20.6
Shoot N concentration (%)	2.9 a	2.9 a	8.7
N accumulation (kg ha^{-1})	27.7 b	32.3 a	24.3

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Stage R2			
SPAD	40.6 a	40.4 a	3.7
LAI	6.0 a	6.2 a	8.6
Dry matter (kg ha^{-1})	3797.8 a	4041.6 a	19.8
Shoot N concentration (%)	2.8 a	2.9 a	14.8
N accumulation (kg ha^{-1})	105.6 a	117.9 a	22.1
Stage R4			
SPAD	44.7 a	44.2 a	3.7
LAI	7.5 a	7.4 a	5.7
Dry matter (kg ha^{-1})	5359 a	5934 a	14.8
Shoot N concentration (%)	3.0 a	3.0 a	13.3
N accumulation (kg ha^{-1})	158.1 a	176.2 a	18.7
Stage R5.4			
SPAD	48.4 a	47.7 a	4.9
LAI	5.9 a	5.6 a	8.0
Dry matter (kg ha^{-1})	8222 a	8778 a	13.3
Shoot N concentration (%)	2.7 a	2.8 a	11.3
N accumulation (kg ha^{-1})	217.9 a	243.4 a	17.5

[1] Means followed by the same lowercase letter in a row are statistically equal by the F test.

Table 6

SPAD Index, Leaf area index (LAI), plant biomass (kg ha^{-1}), shoot nitrogen concentration (%) and nitrogen accumulation (kg ha^{-1}) at different soybean development stages, initial and final plant density (thousand plants ha^{-1}) and grain yield (kg ha^{-1}) in response to two levels of nitrogen fertilization, with 300 kg ha^{-1} of N applied to the *Urochloa brizantha* pasture (averages of five intervals between pasture desiccation and soybean sowing). Londrina, PR, 2017/18 growing season

Variables	Nitrogen fertilization		CV (%)
	0 kg ha^{-1}	30 kg ha^{-1}	
Initial density (× 1000 plants ha^{-1})	464 a[1]	456 a	7.3
Final density (× 1000 plants ha^{-1})	427 a	415 a	7.6
Grain yield (kg ha^{-1})	4767 a	4680 a	5.8
Stage V3			
SPAD	29.3 b	31.8 a	7.7
LAI	0.93 b	1.03 a	20.0
Dry matter (kg ha^{-1})	305 a	307 a	17.4
Shoot N concentration (%)	3.1 a	3.3 a	10.0
N accumulation (kg ha^{-1})	9.5 a	10.2 a	20.4

continue...

continuation...

	Stage V6		
SPAD	34.2 b	35.0 a	4.1
LAI	2.7 b	3.0 a	15.0
Drymatter (kg ha^{-1})	1063 a	1106 a	18.2
Shoot N concentration (%)	2.9 a	3.0 a	7.9
N accumulation (kg ha^{-1})	30.7 a	33.0 a	18.6
	Stage R2		
SPAD	40.0 a	40.3 a	3.9
LAI	5.8 a	5.8 a	6.6
Dry matter (kg ha^{-1})	3774 a	3977 a	14.6
Shoot N concentration (%)	2.8 a	2.8 a	13.7
N accumulation (kg ha^{-1})	108.2 a	111.2 a	20.9
	Stage R4		
SPAD	44.3 a	44.4 a	3.6
LAI	7.1 a	6.9 a	5.6
Dry matter (kg ha^{-1})	5991 a	5822 a	13.5
Shoot N concentration (%)	3.0 a	3.0 a	15.2
N accumulation (kg ha^{-1})	180.5 a	173.1 a	18.2
	Stage R5.4		
SPAD	47.7 a	47.0 a	4.3
LAI	6.4 a	6.1 a	7.5
Dry matter (kg ha^{-1})	8981 a	8420 a	14.6
Shoot N concentration (%)	2.6 a	2.6 a	14.6
N accumulation (kg ha^{-1})	231.5 a	221.7 a	20.6

[1] Means followed by the same lowercase letter in a row are statistically equal by the F test.

At stages R2, R4, and R5.4 soybean N fertilization did not affect the SPAD index, LAI, plant biomass, N concentration and N accumulation, in the three experiments (Tables 4, 5, and 6). In the non-N-fertilized pasture, N supply to soybean may have been counterbalanced by greater biological N fixation (Balbinot et al., 2016a). In a study of Balbinot et al. (2016b), no significant differences for N concentration and shoot biomass were found either in response to different rates (20 and 45 kg ha^{-1} of N) or N application times (sowing, R1, and R5.2) after two years of *U. brizantha* pasture. In a study of Franchini et al. (2015b), the application of 30 kg ha^{-1} of N at soybean sowing did not change the canopy cover and the final plant stand either. According to studies in different environments, biological N fixation associated with the mineralized N from soil organic matter is sufficient to supply the soybean N requirement, dismissing mineral N fertilization (Hungria & Mendes, 2015).

There was no effect of soybean N fertilization on grain yield in the three experiments (Table 4, 5, and 6). These results strengthen that the correct inoculation with N-fixing bacteria, along the mineral N supplied by the soil, provides enough N for soybean nutrition, dismissing supplemental mineral N fertilization (Franchini et al., 2015a; Werner et al., 2016). In a study of Balbinot et al. (2016b), N fertilization of soybean at different rates (20 or 45 kg ha^{-1} of N) applied at different times (sowing, initial flowering, and initial grain filling), did not increase soybean yield grown for two years after *U. brizantha* pasture, in a sandy soil with high amount of *U. brizantha* residues.

The immobilization of soil N resulting from microbial growth on residues with high C/N ratio, as those from *Urochloa* species (Calonego et al., 2012), has usually been used to justify mineral N fertilization at soybean sowing. However, as observed in this study, soybean development after full flowering, as well as the amount of N accumulated in shoots, were not favored by N application at soybean sowing. Therefore, N fertilization of soybean was unnecessary, even when pasture was not fertilized with N.

Conclusions

Early desiccation of *U. brizantha* cv. BRS Piatã pasture favors the establishment of soybean by increasing plant biomass and N accumulation at the vegetative stages. However, these differences disappear during the grain filling stage, regardless of soybean N fertilization, and does not affect yield.

Soybean N fertilization with 30 kg ha^{-1} of N at sowing intensifies plant growth at the vegetative phase, but this affect disappears after full flowering, with no effect on biomass and grain yield, regardless of the desiccation time of the pasture before soybean sowing.

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