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Biological soil loosening by grasses from genus *Brachiaria* in crop-livestock integration

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ABSTRACT. Soil compaction associated with pastures degradation can decrease animal productivity, forage longevity and compromise environmental sustainability. To confront this serious issue, the loosening potential of forages should be recognized. We evaluated the least limiting water range as indicator of biological loosening potential in relation to cultivation of grasses the genus *Brachiaria* in crop-livestock integration. We also evaluated the water availability to soybean crop that succeeded these grasses. Our studies were performed in two stages. In the first stage, we divided 32 plots into four randomized blocks in which we cultivated corn combined with following treatments: 1 - *Brachiaria brizantha* cultivar Marandu; 2 - Xaraes; 3 - Piata; 4 - MG4; 5 - *B. decumbens*; 6 - *B. ruziziensis*; 7 - Invasive plants; and 8 - uncovered soil. We evaluated soil, to quantify the biological soil loosening, and also forages. In the second stage, we cultivated soybean and added: 9 - conventional tillage as a control treatment, increasing number of plots to 36. Our results suggest that it is possible to cultivate *Brachiaria brizantha* or *Brachiaria decumbens* as management strategy to aid edaphic recovery. Xaraes and Piata grasses provide greater soil loosening while increasing water availability to successive soybean crop.

Keywords: pasture recovery, soil structural quality, least limiting water range.

Descompactação biológica do solo por capins do gênero *Brachiaria* em Integração Agricultura-Pecuária

RESUMO. A compactação do solo associada à degradação das pastagens reduz a produtividade animal e da forrageira e compromete a sustentabilidade ambiental. No enfrentamento desta grave questão, faz-se necessário o conhecimento do potencial de descompactação do solo promovido por algumas forrageiras. Este trabalho objetivou avaliar o intervalo hídrico ótimo como indicador da descompactação biológica do solo decorrente do cultivo de capins do gênero *Brachiaria* em integração agricultura-pecuária, bem como a disponibilidade hídrica à soja cultivada em sucessão. O estudo foi realizado em duas etapas. Inicialmente foram implantadas 32 parcelas em quatro blocos casualizados, cultivando milho consorciado com os seguintes com os tratamentos: 1 - *Brachiaria brizantha* cultivares Marandu, 2 - Xaraes, 3 - Piata e 4 - MG4, 5 - *B. decumbens*, 6 - *B. ruziziensis*, 7 - Plantas invasoras e, 8 - Solo descoberto. Foi avaliado o solo para quantificação da descompactação biológica, e também as forragens. Na segunda etapa cultivou-se soja, acrescentando-se como tratamento testemunha: 9 - plantio convencional, totalizando 36 parcelas. Os resultados sugerem o cultivo de *B. brizantha* ou *B. decumbens* na recuperação edáfica. Destacam-se os capins Xaraes e Piata que proporcionaram maior descompactação do solo e, consequentemente, aumento da disponibilidade hídrica à soja em sucessão.

Palavras-chave: recuperação de pastagens, qualidade estrutural do solo, intervalo hídrico ótimo.

Introduction

The extensive and continuous grazing activity of the Brazilian livestock industry is the leading cause of pasture degradation. Physical degradation of the soil occurs because of compaction caused by animal trampling and machinery traffic under unfavorable conditions with regards to soil water content (LANZANOVA et al., 2007). This degradation results in an accelerated decrease in pasture productivity and longevity (IMHOFF et al., 2000).

Pasture recovery and improved soil physical characteristics are achieved by reversing this process of degradation. By combining techniques to amortize operating costs and increase sustainability, as with Crop-Livestock Integration (CLI) (COSTA et al., 2010), the chemical, physical and biological soil properties can be improved. In addition, no-tillage systems can enable straw formation (PETTER et al., 2011).

Although many farmers are reluctant to adopt this system because of the possible negative effects of animal trampling (BAVOSO et al., 2010; FLORES et al., 2007), the use of forage plants provides an alternative for soil physical recovery. Unlike tillage performed by farm equipment, tillage by plants occurs uniformly throughout the soil layers by roots and forms biopores favorable to root growth, water infiltration and gas diffusion (SEVERIANO et al., 2010). Consequently, tillage plants mitigates deleterious effects and provides a favorable environment for succession crops (CHIODEROLI et al., 2012; GUIMARÃES et al., 2009).

Although some plants are known to penetrate compacted soil layers (LIMA et al., 2012), little is known about the tillage potential of Brachiaria (Trin.) Griseb. spp. (syn. Urochloa P. Beauv. spp.), especially its new cultivars. This knowledge is relevant when considering the significant area occupied by the genus (approximately 85% of the pastures cultivated in Brazil) because of both its nutritional value and its high stress resistance (ARROYAVE et al., 2011) and its increasing adoption into integrated production systems in tropical regions (PACHECO et al., 2008), given its feasibility for intercropping with annual crops (CALONEGO et al., 2011).

The aim of the present study was to evaluate the least limiting water range of the soil as an indicator of both its biological soil loosening potential for cultivating grass of the genus *Brachiaria* in CLI and its water availability for a successor soybean crop.

Material and methods

Our study was conducted in the experimental area of the Federal Institute of Education, Science and Technology Goiano, Rio Verde Câmpus, in the municipality of Rio Verde-Goiás State, 17° 48' 34.25" S and 50° 54' 05.36" W, at an altitude of 731 m and in an area covered with Dystroferric Red Latosol (EMBRAPA, 2006). A chemical and physical characterization of the soil is presented in Table 1.

According to Köppen's classification, the climate is megathermal or humid tropical (Aw) of the tropical savanna subtype, with dry winters and rainy summers. The average annual temperature in the region is 25°C, and the average annual rainfall is approximately 1,600 mm, with the maximum precipitation occurring in January and the minimum occurring in June, July and August (< 50 mm month^{-1}).

A 2,016 m^2 area was planted with corn (*Zea mays*) on November 19, 2010 and was intended for silage. The spacing between rows was 0.88 m (population of 55,000 plants ha^{-1}). Fertilization was performed at planting according to soil analysis results (Table 2) with 30 kg ha^{-1} N, 200 kg ha^{-1} P_2O_5, 60 kg ha^{-1} K_2O, 2 kg ha^{-1} B and 0.4 kg ha^{-1} Mo. The following fertilizer sources were used: simple superphosphate, potassium chloride, boric acid and sodium molybdate, following the recommendations of Sousa and Lobato (2004).

After crop emergence, plant thinning was conducted, and 36 plots of 5.4 × 6 m (32.4 m^2) were defined and randomly arranged into four blocks. Topdressing, which consisted of an application of 30 kg ha^{-1} N from ammonium sulfate and 90 kg ha^{-1} K_2O from potassium chloride, was performed thirty days after the corn emerged. Grass oversowing was performed with 9 kg ha^{-1} pure viable seeds of the genus *Brachiaria* to implement the CLI system according to the following treatments: 1. *Brachiaria brizantha* cv. Marandu; 2. *Brachiaria brizantha* cv. Xaraes; 3. *Brachiaria brizantha* cv. Piata; 4. *Brachiaria brizantha* cv. MG4; 5. *Brachiaria decumbens* and, 6. *Brachiaria ruziziensis*.

For comparison, the following control treatments were adopted: 1. mechanical recovery by tillage with subsoiling and delumping by rotary hoe (conventional tillage); 2. fallow soil in the absence of plant coverage; and 3. plant community (invasive plants) in terms of density and diversity predominated by a canopy of dicotyledonous plants of the following species: *Amaranthus spinosus* L. (caruru-de-espinho), *Nicandra physalodes* (L.) Gaertn. (joá-de-capote), *Crotalaria incana* L. (xique-xique), *Sida spinosa* L. (guanxuma), *Waltheria indica* L. (malva-veludo), (L.), *Conysa canadensis* (L.) Cronquist (buva), *Spermacoce latifolia* Aubl. (erva-quente), *Ageratum conyzoides* L. (mentrasto), *Stellaria media* (L.) Vill. (erva-de-passarinho). Monocotyledons, which were present to a lesser extent, were identified as follows: *Digitaria insularis* (L.) Fedde (capim-amargoso), *Eleosine indica* (L.) Gaertn., (capim-pé-de-galinha) and *Commelina benghalensis* L. (trapoeraba).

Table 1. Physical and chemical characterization of the Dystroferric Red Latosol used to cultivate crop-livestock integration systems, in the municipality of Rio Verde, Goiás State.

Depth	Pd	Bd	Particle Size							Sulfuric attack			Ki	Kr
			VCS	CS	MS	FS	VFS	Silt	Clay	SiO_2	Al_2O_3	Fe_2O_3		
(cm)	(kg dm^{-3})		---------------------------- (g kg^{-1}) ------------------------------											
0–20	2.8	1.2	1	15	154	141	53	195	441	41	204	204	0.34	0.21

Pd: Particle density; Bd: Bulk density; VCS: very coarse sand; CS: coarse sand; MS: medium sand; FS: fine sand; VFS: very fine sand; Ki: molecular ratio (SiO_2/Al_2O_3); Kr: molecular ratio $SiO_2/(Al_2O_3 + Fe_2O_3)$.

Corn intended for silage production was mechanically harvested 90 days after sowing on February 17, 2011, with the dry matter content ranging from 30 to 35%. The development of *Brachiaria* grasses was subsequently monitored for 250 days during dry mass production, which varied with climatic seasonality.

We collected samples from areas measuring 1 m^2 to evaluate the forage by randomly placing a square within each plot and cutting 20 cm of height, the product of which was prepared and packaged for subsequent studies. The cuts were performed on 03/21/2011 (1st cut), 05/11/2011 (2nd cut), 07/04/2011 (3rd cut), 09/12/2011 (4th cut), 10/24/2011 (5th cut) and 11/25/2011 (6th cut).

Forage management was preceded by topdressing during the rainy season with 50 kg ha^{-1} N and 25 kg ha^{-1} K_2O applied in the form of urea and potassium chloride, respectively. After evaluation, a standardization cut was performed throughout the experimental area, and the resulting residue was removed.

After the mechanized collection of corn silage and after each forage cutting, we continued the undisturbed sampling of the soil in each plot, randomly sampling layers of 0 to 20 cm using metal rings with a 6.4 cm diameter and 5.0 cm height. After the samples were removed, they were wrapped in PVC film, embedded in paraffin and packaged in styrofoam boxes for transport and storage in the laboratory.

The undisturbed samples were initially saturated and subjected to a matrix potential of - 6 kPa to determine their microporosity and field capacity (EMBRAPA, 2011a; SEVERIANO et al., 2011). The water content of the soil was subsequently adjusted to 0.04 to 0.53 dm^3 dm^{-3}, and the samples were subjected to penetrometer testing according to the method of Tormena et al. (1998) using a MARCONI-MA 933 bench penetrometer equipped with an electronic speed variator and a data logging system.

Then, the samples were dried in an oven at 105°C for 48 hours to determine the bulk density (Bd) according to the method of Embrapa (2011a). The total porosity (TP) was determined by equation 1 as follows:

$$TP = [1 - (Bd/Pd)] \quad (1)$$

in which Pd is the particle density.

The penetration resistance curve (PRC) was obtained by adjusting the penetration resistance (PR) values as a function of the volumetric water content (θ) and Bd using the non-linear model proposed by Busscher (1990) according to equation 2:

$$PR = 0.34\theta^{-0.78} Bd^{5.65}; R^2 = 0.82^{**} \quad (2)$$

The LLWR was determined according to the procedures described by Silva et al. (1994). Either the upper bound of the soil water content retained at the matrix potential of - 6 kPa or the point at which the air-filled porosity (θ_{AP}) was 10% was considered the field capacity (θ_{FC}) (SEVERIANO et al., 2008). The θ_{AP} (GRABLE; SIEMER, 1968) was calculated for each sample using Eq. 3:

$$\theta_{AP} = TP - 0.1 \quad (3)$$

in which TP is the total porosity.

For the lower bound, we considered the water content retained at the matrix potential of - 1,500 kPa the permanent wilting point (θ_{PWP}) (RICHARDS; WEAVER, 1943) and/or the water content corresponding to a penetration resistance of 2.5 MPa (θ_{PR}) (SEVERIANO et al., 2011). These values were used in Equation 2. The LLWR was obtained by adjusting the bounds of soil water content as a function of Bd with upper bound set as the lowest value between θ_{FC} and θ_{AP} and lower bound set as greatest value between θ_{PWP} and θ_{PR}.

A soil sample collected 32 days after the last forage evaluation was cut to assess the current chemical condition of the soil. Then, the grasses were desiccated with a glyphosate herbicide at a dosage of 1,500 g ha^{-1}. The soybean crop (*Glycine max* L. Merril) was then sown at a rate of 400,000 plants ha^{-1} with row spacings of 0.47 m to begin the second portion of the study. Fertilization was then performed according to the results of the soil analysis (Table 2) following the recommendations of Sousa and Lobato (2004).

Table 2. The sorption complex of Dystroferric Red Latosol used to cultivate crop-livestock integration systems during the seeding of *Brachiaria* grasses intercropped with corn (harvested 2010/2011) and soybean (harvested 2011/2012) in the municipality of Rio Verde, Goiás State.(1)

Ca	Mg	Al	H + Al	P	K	V(2)	m(3)	O.M.(4)	pH ($CaCl_2$)
---------- cmolc dm^{-3} ----------				----- mg dm^{-3} -----		----- % -----		g kg^{-1}	
Harvest 2010/2011									
3.2	1.3	0.0	5.6	2.9	104.0	46.6	0.0	27.3	5.2
Harvest 2011/2012									
2.76	1.41	0.03	5.34	2.12	138.33	45.8	0.74	45.49	5.21

(1)20 cm depth; (2)V: base saturation; (2)m: aluminum saturation; (4): O.M.: organic matter. P: determined by Mehlich extraction.

Daily monitoring of the soil water content (θ) was initiated at the time of soybean crop planting and was extended until physiological maturity, which occurred between 12/08/2011 and 03/23/2012 in the 0–20 cm soil layer. Sampling was performed using a Saci, model S-20, semi-automatic soil sampler, and most sampling took place in the morning. The samples were packaged and sent to the laboratory for humidity determination using a gravimetric technique according to Embrapa (2011a).

We established a frequency of θ within the available water amplitude during the soybean cycle (Fwithin) according to Silva and Kay (1997) to evaluate the water availability of biological soil loosening for each system, considering the vegetative and reproductive phases of the soybean crop.

The temperature and rainfall were monitored during the experiment, and the results are shown in Figure 1.

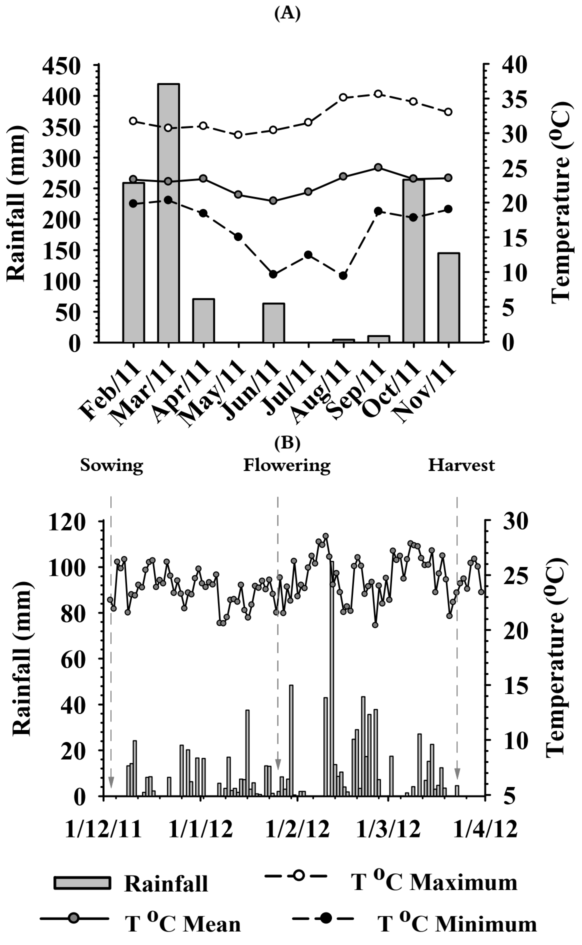

Figure 1. Rainfall (mm) and temperature (°C): (A) monthly and (B) daily during the cultivation of *Brachiaria* grasses and soybean, respectively, in Rio Verde, Goiás State.

The dry matter production of *Brachiaria* grasses was subjected to an analysis of variance using a randomized block design, and, when significant, the mean values were compared using the Tukey test ($p < 0.05$).

Results and discussion

The variation in soil water content with increasing Bd and an emphasis on the LLWR are represented by the shaded area in Figure 2. The water retention increases with increasing Bd for both the field capacity (FC) and the permanent wilting point (PWP), which can be attributed to the change in pore size that arises from soil compaction (OLIVEIRA et al., 2007), especially the reduction in air-filled porosity with increasing density commonly observed in crop-livestock integration systems (SPERA et al., 2004).

If the increase in Bd provided a larger water adsorption surface for the solid particles (BLAINSKI et al., 2009) with a 0.15 $dm^3\ dm^{-3}$ maximum value for the LLWR at a Bd equal to 1.15 kg dm^{-3}, the mechanical impedance caused by the increase in PR prevented the soil water availability from reaching its maximum until it passed the critical density value (Bd_c) of 1.25 kg dm^{-3},at which the LLWR became null. This finding is consistent with the value obtained by Lima et al. (2012). Under these conditions, plant growth was limited at any humidity level, which suggests that the soil was physically degraded (SILVA et al., 1994). The amplitude of LLWR ranged from 0.01 to 0.15 $dm^3\ dm^{-3}$, which is common when latosols of this textural class are subjected to intensive handling (BLAINSKI et al., 2009), especially considering the critical penetration resistance (PR).

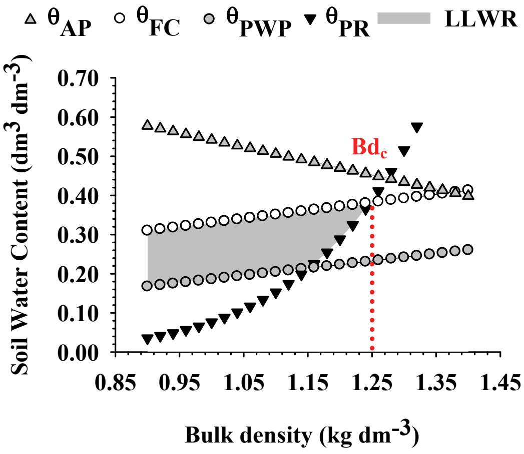

Figure 2. Variation in the soil water content (θ) with an increase in bulk density (Bd) within the critical bounds of the field capacity (θ_{FC}, - 6 kPa), the permanent wilting point (θ_{PWP}, - 1500 kPa), the air-filled porosity at 10% (θ_{AP}) and the soil penetration resistance of 2.5 MPa (θ_{PR}) for the Dystroferric Red Latosol used to cultivate crop-livestock integration systems in Rio Verde, Goiás State. The shaded area represents the least limiting water range (LLWR); Bd_c represents the critical density for plant development.

The decrease in soil porosity did not limit oxygenation (Figure 2) largely due to the development of structural pores in oxidic latosols (REATTO et al., 2007), which in turn favor their excessive aeration. According to Severiano et al. (2011), problems related to soil anoxia occur only when the structure is extremely degraded ($Bd > Bd_c$), or for a relatively short time after intense rainfall when the soil water content is above the field capacity because of the dynamic behavior of water in soil.

According to Blainski et al. (2008), the adoption of crop-livestock integration systems may provide an alternative for reestablishing soil physical quality characteristics. However, species and cultivars may vary in their capacity for biological loosening, as observed in Figure 3. The pastures of the evaluated genus *Brachiaria* exhibited variations in the degree to which the LLWR increased with the greater increase found in *B. brizantha*, particularly the cultivars Xaraes and Piata, whose forage root systems demonstrated high aggressiveness in the disruption of the compacted layers.

These results are in agreement with those of Bonelli et al. (2011), who, while assessing the effects of soil compaction on the yield and morphological characteristics of Piata and Mombaça grasses, found that soil compaction did not influence the production of Piata grass. This finding suggests that this plant has a more aggressive root system related to physiological processes and environmental interactions that can, in turn, enable these cultivars roots to break up the compacted layers.

Flores et al. (2008) reported that Xaraes grass has advantages over other cultivars of *Brachiaria*, such as faster regrowth rate and greater forage production, particularly during dry season. This greater metabolic activity appears to have contributed to loosening efficiency.

Marandu grass and *B. decumbens* exhibited an intermediate potential disruption of the compacted layers, which is consistent with the findings of Chioderoli et al. (2012) who observed higher yields in the successor crop when these two forages were sown at the time of the preceding corn topdressing. Calonego et al. (2011) also demonstrated that when *Brachiaria* was intercropped with corn for two consecutive years, it improved the structural conditions of soil, reducing its penetration resistance and consequently increasing the LLWR.

Moreover, MG4 grass and *B. ruziziensis* behaved as invading weed communities and exhibited limited potential for assisting in physical soil recovery. In addition, mechanical recovery via tillage provided the greatest recovery rates, as represented in Figure 3, which only covers last evaluation period because the tillage was performed while planting the summer crop.

When their nutritional demands were met, the cultivars Xaraes and Piata exhibited high yield potential for both the plant and animal components and adaptability to climatic challenges in production systems at high technological levels (COSTA et al., 2010; FLORES et al., 2008). This capacity mitigated the effects of seasonality in forage production caused by low rainfall and nocturnal temperatures during the fallow period (Figure 1).

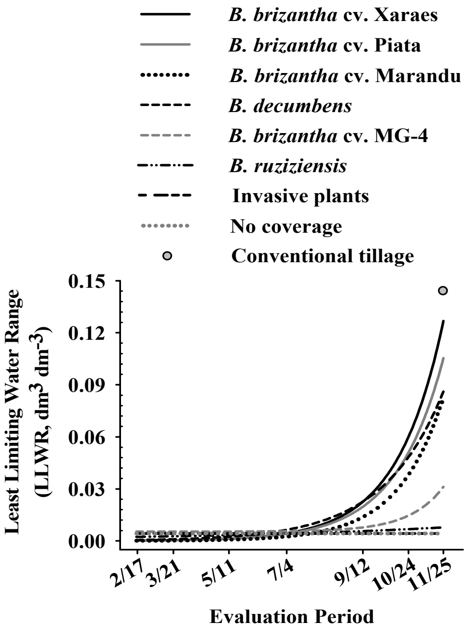

Figure 3. Changes in the least limiting water range (LLWR, dm^3 dm^{-3}) of Dystroferric Red Latosol cultivated in crop-livestock integration systems in Rio Verde, Goiás State after cutting the forage plants (1st evaluation of LLWR was performed upon harvest of previous corn crop).

Thus, even with the drastic reduction in forage production that occurs during the dry season, the highest yields for the cultivars were observed at the third, fourth and fifth grass cuttings compared with cuttings performed in the rainy season (1st, 2nd and 6th), as shown in Table 3. Thus, we suggest that accumulation of organic reserves in the stems of these grasses contributed to greater metabolic activity and regrowth in the resumption of rainy season. Consequently, greater root aggression led to improved biological loosening (Figure 3).

The increase in LLWR from the cultivation of *Brachiaria* grasses mitigated the effects of structural degradation on the soybean successor crop. In addition, Figure 4 suggests that the presence of straw on the soil surface from pasture drying enhanced the water availability to the crop. According to Andrade et al. (2011), water losses via evaporation in no-tillage systems, as compared with conventional tillage, are reduced in proportion to increases in waste, which preserves the water content of the soil by reducing thermal oscillation in the surface layer (BRAIDA et al., 2006; CHIODEROLI et al., 2012).

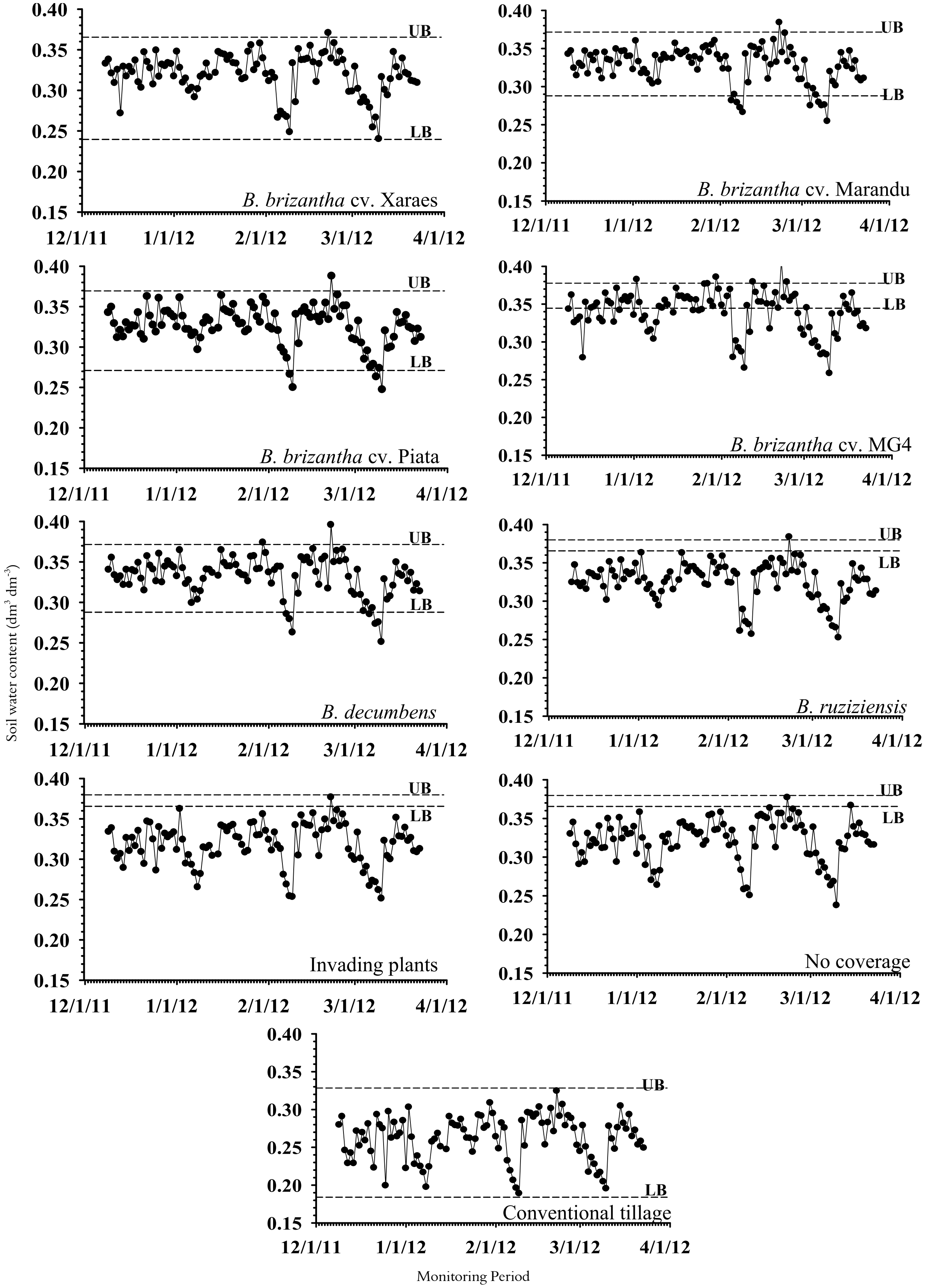

Figure 4. Temporal variation in the soil water content during the soybean crop cycle in relation to the critical bounds of the least limiting water range in a Dystroferric Red Latosol under crop-livestock integration systems. Ub: upper bound (θ_{FC}, - 6 kPa) and Lb: lower bound (θ_{PWP}, - 1500 kPa or $\theta_{PR,}$ 2.5 MPa) of the LLWR for the monitored period.

Table 3. Production of forage grass dry mass of the genus *Brachiaria* in crop-livestock integration systems in Rio Verde, Goiás Stsate.(1)

Grass	Evaluation cut(2)						Total
	First	Second	Third	Fourth	Fifth	Sixth	
	---------- kg ha^{-1} ----------						
B. brizantha cv. Xaraes	5.433Ca	3.947Cb	1.446Ac	858Ad	1.119Ad	4.140Bb	16.943AB
B. brizantha cv. Piata	7.373Aa	3.847CDc	1.255Ad	883Ad	1.053Ad	4.915Ab	19.325A
B. brizantha cv. Marandu	5.302Ca	4.236BCb	976ABc	980Ac	786Ac	3.781BCc	16.060B
B. decumbens	6.136Ba	4.543Bb	1.283Ad	774Ae	1.053Ade	3.699Cc	17.487AB
B. brizantha cv. MG4	4.800Da	5,110Aa	1,268Ac	851Ac	839Ac	3.667Cb	16.536B
B. ruziziensis	5.528Ca	3.434Db	604Bd	286Bd	331Bd	2.217Dc	12.401C

(1)For each grass, mean values are followed by same uppercase letters in columns, and for each evaluation cut, mean values followed by same lower case letters in rows did not differ according to the Tukey's test at 5% probability (average of four replicates). 1st evaluation cut: 03/21/2011; 2nd evaluation cut: 05/11/2011; 3rd evaluation cut: 07/04/2011; 4th evaluation cut: 09/12/2011; 5th evaluation cut: 10/24/2011; 6th evaluation cut: 11/25/2011. (2)Sum of production from the six evaluation cuts.

Temporal variation in the soil water content during the subsequent crop cycle demonstrated that the upper limit of the LLWR had little influence on the water availability (Figure 4), even for systems in which the forages exhibited low tillage potential (Figure 3).

We observed occasional overall anoxia problems when monitoring was conducted following intense rainfall (e.g., 02/22/2012, Figure 1). As previously discussed, soil water content returned to LLWR bounds in subsequent evaluations due to predominance of structural pores and the dynamic behavior of water, as corroborated by Blainski et al. (2009).

The lower bound of the LLWR provided greater water restrictions on all crop-livestock integration systems (Figure 4) in accordance with Leão et al. (2006), which increases the likelihood of stress in the subsequent crop due to mechanical impediment to the root system (KLEIN; CÂMARA, 2007). However, because the soil was tilled by grass cultivation, the frequency with which θ remained within the LLWR bounds increased (Fwithin), as shown in Table 4.

Table 4. Least limiting water range (LLWR), physical soil recovery rate and analysis of θ frequency within the LLWR bounds (Fwithin) during the soybean cycle for crop-livestock integration systems using grasses of the genus *Brachiaria* on a Dystroferric Red Latosol in Rio Verde, Goiás State.

Treatment	LLWR	Physical Recovery	Fwithin (%)	
	dm^3 dm^{-3}	(%)	VP	RP
B. brizantha cv. Xaraes	0.13	88	100.0	98.3
B. brizantha cv. Piata	0.10	69	100.0	89.8
B. brizantha cv. Marandu	0.08	54	100.0	83.1
B. decumbens	0.08	54	100.0	84.7
B. brizantha cv. MG4	0.03	20	56.5	42.4
B. ruziziensis	0.01	7	0.0	0.0
Invading plants	0.01	7	0.0	1.7
No coverage	0.01	7	0.0	3.4
Conventional tillage	0.14	98	100.0	100.0

VP: Vegetative phase; RP: Reproductive phase.

Although conventional tillage systems allow the soil to remain uncovered and may lead to water loss via evaporation unlike a soil with straw on its surface (PERES et al., 2010), the mechanical action of tillage equipment was proven to provide greater physical recovery of the soil (Table 4) and consequently an increase in water available to the successor crop. Conventional tillage was the only treatment in which the PR was not within the lower bound, as corroborated by Serafim et al. (2008). Therefore, an absence of water stress is suggested and quantified by the occurrence of a θ value within the LLWR bounds (Fwithin) in 100% of the monitoring evaluations of this treatment. These data demonstrate that crop dependence on the regular rain distribution occurred during the crop cycle (Figure 1).

Table 4 also indicates that the biological recovery promoted by Xaraes grass resulted in a small reduction in Fwithin during the reproductive phase of the soybean (LLWR$_{100\%VP}$ and LLWR$_{98.3\%RP}$). We observed similar effects in the treatments with piata grass (LLWR$_{1.00\%VP}$ and LLWR$_{89.8\%RP}$), followed by *B. decumbens* (LLWR$_{100\%VP}$ and LLWR$_{84.7\%RP}$) and marandu grass (LLWR$_{100\%VP}$ and LLWR$_{83.1\%RP}$), which is agreement with data obtained by Bonelli et al. (2011), Calonego et al. (2011) and Chioderoli et al. (2012).

These results emphasize that the occurrence of water stress is coincident with the phenological stages of increased water demand by crop. According to Embrapa (2011b), the water requirements of soybean crop increase with plant development and peak at flowering and grain filling. Significant water deficits during these stages can cause physiological changes in the plants and lead to premature leaf and flower fall and pod abortion, which can also reduce grain yield. Because the soil is exposed in intensive agricultural production systems, the choice of grass cultivars as rotation crops is therefore critical as they provide a potentially effective form of biological loosening (Figure 3 and Table 4).

MG4 grass yielded an intermediate response (LLWR$_{56.5\%VP}$ and LLWR$_{42.4\%RP}$). An inferior response was observed in treatments that contained weeds (LLWR$_{nullVP}$ and LLWR$_{1.7\%RP}$) and were no coverage (LLWR$_{nullVP}$ and LLWR$_{3.4\%RP}$), suggesting that physical environment unfavorable to plant growth these conditions (SEVERIANO et al., 2011).

The species *B. ruziziensis* has been widely used as a cover crop for no-tillage systems in the Cerrados region because of its ease of desiccation during the formation of straw with its rapid death and clump reduced, which favor mechanized sowing. Moreover, the use of *B. ruziziensis* in intensive production systems is limited when the low potential for physical soil recovery is considered (LLWR = 0.01 dm^3 dm^{-3}, establishing an Fwithin of 0.0 and 0.0% for the vegetative and reproductive phases, respectively, as shown in Table 4).

We emphasize that the choice of tillage plants can be part of a management strategy for the recovery of soil structural quality in crop-livestock integration systems, in contrast with the mechanical recovery promoted by conventional tillage. Plant-based tillage can be used in addition to diversifying and verticalizing production, minimizing costs, diluting risks and aggregating the value of agricultural products. Plant-based tillage is also a strategy for environmental preservation because it is a low-carbon agricultural model.

Conclusion

Our results evidence that led to the following observations:

- The cultivation of *Brachiaria brizantha* or *Brachiaria decumbens* can be used as a management strategy in the edaphic recovery of crop-livestock integration systems; and
- The Xaraes and Piata grasses provided greater biological loosening and consequently increased water availability for the successor soybean crop.

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