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Maize and soybeans production in integrated system under no-tillage with different pasture combinations and animal categories[1]

Produção de milho e soja em sistema integrado sob plantio direto com diferentes combinações de pastos e categorias animais

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ABSTRACT - The adoption of no-till system (NTS) combined with crop-livestock integration (CLI) has been a strategy promoted in Brazil, aiming to maximize areas yield and increase agribusiness profitability. This study aimed to evaluate grains yield and phytotechnical attributes from maize and soybean culture by CLI system under NTS after winter annual pure and diversified pastures with the absence or presence of grazing animals. The experiment was installed in Castro (Paraná State, Brazil) on in a dystrophic Humic Rhodic Hapludox with a clay texture, using experimental design of randomized complete blocks in 4 x 2 factorial scheme with three replications. Treatments included four pasture combinations (diversified or pure) and animal categories (light and heavy) subjected or not to grazing animals during the winter. During 2008/09 and 2009/10 summers, the area was cultivated with soybeans and maize, respectively, with yield assessment of grains and phytotechnical attributes. Treatments did not alter the yield and weight of a thousand seeds (WTS) of soybeans. In maize culture, the grazing animal during the winter increased the plant population and grains yield, but gave slight decrease in WTS. Pasture combinations (diversified or pure) and animal categories (light and heavy) did not interfere in soybean culture, but benefited the maize crop.

Key words: *Zea mays* L. *Glycine max* (L.) Merrill. Crop-livestock system integration. Conservationist agriculture.

RESUMO - A adoção do sistema de plantio direto (SPD), aliado a integração lavoura pecuária (ILP) tem sido uma estratégia fomentada no Brasil, visando maximizar o rendimento das áreas e aumentar a lucratividade do agronegócio. O objetivo deste trabalho foi avaliar o rendimento de grãos e atributos fitotécnicos nas culturas de milho e soja, em sistema de ILP, sob plantio direto, após o cultivo de pastos anuais de inverno, puros ou diversificados, com ausência ou presença de animais em pastejo de diferentes categorias. O experimento foi instalado no município de Castro (PR), em um Latossolo Bruno distrófico textura argilosa, empregando-se delineamento experimental de blocos completos aleatorizados, em esquema fatorial 4 x 2, com três repetições. Os tratamentos incluíram quatro combinações de pastagens (diversificadas ou puras) e categorias de animais (leves e pesados), submetidas ou não ao pastejo animal durante o inverno. Durante o verão de 2008/09 e 2009/10 a área foi cultivada com soja e milho, respectivamente, e procederam-se avaliações de rendimento de grãos e atributos fitotécnicos. Os tratamentos não alteraram o rendimento e o peso de mil sementes (PMS) de soja. Na cultura do milho, o pastejo animal, durante o inverno, aumentou a população de plantas e o rendimento de grãos, mas proporcionou ligeira diminuição no PMS. As combinações de pastos (diversificados ou puros) e categorias de animais (leves e pesados) não interferiram na cultura da soja, mas beneficiaram a cultura do milho.

Palavras-chave: *Zea mays* L. *Glycine max* (L.) Merrill. Integração lavoura-pecuária. Agricultura conservacionista.

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INTRODUCTION

Agribusiness represents an average 25% of Brazilian GDP - Gross Domestic Product (CENTRO DE ESTUDOS AVANÇADOS EM ECONOMIA APLICADA, 2008) and particularly in the region of Campos Gerais, where agricultural production accounts for 10.4% of Gross Value of crop-livestock Production (GVP) of Paraná State (VALOR …, 2008). However, not all agricultural activities and livestock are managed under an integrated and sustainable way. In 2009/2010 summers, 702,000 ha in the region of Campos Gerais were cultivated with soybean [*Glycine max* (L.) Merrill], maize (*Zea mays* L.), and beans (*Phaseolus vulgaris* L). In winter, only 27% of this area was cultivated with grains production (SECREATARIA DA AGRICULTURA E DO ABASTECIMENTO DO PARANÁ, 2010). The remaining area (512,460 ha) was left fallow or was planted with ground cover plants predominantly black oats (*Avena strigosa* Schreb) and annual ryegrass (*Lollium multiflorum* L.), which have high forage potential (MACARI *et al*., 2006).

Hence the importance of crop-livestock integration (CLI) in no-tillage system (NTS), which makes it an important alternative to occupy these areas and increase the sustainability of rural productions, providing: (i) biological and economic advantages (BALBINOT JUNIOR *et al*., 2009); (ii) enhancing and maximizing the exploitation land use (LANDERS, 2007); (iii) increasing yield and risks reduction (FONTANELI *et al*., 2006); (iv) carbon sequestration and reducing the emission of greenhouse gases - global warming effect - (CERRI *et al*., 2010). In Brazil southern, there is great potential for beef production in pure or mixed winter pastures (ASSMANN *et al*., 2004; NICOLOSO; LANZANOVA; LOVAZO, 2006). Also, there is high potential for milk production in annual winter pastures (black oats and annual ryegrass) associated with the decreased amount of concentrated supplementation (SILVA *et al*., 2008). Additionally, the appropriate animal grazing during the winter, CLI under NTS can result in: (i) increase in nutrients cycling particularly nitrogen and maize yield (ASSMANN *et al*., 2003); (ii) not changing both nodulation (FONTANELI *et al*., 2000) and soybean yield (NICOLOSO; LANZANOVA; LOVAZO, 2006). However, issues surrounding the soil-plant-animal system are not yet well understood, implying for more interdisciplinary research with different forages species and agricultural crops, animal categories, and pasture systems (BALBINOT JUNIOR *et al*., 2009).

In this experiment with grazing of dairy heifers on a large scale, the hypothesis was tested about the presence of animals in appropriate charges, which does not affect both the production of forage biomass in winter and subsequent crop yields, grains producers. This study aimed to evaluate the grain yield and phytotechnical attributes in soybean and maize crops in CLI system under no-tillage, after winter annual pure and diversified pastures with the absence or presence of grazing animals.

MATERIAL AND METHODS

Experiment localization, area history, and edafoclimatic characterization

This experiment was performed at the Heifer Production Unit of the Castrolanda Agricultural Cooperative (latitude: 24°47’28” S, longitude: 50°00’25” W, and average altitude: 1,005 m) in the municipality of Castro (Paraná State, Brazil). The experimental area is located in the physiographic region called *Primeiro Planalto Paranaense* with a climate of Cfb type humid subtropical in the Köppen classification; this region has mild summers and winters with severe and frequent freezing, and it does not have a defined dry season (INSTITUTO AGRONÔMICO DO PARANÁ, 1994). In the Table 1 is presented the temperature and precipitation values during the experimental period (from September/2008 to April/2010). According to Empresa Brasileira de Pesquisa Agropecuparia/Fundação ABC (2001), the predominant soil in the experimental area is dystrophic Humic Rhodic Hapludox with a clay texture, with a gently undulating relief (2 to 4%), and sand, clay, and silt concentrations of 384, 439, and 177 g kg^{-1}, respectively.

The area for experiment has been managed in NTS since 2003, cultivating maize or soybeans for grains production in the spring/summer, and annual ryegrass and/or black oats for grazing animals (dairy heifers) during the fall/winter. In maize crops, 300 kg ha^{-1} of 10-20-20 (N-P_2O_5-K_2O) formulated were used at the time of sowing and 400 kg ha^{-1} of 22-00-21 formulated as top dressing. In soybean crops, 300 kg ha^{-1} of 00-20-20 formulated were used at the time of sowing and 150 kg ha^{-1} of potassium chloride (60% K_2O) as top dressing.

In addition, 50 m^3 ha^{-1} $year^{-1}$ of pig manure was applied prior to 2008, and in July 2009, surface application, without incorporation, of dolomitic limestone began at a dosage of 3.0 Mg ha^{-1} with an effective calcium carbonate equivalent of the lime (ECCE), calcium oxide (CaO), and magnesium oxide (MgO) of 898, 286, and 195g kg^{-1}, respectively. The area main chemical attributes at the time of experiment deployment are shown in Table 2.

Table 1 - Rainfall monthly mean, maximum temperature (maxT), minimum temperature (minT), and medium temperature (medT) during the experiment (September/2008 to April/2010) in the municipality of Castro (Paraná State, Brazil)

Attribute/Month	Spt	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Medium
	2008/2009								
Rainfall, mm	48.5	177.0	164.9	76.6	248.5	215.0	77.8	21.1	128.7
maxT, ºC	20.3	22.1	23.6	26.1	24.3	26.6	27.0	24.8	24.4
minT, ºC	9.7	14.1	14.3	13.9	15.9	17.0	15.9	12.9	14.2
medT, ºC	14.4	17.5	18.0	19.2	19.3	20.8	20.6	17.9	18.5
	2009/2010								
Rainfall, mm	222.7	181.2	115.7	124.3	191.4	110.5	122.2	108.8	147.1
maxT, ºC	21.8	23.4	28.0	26.7	26.4	27.4	26.2	23.5	25.4
minT, ºC	12.8	13.7	17.8	16.9	17.7	18.1	16.5	13.2	15.8
medT, ºC	16.9	18.1	22.8	21.5	22.1	22.7	21.3	18.4	20.5

Source: ABC Foundation's weather station, located approximately 5.0 km far from the experiment localization

Table 2 - Soil chemical attributes at the time of the experiment

Block	Layer	pH ($CaCl_2$)	H+Al	Al	Ca	Mg	K	P[(1)]	TOC[(2)]	TN[(3)]	V[(4)]
	cm		------------------- $mmol_c$ dm^{-3} -------------------					mg dm^{-3}	------ g dm^{-3} ------		%
1	0-10	5.1	75	0	58	16	6	52.3	36.8	2.3	51
	10-20	4.8	86	1	51	15	7	131.9	38.7	1.8	46
2	0-10	5.0	78	0	53	20	6	72.9	38.7	2.6	50
	10-20	4.8	95	2	43	16	6	101.3	35.4	1.9	41
3	0-10	5.2	76	0	62	16	7	76.7	36.8	2.4	53
	10-20	4.8	97	2	53	15	8	172.2	32.1	2.2	41

(1) Available P by Mehlich-1 solution, (2) TOC: total organic carbon, (3) TN: total nitrogen, (4) V: bases saturation

Experimental design, treatments, and experiment management

The experiment began at the pasture cycle of autumn-winter, in June/2008. The experimental design was completely randomized blocks in 4 x 2 factorial scheme with three replications. Treatments included four combinations of pastures and animals categories (dairy heifers), submitted or not to grazing.

During the winter, four treatments were studied: *C1* - light animals (192 ± 40.9 kg of body weight and age of 9.4 ± 2.31 months) on diversified pasture composed by common annual ryegrass, common black oats, white clover (*Trifolium repens* L.), and red clover (*Trifolium pratense* L.); *C2* - heavy animals (278 ± 41.2 kg of body weight and age of 19.6 ± 2.47 months) on diversified pasture; *C3* - light animals on pure pasture consisting of annual ryegrass, and; *C4* - heavy animals on pure annual ryegrass pasture.

Treatments pickets with light and heavy animals had 1.2 (±0.42) and 1.4 (±0.59) ha, respectively. In each plot, control areas were isolated with electric fence (5 x 10 m size) that received no grazing. During the experimental period, animals also received water "ad libitum" and energetic mineralized salt at the proportion of 100 grams per 100 kg of body weight per day.

The diverse winter pasture was sown on May 15th 2008 (sixty days after maize harvest), using 17 cm row spacing. Simultaneously, annual ryegrass, black oats, white clover, and red clover sowings were done of 50, 80, 1.7, and 2.0 kg ha^{-1}, respectively. Pure pasture (annual ryegrass) was sown on May 12th 2008, using 80 kg ha^{-1} of annual ryegrass seeds (common) and the same row spacings.

On May 6, 2009, annual ryegrass seeds (common), black oats, white clover, and red clover were sown, using 60, 60, 4, and 8 kg ha^{-1}, respectively for diversified pasture. It is noted that the clover seeds were inoculated with *Rhizobium leguminosarum* bv. Trifolii and pelleted. The pure ryegrass pasture was sown on May 5, using 60 kg ha^{-1} of seeds. Fertilizations for both pasture types were carried out in (i) 12 and 76 kg ha^{-1} of N and P_2O_5 doses, respectively in the sowing furrow, (ii) 54 and 54 kg ha^{-1} of N and K_2O, respectively sixteen days after emergence (DAE).

Grazing method of continuous stocking was adopted, using put and take technique (MOTT; LUCAS, 1952), keeping four experimental animals fixed of Dutch Black Pied (DBP) and DBP and Jersey crosses per plot with a variable number of regulators animals. The adjustment of stocking was performed weekly, entering or removing regulators animals after measuring the pasture height in order to maintain the grass average height of 20 cm (CARVALHO, 2005). Height measurements were made weekly randomly (100 samples per plot), using sward stick (BARTHRAM, 1985).

Experimental animals left the area on October 22, 2008, totaling eighty-nine days of grazing. Then, the pasture drying was done with glyphosate at 1,440 g ha^{-1} dose of active ingredient (a.i.). At thirty-three days after desiccation, soybean cultivar CD 205 sowing was performed, using 40 cm row spacing and fertilizer in the sowing furrow of 300 kg ha^{-1} of 00-20-20 formulated (N-P_2O_5-K_2O). Soybean seeds were inoculated with selected strains of *Bradyrhizobium*.

The animals were removed from the experimental area on October 05, 2009, totaling eighty-eight days of grazing. Then, pasture desiccation was done with glyphosate at 1,200 g ha^{-1} dose of a.i. At twenty-five days after animals' removal, maize sowing was done (ATL 200 modified simple hybrid), using 80 cm row spacing. Basic fertilization was carried out alongside the sowing furrow, using 320 kg ha^{-1} of 10-20-20 formulated (N-P_2O_5-K_2O). Maize final stand was of 66,536 plants ha^{-1}. Top dressing was done in total area at 18 DAE (when the culture was at the V4 stage) at 400 kg ha^{-1} dose of 22-00-21 formulated (N-P_2O_5-K_2O). Other cultural practices were used in both cultures of maize and soybeans in order to allow for appropriate growth and development.

Evaluations and statistical analysis

In soybean crop (2008/09), grains yield was evaluated by harvesting manually four center lines of 4.0 m (7.2 m^2 of area) per plot, processing, weighing, and moisture correction to 130 g kg^{-1} and also the weight of a thousand seeds (WTS). In maize crop (2009/10), the following attributes were evaluated: (i) plant population, (ii) grains yield by harvesting manually four central rows of 4.0 m (area of 12.8 m^2) per plot, processing, weighing, and correction of moisture to 130 g kg^{-1}, (iii) WTS, (iv) percentage of damaged kernels.

Results were analyzed by univariate statistics according to experiment model in completely randomized blocks in 4 x 2 factorial scheme. When F was significant ($P < 0.05$), the means were compared by Tukey test ($\alpha = 0.05$). When there was no significant interaction among pasture combinations and animal categories (A Factor), subjected or not to grazing animals (B Factor), treatments effects were compared by observations average. All statistical analyzes were performed by SAS version 9.1 statistical program (SAS, 2004).

RESULTS AND DISCUSSION

At the experiment time, experimental units had high fertility (Table 2), due to the area management history and constant additions of organic (pig manure), mineral, and corrective fertilizers. This situation associated with NTS implementation and consolidation resulted over the years to high concentrations of available calcium, magnesium, potassium, and phosphorus, improvement of soil acidity, and high concentrations of total organic carbon and total nitrogen (Table 2). These attributes have provided the high productive capacity of the area, both for grain crops and forage plants.

During 2008 and 2009 winter, pastures (diversified or pure) were used in continuous grazing, using proper management strategy. These pastures have provided appropriate AWG (average weight gain) [values above the range of 800-900 g day^{-1} (NATIONAL RESEARCH COUNCIL, 2001)] for tested animals (light and heavy), with an average stocking rate of 1,029 kg ha^{-1} of live weight (Table 3).

The pasture in this period showed an average growth rate of 58 kg ha^{-1} day^{-1} of dry matter (DM), with average forage mass of 2,673 kg ha^{-1} and production of forage accumulated of 6,549 kg ha^{-1} of DM (Table 3). Whereas, for NTS maintenance in Brazil southern, an annual input of approximately 8,000 kg ha^{-1} of DM is needed (MIELNICZUK *et al.*, 2003). The amount of winter residual biomass in this study (Table 3) can be considered suitable for the adopted production system, which includes alternate croppings of soybeans and maize in the summer.

There were no interactions among pasture combinations and animal categories with presence or absence of grazing during the winter for all the studied plants attributes (Table 4). Treatments that were used did not cause changes in the grains yield and soybean WTS (Figure 1). Obtaining higher yields than 2,800 kg ha^{-1} of

Table 3 - Treatments characteristics used during the winter annual pasture, average and standard deviation data for 2008 and 2009

Attribute	C1	C2	C3	C4
Stocking rate (kg ha^{-1})	1,003 ± 108	1,145 ± 315	849 ± 71	1,122 ± 312
Growth rate (kg DM ha^{-1} day^{-1})	55 ± 22	60 ± 17	57 ± 22	61 ± 21
Forage mass (kg DM ha^{-1})	2,354 ± 821	2,860 ± 1288	2,832 ± 920	2,647 ± 1147
Forage accumulated yield (kg DM ha^{-1})	6,468 ± 1110	7,240 ± 1362	6,055 ± 1003	6,426 ± 1025
Final residue (kg DM ha^{-1})	2,304 ± 1213	2,705 ± 1746	3,143 ± 1161	2,732 ± 1491
Height (cm)	26 ± 7	34 ± 15	32 ± 7	28 ± 10

C1: diverse pastures (black oats, annual ryegrass, white clover, and red clover) under grazing by light animals (192 ± 40.9 kg); C2: diverse pastures under grazing by heavy animals (278 ± 41.2 kg), C3 : pure pastures (annual ryegrass) under grazing by light animals, C4: pure pasture under grazing by heavy animals. DM: dry matter

Table 4 - F values of evaluated attributes in soybean (2008/09) and maize (2009/10) croppings, in a completely randomized blocks experiment in 4 x 2 factorial scheme

Variation	Soybeans			
	-------------Grains yield------------		--------------------Weight of 1,000 seeds-------------------	
A factor	0.75^{NS}		1.67^{NS}	
B factor	2.58^{NS}		0.28^{NS}	
A factor vs. B factor	0.47^{NS}		0.33^{NS}	
	Maize			
	Grains yield	Plants population	Weight of 1,000 seeds	Percentage of damaged kernels
A factor	1.04^{NS}	2.62^{NS}	9.40**	0.63^{NS}
B factor	11.42 **	10.51**	18.36**	0.42^{NS}
A factor vs. B factor	0.86^{NS}	0.59^{NS}	2.90^{NS}	0.23^{NS}

Factor A: pastures and livestock category combination (*C1* - light animals in composed and diverse pasture of annual ryegrass, black oats, white clover, and red clover; *C2* - heavy animals in diversified pasture; *C3* - light animals in composed and pure pasture ryegrass; *C4* - heavy animals in pure pasture of annual ryegrass); B factor: presence or absence of animals grazing during the winter; *: $P < 0.05$; **: $P < 0.01$; ^{NS}: not significant

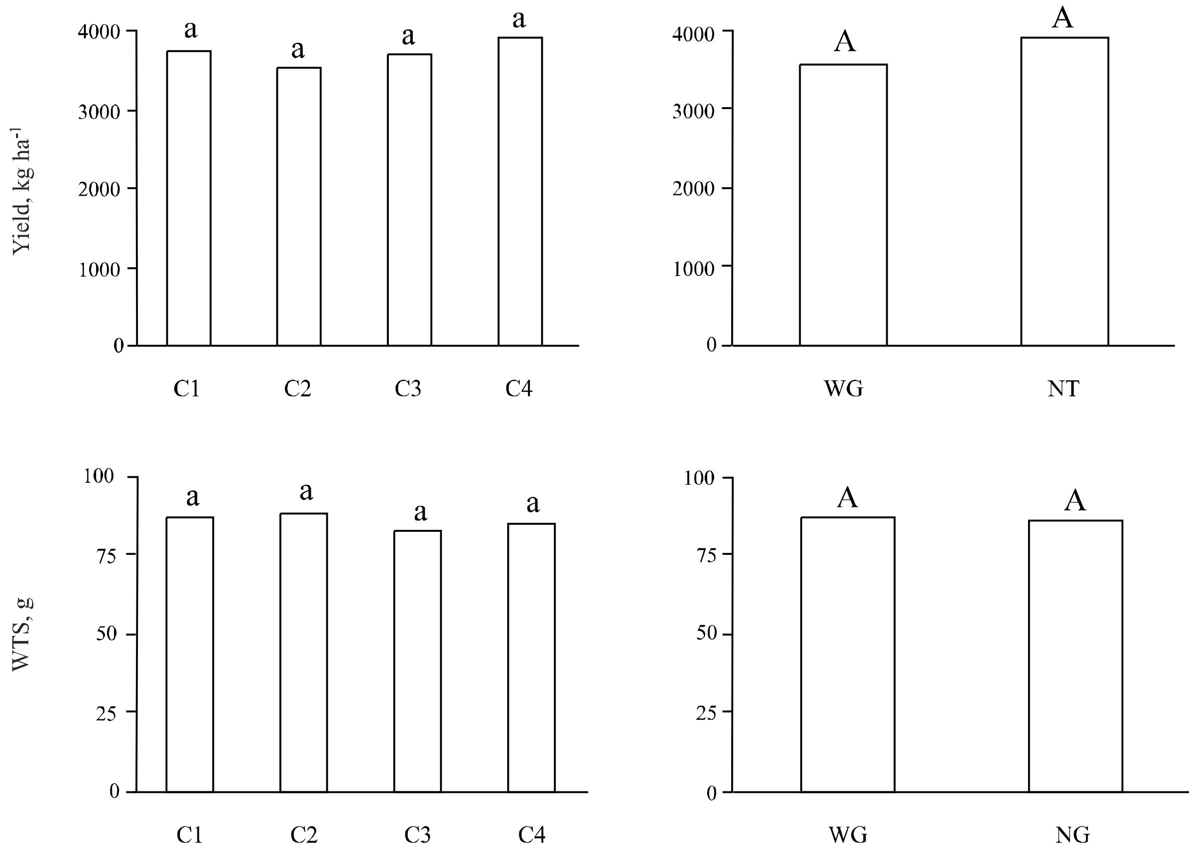
soybeans in the summer has been common when animal grazing during the winter (in a similar manner to that performed in this study) is well carried out, as reported in Nicoloso, Lanzanova e Lovato (2006) and Flores *et al.* (2007) works.

Treatments did not have effect on WTS what is consistent with the change in grains yield. Observed WTS values in this study are lower than those reported by Lunardi *et al*. (2008). However, these last authors obtained average yields of grains smaller than those observed in this study and also worked with another soybean cultivar.

The pasture and animal categories combinations have changed WTS, but did not affect plants population attributes, percentage of damaged kernels, and maize grains yield (Figure 2). Major and minor WTS were observed in C3 and C1 treatments, respectively. No differences were observed among WTS for treatments of C1 and C2, C2 and C4, and C3 and C4 (Figure 2). Despite being significant, these effects were not enough to provide change in grains yield (Figure 2).

In maize, animal grazing during the winter resulted in (i) higher plant population and grains yield, (ii) a slight decrease in WTS and no change in damaged kernels percentage (Figure 2). The highest grains yield was partly due to higher plant population that consequently may have resulted in more ears and grains production per area, but slightly lighter. However, WTS reduction was not enough to influence the crop yield. Scheeren *et al.* (2004) found that maize grains

Figure 1 - Effects of pasture and animal categories combination with presence or absence of grazing during the winter on grains yield and weight of soybeans thousand seeds (WTS). C1: light animals on diversified pasture composed by annual ryegrass, black oats, white clover, and red clover. C2: heavy animals on diversified pasture. C3: light animals on pure pasture composed of annual ryegrass. C4: heavy animals on pure pasture of annual ryegrass. WG: with animals grazing. NG: No animal grazing. Lowercase letters are for combinations and uppercase letters are for pasture and do not differ statistically by Tukey test (α = 0.05)



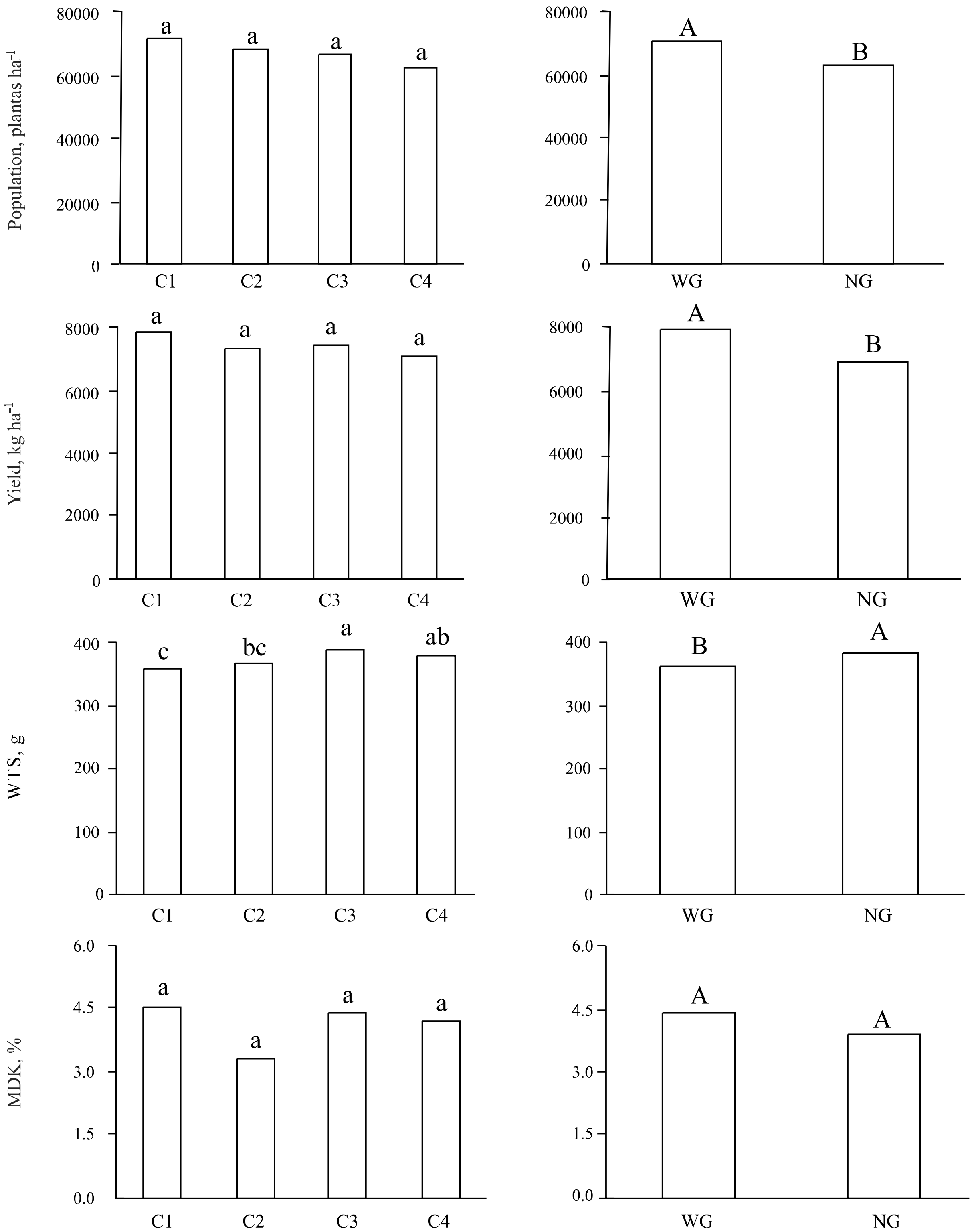
yield is directly related to plant population. Another factor that may have contributed to the higher yield of maize grown after animal grazing is the improvement in nutrients cycling particularly nitrogen. Assmann *et al*. (2003) observed that the maize crop in integrated production system increased grains yield in grazed areas during the winter. In CLI system (as adopted in this study), the animal has the ability to modify the nutrient cycling dynamics, something that occurs less significantly in systems where the forage is grown solely for the purpose of soil cover (CARVALHO *et al*., 2010).

The increasing population of maize plants due to animals grazing during the winter (Figure 2) can be attributed to proper pasture management and animal in the experimental area, providing major renovation of the root system and more uniform distribution of residual phytomass (CARVALHO *et al*., 2011). Probably, as the animals fed the grass leaves, part of the root system died, improving soil physical characteristics and favoring the germination, emergence, and maize development.

Khurshid *et al*. (2006) found positive effects in improving the soil physical attributes due to vegetation cover management on maize growth and yield. In CLI under NT, moderate grazing in winter annual pastures improve aggregation (SOUZA *et al*., 2010a) and soil biological attributes (SOUZA *et al*., 2010b), benefiting subsequent crops (SILVA *et al*., 2000).

In general, observed WTS values in this study are similar to those reported by Scheeren *et al*. (2004). Damaged kernels percentage observed in this experiment are consistent with those reported in Casa *et al*. (2007). Maize population and yield are according to characteristics of hybrid that are higher than national averages.

Figure 2 - Effects of pasture and animal categories combination with presence or absence of grazing during the winter on plant population, grains yield, weight of thousand seeds (WTS), and percentage of maize damaged kernels (MDK). C1: light animals on diversified pasture composed by annual ryegrass, black oats, white clover, and red clover. C2: heavy animals on diversified pasture. C3: light animals on pure pasture composed by annual ryegrass. C4: heavy animals on pure pasture of annual ryegrass. WG: with animals grazing. NG: No animal grazing



CONCLUSIONS

1. Pasture (pure and diverse) and animal categories (light and heavy) combinations with presence and absence of grazing did not alter the yield and weight of soybeans thousand seeds;
2. In maize crop, pasture and animal categories combinations did not affect plant population attributes and yield and percentage of damaged kernels. The animal grazing during the winter, despite having provided a slight decrease in weight of thousand seeds of maize, caused increase in the plant population and grains yield.

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