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Forage production, straw, structural characteristics and nutritional value of white oat in crop-livestock integrated systems

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This study was aimed to evaluate the production of forage and residual straw, structural characteristics and nutritional value of white oat under different soil use in an integrated crop-livestock system. The experiment was conducted in the autumn–winter seasons of 2009, 2010 and 2011 using a randomized block design in a scheme of tracks. Six forms of soil were distributed in tracks and were used to cultivate oats: residue grazing with a height of 10 or 20 cm (G10 and G20); cutting for haymaking with a residue height of 10 or 20 cm (C10 and C20); without grazing or cutting of oat plants with subsequent direct sowing of the summer crop (NC - TS) and without grazing or cutting with subsequent conventional tillage of the soil for sowing of the crop summer (NC - CS). In 2009, 2010 and 2011 three, one and two evaluations were accomplished each year, respectively. We studied the production of forage and residual straw, structural characteristics and nutritional quality of the forage produced. The total forage production in 2009 and 2011 did not differ between soil uses; however, it was higher in the uses with a residue height of 10 cm in 2010. The white oat under cuts or grazing gave high forage dry matter, while straw production was reduced with cuts or grazing. Forage of superior quality and with better production distributed throughout the autumn–winter was obtained when the white oat was managed with grazing or cuttings.

Key words: *Avena*, proteins, nutritional analysis.

INTRODUCTION

Pastures are the major component of the diets of ruminants and are the most economical source in livestock systems (Skonieski et al., 2011). Even though southern Brazil possesses favorable soil and climatic

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Table 1. Physico-chemical characteristics of soil experimental area.

Depth	P	OM	pH	Al+H	Al^{3+}	K^{+}	Ca^{2+}	Mg^{2+}	BS	CEC	V	Sand	Silt	Clay
cm	mgdm^{-3}	g dm^{-3}	$CaCl_2$	--------------cmol$_c$.dm^{-3} --------------							%	---------g kg^{-1}--------		
0-10	19.6	21.1	4.9	5.0	0.0	0.9	5.1	2.2	8.2	13.3	62.1	54.2	117.6	828.2
10-20	19.5	19.9	4.9	5.0	0.0	0.9	5.1	2.2	8.2	13.2	61.9	54.2	117.6	828.2

OM: organic matter; BS: bases sum; CEC: cation exchange capacity; V: saturation of bases.

conditions for growing many forage species (Meinerz et al., 2011), it still faces shortage of fodder in the autumn–winter.

In order to rectify the shortage of high quality forage (Aguinaga et al., 2008), hibernal forages like white oat can be grown under an integrated crop-livestock system in areas of direct seeding kept in fallow during the winter period (Balbinot Junior et al., 2011). Such system not only helps to provide vegetal cover (Cassol et al., 2011) but also contributes to the sustainability over time.

However, maximum forage production and the success of an integrated crop-livestock system (Confortin et al., 2010) depend on the interaction of various components that interfere with plant growth (Aguinaga et al., 2008; Carvalho et al., 2010). Despite their high yield potential, hibernal pastures are characterized by a short cycle of use with rapid and abrupt changes in the structure of plants and nutritional value of the forage produced (Carvalho et al., 2010).

Among the components that alter plant development, management can potentially define the growth and productivity of pastures (Skonieski et al., 2011), which also affects their nutritional value. The height management, for example, determines the dry matter produced and the level of residual straw through defoliation (Aguinaga et al., 2008).

Black oat and ryegrass, or their associations have been studied for production of forage and straw under different managements (Cassol et al., 2011; Balbinot Junior et al., 2011), but results for white oat (*Avena sativa*) are still scarce in scientific circles.

In this context, the objective of the present work was to study forage production and residual straw, the structural characteristics and nutritional value of white oats under different soil uses in an integrated crop-livestock systems.

MATERIALS AND METHODS

The study was conducted during May 2009 to September 2011 in an experimental area with coordinates: latitude 24°33' 22'' S and longitude 54° 03' 24'' W and approximate altitude of 400 m. The soil (Table 1) was classified as oxisol (LVe). The area was under a direct seeding system in succession soy/corn/oats since 2006.

The climate of the region, according to the Köppen classification is Cfa type shrub soil, with well-distributed rainfall throughout the year and summers. Climatic data of the experimental period were obtained in an automatic climatological station of the State University of West of Paraná, which is approximately 100 m from the experimental area and is presented in Figure 1. The experiment was implemented in the autumn–winter of 2009, 2010 and 2011 in a randomized block design in a track scheme with three blocks and six tracks totaling 18 experimental units of 15 × 30 m each. In the strips were distributed six forms of soil use cultivated with oats: grazing with a residue height of 10 cm (G10); grazing with a residue height of 20 cm (G20); cutting for haymaking with a residue height of 10 cm (C10); cutting for haymaking with a residue height of 20 cm (C20); without grazing or cutting with subsequent direct seeding of the summer crop (NC - TS) and without grazing or cutting with conventional tillage of the soil for sowing of the summer crop (NC - CS).

Data were studied separately for each year, and due to variability in the year-to-year number of cuts or grazing, the experimental designs adopted for the analysis of the data were also variable. For the analysis of data collected in 2009, a randomized block design with scheme tracks in time as split plots was adopted. In the strips (plots), the six forms of soil use cultivated with white oat (G10, G20, C10, C20, NC-TS and NC-CS) and subplot-sampling growing periods (1st, 2nd and 3rd) were allocated. In 2010, due to the occurrence of drought (Figure 1) only one cut or grazing was performed, so the experimental design was randomized block schemes on tracks.

In 2011 were sampled again in the design of randomized blocks on tracks with split plot in time, where the six ways of using soil cultivated with oats were allocated to main plots (G10, G20, C10, C20, NC-TS and NC-CS) and two growing periods were allocated to subplots (1st and 2nd). The 2009, 2010 and 2011 sowings were made on 24 May, 10 June and 29 May, respectively. In 2009 and 2011, the oats IPR 126 were sown, while in 2010, the oats URS Guapa lineage UFRGS 998011-2 were cultivated. In the three years, oats were seeded with a precision seeder coupled to a tractor in rows spaced 0.17 m apart using 70 Kg ha^{-1} seed without the use of fertilizer.

In 2009, the 1st grazing or cutting was made on July 20 (55 days after sowing), while the 2nd and 3rd cuttings or grazing were respectively performed on 19 August and 15 September, 2009. In 2010, the 1st grazing or cutting was performed on 8 August while maintaining similar interval after sowing as that of 2009. Due to the occurrence of drought (Figure 1) and the shorter cycle of oats URS Guapa than that of IPR 126, no re-growth was possible after the 1st grazing or cutting in the area in 2010. In 2011, as there was adequate and regular rainfall than in 2010, the 2nd grazing or cutting was performed 32 days after the 1st grazing or cutting which was made on 24 July (56 days after sowing).

Lactating Holstein cows with live weights of approximately 550 ± 28.5 kg and an average milk production of 18 ± 2.5 kg day^{-1} were used in the grazing. The cows were distributed in paddocks and grazed for about two days until the desired residue heights (10 and 20 cm) were obtained. In order to get the desired residue heights in

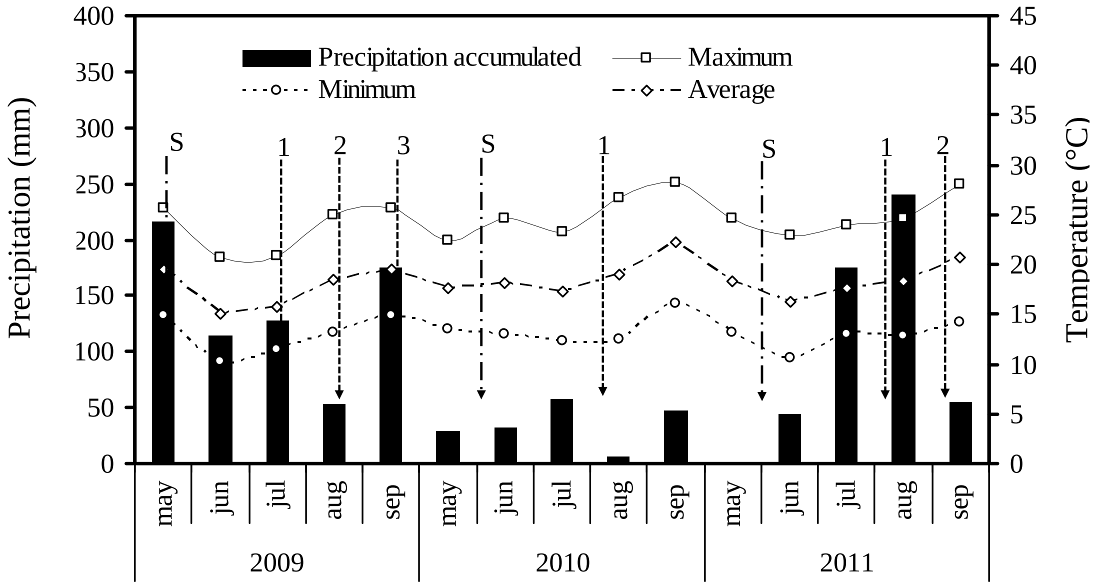

Figure 1. Monthly averages of maximum temperature, minimum and average and cumulative rainfall during the months of the experimental period in each year. S: sowing oats, 1, 2 and 3: cutting or grazing performed each year. Source: Climatological Station Auto Center of Experimental Stations Unioeste, Rondon-PR, 2009-2011.

the paddocks, manning variables were used according to the technique *put-and-take* (Mott and Lucas, 1952). For soil uses with cut, a mechanical mower coupled to the tractor regulated set at the desired cutting height (10 and 20 cm) was used and cutting was always made on the closing day of grazing. In tracks of soil uses without cutting or grazing, without were performed in oats, only its free development up to the point of desiccation.

In the years 2009 and 2010, corn and soybean were sown in succession to oats, respectively. During these sowings, the tracks submitted to the soil use for grazing or cutting and strip intended for use without grazing or cutting for direct sowing of the summer crop were desiccated using the herbicide glyphosate (1800 g of ai ha^{-1}) with a volume spray of 250 L ha^{-1}. The band destined for soil use without cutting or grazing and with subsequent conventional tillage of soil for sowing of the summer crop was mechanically prepared with the aid of a light grid. After harvesting the grain crops in each year, the experimental area remained fallow until the new sowing of oats.

Measurements of structural characteristics (plant height, number of tillers, number of leaves per tiller, final leaf length, stem diameter and leaf/stem ratio) and sampling to determine the dry matter yield of oats were performed immediately before each cutting or grazing, while sampling to determine the residual straw was mad after cutting or grazing. Plant height was measured at five random points in each plot using a ruler. The tiller density was determined by manual counting of all tillers contained in a known area (0.25 m²) in each plot. The number of leaves per tiller, final leaf length and stem diameter were measured in 10 randomly selected tillers in each plot. The stem diameter was determined with the aid of digital pachymeter. The leaf/stem ratio was determined using approximately 50 g samples collected from each plot and subjected to manual separation into leaf blades and stems + sheaths and kiln dried.

The dry matter production was estimated by sampling using a metallic square of 0.25 m² area randomly placed twice in each plot. All plants contained in the interior of the specified were cut and placed in labeled plastic bags for weighing in the laboratory in order to compose a sample containing two sub-samples for each plot. After weighing one representative sub-sample of forage produced on each plot, it was subjected to drying in an oven with forced air circulation at 55°C for 72 h. After drying the samples, they were ground using a mill with knives and a stainless steel chamber type Willey with a 1 mm sieve for subsequent determination of the nutritive value.

In soil uses with cuts or grazing, plants were sampled at predetermined heights, while in plots destined for soil uses without cutting or grazing oats, the samples were collected at a height of 15 cm from the ground level, featuring forage that would be available to be harvested, either in the form of cutting or grazing. For determining the residual straw, a metallic square of 0.25 m² in area was again randomly placed twice in each plot, and all the plant material contained inside it was collected at the level of the ground surface and kiln dried. The nutritional values of forage including crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, lignin and cellulose were determined by chemical analyses (Silva and Queiroz, 2006). The data collected were subjected to analysis of variance, and averages were compared using Tukey's test at 5% probability.

RESULTS AND DISCUSSION

In year 2009, both forage dry matter and residual straw yields were significantly affected by the interaction effects of the factors involved (Table 2). In the 1st growth period, dry matter production was similar in all the soil uses. In the 2nd and 3rd growth periods, the highest dry matter yield were obtained when the oats in soil uses without

Table 2. Dry matter production of residual straw by white oat cv. IPR 126 under different soil uses in three growth periods in the autumn-winter 2009.

Usage soil	Dry matter production (kg ha^{-1})				Residual straw (kg ha^{-1})			
	Growth periods			Total	Growth periods			Total
	1º	2º	3º		1º	2º	3º	
G10	1374_{aA}	1017^{cB}	891^{bB}	3282^{ns}	1183^{aA}	891^{bAB}	646^{bB}	2720^{b}
G20	1451_{aA}	1511^{bA}	988^{bB}	3950	1242^{aA}	1222^{bA}	714^{bB}	3178^{b}
C10	1412^{aA}	1042^{cB}	902^{bB}	3356	1176^{aA}	959^{bAB}	679^{bB}	2814^{b}
C20	1289^{aB}	1580^{bA}	1049^{bB}	3918	1180^{aA}	1007^{bAB}	809^{bB}	2996^{b}
NC - TS	1380^{aC}	2349^{aB}	4467^{aA}	4467	1480^{aC}	2482^{aB}	4415^{aA}	8377^{a}
NC - CS	1290^{aC}	2208^{aB}	4425^{aA}	4425	1290^{aC}	2208^{aB}	4409^{aA}	7907^{a}
Mean	1366	1618	2120	3900	1259	1462	1946	
CV1 (%)	13.02				12.12			
CV2 (%)	6.29				6.63			
CV3 (%)	8.02				9.23			

^{ns}Not significant. Means followed by the same lowercase and uppercase in the column on the line do not differ statistically at a 5%. CV1, CV2 and CV3 (%): coefficient of variation factor for the period (P), soil use factor (SU) and interaction PxSU respectively. G10 and G20: grazing with residue height of 10 cm and 20 cm, C10 and C20: cutting for haymaking with residue height of 10 cm and 20 cm; NC - TS and NC-CS: no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop.

grazing or cuts, this fact was due by of forage was provided by grazing or cutting, not being deposited on the soil (Table 2).

The dry matter production in soil uses with a residue height of 10 cm, regardless of the use of cutting or grazing, was lower in the 2nd growth period. This could be attributed to the speed of recovery of leaf area of plants, which after grazing or cutting depends mainly on the remaining leaf area (Lemaire and Chapman, 1996). A direct relationship between the height of the forage crop and speed of recovery of leaf area was also previously observed (Rocha et al., 2004). In the 3rd growth period, dry matter production in soil uses with cutting or grazing at residual heights of 10 or 20 cm was similar (Table 2). Due to differences in sampling heights, differences in dry matter production were expected. However, due to the uneven development of the plants as a result of drought (Figure 1), these differences were not detected.

In soil use with a residue height of 10 cm, the dry matter production was higher in the 1st growth period, but decreased in the 2nd and 3rd due to speed of restoration of leaf area of plants after harvest. In grazing trial at a residual height of 20 cm, dry matter production decreased only in the 3rd period, while in cutting, there was an increase in the 2nd period with a subsequent decrease, due to the physiological age of the plants that entered the reproductive stage. No significant difference was observed in total dry matter production among the different soil uses studied (Table 2). The observed yields per period or total are considered satisfactory because they resemble the results of other studies (Bortolini et al., 2004; Cassol et al., 2011).

The production of residual straw was affected by the interaction of factors, being higher in the 2nd and 3rd growth periods in soil uses without grazing or cutting (Table 2). The observed increase in residual straw production with advancing growth period in the treatment without grazing or cutting was attributed to the accumulation of dry matter by plants.

In soil uses with grazing or cutting, there was a decrease in residual straw with the advancing growth period due to an advancement in cycle of oats and stem elongation. When the plants reach the reproductive period and lengthen their stems, the living leaves become part of the extract upper canopy in the pasture. Therefore, only the stem and leaves first issued by the tiller remain in the extract below (0 to 10 or 0 to 20). Introducing the plant with smaller leaves than other dry matter, and low participation in straw residual dry matter.

The interaction effect of the factors on the structural characteristics of oats grown in 2009 was also significant ($p<0.05$). Plant height was higher in soil uses without grazing or cuts and lower in uses with a residual height of 10 cm in the 2nd and 3rd growth periods (Table 3). In the 2nd growth period, the oats subjected to cut of oat at residue height of 20 cm had higher plant height than that subjected to grazing. This could be due to the effects of treading by the animals, which can damage plants and/or tillers and harming the re-growth in the grazing treatment. With the advance in growth period, an increase in plant height was observed in all soil use treatments due to stretching of plant internodes during the beginning of the reproductive stage (Langer, 1979). Similar results were obtained by Confortini et al. (2010) studied different

Table 3. Structural characteristics of white oat cv. IPR 126 under different soil uses in three growth periods in the autumn-winter 2009.

Usage soil	Plant height (cm)			Tiller density (tiller m^{-1})			Number of leaves per tiller		
	Growing period			Growing period			Growing period		
	1º	2º	3º	1º	2º	3º	1º	2º	3º
G10	29.17^{aB}	37.27^{dA}	36.44^{cA}	664.00^{a}A	416.67^{d}B	372.00^{c}	2.33^{aA}	2.33^{bA}	2.20^{bA}
G20	29.67^{aB}	42.27^{cA}	41.45^{bA}	662.67^{a}A	417.33^{d}B	358.00^{c}C	2.52^{aA}	2.35^{bA}	1.93^{bA}
C10	27.83^{aB}	35.70^{dA}	37.44^{cA}	653.33^{a}A	642.67^{a}A	508.00^{a}B	2.30^{aA}	2.58^{bA}	2.13^{bA}
C20	29.67^{aB}	45.40^{bA}	4355^{bA}	645.33^{a}A	557.33^{b}B	444.00^{b}C	2.51^{aA}	2.35^{bA}	1.85^{bA}
NC - TS	29.42^{aC}	66.87^{aB}	96.22^{aA}	672.67^{a}A	486.00^{c}B	286.00^{d}C	2.44^{aC}	4.03^{aB}	5.25^{aA}
NC - CS	30.58^{aC}	66.87^{aB}	96.22^{aA}	643.00^{a}A	484.00^{c}B	285.33^{d}C	2.35^{aB}	3.68^{aB}	5.33^{aA}
Mean	29.39	49.06	58.56	656.83	500.67	375.56	2.41	2.89	3.12
CV1 (%)	5.78			9.91			10.11		
CV2 (%)	4.32			4.18			7.44		
CV3 (%)	2.54			4.72			12.41		

	Final leaf length (cm)			Stem diameter (mm)			Leaf / stem ratio		
G10	37.23^{aA}	30.57^{cB}	29.22^{bB}	2.86^{aA}	2.86^{bA}	2.97^{bA}	3.93^{aA}	3.59^{bA}	2.17^{aB}
G20	38.16^{aA}	40.82^{bA}	33.99^{aB}B	2.73^{aC}	3.83^{aA}	3.36^{bB}	4.25^{aA}	4.66^{aA}	2.37^{aB}
C10	39.66^{aA}	31.52^{cB}	30.36^{bB}	2.79^{aA}	2.84^{bA}	2.99^{bA}	3.98^{aA}	3.53^{bA}	2.10^{aB}
C20	35.36^{aA}B	40.03^{bA}	36.56^{aB}	2.97^{aB}	3.84^{aA}	3.38^{bB}	4.06^{aA}	4.74^{aA}	2.29^{aB}
NC - TS	38.46^{aB}	47.67^{aA}	34.11^{aB}B	3.01^{aB}	4.03^{aA}	4.38^{aA}	3.93^{aA}	2.17^{cB}	0.76^{bC}
NC - CS	38.18^{aB}	46.51^{aA}	33.78^{aB}B	2.84^{aB}	4.05^{aA}	4.21^{aA}	3.94^{aA}	2.32^{cB}	0.77^{bC}
Mean	37.84	39.52	33	2.87	3.57	3.55	4.01	3.5	1.74
CV1 (%)	11.06			5.99			9.72		
CV2 (%)	7.91			5.81			7.01		
CV3 (%)	5.88			6.36			11.42		

Means followed by the same lowercase and uppercase in the column on the line do not differ statistically at a 5%. . CV1, CV2 and CV3 (%): coefficient of variation factor for the period (P), soil use factor (SU) and interaction PxSU respectively. G10 and G20: grazing with residue height of 10 cm and 20 cm, C10 and C20: cutting for haymaking with residue height of 10 and 20 cm; NC - TS and NC-CS: no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop.

intensities by sheep grazing on oats.

Tillering of oats was inhibited with the soil uses adopted, with the exception of soil use with cut at a residue height of 10 cm; in which higher tiller density was recorded in the 2nd and 3rd growth periods (Table 3). The differences are due to the stimulation of tillering promoted by removal of the shoots of plants (cut). However, this stimulus was not enough to keep the tiller density in grazing managements, due to the death of tillers and plants by animal trampling.

A reduction in the number of tillers was observed from the 1st to the 3rd growth periods. This behavior, as well as the lowest number of tillers in plants that were not grazed or cut in the 3rd growth period, was due to the entry of plants into the reproductive phase (Langer, 1979) and the reallocation of photo-assimilates. Upon reaching the reproductive stage, the competition for resources between plants is higher resulting in senescence of the younger tillers senesce as a result of translocation of the photo-assimilates and nutrients to the older tillers to ensure development and seed production (Castagnara et al., 2010).

The number of leaves per tiller was higher in soil uses without grazing or cut in the 2nd and 3rd trial period; but no differences were observed in the 1st period. In soil uses without cutting or grazing, there was an increase in the number of leaves in the course of the growing periods. It is noteworthy that there were only whole leaves that were fully expanded.

In the 2nd growth period, the largest leaf length was observed in soil uses without cutting or grazing, with the lower value recorded for the oat grazed at a residue height of 10 cm. In the 3rd growth period, the highest and lowest length of leaves was observed in soil uses with cutting at residue heights of 20 and 10 cm, respectively.

Therefore, with a residue height of 10 cm, the remaining bundle sheath is shorter in the tiller unlike in the plants managed at a residue height of 20 cm. Thus, the new leaves formed in the apical meristem located at the base of the tiller become smaller because they travel

Table 4. Nutritive value of white oat cv. IPR 126 under different soil uses in three growth periods in the autumn-winter 2009.

Usage soil	CP (g kg^{-1})			NDF (g kg^{-1})			ADF (g kg^{-1})		
	Growing period			Growing period			Growing period		
	1º	2º	3º	1º	2º	3º	1º	2º	3º
G10	234.0^{aA}	219.2^{aA}	205.2^{aA}	494.5aB	510.1^{bB}	574.6^{bA}	288.2^{aB}	298.1^{bB}	353.9^{bA}
G20	233.5^{aA}	238.3^{aA}	201.5^{aA}	498.9^{aB}	510.1^{bB}	581.0^{bA}	301.6^{aB}	307.5^{bB}	357.9^{bA}
C10	233.0^{aA}	210.5^{aA}	197.0^{aA}	498.3^{aB}	519.4^{bB}	575.7^{bA}	292.1^{aB}	302.1^{bB}	359.0^{bA}
C20	241.0^{aA}	235.9^{aAB}	200.9^{aB}	497.7^{aB}	511.4^{bB}	582.5^{bA}	296.7^{aB}	$295,4^{bB}$	354.1^{bA}
NC - TS	239.5^{aA}	157.5^{bB}	75.7^{bC}	501.2^{aC}	562.3^{aB}	691.5^{aA}	291.1^{aC}	334.3^{aB}	422.7^{aA}
NC - CS	233.3^{aA}	160.9^{bB}	80.4^{bC}	498.5^{aC}	568.2^{aB}	683.5^{aA}	294.9^{aC}	331.1^{aB}	417.1^{aA}
Mean	235.7	203.7	160.1	498.2	530.2	614.8	294.1	311.4	377.5
CV1 (%)	6.46			2.14			3.38		
CV2 (%)	6.78			4.06			5.35		
CV3 (%)	9.32			2.91			3.37		
	Hemicellulose (g kg^{-1})			Lignin (g kg^{-1})			Cellulose (g kg^{-1})		
G10	206.2^{aA}	212.0^{bA}	220.7^{bA}	31.8^{aC}	41.4^{bB}	52.6^{bA}	233.6^{aA}	255.9^{bA}	258.7^{bA}
G20	203.3^{aB}	209.9^{bAB}	223.1^{bA}	31.0^{aC}	42.1^{bB}	52.4^{bA}	240.9^{aA}	250.3^{bA}	256.8^{bA}
C10	206.1^{aA}	217.3^{bA}	216.7^{bA}	32.5^{aC}	41.7^{bB}	54.2^{b}A	241.8^{aA}	253.3^{bA}	257.7^{bA}
C20	201.0^{aB}	216.1^{bAB}	228.4^{bA}	31.1^{aC}	41.5^{bB}	53.7^{bA}	242.4^{aA}	252.5^{bA}	258.9^{bA}
NC - TS	210.1^{aC}	228.0^{aB}	268.8^{aA}	29.9^{aC}	43.9^{aB}	63.5^{aA}	243.3^{aB}	290.6^{aA}	315.2^{aA}
NC - CS	203.6^{aC}	237.1^{aB}	266.4^{aA}	31.4^{aC}	45.1^{aB}	62.1^{aA}	240.4^{aB}	299.0^{aA}	311.0^{aA}
Mean	205	220.1	237.3	31.3	42.6	56.4	240.4	266.9	276.4
CV1 (%)	3.61			1.7			3.75		
CV2 (%)	4.43			2.32			7.48		
CV3 (%)	3.39			2.61			4.11		

Means followed by the same lowercase and uppercase in the column on the line do not differ statistically at a 5%. CV1, CV2 and CV3 (%): coefficient of variation factor for the period (P), soil use factor (SU) and interaction PxSU respectively. G10 and G20: grazing with residue height of 10 and 20 cm, C10 and C20: cutting for haymaking with residue height of 10 and 20 cm; NC - TS and NC-CS: no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop.

a shorter way until they emerge and become fully expanded. In contrast, the highest leaf length in soil use where the plants were cut at a residual height of 20 cm was due to the remaining length of the sheath and the absence of animal trampling and uniformity of cut plants. Changes in final leaf length in soil uses with grazing are due to animal trampling and uneven height of the forage crop, which becomes more pronounced following the grazing (Carvalho et al., 2010).

Stem diameter was lower in the 2nd growth period in soil uses with a residue height of 10 cm, while in the 3rd period; higher stem diameter was recorded in plants managed without cutting or grazing soil use system. These changes are due to the development of the shoots of the plants because the diameter of the stems increases in direct proportion to the strength required to support its organs (leaves).

In the leaf/stem ratio, there was a significant difference from the 2nd growth period, in which the largest leaf/stem ratio was obtained in the forage produced on soil uses with a residue height of 20 cm, followed by soil uses with a residue height of 10 cm. However, these managements did not differ in the 3rd period of growth. In soil uses without grazing or cutting, the leaf/stem ratio was much lower in the 2nd and in the 3rd period of growth (Table 3). Changes in leaf/stem ratio are due to the stem elongation of plants due to the inter-node lengthening with the arrival of the reproductive phase (Langer, 1979). Similar results for oat were obtained by Tonate et al. (2014) that compared leaf/stem ratio decreasing grown with the advance of the period, these authors attributed the fact to the natural cycle of the plant in relation to the productive age.

The nutritional value of forage produced in 2009 was affected by interaction of the factors involved (Table 4). The CP concentration in forage differed between the soil uses in the 2nd and 3rd growth periods of oats, with lower and decreasing values observed over the periods of growth in soil uses without grazing or cutting (Table 4). These results are different to those cited by Berbigier et al. (2013) studied ryegrass at different heights of cuts (5,

Table 5. Production of dry matter of forrage and of residual straw, and leaf / stem ratio of white oat cv. URS Guapa grown under different soil uses in the autumn-winter 2010.

Usage soil	Dry matter (kg ha^{-1})	Residual straw (kg ha^{-1})	Leaf / stem ratio
G10	5620^{a}	1364^{c}	0.73^{b}
G20	4708^{c}	1833^{b}	1.04^{a}
C10	5649^{a}	1389^{c}	0.74^{b}
C20	4633^{c}	1861^{b}	1.02^{a}
NC - TS	5289^{b}	6535^{a}	0.81^{b}
NC - CS	5278^{b}	6635^{a}	0.80^{b}
Mean	5196	3270	0.86
CV (%)	1.38	2.00	8.14

Means followed by the same letter in the column do not differ statistically at 5%. G10 and G20: grazing with residue height of 10 and 20 cm, C10 and C20: cutting for haymaking with residue height of 10 and 20 cm; NC - TS and NC-CS: no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop.

7 and 10 cm) in 3rd periods of cuts, which are drop in CP content, which did not occur in this study, only the soil uses that without grazing or cutting oats. With respect to fiber content of the forage (NDF, ADF, hemicellulose, lignin and cellulose), there was a significant difference only in the 2nd and 3rd periods of growth, and the forage produced on soil uses without grazing or cuts had higher fiber contents than the other uses. When the oat was subjected to cutting or grazing, the values of NDF and ADF were similar in the 1st and 2nd periods and increased in the 3rd period, while a progressive increase was observed in other soil uses (without grazing or cutting) (Table 4).

The hemicellulose content remained constant when the oat was managed at a residue height of 10 cm (G10 and C10), but increased with the grow period of evaluations in other soil uses (G20, C20, NC-TS and NC-CS). An increase in lignin concentrations was observed with growth periods for all soil uses studied, while the cellulose content remained constant over the period when the oat was cut or grazed and increased only in the absence of grazing or cutting.

Changes in the concentration of CP and fibrous components of forage are due to structural changes of plants as the inter-node lengthens, resulting from advancing age and the plant entering the reproductive phase (Langer, 1979). As they grow, forage plant density decreases with the decrease in the proportion of leaves and increase in the proportion of stem/stalk. In other words, there is an increase in the levels of structural compounds (cell wall), such as cellulose, hemicellulose and lignin and, in parallel, a decrease in the cellular content, with the consequent reduction in nutritional value (Van Soest, 1994).

In 2010, the highest production of dry matter was obtained for soil uses when oats were handled with a residual height of 10 cm, either for cutting or grazing, and lower dry matter occurred in soil uses with a waste of time 20 cm is for cutting or grazing (Table 5). The yields obtained are similar to those observed in other studies (Bortolini et al., 2004; Cassol et al., 2011) and are adequate despite the unfavorable climatic conditions during the growing period of the plants (Figure 1). A greater amount of residual straw was obtained with the soil uses without cuts or grazing, and lowest in the oats managed at a residue height of 10 cm (Table 5). The results were expected because the amount of residual straw is directly related to the height of harvested forage and the remaining material.

The structural characteristics studied were not altered by soil uses, except for the leaf/stem ratio, which was higher in soil uses with a residue height of 20 cm (Table 5). This result is due to the components of the harvested forage, because with the increase of the height of the forage crop, the amount of harvested leaves was higher than the number of stems in relation to other soil uses, providing a higher leaf/stem ratio.

The nutritional value of forage produced by URS Guapa oats in 2010 was similar in all soil uses studied, and the average values were 140; 644; 339; 305; 37 and 295 g/kg DM for CP, NDF, ADF, hemicellulose, lignin and cellulose, respectively. The possible lack of difference between the soil uses is linked to the performance of only one review (cutting or grazing). This was due to the weather conditions during the growing period of oats in 2010, where severe water stress, which limited crop growth and low production of dry matter occurred (Figure 1). The low rainfall limit the growth of oats and accelerate its cycle from the vegetative stage to the reproductive phase. Thus, the plants quickly gained height due to a stretching of the inter-nodes, causing a reduction in leaf/stem ratio and a decrease in the nutritional value of the forage produced. This fact is also reported by Ramos Junior et al. (2013) who studied the oats on water deficit

Table 6. Dry matter production of residual straw by white oat cv. IPR 126 under different soil uses in two growth periods in the autumn-winter 2011.

Usage soil	Dry matter production ($kg\ ha^{-1}$)			Residual straw ($kg\ ha^{-1}$)		
	Grown period		Total	Grown period		Total
	1º	2º		1º	2º	
G10	4135^{aA}	1853^{bB}	5989^{ns}	1005^{cA}	973^{bA}	1978^{b}
G20	3368^{cA}	1467^{cB}	4835	1239^{bA}	1115^{bA}	2354^{b}
C10	4162^{aA}	1856^{bB}	5892	982^{cA}	981^{bA}	1963^{b}
C20	3392^{cA}	1383^{cB}	4775	1229^{bA}	1131^{bA}	2360^{b}
NC - TS	3757^{bB}	5998^{aA}	5998	4285^{aB}	5998^{aA}	10283^{a}
NC - CS	3751^{bB}	6046a^{A}	6046	4218^{aB}	5980^{aA}	10198^{a}
Mean	3761	3101	3423	2160	2696	
CV1 (%)	4.10			2.32		
CV2 (%)	3.59			2.56		
CV3 (%)	3.50			3.18		

^{ns} Not significant. Means followed by the same lowercase and uppercase in the column on the line do not differ statistically at a 5%. CV1, CV2 and CV3 (%): coefficient of variation factor for the period (P), soil use factor (SU) and interaction PxSU respectively. G10 and G20: grazing with residue height of 10 cm and 20 cm, C10 and C20: cutting for haymaking with residue height of 10 cm and 20 cm; NC - TS and NC-CS: no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop.

reduction and its characteristics compared to other grasses as millet and sorghum.

In 2011, the interaction of the factors studied had significance on forage and residual straw production and on the structural characteristics of oats, except the tiller density. In the 1st growth period, higher forage dry matter was obtained in soil uses where the oat was managed at a residue height of 10 cm. In the 2nd period, dry matter production was higher in soil uses without grazing or cuts and lower when the plant was managed at a residue height of 20 cm (Table 6). The reduction in dry matter production for use with grazing or cutting is due to the advancement in the phenological cycle of oats, beginning in directing photo-assimilates to the formation of reproductive structures (Langer, 1979). On the other hand, the increase in forage production in the uses without grazing or cutting is due to dry matter accumulation that occurred because forage was not harvested. Total forage production over the 2nd growth periods did not differ between the soil use types. The yields observed during the periods of growth individually, or the accumulated total for the two were similar to those reported in other studies under similar conditions (Bortolini et al., 2004; Cassol et al., 2011).

The production of residual straw was higher in soil use without grazing or cuts in both evaluation periods, but in the 1st period, the soil uses with a residue height of 10 cm resulted in less straw production (Table 6). Higher biomass accumulation was observed in the 2nd period, which could be attributed to biomass accumulation by plants deposited on the soil surface, and was similar to that observed in other studies with various soil uses in the winter (Lopes et al., 2009; Balbinot Junior et al., 2011).

The structural characteristics studied in oats were affected by an interaction of factors, except the tiller density that changed only in accordance with the growth periods (Table 7). In the 1st period of growth, the plant heights were similar in all soil uses, however, plant heights increased in the 2nd period in the absence of grazing or cutting. When they are not grazed or cut, the oat pastures accelerate their development cycle, elongating internodes and showing early flowering (Rocha et al., 2004), which in turn results in higher plant height.

The tiller density was reduced from the 1st to the 2nd growth period due to the death of tillers, which occurs when the reproductive stage is reached and the reallocation of photo-assimilates to the formation of reproductive structures (Castagnara et al., 2010). In periods, the growth and number of leaves per tiller was less for soil use with a residue height of 20 cm. This resulted from the heights of sampling and the methodology used in the evaluation, because only whole and fully expanded leaves were counted.

In the 1st period of growth, a greater final leaf length was obtained in the soil uses with a residual height of 20 cm. In the 2nd period, the soil uses with a residue height of 20 cm gave higher leaf length. Variations in the final leaf length are due to the relationship between the height of sampling and length of leaves at different insertion levels in the tiller. From the base to the apex of the leaf blade, the length increases as the leaves succeed in the tiller (Lemire and Chapman, 1996) resulting in longer leaves at harvest.

Table 7. Structural characteristics of white oat cv. IPR 126 under different soil uses in two growth periods in the autumn-winter 2011.

Plant height (cm)			**Density of tillers (tillers m²)**			**Number of leaves per tiller**	
Usage soil	**Grown period**		**Grown period**		**Mean**	**Grown period**	
	1º	**2º**	**1º**	**2º**		**1º**	**2º**
G10	48.29^{aA}	41.43^{bB}	366.25	347.93	357.09^{a}	3.61^{aA}	3.18^{bB}
G20	47.73^{aA}	40.46^{bB}	353.46	308.29	330.87^{a}	2.16^{bA}	2.03^{cA}
C10	48.97^{aA}	40.76^{bB}	360.39	354.04	357.22^{a}	3.37^{aA}	3.06^{bB}
C20	48.50^{aA}	40.64^{bB}	358.56	305.13	331.85^{a}	2.11^{bA}	1.92^{cA}
NC - TS	48.80^{aB}	71.87^{aA}	356.58	292.58	324.58^{a}	3.53^{aB}	4.46^{aA}
NC - CS	48.73^{aB}	72.95^{aA}	349.39	290.92	320.15^{a}	3.37^{aB}	4.31^{aA}
Mean	48.5	51.35	357.44^{A}	316.48^{B}		3.02	3.16
CV1 (%)	2.42		4.41			3.62	
CV2 (%)	4.92		9			10.79	
CV3 (%)	6.65		8.99			2.97	

Final leaf length (cm)			**Stem diameter (mm)**		**Leaf / stem ratio**	
G10	39.31^{cA}	41.48^{bA}	3.58^{aA}	3.31^{bA}	1.56^{cB}	2.12^{bA}
G20	45.61^{aB}	51.08^{aA}	3.46^{aA}	3.66^{bA}	2.33^{aB}	2.80^{aA}
C10	39.71^{cA}	40.50^{bA}	3.47^{aA}	3.24^{bA}	1.55^{cB}	2.05^{bA}
C20	45.86^{aB}	52.86^{aA}	3.51^{aA}	3.62^{bA}	2.24^{aB}	2.69^{aA}
NC - TS	42.55^{bA}	39.79^{bA}	3.58^{aB}	4.55^{aA}	1.76^{bA}	1.09^{cB}
NC - CS	42.58^{bA}	40.45^{bA}	3.59^{aB}	4.54^{aA}	1.71^{bA}	1.08^{cB}
Mean	42.6	44.36	3.53	3.82	1.86	1.97
CV1 (%)	1.47		5.86		0.65	
CV2 (%)	3.36		4.6		2.1	
CV3 (%)	2.52		5.42		2.1	

Means followed by the same lowercase and uppercase in the column on the line do not differ statistically at a 5%. CV1, CV2 and CV3 (%): coefficient of variation factor for the period (P), soil use factor (SU) and interaction PxSU respectively. G10 and G20: grazing with residue height of 10 and 20 cm, C10 and C20: cutting for haymaking with residue height of 10 and 20 cm; NC - TS and NC-CS: no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop.

Stem diameter was influenced by soil uses only in the 2nd growth period, being higher in the uses without cutting or grazing, and yet increasing from the 1st to the 2nd growth period (Table 7). The result is due to the development and dry matter accumulation of plants, as the stem diameter increases to the strength required to support the leaves. For the leaf/stem ratio, a characteristic behavior was observed for the heights of the forage crop. Both in the 1st and 2nd periods of growth, the leaf/stem ratio was higher in soil uses with a residual height of 20 cm. For soil uses with grazing or cutting, there was an increase in leaf/stem ratio of forage obtained from the 1st to the 2nd growth period. While a reduction was observed for soil uses no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop (Table 7). The differences are due to the distribution of extracts of the leaves in the canopy and the heights of the forage crop, which alter the quantities of stem forage. In soil uses without grazing or cutting, the plants accelerated their cycle, and their internodes lengthened early (Rocha et al., 2004), due to the entry into the reproductive phase.

The changes in nutritional value of forage produced by oats IPR 126 in 2011 was consistent with the structural changes observed, and all studied components were altered by the interaction of the factors (Table 8). The CP concentration changed only in the 2nd period of growth being higher in the forage produced on soil uses with a residue height of 20 cm and less in the absence of grazing or cutting. Only the forage produced by oats managed at a residue height of 20 cm did not show a reduction in the concentration of CP from the 1st to the 2nd growth periods (Table 8). This fact is related due to leaf in the forage, then the remaining residue (Table 7).

Concentrations of NDF, ADF, hemicellulose, lignin and cellulose were higher in soil uses without grazing or cutting in comparison to the others only in the 2nd period of growth. However, in this evaluation, all the soil uses favored forage production with higher NDF (Table 8). The other fibrous components of forage studied (ADF, lignin,

Table 8. Nutritive value of white oat cv. IPR 126 under different soil uses in two growth periods in the autumn-winter 2011.

CP (g kg^{-1})			**NDF (g kg^{-1})**		**ADF (g kg^{-1})**	
Usage soil	**Grown period**		**Grown period**		**Grown period**	
	1º	**2º**	**1º**	**2º**	**1º**	**2º**
G10	177.3^{aA}	148.4^{bB}	509.0^{aB}	538.8^{bA}	307.7^{aA}	317.6^{bA}
G20	176.0^{aA}	170.6^{aA}	505.9^{aB}	541.7^{bA}	308.3^{aA}	318.2^{bA}
C10	172.6^{aA}	145.0^{bB}	506.9^{aB}	539.8^{bA}	301.9^{aA}	312.4^{bA}
C20	175.3^{aA}	172.9^{aA}	510.5^{aB}	539.9^{bA}	305.7^{aA}	322.0^{bA}
NC - TS	176.7^{aA}	106.0^{cB}	509.1^{aB}	689.7^{aA}	308.0^{aB}	417.2^{aA}
NC - CS	173.9^{aA}	100.4^{cB}	508.7^{a}B	696.2^{aA}	303.8^{aB}	416.7^{aA}
Mean	175.3	140.5	508.3	591	305.9	350.7
CV1 (%)	3.63		4.86		2.2	
CV2 (%)	5.33		3.27		6.36	
CV3 (%)	3.16		2.59		2.31	

Usage soil	**Hemicellulose (g kg^{-1})**		**Lignin (g kg^{-1})**		**Cellulose (g kg^{-1})**	
G10	201.3^{aA}	221.2^{bA}	44.0^{aA}	45.2^{bA}	289.7^{aA}	295.5^{bA}
G20	197.6^{aA}	223.5^{bA}	41.5^{aA}	43.6^{bA}	282.9^{aA}	295.3^{bA}
C10	205.0^{aA}	227.4^{bA}	41.0^{aA}	43.7^{bA}	290.9^{aA}	289.9^{bA}
C20	204.8^{aA}	217.9^{bA}	45.4^{aA}	44.4^{bA}	282.9^{aA}	288.5^{bA}
NC - TS	201.1^{aB}	272.4^{aA}	42.8^{aB}	55.3^{aA}	289.6^{aB}	338.8^{aA}
NC - CS	204.9^{aB}	279.5^{aA}	44.5^{aB}	55.9^{aA}	283.6^{aB}	334.6^{aA}
Mean	202.4	240.3	43.2	48	286.6	307.1
CV1 (%)	15.15		3.83		5.02	
CV2 (%)	11.85		9.38		8.84	
CV3 (%)	7.63		5.57		4.59	

Means followed by the same lowercase and uppercase in the column on the line do not differ statistically at a 5%. CV1, CV2 and CV3 (%): coefficient of variation factor for the period (P), soil use factor (SU) and interaction PxSU respectively. G10 and G20: grazing with residue height of 10 cm and 20 cm, C10 and C20: cutting for haymaking with residue height of 10 and 20 cm; NC - TS and NC-CS: no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop.

hemicellulose and cellulose) were higher in the 2nd growth period in the forage managed without cutting or grazing (Table 8). The observed differences in the components of the nutritional value of the forage is due to the types and heights of management imposed on oats in different soil uses, and the advancement in the age of the plants and changes in the proportions of the components of the forage (leaves and stems). The determination of fiber components and CP in fodder crops is essential for the study of their nutritional value. In the analysis of NDF, the total concentration of cellulose, hemicellulose and lignin of the cell wall is estimated, and the concentration of these components in the forage is inversely related to the ability of DM intake by animals (Van Soest, 1994). Besides the limitation in dry matter consumption imposed by the effect of the filler on diets with a high concentration of NDF, depression consumption in ruminants can be attributed to a deficiency of CP (Van Soest, 1994).

In three years of conducting the study (2009, 2010 and 2011) and in all the evaluations performed, the forage produced had CP concentrations greater than 70 g kg^{-1}, which is a value considered as the lower limit for ruminants (Van Soest, 1994). The NDF concentration observed throughout the study remained below the maximum limit recommended for ruminant feed (550 to 600 g kg^{-1}) (Van Soest, 1994), except in the forage produced in 2010 (Table 5) and produced by oats in the soil uses no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop. In the last grown period in year 2009 (Table 4) and 2011 (Table 8). Thus in 2010 the soil uses no grazing or cutting with subsequent direct seeding or conventional soil tillage for sowing of the summer crop, and in the year 2009 and 2011 is 3rd grown period not produced conditions for the forage produced would not be recommended for the supply to ruminants as an exclusive food diet.

Conclusions

High dry matter production , close to 5000 kg ha - 1 , are obtained with the management of oat with cuts or grazing residual height of 10 or 20 cm , or When taken with a residual height of 15 cm at the end of the cycle. The dry matter production was drastically reduced with cuts or grazing use, not the realization of the 3rd, 2nd or cutting or grazing of livestock farming systems integration that takes place in grain crops in succession being.To obtain forage of higher quality and better production distributed over the autumn- winter oat should be managed with grazing or cutting.The use of grazing or successive cuts in oats provides forage production with higher nutritional value compared to single crop at the end of the cycle.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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