academicJournals

Vol. 9(13), pp. 1086-1093, 31 March, 2014
DOI: 10.5897/AJAR2013. 8512
Article Number: 3650E0447072
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Oats forage management during winter and nitrogen application to corn in succession

Deise Dalazen Castagnara[1]*, Lucas Guilherme Bulegon[2], Paulo Sérgio Rabello de Oliveira[2], Tiago Zoz[3], Marcela Abbado Neres[2], Bruno Borges Deminicis[4] and Fábio Steiner[3]

[1]Federal University of Pampa, Uruguaiana – Rio Grande do Sul, Brazil.
[2]State University of West Paraná, Brazil.
[3]State University Paulista Júlio Mesquita Filho, Brazil.
[4]Federal University of Espiríto Santo, Brazil.

Received 16 January, 2014; Accepted 21 March, 2014

Tests were conducted aimed at studying the combination of different uses of soil cultivated with white oats cv. IPR 126 during winter with different of nitrogen (N) fertilization managements in corn in succession. Oats management regimes included grazing with 10 or 20 cm of residue heights (G10 or G20); mechanically cut (for haymaking) with 10 or 20 cm of residue heights (C10 or C20); without grazing or cutting with tillage (ST); and without grazing or cutting with conventional (SC) soil preparation. Nitrogen management schemes included 100:0:0; 0:25:75; 0:50:50; 0:75:25; 0:100:0; and 0:50:50 (during pre-sowing and V_4 and V_8 growth stages). The experiment was conducted on Oxisol as a randomized block design in a layout of plots (soil regimes) with split plots (management of N) with three replications. The quantity and characteristics [concentrations of carbon (C) and N] of the straw deposited by oats as well as yield components and grain yield of corn were investigated. The ST and SC soil regimes provided greater deposition of straw with less concentration of N but greater concentration of C, with, consequently, a greater C:N ratio. Addition of C to soil was greater in soil regimes where the oats were not grazed or cut. The management of N did not affect the characteristics of the corn cultivation, and the foliar-N content and productivity were lower in soil regimes ST and SC. The corn had limited productivity when established in succession to white oats with straw higher than 4000 kg ha^{-1} and a C:N ratio more than 34. The use of white oats for grazing or cutting on 10- and 20-cm residue heights did not affect negatively the productivity of corn introduced in succession. Independent of the quantity and C:N ratio of straw in coverage, N management did not alter the foliar-N content, the characteristics of the plants, or the yield components and grain yield of corn.

Key words: *Avena sativa,* immobilization, mineralization, C:N ratio, *Zea mays*.

INTRODUCTION

Crop-livestock integration is a technique that allows the production of forages and grain production to be switched in the same area throughout the year. To obtain income by producers, forage production in times of shortage

*Corresponding author. E-mail: deisecastagnara@yahoo.com.br. Tel/Fax: +55 (55) 34134321.

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	mg dm^{-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.

and the deposition of straw occur simultaneously through thecultivation of forage species in areas normally kept fallow in dry-season grain crops. In this type of crop-livestock integration, the benefits added to the soil by the tillage system are enhanced by the introduction of forage species (Loss et al., 2011), which generally accumulate more carbon than agricultural crops, ensuring soil cover (Embrapa, 2009).

Among the forages used, oats is attractive because it can be used as a cover plant in addition to its applications in forages (Floss et al., 2007). However, the amount of oats straw deposited on the surface of the soil must be in agreement the successor crop. Excessive quantities of straw preceding the sowing of corn are not desired because during decomposition it can compromise the availability of N due to its high carbon:nitrogen ratio (C:N) (Silva et al., 2006) and the occurrence of microbial immobilization of N (Amado et al., 2003).

Cultivation of corn is one of the most demanding of fertilizers, especially N (Cancellier et al., 2011). Greater quantity requirements and other factors influence the productivity and burdens of production costs (Melo et al., 2011).

Times and methods of N fertilizer application on corn are widely studied in agriculture, especially in systems exclusive for direct seeding. However, in crop-livestock integration systems, N application studies are still scarce (Sandini et al., 2011). Its handling is more complex due to the great dependence on climatic conditions (Cantarella and Duarte, 2004), and techniques that maximize the absorption of N by plants and minimize their losses to the environment can contribute to improving the sustainability of production systems.

The above work has been prepared on the assumption that the maintenance of adequate amounts of crop residue on the soil surface associated with split applications of N can reduce N losses in the system through immobilization and synchronize N availability to plants by mineralization. In this context, this study aimed to investigate combining different regimes of soil cultivated with white oats during the winter period with different splitting of N fertilization in oats/corn succession in a crop-livestock integration system.

MATERIALS AND METHODS

This work was conducted during the period from May 2009 to March 2010 at the “Antonio Carlos dos Santos Pessoa Teacher” experimental farm (latitude 24°33'22'' S and longitude 54º03'24'' W, at an altitude of approximately 400 m) at the State University of West Paraná - Campus Marechal Cândido Rondon, on an Oxisol. The area was being managed under no tillage, following the succession of soybean/corn/oats crops in the three latest agricultural yields. At the time the study was implemented, the soil had the physicochemical properties described in Table 1.

The climate of the region, according to the Köppen classification, is a Cfa-type shrubland, with well-distributed rainfall throughout the year (IAPAR, 2006). Climatic data of the experimental period were obtained from an automatic climatological station at the State University of West of Paraná, about 100 m from the experimental area and are presented in Figure 1.

The experimental design was a randomized block in a track with split plots with three replications. On the plots were allocated six soil regimes: G10, grazing with a 10-cm height of residue; G20, grazing with a 20-cm height of residue; C10, mechanically cut (for haymaking) with residue of 10 cm; C20, cut with a residue of 20 cm; ST, without grazing or cuts with tillage for sowing of the summer crop; and SC, without grazing or cuts with conventional preparation of soil for sowing of the summer crop; these were also in the sub-plots of the N fertilization management regimes (Table 2). Plots had dimensions of 15 × 30 m, and each plot was subdivided into six sub-plots with dimensions of 5 × 15 m.

The white oats (*Avena sativa* cv. IPR 126) sowing occurred on May 24 using a precision seed drill attached to a tractor at a seed density of 70 kg ha^{-1} distributed in rows spaced 0.17 m apart without a starter fertilizer. Three cuts or grazings were made, the first 55 days after the emergence of oats and the others at 30-day intervals.

For the three grazings, Holstein cows in lactation were used, which weighed approximately 550 ± 28.5 kg. The cows were distributed in the plots (paddocks) where they grazed for two days to obtain the desired heights of residue (10 and 20 cm). To obtain the desired heights, manning variables were used according to the put-and-take technique (Mott and Lucas, 1952). For treatments that were cut, a mechanical harvester coupled to a tractor set to the desired cutting height (10 and 20 cm) was used, always on the final day of grazing.

In succession of oats, corn was sown. At the time, the plots intended for soil regimes G10, G20, C10, C20, and ST were desiccated using the herbicide glyphosate (1800 g ha^{-1} active ingredient) with a volume of 250 L ha^{-1}, while the plots designated for soil regime SC were prepared mechanically via grating and leveling.

To determine the quantity of straw, sampling occurred seven days before the sowing of corn with the aid of a metallic square with known area (0.25 m²). The square was randomly placed twice in each sub-plot, and all straw on the soil surface contained inside was collected. Following collection, the material was passed through a sieve with a mesh of 3 mm for the withdrawal of excess soil. It was then subjected to kiln-drying with forced ventilation of air at a temperature of 55°C for 72 h and later weighed to determine the dry mass. After weighing, the quantities of straw deposited per hectare and the material was crushed in a Willey grinder to

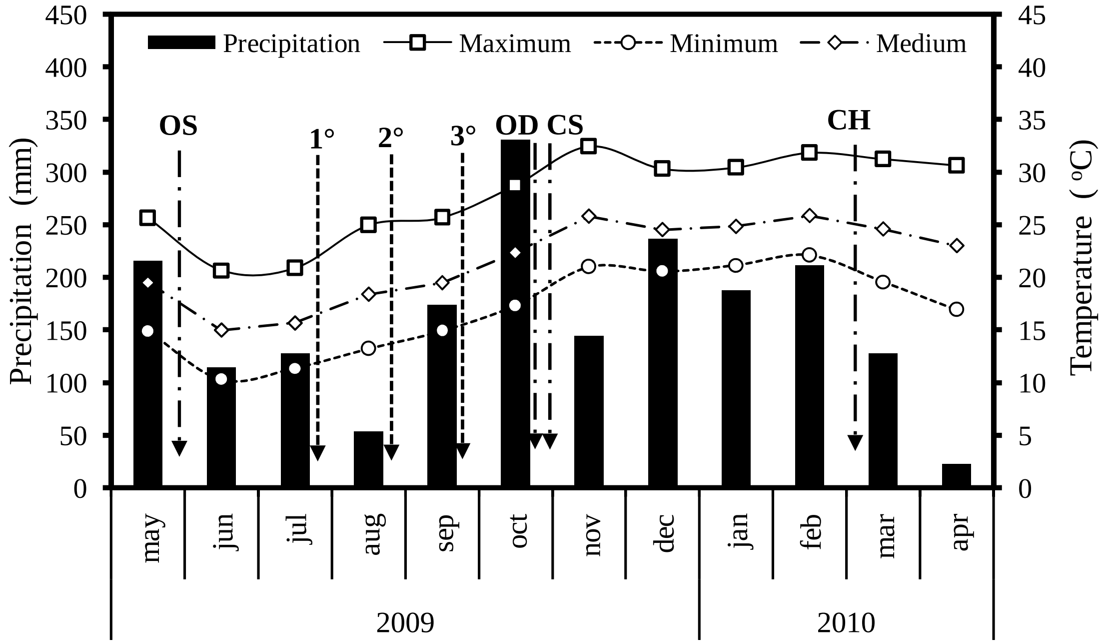

Figure 1. Monthly averages of maximum, minimum, average and cumulative rainfall during the months of the trial period. OS: Oats sowing; 1º, 2º, 3º: first, second and third grazing or cutting oats, respectively; OD: Oat desiccation; CS: Corn sowing; CH: Corn harvest. Source: Automatic Climatological station of Experimental Stations of Unioeste, Marechal Candido Rondon-PR, 2009-2010.

Table 2. Managements of nitrogen for corn.

Managements (kg ha^{-1})	Pre sowing*	Sowing **	Coverage	
			V_4	V_8
100:0:0	100	40	0	0
0:25:75	0	40	25	75
0:50:50	0	40	50	50
0:75:25	0	40	75	25
0:100:0	0	40	100	0
50:50:0	50	40	50	0

*Application seven days before to sowing of corn; ** Provided by formulated 8:20:15 (N: P_2O_5: K_2O). V_4, V_8: stages of vegetative development of corn.

determine the concentrations of N and C. The N concentration was determined by sulfuric acid digestion and distillation using a Kjeldhal semi-micro system (Embrapa, 2009), while C was obtained from the determination of organic matter using a muffle furnace, as described by Silva and Queiroz (2006). To estimate the concentration of C in organic matter, organic matter content values of samples were divided by 1.72, as recommended by Peixoto et al. (2007). The C and N stocks were calculated from the residual straw and concentrations of elements.

The additions of C and N to the soil by the systems studied were estimated from the amount of dry matter of straw deposited by the oats and their concentrations. Average contribution of the root system is considered to be 30% of total C and N contained in the shoot. When calculating C addition, it was considered an average of 40% of this element in plant dry matter of oats (Costa et al., 2008).

The sowing of corn occurred on October 29, 2009, using the triple hybrid CD 384 with a row spacing of 0.70 m and density of 4.2 seeds per meter, with a population density goal of 60,000 plants ha^{-1}. A starter fertilizer was used at a rate of 200 kg ha^{-1}, formulated as 8-20-15. Fertilization occurred in the RS and SC regimes based on recommendations for corn of the Committee on Chemistry and Soil Fertility (CQFS-RS/SC, 2004). The fertilizer was a fixed dose of 40 kg ha^{-1} of N for all management schemes adopted, and applications were performed at the V_4 and V_8 phenological stages, as recommended by Ritchie et al. (2003) (Table 2). The pre-seeding application was performed seven days prior to sowing corn, and in all applications the source of N was urea (45% N).

When the emergence of female inflorescences occurred, sampling was performed to diagnose leaf N content according to Malavolta (1997). The sampled leaves were washed with deionized water, had the midrib discarded, and were dried in an oven with

Table 3. F values calculated for the amount, concentration ([ ]), stock (S), added (A) and C/N ratio of straw deposited by oat cv. IPR 126 under different soil uses.

Source of variation	DF	Straw	[ ] of N	[ ] of C	S of N	S of C	A of N	A of C	C:N ratio
Block	2	3.839^{ns}	0.726^{ns}	0.154^{ns}	3.003^{ns}	4.584^{ns}	3.003^{ns}	3.839^{ns}	0.066^{ns}
Nitrogen (N)	5	0.459^{ns}	0.768^{ns}	2.102^{ns}	0.604^{ns}	0.467^{ns}	0.604^{ns}	0.459^{ns}	0.327^{ns}
Error 1	10								
Soil uses (SU)	5	68.023**	436.251**	27.025**	6.186**	69.223**	6.186**	68.023**	408.807**
Error 2	10								
NxSU	25	1.014^{ns}	1.409^{ns}	2.041^{ns}	1.263^{ns}	1.240^{ns}	1.263^{ns}	1.014^{ns}	1.397^{ns}
Error 3	50								
CV1 (%)		13.96	9.38	1.92	14.78	13.40	14.78	13.96	10.96
CV2 (%)		20.18	6.55	3.03	15.05	22.03	15.05	20.18	9.49
CV3 (%)		14.34	7.63	2.39	14.99	14.56	14.99	14.34	12.31

^{ns},**: Not significant, significant at 1% probability by the F test, respectively. CV1, CV2 and CV3 (%): coefficients of variation for nitrogen (N), soil use (SU), and interaction NxSU, respectively.

Table 4. Amount, concentration ([ ]), stocks (S), added (A) and C/N ratio of straw deposited of white oat cv. IPR 126 in different soil uses.

Soil uses	Straw (kgha^{-1})	[] of N (gkg^{-1})	[] of C (gkg^{-1})	S of N (kgha^{-1})	S of C (kgha^{-1})	A of N (kgha^{-1})	A of C (kgha^{-1})	C:N ratio
G10	1886^{b}*	31.58^{a}	490.17^{b}	58.77^{bc}	924.48^{b}	76.40^{bc}	980.61^{b}	15.58^{b}
G20	2162^{b}	32.02^{a}	500.81^{b}	69.24^{ab}	1084.60^{b}	90.01^{ab}	1124.27^{b}	15.74^{b}
C10	1790^{b}	32.04^{a}	489.84^{b}	57.19^{c}	875.83^{b}	74.34^{c}	930.57^{b}	15.34^{b}
C20	2269^{b}	31.31^{a}	496.13^{b}	70.97^{a}	1126.61^{b}	92.27^{a}	1179.73^{b}	15.93^{b}
ST	4050^{a}	15.49^{b}	527.39^{a}	62.18^{abc}	2136.68^{a}	80.83^{abc}	2106.21^{a}	34.58^{a}
ST	4051^{a}	15.21^{b}	531.90^{a}	61.62^{abc}	2156.47^{a}	80.11^{abc}	2106.71^{a}	35.40^{a}

Means followed by the same letter within a column are not significantly at 5%. G10, grazing with 10 cm height of the residue of; G20, grazing with a height of 20 cm of waste; C10, cut for haymaking with residue of 10 cm; C20, cut for haymaking with residue of 20 cm; ST, without grazing or cuts with tillage sowing of the summer crop; SC, without grazing or cuts with conventional preparation of soil for sowing of the summer crop

forced-air ventilation at a temperature of 55ºC for 72 h. Grinding and determination of N content occurred according to the methodology proposed by Embrapa (2009).

When harvest occurred on March 5, 2010, biometric characteristics were determined on 10 plants selected at random within the area of each plot. Data collected included stem diameter (with the aid of digital caliper measured between the first node visible from the ground surface), plant height (distance between the ground surface and the insertion of the last fully expanded leaves), and height insertion spike (distance between the ground surface and the base of the first spike).

Following biometric evaluations, manual harvest occurred (during March 2010) by collecting all the useful cobs from each plot. Of these, 10 spikes were taken at random to determine the number of kernel rows per spike and number of kernels per row (by manual counting), spike diameter (with the aid of a digital caliper), and spike length (with the aid of ruler graduated in centimeters). All harvested ears were subjected to a mechanized trail. The yield was estimated by weighing the grain obtained from the trail and corrected for kg ha^{-1} densities. The mass of 1000 grains was estimated by manually counting and weighing eight samples of 100 grains. The humidity of the samples was corrected to 13% moisture using a digital determiner.

The data were subjected to analysis of variance, and means were compared using the Tukey test at 5% probability.

RESULTS AND DISCUSSION

There was a significant effect of soil regime on the C:N ratio of oat straw. There were also significant effects in concentrations and stock of N and C in the straw and quantities of N and C added to the soil by oat straw (Table 3).

When the oats were subjected to cutting or grazing, the production of straw was lower than the soil regimes without cutting or grazing (Table 4). The result was expected due to harvesting of dry matter forage, because the regrowth capacity of the plants will be reduced as they undergo successive harvests, hampering the recovery of new leaf area and new accumulation of dry mass. Similar results were obtained by Flores et al. (2007) and Lopes et al. (2009). When working with oats and ryegrass intercrop under grazing stubble heights of 10, 20, 30, and 40 cm post grazing, these authors obtained values ranging from 1850-1860 to 5170-5400 kg ha^{-1} dry matter, from lowest to maximum height, respectively. In the same study, Flores et al. (2007) had residual straw amounts of 6050 kg ha^{-1} dry matter in an area not subject to grazing. The presence of straw on the soil surface acts as a barrier for absorbing animal trampling (Lopes et al., 2009), and even amounts of straw near 2000 kg ha^{-1} are unable to compromise the yield of subsequent crops (Flores et al., 2007).

The soil regimes not cut or grazed led to deposition of straw with higher concentrations of C and lower N concentrations compared to the straw deposited by oats in other soil regimes (Table 4). The results obtained for the concentration of N in straw were expected, as the cutting or grazing of plants eliminates the possibility of lignification of plant structures and stimulates the regrowth and emergence of new shoots and new leaves, which, in turn, have N contents higher than that contained in the biomass of older plants. When oat plants are maintained under free growth (such as ST and SC), lignification of the cell wall (Campos et al., 2002) and reduction in crude protein (Vasconcelos et al., 2009) occur with a consequent reduction in N concentration (Henriques et al., 2007). When oats had been subjected to cutting or grazing, tillering and leaf area renewal were stimulated, and the plants remained in a vegetative stage with higher N concentration in dry matter.

In the stocks of estimated N in the straw and addition of N to the soil, higher values were obtained when oats were harvested by cutting with a height of 20-cm residue compared to the samples that received cutting or grazing with a residual height of 10 cm. The result is due to the deposited amounts of straw and differences in the concentration of this nutrient in the straw deposited. When the oats were not subjected to grazing or cutting, the N concentration was reduced by more than 50%, but higher straw deposition compensated for this reduction. In the areas where the oats were subjected to cutting or grazing, the obtained concentrations of N were similar to the straw of 10- and 20-cm heights by providing greater deposition amounts of straw; the plots cut with a residual height of 20 cm consequently provided a greater N stock (Table 4). Already for C, the largest stock and greater addition of C were obtained in soil regimes without cutting or grazing of the oats compared to other regimes (Table 4). The results observed for C are consistent with the concentration of the dry weight and amount of straw deposited.

The study of C stocks in the straw has received increased attention with the adoption of new concepts of sustainability, since the addition of plant residue in soil tillage is of utmost importance to maintaining and increasing the levels of organic matter in the soil (OMS), which has a key role in maintaining sustainable production over time (Lopes et al., 2009). Regarding the addition of C, grasses have great potential to add it to the soil, as reported by Rossi et al. (2012). The authors also noted the addition of C to the soil to inter plant with grain crops. The study of C addition to soil is important since it has a direct relationship with soil properties, enabling the soil to perform its functions and ensuring its quality (Vezzani and Mielniczuk, 2009).

In the case of the C:N ratio, the amount of straw obtained in the area where the oats had not been managed was higher than the straw deposited in areas where oats were subjected to cutting or grazing (Table 4). The values observed for the C:N ratio showed a direct relationship with age of plant development. This is because increased age of development causes an increase in the concentration of dry weight structural components, which are rich in C. There is also a concomitant decrease in cellular contents (Zanine and Macedo, 2006) and reduction in the amount of N in dry matter. Based on the classification proposed by Moreira and Siqueira (2006), the straw deposited by oats that was not subject to cutting or grazing had a high C:N ratio (>30), while the ratio of straw deposited by oats cut or grazed was considered low (<20). The addition of crop residues with high C:N ratios in the soil can cause a depletion in N due to the high demand of N by microbes causing N immobilization in soil. When the C:N ratio is low, the liberation of the element via mineralization occurs (Moreira and Siqueira, 2006).

In corn, only significant effects of soil regime on the leaf N content and grain yield were observed (Tables 5 and 6). None of the characteristics or yield components of the studied corn plants were affected by N management regimes or their interactions with soil regimes (Tables 5 and 6). This result may be related to the climatic conditions of the experiment (Figure 1), especially the period that encompassed the N applications.

The leaf N content of corn grown in areas subjected to cutting or grazing was higher than corn grown in areas where oats were not handled (Table 7). This result shows the occurrence of balance between the decomposition of straw and the processes of immobilization and mineralization of nutrients and the nutritional requirements of corn and is consistent with those observed by other authors (Hurtado et al., 2010). It is worth noting that cutting or grazing contribute to N cycling (Assmann et al., 2003) by stimulating the renewal of plant leaves, which retains N longer in the system and slows losses mainly due to leaching.

The lower leaf N content in soil regimes where there was greater deposition of straw can be attributed to immobilization of N due to the high C:N ratio present in these residues (Silva et al., 2007). In accordance with a high C:N ratio, the higher level of C in the straw added to soil by oats that is available for soil microbes enables greater immobilization of N, resulting in reduction in levels of mineral N in the soil and possibly lower concentration of nutrients in plant dry matter (Silva et al., 2007).

The productivity followed a similar pattern to that observed for leaf N. Productivity was higher in soil regimes with cutting or grazing and lower in soil regimes with greater deposition of straw (Table 7). The lowest

Table 5. F values calculated for the characteristics of corn plants grown under different soil uses (Soil Use) and managements of nitrogen (Nitrogen).

Source of variation	DF	Foliar nitrogen	Plant stand	Spikes index	Plants height	Height spikes insertion	Stem diameter
Block	2	6.012^{ns}	1.260^{ns}	0.428^{ns}	2.476^{ns}	5.110^{ns}	1.084^{ns}
Nitrogen (N)	5	1.791^{ns}	1.583^{ns}	0.200^{ns}	1.253^{ns}	0.430^{ns}	1.031^{ns}
Error 1	10						
Soil use (SU)	5	12.882**	1.091^{ns}	1.668^{ns}	1.680^{ns}	0.566^{ns}	1.096^{ns}
Error 2	10						
NxSU	25	1.724^{ns}	1.551^{ns}	1.662^{ns}	0.989^{ns}	1.002^{ns}	1.016^{ns}
Error 3	50						
CV1 (%)		3.60	8.65	16.15	4.62	8.33	6.52
CV2 (%)		7.23	7.12	12.2	5.11	7.27	5.45
CV3 (%)		3.22	6.84	11.57	5.03	7.5	7.54

^{ns},**: Not significant, significant at 1% probability by the F test, respectively. CV1, CV2 and CV3 (%): coefficients of variation for nitrogen (N), soil use (SU), and interaction NxSU, respectively.

Table 6. F values calculated for the yield components and corn productive under different soil uses (Soil Use) and managements of nitrogen (Nitrogen).

Source variation	DF	Spike diameter	Length spikes	Kernels rows per Spike	Grains per row	Thousand grains weight	Grain yield
Block	2	0.497^{ns}	1.400^{ns}	1.985^{ns}	0.752^{ns}	0.031^{ns}	1.361^{ns}
Nitrogen(N)	5	1.129^{ns}	1.218^{ns}	0.652^{ns}	0.567^{ns}	1.205^{ns}	2.471^{ns}
Error 1	10						
Soil use (SU)	5	2.687^{ns}	0.227^{ns}	0.938^{ns}	0.771^{ns}	1.676^{ns}	56.882**
Error 2	10						
N*SU	25	1.275^{ns}	1.788^{ns}	1.173^{ns}	1.728^{ns}	1.663^{ns}	1.494^{ns}
Error 3	50						
CV1 (%)		2.51	9.75	4.51	7.51	12.06	3.36
CV2 (%)		2.23	10.47	6.57	6.39	9.98	3.74
CV3 (%)		2.69	8.36	5.25	5.04	9.26	5.17

^{ns},**: Not significant, significant at 1% probability by the F test, respectively. CV1, CV2 and CV3 (%): Coefficients of variation for nitrogen (N), soil use (SU), and interaction NxSU, respectively.

Table 7. N foliar content and productivity of corn in succession of white oat under different soil uses.

Soil uses	Foliar N (g kg^{-1})	Grain yield (kg ha^{-1})
G10	34.39^{a}	8025^{a}
G20	34.21^{a}	8070^{a}
C10	33.80^{a}	8339^{a}
C20	33.07^{a}	8271^{a}
ST	30.04^{b}	7364^{b}
SC	30.18^{b}	7057^{b}

Means followed by the same letter within a column are not significantly at 5%. G10-grazing with 10 cm height of the residue of; G20, grazing with a height of 20 cm of waste; C10, cut for haymaking with residue of 10 cm; C20, cut for haymaking with residue of 20 cm; ST, without grazing or cuts with tillage sowing of the summer crop; SC, without grazing or cuts with conventional preparation of soil for sowing of the summer crop.

yield of corn when no cutting or grazing of oats occurred was caused by low N availability to plants because the inadequate supply of N is considered a major factor limiting the yield of corn (Cancellier et al., 2011). The deposition of large amounts of straw with a high C:N ratio (Table 4) and its decomposition contributed to the occurrence of microbial immobilization of N available in the soil (Hutchison and Walworth, 2007), reducing availability of this nutrient to plants. Sandini et al. (2011) observed a reduction in the productivity of the crop when grown in rotation with winter forage that received no N fertilizer and also attributed their results to the occurrence of microbial immobilization due to high input of crop residues with high C:N. Another factor that should be emphasized is that soil preparation induced more favorable conditions for leaching of N in the soil. This occurs when the soil structure is disrupted, thereby hindering the fixation of N in the soil with the other molecules present. Still worth highlighting is that N moves and is absorbed primarily via mass flow. Thus, due to disruption of the soil that is damaged, N can be leached by water. Unstructured soil has lower water retention enabling water to quickly reach greater depths where the plants are unable to make use of the N.

The greater yield in plots subjected to grazing or cutting reveals that there was no competition between corn plants and soil microorganisms for N in the soil and applied through fertilization. The lack of statistical difference between plots that were cut or grazed also shows that potential productivity losses caused by animal trampling were offset by their waste disposal, balancing productivity in areas with the presence of animals. In a study of soil management in corn, Balbinot Jr. (2011) also found no differences in crop yield when grown in rotation with winter forage.

The process of N immobilization due to the maintenance of large amounts of straw on the soil surface is not completely negative in production systems aimed at sustainability. The maintenance of organic N helps prevent or at least minimizes the occurrence of nitrogen loss due to leaching. Its gradual accumulation of organic forms enhances the ability of N supply over time, while the benefits of the straw can mitigate the effects of drought, reducing the evaporation of water and maintaining soil moisture for a longer period (Cruz et al., 2007), contributing to the development of corn (Ferreira et al., 2009).

The lack of significance of the N fertilization managements on corn yield can be explained by timing of N application, since all others received the application in the V_4 stage (with the exception of management 100:0:0), time is defined as the potential crop yield (Ritchie et al., 2003). This result confirms that even in the 0:25:75-management scheme, applying the lower portion (25 kg ha^{-1} N) was sufficient to determine the maximum crop yield potential in the environmental conditions and management regimes studied.

In the 100:0:0-management scheme, in which all applied side-dressed N was applied in advance (as is typical), the presence of crop residues on the surface may have contributed to the retention of applied N, which was initially held but mineralized in order to meet the demand for corn, even in soil regimes with higher amounts of crop residues and the lowest C:N ratio. This management aims to increase the availability of N in the early stages of crop development and reduce the effect of N immobilization by soil microorganisms to decompose crop residues with high C:N ratios (Pöttker and Wiethölter, 2004).

These results show that all N-management schemes studied are applicable to corn using the soil regimes tested. However, according to Kluthcouski et al. (2006), only in soils with straw provided with a continuous supply of adequate organic matter content can N fertilization be anticipated in years with regular rainfall. Otherwise, in addition to rising costs with the increase in applications, there is the risk of loss of applied mineral N by leaching due to excess rains.

Conclusions

Corn has limited productivity when established in succession to oats with straw greater than 4000 kg ha^{-1} and a C:N ratio greater than 34, regardless of anticipation or of split-N fertilization. The use of oats for grazing or crop residue on heights of 10 and 20 cm does not compromise the productivity of corn introduced in succession. When corn is established with a fixed dose of 40 kg ha^{-1} N at seeding, the amount of N in pre-sowing and side-dressing at the V_4 and V_8 leaf stages does not affect the leaf N content, characteristics of the plants, or yield components and production, regardless of the quantity and C:N ratio of crop residue cover.

Conflict of Interests

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

REFERENCES

Amado T, Santi JCA, Acosta JAA (2003). Effect of nitrogen application rates on black oat residue decomposition, nitrogen release and corn yield in soil under no-tillage. Rev. Bras. de Ciênc. Solo. 27(6):1085-1069.

Assmann TS, Ronzelli Júnior P, Moraes A, Assmann AL, Koehler HS, Sandini I (2003). Corn yield on no tillage crop-pasture rotation in presence and absence of white clover, grazing and nitrogen. Rev. Bras. de Ciênc. Solo. 27(4):675-683.http://dx.doi.org/10.1590/S0100-06832003000400012

Campos FP, Lanna DPD, Bose MLV, Boin C, Sarmento P (2002). Elephantgrass degradability at different maturity stages evaluated by the in vitro/gas technique. Sci. Agric. 59(2):217-225. http://dx.doi.org/10.1590/S0103-90162002000200003

Cancellier LL, Afférri FS, Carvalho EV, Dotto MA, Leão FF (2011). Nitrogen use efficiency and phenotypic correlations of tropical maize populations in Tocantins. Rev. Ciênc. Agron. 42(1):139-148.

Cantarella H, Duarte AP (2004). Soil fertility management for corn. In:

Galvão JCC, MIRANDA GV.(eds). Technology of production of corn,Viçosa. Universidade Federal de Viçosa, pp. 139-182.
COMISSÃO DE QUÍMICA E FERTILIDADE DO SOLO - CQFS-RS/SC (2004). Manual recommendations for fertilizing and liming in the states of Rio Grande do Sul and Santa Catarina. Porto Alegre, Sociedade Brasileira de Ciência do Solo - Núcleo Regional Sul, P. 394.
Costa FS, Bayer C, Zanatta JÁ, Mielniczuk J (2008). Carbon stock and carbon dioxide emissions as affected by soil management systems in Southern Brazil. Rev. Bras. de Ciênc. Solo. 32(1):323-332.http://dx.doi.org/10.1590/S0100-06832008000100030
Cruz CC, Alvarenga RC, Novotny EH, Pereira Filho IA, Santana DP, Pereira FTF, Hernani LC (2007). Tillage. Embrapa Milho e Sorgo, P. 200.
Empresa Brasileira de Pesquisa Agropecuária (2009). Manual for Chemical Analysis of Soils, Plants and Fertilizer. Brasília, Embrapa Informações Tecnológica, P. 627.
Ferreira AO, Sá JCM, Briedis C, Figueiredo AG (2009). Corn genotype performance under black oat crop residues and nitrogen fertilization. Pesq. agropec. Bras. 44(2):173-179.
Flores JPC, Anghinoni I, Cassol LC, Carvalho PCF, Leite JGDB, Fraga TI (2007). Soil physical attributes and soybean yield in an integrated livestock-crop system with different pasture heights in no-tillage. Rev. Bras. de Ciênc. Solo. 31(4):771-780.http://dx.doi.org/10.1590/S0100-06832007000400017
Floss EL, Palhano AL, Soares Filho CV, Premazzi LM (2007). Growth, productivity, characterization and chemical composition of white oat. Acta Sci. Anim. Sci. 29(1):1-7.
Henriques LT, Coelho da Silva JF, Detmann E, Vásquez HM, Pereira OG (2007). Fractions of nitrogenous compounds of four tropical grasses in the different cutting ages and nitrogen fertilizer levels. Arq. Bras.de Med. Vet. Zootec. 59(3):740-748.http://dx.doi.org/10.1590/S0102-09352007000300028
Hurtado SMC, Silva CA, Resende AV, Corazza EJ, Shiratsuchi LS, Higashikawa FS (2010). Sensitivity of the chlorophyll meter for nutritional diagnostic of nitrogen in corn (*Zea mays* L.). Ciênc. Agrotec. 34(3):688-697.http://dx.doi.org/10.1590/S1413-70542010000300023
Hutchison CMW, Walworth JL (2007). Evaluating the effects of gross nitrogen mineralization, immobilization, and nitrification on nitrogen fertilizer availability in soil experimentally contaminated with diesel. Biodegradation 18(2):133-144.http://dx.doi.org/10.1007/s10532-006-9049-7 PMid:16897581
INSTITUTO AGRONÔMICO DO PARANÁ – IAPAR (2006). Climate charts of Paraná, P. 30.
Kluthcouski J, Aidar H, Thung M, Oliveira FRA (2006). Anticipated Nitrogen management in major annual crops. Piracicaba: Potafos, P. 50.
Lopes MLT, Carvalho PCF, Anghinoni I, Santos DTD. Aguinaga AAQ, Flores JPC, Moraes AD (2009). Crop-livestock integration system: effect of oat and italian ryegrass sward height management on soybean yield. Ciênc. Rural. 39(5):1499-1506.http://dx.doi.org/10.1590/S0103-84782009005000096
Loss A, Pereira MG, Giácomo SG, Perin A, Anjos LHC (2011). Aggregation, carbon and nitrogen in soil aggregates under no-tillage with crop-livestock integration. Pesq. Agropec. Bras. 46(10):1269-1276.http://dx.doi.org/10.1590/S0100-204X2011001000022
Melo FB, Cora JE, Cardoso MJ (2011). Nitrogen fertilization, plant density and maize yield cropped under no-tillage system. Rev. Ciênc. Agron. 42(1):27-31.
Moreira FMS, Siqueira JO (2006). Soil Microbiology and Biochemistry. Lavras: UFLA, pp. 729.
Mott GE, Lucas HL (1952). The design, conduct en interpretation of grazing trials on cultivated and improved pastures. In: INTERNATIONAL GRASSLAND CONGRESS, 6., 1952, Pensilvania, Proceedings … Pensilvania: State College, pp. 1380-1395.
Peixoto AM, Souza JSI, Toledo FF, Reichardt K, Molina Filho J (2007). Brazilian Agricultural encyclopedia, Brasília, P. 631.
Pöttker D, Wiethölter S (2004). Timing and methods of nitrogen application for corn under no-tillage. Ciênc. Rural. 34(4):1015-1020.
Ritchie SW, Hanway JJ, Benson GO (2003). As the corn plant develops. Informações Agronômicas 103:1-11.
Rossi CQ, Pereira MG, Giácomo SG, Betta M, Polidoro JC (2012). Labile fractions of organic matter in cropping system with straw of brachiaria and sorghum. Rev. Ciênc. Agron. 43(1):38-46.
Sandini IE, Moraes A, Pelissari A, Neumann M, Falbo MK, Novakowiski JH (2011). Residual effect of nitrogen in the maize production in crop livestock integration. Ciênc. Rural. 41(8):1315-1322.http://dx.doi.org/10.1590/S0103-84782011005000099
Silva AA, Silva PRF, Suhre E, Argenta G, Strieder ML,Rambo L (2007). Soil covering systems in the winter and its effects on maize grain yield grown in succession. Ciênc. Rural. 37(4):928-935.http://dx.doi.org/10.1590/S0103-84782007000400002
Silva DJ, Queiroz AC (2006). Food Analysis: chemical methods and biological. UFV, P. 235.
Silva PRFD, Argenta G, Sangoi L, Strieder ML, Silva AADE (2006). Management strategies of winter cover crops to maize grown in succession in no-till system. Ciênc. Rural. 36(3):1011-1020.http://dx.doi.org/10.1590/S0103-84782006000300049
Vasconcelos WA, Santos EM, Zanine AM, Pinto TF, Lima WC, Edvan RL, Pereira OG (2009). Nutritive value of silages of monbaça grass ("Panicum maximum" Jacq) harvested at different regrowth ages. Rev. Bras. Saúde Prod. Anim. 10(4):874-884.
Vezzani FM, Mielniczuk J (2009). An overview of soil quality. Rev. Bras. de Ciênc. Solo. 33(4):743-755.http://dx.doi.org/10.1590/S0100-06832009000400001
Zanine AM, Macedo JGL (2006). Importance of consume of fiber for nutrition of ruminant. Rev. Electr. Vet. 7(4):1-12.