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RESEARCH PAPER

Forage potential of black oat Iapar 61 alone or in association with birdsfoot trefoil

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Abstract

C. Ducati, M.A. Neres, D.D. Castagnara, P.S.R. Oliveira, D. Weirich, G.M. Silva, and S.M.M. Sunahara. 2015. Forage potential of oat Iapar 61 alone or in association with birdsfoot trefoil. Cien. Inv. Agr. 42(3): 341-351. The objective of this study was to evaluate the structural characteristics, dry matter production, residual mass, chemical composition and *in vitro* dry matter digestibility of Iapar 61 black oat (*Avena strigosa* cv Iapar 61) pasture, both in isolation and in association with birdsfoot trefoil (*Lotus corniculatus* L., cv. St. Gabriel), under different forms of management in three growth cycles. A randomized block design was used with split plots in time with four treatments: conventional tillage oats, oat tillage, oats associated with birdsfoot trefoil and single birdsfoot trefoil, with three periods of evaluation and four replications. The apical meristem of oats increased from the first to the second cycle. The dry matter production of single birdsfoot trefoil was 579.65 kg on average, and the oats tillage production was 2597.78 kg. Oats exhibited high nutritional value before the first grazing in all treatments; however, at the end of its cycle, the association with birdsfoot significantly increased the crude protein content of the forage. The *in vitro* dry matter digestibility was similar between crops and decreased in the third cycle. Birdsfoot increased the nutritional value of oats at the end of the oat life cycle.

Key words: Apical meristem, crude protein, dry matter production, winter legume.

Introduction

Because the main objective of the pasture production system is to reduce the cost of animal feed, techniques that may fully or partially replace

the need for chemical nitrogen fertilizer and ultimately reduce costs are highly desirable for promoting economic sustainability. This research has demonstrated that a viable alternative to this problem is to introduce legumes into the production system via intercropping with other fodder cultivation or by replacing other crops (Alexandrian *et al.*, 2004).

Intercropping of oats with fodder legumes have generated increased biomass production. Abreu *et al.* (2005) claimed that the addition of legumes increased yields and may provide a viable means to increase productivity on the pasture.

Nitrogen is one of the most limiting nutrients for the development of fodder plants; thus, an alternative to the application of urea is to intercrop with legumes for biological nitrogen fixation. According to Aita and Giacomini (2003), the practice of growing mixed stands of grasses with legumes increases productivity and increases economic efficiency, resulting from nitrogen fixation by legumes, which increases their availability in the soil.

Neres *et al.* (2012) found that using legumes with tropical grasses increases productivity; however, whether legumes have the same effect on cool season species is unknown. Thus, there is a need for studies that examine the benefits of integrating crops and livestock farming with the use of perennial legumes in a single production system on the forage, structure and production of straw.

The objective of this study was to evaluate the dry matter production of residual mass, structure, chemical composition and *in vitro* dry matter digestibility of oat Iapar 61 using different forms of cultivation.

Material and methods

The experiment was conducted in September 2012 at the Experimental Farm Professor Antonio Carlos dos Santos Pessoa, which belongs to the State University of West Paraná, campus. Marechal Cândido Rondon from Paraná, Brazil, conducted the field experiments to evaluate the forage potential of oat (*Avena strigosa* cv. Iapar 61) grown singly and in association with birdsfoot trefoil (*Lotus corniculatus* L. cv. St. Gabriel).

Climatic data of the experimental period were obtained automatically from the meteorological

station at the State University of West Paraná, which is located approximately 100 m from the experimental area with soil classified as Oxisol (Embrapa, 2006). The following chemical characteristics of the soil were inferred from the collection of 24 samples at a 0- to 20-cm depth: pH in CaCl₂: 5.05; P (Mehlich): 28.87 mg dm⁻³; K (Mehlich): 1.50 cmolc dm⁻³; Ca²⁺ + (KCl 1 mol L⁻¹): 4.37 cmolc dm⁻³; Mg²⁺ + (KCl 1 mol L⁻¹): 2.03 cmolc dm⁻³; Al³⁺ + (KCl 1 mol L⁻¹): 0.29 cmol c dm⁻³; H + Al (calcium acetate 0.5 mol L⁻¹): 7.7 cmolc dm⁻³; SB – 8.66 cmolc dm⁻³; CEC: 13.88 cmolc dm⁻³; V: 55.33%, organic matter (Boyocus Method) = 23.95 g dm⁻³; Cu: 5.5 mg dm⁻³; Zn: 2.02 mg dm⁻³ and Fe: 23.54 mg dm⁻³.

The experiment was conducted using a randomized complete block design with a split plot in time with four replicates. The plots allocated crops as follows: oat (*Avena strigosa* cv. Iapar 61) grown in conventional tillage (CT), oat tillage (OT) and intercropped with birdsfoot trefoil (O+B) (*Lotus corniculatus* L. cv. San Gabriel) and single trefoil (B) in three grazing cycles (1st: July 4, 2012, 2nd: August 4, 2012 and 3rd: September 9, 2012).

Birdsfoot was planted manually with seeds sown on June 1, 2011, at a density of 70 kg ha⁻¹ and was pelleted with *Mesorhizobium loti* before planting (minimum guaranteed 1x10⁹ viable cells g⁻¹) at a 2-cm depth for both.

Oats in the tillage-absent treatment were planted under the straw of corn from the previous year and intercropped with birdsfoot trefoil in areas that were already planted (1st year) and managed in winter oats. The plots had dimensions of 8x12 (96 m²) and were separated by an electrified fence.

The oats were sowed in both treatments mechanically with a precision seeder coupled to a tractor on May 3, 2012, at a seed density of 80 kg ha⁻¹, with a spacing of 0.17 m, where 200 kg ha⁻¹ of triple super phosphate was applied and planted at a depth of 2 cm.

In total, 60 kg ha⁻¹ of nitrogen as urea and 50 kg ha⁻¹ of potassium in the form of potassium chloride were applied for twenty-five days. After applying fertilizer and the canopy height reached 40 cm, the structure of the plants was examined, and materials were collected to quantify dry matter production, chemical composition and *in vitro* dry matter digestibility. After collecting the materials, Holstein cows in lactation were used to lower the pickets and were removed when they reached a residual height of 15 cm. Animals were measured with a ruler-graduated height, and the amount of residual dry matter was determined using a metallic square of 0.25 m².

Structure was evaluated by measuring plant height (15 points per plot) with a ruler graduated in centimeters. Other traits that were measured with rulers included the apical meristem height of oats (15 points per plot) and the leaf/stem ratio (15 points per plot). Stem diameter was measured using digital calipers (15 points per plot). The number of leaves per tiller oats (15 points per plot) was also measured. Tiller oats (9 samples of 0.25 m² per plot) were collected after measuring them for the determination of dry matter production.

Samples were collected to determine the dry matter production using metal squares with an area of 0.25 m² that were randomly placed four times in each plot. After releasing the metal, all plants contained inside were cut 15 cm into the soil with the help of a knife and placed into labeled plastic bags.

In the laboratory, the samples were separated and weighed into two sub-samples. Of these, the first was used to determine dry matter production and chemical characteristics. The samples were ground in a knife mill with a 1-mm sieve for the further analysis of dry matter (DM), mineral matter (MM), crude protein (CP) according to AOAC (1990), neutral detergent fiber (NDF), acid detergent fiber (ADF) according to Van Soest *et al.* (1991) lignin and cellulose (Silva and Queiroz, 2006).

The second sub-sample was separated into leaves (leaf blades) and stems (stems and sheaths) to obtain the leaf/stem ratio.

All samples were sorted and packaged in paper bags, weighed and placed in an oven with forced ventilation and maintained at a temperature of 55 °C for 72 h to dry. After drying, the samples were weighed and data on the percentage of dry matter was obtained. The dry matter production and leaf/stem ratio (obtained from the ratio of the dry weight of leaves and dry weight of stems) were calculated.

To determine the *in vitro* dry matter digestibility, the technique described by Tilley and Terry (1963) adapted from the Artificial Rumen as described by Holden (1999) was used.

Data were statistically analyzed using the Sisvar program (Ferreira, 2008), and treatments were compared using Tukey's HSD at the 5% level. The Spearman correlation for structural assessment data was used.

Results and discussion

A significant interaction was detected for the production of dry oat matter ($P \leq 0.05$). We observed a higher mean DM in the second cycle of growth compared with the other cycle; however, the DM production of a single oat in the conventional tillage exceeded the mean yields obtained for both oats, even when it was grown with birdsfoot trefoil (Table 1). This pattern may be explained by the tendency of oats to reduce the production of DM from the 2nd cycle when intercropped with birdsfoot trefoil, resulting from the effect of competition with legumes (Floss, 2004).

However, when the DM yields of oats grown with birdsfoot trefoil and cultured with oat are added together from the first to the third cycle, the following productions are obtained: 1st: 1489.92, 2nd: 3512.73 and 3rd: 2053 kg ha⁻¹. These values

Table 1. Dry matter production of oat Iapar 61 alone or associated with birdsfoot trefoil. June to September 2012.

| Crops | DM Production (kg ha ⁻¹) | | | Mean |
|---------|--------------------------------------|------------|------------|-----------|
| | 1°Cycle | 2°Cycle | 3°Cycle | |
| CT | 1472.09 aB | 3244.19 bA | 2016.8 aB | 2244.36 b |
| OT | 1367.64 aC | 4451.98 aA | 1973.73 aB | 2597.78 a |
| B (O+B) | 434.45 bA | 720.2 cA | 584.3 bA | 579.65 d |
| O (O+B) | 1055.47 baB | 2792.53 bA | 1468.7 aB | 1772.23 c |
| Mean | 1082.41 C | 2802.22 A | 1510.88 B | |
| CV1 (%) | | | 6.73 | |
| CV2 (%) | | | 15.00 | |

Means followed by the same letter in the column or capital on the line do not differ by Tukey's HSD at the 5% level. CT: conventional tillage oats. OT: oats tillage. O+B: oats grown with birdsfoot trefoil. B: single birdsfoot trefoil.

are similar to those found for other oat production crops. The production increase from the first to the second cycle is due to the tillering caused by grazing, which results in the stimulation of the emergence of new tillers that, when they begin their photosynthetic activity, contribute to the accumulation of DM.

The tropical forage of grasses guarantees its persistence after cutting or grazing by the regeneration capacity of leaf tissue, specifically by building new apical meristem leaves that fall below the cutting plane through tillering (Corsi, 1993).

The height of the apical meristem (Table 2) was different between crops and cycles ($P \leq 0.05$) and differed in the interaction term (crops and cycles).

Increases in height apical meristem were noted for both cultures from the first to the second cycle of growth and did not differ statistically from the second to the third. Nevertheless, the apical meristem height increased from the first to the second cycle of growth. This increase in growth is due to the structural development of plants and the height of waste adopted for animal grazing (15 cm). The apical meristem was removed in the second cycle.

In contrast, in the second to third cycle, the meristem had been removed by grazing due to the elongation of the stem, so the growth became slower. Thus, growth from the second to the third

cycle depended on the development of new shoots from the basal meristem (Larcher, 2000).

However, the height of the apical meristem showed a positive Spearman correlation (Table 3) for the number of leaves per tiller (0.53) and the number of tillers (0.45) and was negatively correlated to leaf/stem ratio (-0.73), which suggests that as the height of the apical meristem of oat increases, the number of leaves per tiller and tiller number with reduced leaf/stem ratio is increased. This relationship appears to be related to the structural development of oats to grow to the vegetative stage.

The stem diameter differed for the unfolding of crops x cycles and the interaction between crops and between cycles ($P \leq 0.05$), with smaller diameters for oats grown conventionally and in association with the third cycle compared with the first and second cycles. This difference likely results from the fact that plants initially increase the diameter of the structures to support their increased weight during growth cycles.

Canopy height (Table 2) yielded a significant effect of cropping system and a negative Spearman correlation (Table 3) with the number of leaves per tiller (-0.42) and tiller number (-0.52). The values were greater when oats were grown with birdsfoot trefoil in the second cycle of crops and obtained higher mean sward heights for the third cycle.

Table 2. Structural characteristics of oat cultivated Iapar 61 alone or in association with birdsfoot trefoil. June to September 2012.

| Crops | Apical meristem height (cm) | | | | Diameter stem (mm) | | | |
|---------|-----------------------------|---------|---------|----------|-------------------------------------|------------|------------|-----------|
| | 1°Cycle | 2°Cycle | 3°Cycle | Mean | 1°Cycle | 2°Cycle | 3°Cycle | Mean |
| CT | 2.3 | 15.0 | 12.7 | 10.11 b | 2.49 A | 2.51 A | 1.86 B | 2.29 |
| OT | 4.9 | 16.0 | 12.9 | 11.27 a | 2.49 A | 2.48 A | 1.94 A | 2.30 |
| O+B | 4.7 | 14.0 | 12.8 | 10.55 ab | 2.16 AB | 2.67 A | 1.76 B | 2.20 |
| Mean | 4.01 B | 15.07 A | 12.85 A | | 2.38 A | 2.55 A | 1.85 B | |
| CV1(%) | | 6.09 | | | | 11.3 | | |
| CV2(%) | | 17.87 | | | | 14.62 | | |
| Crops | Number of leaves per tiller | | | | Number of tillers (m ²) | | | |
| | 1°Cycle | 2°Cycle | 3°Cycle | Mean | 1°Cycle | 2°Cycle | 3°Cycle | Mean |
| CT | 2.0 | 3.2 | 1.4 | 2.22 | 706.13 aB | 963.10 abA | 828.88 abA | 832.70 ab |
| OT | 1.8 | 3.2 | 1.33 | 2.15 | 798.10 aA | 838.22 bA | 677.77 bA | 771.30 b |
| O+B | 2.0 | 3.2 | 1.6 | 2.26 | 736.89 aB | 1191.50 aA | 987.10 aAB | 971.85 a |
| Mean | 1.95B | 3.24A | 1.44B | | 747.05 B | 997.62 A | 831.25 B | |
| CV1(%) | | 24.88 | | | | 14.55 | | |
| CV2(%) | | 18.72 | | | | 13.09 | | |
| Crops | Leaf / stem | | | | Canopy height (cm) | | | |
| | 1°Cycle | 2°Cycle | 3°Cycle | Mean | 1°Cycle | 2°Cycle | 3°Cycle | Mean |
| CT | 4.42 aA | 0.44 aB | 0.19 aB | 1.68 a | 40.2 aAB | 37.14 abB | 45.46 aA | 40.94 a |
| OT | 5.81 aA | 0.30 aB | 0.33 aB | 2.15 a | 34.2 abB | 33.64 bB | 47.40 aA | 38.41 a |
| B (O+B) | 0.0 bA | 0.9 aA | 0.7 aA | 0.56 b | 29.23 bA | 14.86 cB | 14.86 bB | 19.65 b |
| O (O+B) | 5.5 aA | 0.34 aB | 0.29 aB | 2.04 a | 39.2 aA | 40.5 aA | 44.4 aA | 41.4 a |
| Mean | 3.93 A | 0.50 B | 0.40 B | | 35.7 A | 31.5 B | 38.0 A | |
| CV1(%) | | 23.27 | | | | 7.48 | | |
| CV2(%) | | 43.4 | | | | 7.8 | | |

Means followed by the same letter in the column or capital on the line do not differ by Tukey's HSD at the 5% level. CT: conventional tillage oats. OT: oats tillage. O+B: oats grown with birdsfoot trefoil. B: single birdsfoot trefoil.

Table 3. Spearman correlation between the structural characteristics of oat.

| Parameters | CH | AMEA | SD | NLT | NT | L/S |
|------------|--------------------|--------------------|-------------------|-------------------|--------------------|------|
| AD | 1.00 | | | | | |
| AMEA | -0.32 | 1.00 | | | | |
| DC | -0.11 | 0.08 | 1.00 | | | |
| NFP | -0.42 ¹ | 0.53 ¹ | 0.51 ¹ | 1.00 | | |
| NP | -0.52 ¹ | 0.45 ¹ | 0.13 | 0.50 ¹ | 1.00 | |
| F/C | -0.10 | -0.73 ¹ | 0.14 | -0.21 | -0.43 ¹ | 1.00 |

¹P < 0.05.

CH: canopy height; AMEA: apical meristem height; SD: stem diameter; NLT: number of leaves per tiller; NT: number of tillers; L/S: leaf/stem ratio.

Similar results were obtained by Floss *et al.* (2004), who observed that oat increased in plant height during the sampling ages and had an appreciable effect on stem diameter, which was higher in the second cycle and reduced as a result of stretching. The maximum height

achieved by oats in association with birdsfoot trefoil may be associated with stem elongation rate stimulated by competition for light, but the height achieved by these plants in this experiment did not differ (P > 0.05) from oat planted in the absence of birdsfoot trefoil.

For number of tillers, a significant effect was detected for the cycle of growth and cropping system (Table 2). The effect was stronger for the second cycle of growth and for oat planted with birdsfoot trefoil.

The number of leaves per tiller increased from the first to the second cycle, corresponding with the timing of emergence of leaves and tillers, which can be observed by a positive Spearman correlation (Table 3) of 0.50. A reduction was observed in the third cycle by Godoy *et al.* (2005) and Reis *et al.* (1992), and it resulted from the senescence of older leaves during grazing cycles or growth cycles.

The leaf/stem ratio (Table 3) differed in the unfolding of crops x cycle interaction between crops and cycles ($P \leq 0.05$). The first cycle showed a higher mean ratio compared with the second and third cycles, rather than the higher initial growth in the development of oat plants (Martins *et al.*, 2008).

For those crops yielded lower leaf/stem ratio for birdsfoot trefoil grown with oat, lower values were reached similar to those of Soster *et al.* (2004), who evaluated the agronomic characteristics of the genotypes of birdsfoot trefoil and found that the leaf/stem ratio was 1.4.

Oats had few leaves and longer stems, a result of the stretch between them, with subsequent lengthening of the stem and greater participation of these fractions in forage over the leaves, reducing the relative leaf/stem ratio due to the removal of the apical meristem in the second grazing, in turn, causing a decrease in leaf/stem ratio during growth cycles. This decrease can be explained by the negative Spearman correlation obtained between the leaf/stem ratio and the number of tillers (Table 3), where he obtained a correlation of -0.43 because the ratio decreases as the number of tillers increases.

For the unfolding of crops, the significant variable x cycles leaf/stem ratio (Table 2) interaction effect

($P \leq 0.05$) was obtained in the first cycle of crops, for which no evaluation of birdsfoot trefoil (0.00) was carried out at the expense of early development of grassland at the first assessment.

A significant effect ($P \leq 0.05$) on the production of straw from oats (Table 4) for the crop cycles x interaction between crops and between cycles was obtained when grown in no-till. The oats produced more residual straw (mean) when interacting with other crops but gave lower values for the trefoil in the absence of the first review cycle because the oats were in a phase of recovery following the cultivation of maize that had been planted the previous year, which resulted in shading and dramatically reduced the development of birdsfoot trefoil the following year.

Between cycles, the increased production of straw for the second cycle of growth was observed, which decreased in the third cycle due to the consumption of dry mass by animal grazing. This resulted in the reduced sprouting capacity of the plants, which damaged the recovery of new leaves and the accumulation of straw. The crop residue on the soil surface acts as a cushioning barrier to animal trampling. Even levels of straw close to 2000 kg ha⁻¹ of DM cannot compromise grain production in subsequent cultivation seasons (Flores *et al.*, 2007).

Significant effects were obtained for the crops x cycles interaction both between crops and between cycles ($P \leq 0.05$) for the effects of DM production after grazing residue (Table 4). The DM yield of post-grazing residue for oats managed under conventional tillage (1861.6 kg ha⁻¹) was lower than that obtained by oat grown under no-tillage (2222.1 kg ha⁻¹); however, as Kluthouski and Yokoyama (2003) mentioned, oat requires at least 7 t ha⁻¹ residual dry matter to fully cover the surface of the soil.

There was a significant difference in the height of the residue in crops x cycles ($P \leq 0.05$), where the oats grown in association with birdsfoot height

Table 4. Production of residual mass and height of the oat residue Iapar 61 grown under different managements. June to September 2012.

| Crops | DM residual (kg ha ⁻¹) | | | | Residue height (cm) | | | |
|---------|------------------------------------|-----------|------------|----------|---------------------|-----------|----------|---------|
| | 1°Cycle | 2°Cycle | 3°Cycle | Mean | 1°Cycle | 2°Cycle | 3°Cycle | Mean |
| CT | 1139.7 aA | 3002.9 bA | 1442.2 abA | 1861.6 b | 12.8 bB | 17.1 aA | 13.2 aAB | 14.4 a |
| OT | 1059.7 aA | 3874.1 aA | 1732.5 aA | 2222.1 a | 10.4 bB | 16.1 abA | 13.4 aAB | 13.3 ab |
| B (O+B) | 00.0 cA | 479.0 cA | 376.4 cA | 285.1 d | 0.0 cB | 12.4 bA | 10.1 aA | 7.5 b |
| O (O+B) | 507.6 bA | 894.6 cA | 1101.3 bA | 834.5 c | 18.9 aA | 15.3 abAB | 14.0 aB | 16.1 a |
| Mean | 676.7 C | 2062.69 A | 1163.15 B | | 10.57 C | 15.28 A | 12.73 B | |
| CV1 (%) | | 8.64 | | | | 29.49 | | |
| CV2 (%) | | 13.81 | | | | 15.44 | | |

Means followed by the same letter in the column or capital on the line do not differ by Tukey's HSD at the 5% level. CT: conventional tillage oats. OT: oats tillage. O+B: oats grown with birdsfoot trefoil. B: single birdsfoot trefoil.

was above the first cut compared with other crops. An interaction was also observed in means between crops that was likely due to competition with birdsfoot trefoil, which lengthens oats. Oats grown conventionally showed the same pattern, which competed in the second cycle with wild radish (*Raphanus sativus*) that developed in the area (Table 5).

Among crops, there were no significant differences ($P \leq 0.05$): smaller heights were recorded for birdsfoot trefoil during all cycles of evaluation. Between cycles, a significant effect ($P \leq 0.05$) was observed between the height of the waste from the first to the second cycle and decreased for the third cycle.

The nutritive value of forages in the year 2012 was altered by the interaction of several factors (Table 6). NDF was inversely related to the percentage of crude protein, with the exception of the first cycle, and increased with the cycles of the cultivars ($P \leq 0.05$). This was the same pattern observed by Rocha *et al.* (2007), who evaluated the production of forage species and forage cultivars of winter and reported gradual increases in NDF and reductions in the levels of CP.

Significant differences were obtained between crops ($P \leq 0.05$) with lower NDF for oats grown with and without birdsfoot trefoil. Similar results were obtained by Rocha *et al.* (2007), who found mean levels of 35.4 to 63.9% for birdsfoot trefoil and oats.

The interaction of crop cycles x factors differed ($P \leq 0.05$), where the association of oats with birdsfoot trefoil reduced the NDF in the second and third cycles compared with oats grown singly likely stemmed from the dilution effect of the levels of NDF present in single oat and lower levels of birdsfoot trefoil.

The ADF values differ between cycles and crops and the interaction between factors ($P \leq 0.05$) between the levels of ADF cycles were reduced from the first to the second cycle. These values increased again in the third cycle; however, the association between crops of oats with birdsfoot trefoil did not result in the reduction or absence of ADF. In contrast, the single birdsfoot trefoil had a lower mean than did crops with oats because legumes have lower levels of ADF compared with the levels present in grasses (Thomson *et al.* 1985).

There was a gradual increase in the ADF levels for the oat crop in the conventional system and an

Table 5. Number of plants (m²) of *Raphanus sativus* in cultures. June to September 2012.

| Crops | Number of turnip plants | | |
|---------|-------------------------|---------|---------|
| | 1°Cycle | 2°Cycle | 3°Cycle |
| CT | 10 | 32 | 24 |
| OT | 32 | 20 | 16 |
| B (O+B) | 0 | 4 | 4 |
| O (O+B) | 0 | 0 | 0 |

CT: conventional tillage oats. OT: oats tillage. O+B: oats grown with birdsfoot trefoil. B: single birdsfoot trefoil.

opposite pattern it was when grown with single birdsfoot trefoil; however, the levels of intercropping were stable during growth cycles, which may be explained by intercropping with legumes.

Cellulose and hemicellulose are major constituents of the cellulose cell wall (Van Soest, 1994), and this study shows that the levels of cellulose and hemicellulose varied between crops, cuts and interaction of cultures x cycles ($P \leq 0.05$) factors. Among the crops that had higher levels of cellulose, the amounts in single oat managed conventionally and tillage were lower than those for single birdsfoot trefoil and when oat was grown with birdsfoot trefoil. Thomson *et al.* (1985) concluded that comparing pasture fertilized with nitrogen, mixtures of grasses and legumes, grass generally have higher levels of protein but lower levels of cellulose and hemicellulose, as observed in this study.

Hemicellulose (Table 6) increased between cycles because the supporting tissues (cellulose, hemicellulose and lignin) increase in proportion during the development of the plant. However, the lignin concentration in birdsfoot trefoil decreased between cuts, which may be explained by the fact that farming can recover the previous crop (corn), which was associated with the development of the plant that had a few more leaves and stem and resulted in a low-DM for the first cut. An interaction is noticeable in the second cycle: oats grown with birdsfoot trefoil and single trefoil showed lower levels compared with those obtained in other sole crops of oats. However, Lacerda *et al.* (2006) obtained a mean value of 7.7% for whole-plant lignin oat at 45 days, which is higher than the means obtained in this study (Table 6) for oats grown under conventional tillage (4.24%), alone (4.35%) or in association with trefoil (6.39%).

Moreira *et al.* (2005) worked with oats and oat genotypes for forage production and found values that were below those obtained in this work for hemicellulose in oats under conven-

tional tillage (25.58%) and no tillage (25.96%). The crude protein differed ($P \leq 0.05$) between cycles and crops and in the interaction between factors (Table 6) between crops. Higher crude protein content was observed in growing single birdsfoot trefoil compared with crops of oats because, as a legume, birdsfoot trefoil has more crude protein compared with oats. However, the mean values obtained in this study were higher than those obtained by Salerno and Tcacenco (1986), who found a CP value of 17.25% for birdsfoot trefoil.

The lowest percentages of CP observed in the final cycle of oats can be explained by the physiological state of the cultivars to be cut because the forage quality decreases when the plant is in the reproductive stage. Regarding the intercropping of oats with birdsfoot trefoil, we saw an increase in the CP content compared with other sole crops of oats (Table 6). In general, the presence of legumes improves levels of crude protein chaperone grass, even compared with nitrogen fertilization (Pereira *et al.*, 1990).

In vitro dry matter digestibility (Table 6) was different between cultures, cycles and the interaction between factors ($P \leq 0.05$). Among crops, *in vitro* dry matter digestibility was higher for oats grown under no-tillage in the first cycle (86.46%) than for conventional oat crop (82.75%). However, the association of oats with birdsfoot trefoil did not result in an improved digestibility of oats in the third cycle compared with other treatments (64.68%), probably because the oats compete with the culture when associated with birdsfoot trefoil. This competition may result in an increased canopy height and reduced leaf/stem ratio, which may, in turn, increase the involvement of the stem fraction.

The periods between means decreased from the first to the third cycle due to the increased levels of plant cell wall constituents. Pulses can provide increased production and improved quality of forage mass, thereby increasing the concentra-

Table 6. Chemical composition and *in vitro* dry matter digestibility of birdsfoot trefoil and single oat Iapar 61 alone or associated with birdsfoot trefoil cultivation. June to September 2012.

| Crops | NDF (%) | | | | ADF (%) | | | |
|---------|-------------------|----------|----------|---------|--|------------|-----------|---------|
| | 1°Cycle | 2°Cycle | 3°Cycle | Mean | 1°Cycle | 2°Cycle | 3°Cycle | Mean |
| CT | 49.59 aB | 53.22 aB | 63.28 aA | 55.37 a | 25.62 bB | 29.21 aB | 38.64 aA | 31.16 a |
| OT | 49.59 aB | 52.97 aB | 59.30 aA | 53.95 a | 32.27 aA | 26.35 a bB | 32.38 bA | 30.33 a |
| B (O+B) | 47.20 abB | 46.01 bB | 51.36 bA | 48.19 b | 28.19 abA | 29.78 aA | 29.62 bA | 29.20 a |
| O (O+B) | 43.24 bA | 35.39cB | 36.66cB | 38.43 c | 32.85 aA | 21.71 bB | 15.31cC | 23.29 b |
| Mean | 47.41 B | 46.90 B | 52.66 A | | 29.73 A | 26.76 B | 28.99 AB | |
| CV1 (%) | | 5,19 | | | | 8,58 | | |
| CV2 (%) | | 4,61 | | | | 9,34 | | |
| Crops | Cellulose (%) | | | | Hemicellulose (%) | | | |
| | 1°Cycle | 2°Cycle | 3°Cycle | Mean | 1°Cycle | 2°Cycle | 3°Cycle | Mean |
| CT | 20.23 bC | 24.99 aB | 31.53 aA | 25.58 a | 23.97 a A | 24.01 aA | 24.63 aA | 24.20 a |
| OT | 26.06 aA | 22.44 aA | 26.3bA | 25.96 a | 17.32 bB | 26.61 aA | 26.92 aA | 23.61 a |
| B (O+B) | 21.44 bA | 21.85 aA | 22.2bA | 21.85 b | 19.00 abA | 16.22 bA | 21.74 aA | 18.99 b |
| O (O+B) | 20.43 bA | 12.96 bB | 10.59 cB | 14.66 c | 10.39 cA | 13.67 bA | 21.34 a | 15.13 c |
| Mean | 22.04 AB | 20.56 B | 22.69 A | | 17.67 B | 20,13 B | 23.66 A | |
| CV1 (%) | | 9.33 | | | | 8.69 | | |
| CV2 (%) | | 10.45 | | | | 15.37 | | |
| Crops | Crude Protein (%) | | | | Mineral matter (%) | | | |
| | 1°Cycle | 2°Cycle | 3°Cycle | Mean | 1°Cycle | 2°Cycle | 3°Cycle | Mean |
| CT | 18.26 cA | 19.66 cA | 9.33 cB | 15.75 c | 13.31 aA | 10.96 bB | 4.81 cC | 9.69c |
| OT | 26.27 aA | 23.68 bB | 10.51 cC | 20.15 b | 12.95 aA | 10.20 cB | 4.89 cC | 9.35c |
| B (O+B) | 22.01 bA | 23.4 bA | 14.09 bB | 19.83 b | 12.11 bA | 11.60 aB | 7.70 bC | 10.47b |
| O (O+B) | 22.48 bB | 26.58 aA | 24.06 aB | 24.37 a | 11.39 cA | 11.53 aA | 10.73 aB | 11.22a |
| Mean | 22.25 A | 23.33 A | 14.50 B | | 12.44 A | 11.07 B | 7.03 C | |
| CV1 (%) | | 6.11 | | | | 5.26 | | |
| CV2 (%) | | 6.49 | | | | 2.62 | | |
| Crops | Lignin (%) | | | | <i>In vitro</i> dry matter digestibility (%) | | | |
| | 1°Cycle | 2°Cycle | 3°Cycle | Mean | 1°Cycle | 2°Cycle | 3°Cycle | Mean |
| CT | 4.09 bAB | 2.55 bB | 6.08 aA | 4.24 c | 82.75 abA | 72.25 bB | 64.11 bB | 73.04 |
| OT | 5.39 bA | 2.79 bB | 4.85 aAB | 4.35 c | 86.46 aA | 73.85 abB | 70.84 abB | 77.05 |
| B (O+B) | 5.72 bA | 6.99 aA | 6.45 aA | 6.39 b | 75.54 bA | 75.23 abA | 64.68 bB | 71.82 |
| O (O+B) | 11.53 aA | 8.04 aB | 4.32 aC | 7.98 a | 74.37 bA | 82.95 aA | 77.78 aA | 78.37 |
| Mean | 6.68 A | 5.11 B | 5.43 AB | | 79.78 A | 76.07 A | 69.35 B | |
| CV1 (%) | | 12.43 | | | | 5.94 | | |
| CV2 (%) | | 25.12 | | | | 5.93 | | |

Means followed by the same letter in the column or capital on the line do not differ by Tukey's HSD at the 5% level. Values expressed in %. CT: conventional tillage oats. OT: oats tillage. O+B: oats grown with birdsfoot trefoil. B: single birdsfoot trefoil.

tion of protein and digestibility by reducing the concentration of fibers (Fraser and Kunelius, 1995) because grass fibers typically have more legumes, especially in sheets.

In conclusion, advancement to the vegetative stage modifies the structural and nutritional composition of oats in both single-head or in association with conventional and birdsfoot trefoil

tillage cultivation. Growing oats with birdsfoot trefoil did not result in changes in the structural characteristics of oats, but it did increase the nutritional value of oats + birdsfoot trefoil at the end of the cycle.

Resumen

C. Ducati, M.A. Neres, D.D. Castagnara, P.S.R. Oliveira, D. Weirich, G.M. Silva y S.M.M. Sunahara. 2015. Potencial forrajero de avena Iapar 61 solo o en combinación con la lotera. Cien. Inv. Agr. 42(3): 341-351. El objetivo de este estudio fue evaluar las características estructurales, la producción de materia seca, masa residual, composición química y digestibilidad de la materia seca *in vitro* de la avena negra (*Avena strigosa*) Iapar 61, sola y en asociación con la lotera (*Lotus corniculatus* L., cv. San Gabriel), bajo diferentes formas de manejo, en tres ciclos de crecimiento. El diseño experimental fue de bloques al azar con parcelas divididas en el tiempo, con tres tratamientos: avena con siembra convencional, avena con siembra directa, avena asociado con la lotera con tres periodos de evaluación y cuatro repeticiones. El meristema apical de la avena fue incrementándose desde la primera hasta el segundo ciclo. La producción de materia seca de la lotera sola fue baja en todos los periodos con una media de 579,65 g kg⁻¹, mientras que la producción de avena sola con siembra convencional fue de 2.597 kg ha⁻¹. La avena reveló un alto valor nutricional antes del primer pastoreo en todos los tratamientos; sin embargo, al final de su ciclo, la asociación con lotera contribuyó a elevar el contenido de proteína cruda del forraje, debido a que ésta es la etapa final de su ciclo. La digestibilidad de la materia seca *in vitro* fue similar entre los cultivos evaluados con una disminución en el tercer ciclo. La asociación promovió mejora el valor nutricional de la avena asociados con lotera al final del ciclo de la avena.

Palabras clave: Abonos de invierno, meristemo apical, pasto, producción de materia seca.

References

- Abreu, G.T., L.O.B. Schuch, M.S. Maia, M.D. Rosenthal, S. Bacchi, E. Pereira, and L.D. Cantarelli. 2005. Produção de biomassa em consórcio de aveia branca (*Avena sativa* L.) e leguminosas forrageiras. *Revista Brasileira de Agrociência* 11:19-24.
- Aita, C., and S.J. Giacomini. 2003. Decomposição e liberação de nitrogênio de resíduos culturais de plantas de cobertura de solo solteiras e consorciadas. *Revista Brasileira de Ciências do Solo* 27:601-612.
- Alexandrino, E., D.N. Júnior, A.J. Regazzi, P.R. Mosquim, F.C. Rocha, and D.P. Souza. 2004. Características Morfogênicas e Estruturais na Rebrotagem da *Brachiaria brizantha* cv. Marandu Submetida a Três Doses de Nitrogênio. *Revista Brasileira de Zootecnia* 33:1372-1379.
- AOAC - Association of Official Analytical Chemists. 1990. Official methods of analysis. 15ed., Virginia: Arlington. 1117 pp.
- Corsi, M. 1993. Forragens de inverno. *In: Peixoto, A.M., Moura, J.C., Faria, V.P. (eds.). Confinamento de bovinos leiteiros.* Piracicaba: FEALQ, 143-152.
- EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária. 2006. Sistema Brasileiro de Classificação de solos, Brasília. 412 pp.
- Ferreira, D.F. 2008. SISVAR: um programa para análises e ensino de estatística. *Revista Symposium* 6:36-41.
- Flores, J.P.C., I. Anghinoni, L. C. Cassol, P. C. F. Carvalho, J.G.D.B. Leite, and T.I. Fraga. 2007. Atributos físicos do solo e rendimento de soja em sistema plantio direto em integração lavoura-pecuária com diferentes pressões de pastejo. *Revista Brasileira de Ciência do Solo, Viçosa-MG* 31:771-780.

- Floss, E.L. 2004. Fisiologia das plantas cultivadas: O estudo que está por trás do que se vê. 2.ed. Passo Fundo: UPF. 536 pp.
- Fraser, J. and H.T. Kunelius. 1995. Herbage yield and composition of white clover/grass associations in Atlantic. Canada. The Journal of Agricultural Science 125:371-377.
- Godoy, R., L.A.R. Batista, P.M. Santos, and F.H.D. Souza. 2005. Avaliação agrônômica de linhagens selecionadas de guandu (*Cajanus cajan* (L.) Millsp). Revista Brasileira de Zootecnia 34:7-19.
- Holden, L.A. 1999. Comparison of methods of in vitro matter digestibility for ten feeds. Journal Dairy Science 2:1791-1794.
- Kluthcouski, J. and L.P. Yokoyama. 2003. Opções de integração lavoura-pecuária. p. 131-181. In: Kluthcouski, J., L.F. Stone, and H. Aidair. (eds.). Integração lavoura pecuária. Santo Antônio de Goiás: Goiás, Brazil. Embrapa Arroz e Feijão.
- Lacerda, R.S., C.A. Gomide, and R.S. Fukushima. 2006. Lignin concentration in oat (*Avena byzantina* L.) aerial part as measured by analytical methods. Brazilian Journal Reserch Animal Science, São Paulo 43:400-407.
- Larcher, W. 2000. Ecofisiologia vegetal. 1.ed. São Carlos: RIMA Artes e Textos. 531 pp.
- Martins, J.D., H. Debiasi, and E.L. Missio. 2008. Influência da densidade e velocidade de semeadura no crescimento da aveia preta (*Avena strigosa* Schreb.), em semeadura direta. Pesquisa Agropecuária Gaúcha, Porto Alegre 14:33-40.
- Moreira, M.R., A.G. Ponce, C.E. Del Valle, and S.I. Roura. 2005. Inhibitory parameters of essential oils to reduce a foodborne pathogen, LWT 38:565-570.
- Neres, M.A., D.D. Castagnara, P.S.R. Oliveira, E. Oliveira, C.C. Jobim, T.T. Tres, and E.E. Mesquita. 2012. IPR 126 white oat forage potential under free growth, cutting and grazing at two management heights. Revista Brasileira de Zootecnia 41:889-897.
- Pereira, B.A.S., R.C. Mendonça, T.C. Filgueiras, J.E. Paula, and E.P. Heringer. 1990. Levantamento florístico da Área de Proteção Ambiental (APA) da bacia do Rio São Bartolomeu. Brasília: Sociedade Botânica do Brasil 1:419-492.
- Reis, J.C.L., R.W. Coelho, and A.T. Primo. 1992. Caracterização e avaliação de germoplasma de forrageiras em terras baixas. Capão do Leão, RS: EMBRAPA-CPATB. 28 pp.
- Rocha, M.G., L.E.T. Pereira, L.F.B. Scaravelli, C.J. Olivo, C.A. Agnolin, and M.F. Ziech. 2007. Produção e qualidade e de forragem da mistura de aveia e azevém sob dois métodos de estabelecimento. Revista Brasileira de Zootecnia 36:7-15.
- Salerno, A.R., and F.A. Tcacenco. 1986. Características e técnicas de cultivo de forrageiras de estação fria no Vale do Itajaí e Litoral de Santa Catarina. EMPASC. 56 pp.
- Silva, D.J., and A.C. Queiroz. 2006. Análise de alimentos: métodos químicos e biológicos. UFV.
- Soster, M.T.B., S.M. Scheffer-Basso, M. Dall'Agnol, R. Brustolin, and R.S. Fontaneli. 2004. Caracterização agrônômica de genótipos de cornichão (*Lotus corniculatus* L.). Revista Brasileira de Zootecnia 33:1662-1671.
- Thomson, D.J., D.R. Beever M.J. Haines, S.B. Cammell, R.T. Evans, M.S. Dhanoa, and A.R. Austin. 1985. Yield and composition of milk from fries an cows grazing either perennial ryegrass or White clover in early lactation. Journal Dairy Research 52:17-31.
- Tilley, J.M.A., and R.A. Terry. 1963. A two stage technique for *in vitro* digestion of forages crops. Journal of the British Grassland Society 18:104-111.
- Van Soest, P.J. 1994. Nutritional ecology of the ruminant. 2ed. New York: Cornell University. 476 pp.
- Van Soest, P.J., J.B. Robertson, and B.A. Lewi. 1991. Methods for dietary fiber, neutral detergent fiber, and non starch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74:3583-3597.

