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Scientific Article
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Corn yield for silage and grains in different integrated crop-livestock systems[1]

Produtividade do milho para silagem e grãos em distintos sistemas integrados de produção agropecuária

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ABSTRACT - In this study, the objective was to assess the influence of two doses of N (90 and 180 kg N ha^{-1}, added to the winter pastures), two integrated crop-livestock systems (ICLS, with and without trees) and five positions between the tree rows, on the corn (*Zea mays* L.) quality and productivity, for silage and grain. Adopting the complete randomized block design, the treatments included three replicates. In 2006, following the 14 x 3 m spacing (currently with 158 trees ha^{-1}) the trees were planted in 6 out of the 12 paddocks. While the corn was implemented during summer of 2013/2014, cattle grazing on the annual pasture was done during the prior winter, in both ICLS. Corn for silage was reaped at the R5 phenological stage, whereas for grains it was done at 176 days post seeding. For silage, the corn plants were grinded and then stocked in the experimental mini PVC silos. The silage varied slightly in quality along the positions between the tree rows. The differences observed between N levels in the dry matter, crude protein (CP) and grain productivity are expressions of the residual effects of the winter fertilization. Silage quality was improved by the shade effect which minimized the acid detergent fiber and raised the CP, although it reduced the corn production for silage and grains by 52%. Some feasible techniques to reduce these losses are discussed.

Key words: Agroforestry. *Eucalyptus dunnii. Grevillea robusta.* Nitrogen fertilization. Silage quality.

RESUMO - O objetivo do presente trabalho foi avaliar o efeito de duas doses de adubação nitrogenada (90 e 180 kg de N ha^{-1}, aplicadas na pastagem de inverno), dois sistemas integrados de produção agropecuária (SIPA, com e sem árvores) e cinco posições entre renques arbóreos na qualidade e na produtividade do milho (*Zea mays* L.) para silagem e grãos. Os tratamentos foram investigados em um delineamento em blocos completos casualizados, com três repetições. As árvores foram plantadas em 2006 num arranjo de 14 x 3 m (atualmente com 158 árvores ha^{-1}), em 6 das 12 parcelas. Ambos SIPAs foram conduzidos com milho durante o verão 2013/2014 e com gado de corte em pastagem anual durante o inverno anterior. O milho foi colhido para silagem no estádio fenológico R5 e para grãos aos 176 dias após a semeadura. As amostras para silagem foram trituradas e armazenadas em mini silos de PVC. Pequenas variações foram observadas na qualidade da silagem em relação a posição entre renques arbóreos. Diferenças entre doses de N no teor em matéria seca, proteína bruta (PB) e produtividade em grãos evidenciam o efeito residual da adubação de inverno. A associação com árvores proporcionou a colheita de uma silagem de melhor qualidade (menor teor de fibra em detergente ácido e maior teor em PB), mas reduziu em 52% a produtividade do milho colhido tanto para silagem como para grãos. Possíveis estratégias são discutidas para reduzir tais perdas.

Palavras-chave: Adubação nitrogenada. *Eucalyptus dunnii. Grevillea robusta.* Qualidade da silagem. Sistema silviagrícola.

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INTRODUCTION

Boosting the production systems involves employing new technologies and investments which will intensify soil usage, implements and manpower. In light of this context, the integrated crop-livestock systems (ICLS) include the improvement of a variety of agricultural pursuits in the same location, in a sustainable manner, imparting many medium- and long-term advantages. These comprise heightened nutrient cycling, enhanced soil organic matter content, the judicious utilization of inputs and natural resources, lowered cycle of pests and unwanted plants, and reduced liability of activity, so reducing the cash flow fluctuation (CARVALHO *et al*., 2010; LEMAIRE *et al*., 2014).

In the Brazilian subtropics, the inclusion of animals during the winter seasons together with the annually cultivated summer pastures like corn is an attractive alternative to utilize the vast unproductive expanses of land during this season (MORAES *et al*., 2014). Besides, including trees for wood production in the ICLS offers benefits, like drawing up the deeply buried soil nutrients, utilizing the decomposed leaf litter, and contributing towards the carbon sequestration process, thus minimizing the effect of the greenhouse gases (TONUCCI *et al*., 2010), as well as the diversification of the producers' income sources. However, any alterations in the solar radiation, either in quality or quantity, will affect the plants with these crops, as well as the yield of these crop themselves in the woody ICLS, a phenomenon especially observed in the C_4 grasses, like corn (PENG *et al*., 2009). Apart from this, many other features are related to the presence of trees, including alterations in the microclimate (eg. wind speed, air temperature and humidity) and influences of the soil (eg. rise in the nutrient availability) (WILSON *et al*., 1990). Such alterations will influence the competition for the availability of water and nutrients among the associated species (DORMORMNE *et al*., 2004). Therefore, further investigations are necessary to explore the interactions among the various factors, like shade and nutrient availability.

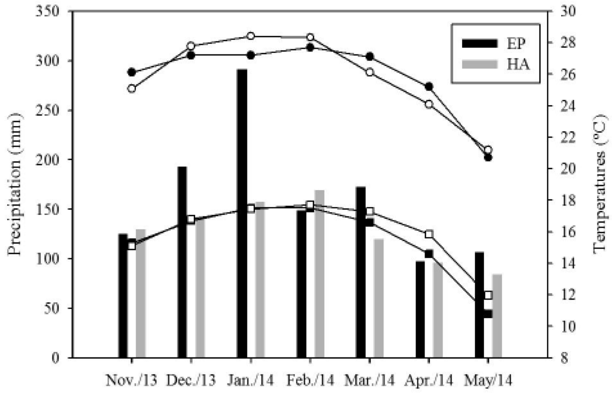
According to some studies the maize yield was seen to drop when found in association with trees (MBEWE; HUNTER, 1986; REYNOLDS *et al*., 2006). Corn, being the third most produced cereal, globally, (ESKANDARI; GHANBARI, 2009) and coupled with the objective of advocating the implementation of ICLS with forestation for the advantages stated earlier, the aim is to quantify the likely losses and develop strategies to neutralize or minimize such losses (REYNOLDS *et al*., 2006). These losses can be quite variable depending on the species and the tree density used (PENG *et al*., 2006). While some studies have not reported any negative effect exerted by the trees on the maize yield (PORFÍRIO-DA-SILVA *et al*., 2015), a few others have recorded a variable effect due to tree distance (NEWMAN; BENNETT; WU, 1998). Some studies have also implied the positive influence of tree shading on the nutritive value of intercropping, including a rise in the crude protein (MBEWE; HUNTER, 1986). This is significant specifically for maize cultivation, as it produces forage low in protein.

This work aimed at estimating the influence exerted by both the ICLS (with and without trees), the residual effect of two nitrogen fertilization dosages and five positions between the tree rows, on the corn harvested for silage and grains, as well as on the bromatological features of the corn silage.

MATERIAL AND METHODS

The experiment was performed at the Fazenda Modelo / IAPAR Experimental Station in Ponta Grossa, Paraná, located at 25°07'22 " S, 50°03'01" W, at an elevation of 953 m. Based on the Köppen classification, this region experiences subtropical Cfb humid mesothermic type of climate, enjoying an annual average precipitation of 1,400 mm. The maximum and minimum temperatures are 24.3 and 8.5 ºC, respectively, with an annual average temperature of 17.6 ºC. Figure 1 shows the rainfall data, as well as the minimum and maximum temperatures during the experimental timeframe. The experimental area extended across 13.07 ha, 6.09 ha of which were forested. As these areas were contiguous, an association of soils (Cambisol and Ferralsol, Embrapa, 2006) were observed, sandy in texture, with relief of a 4-9% slope.

Figure 1 - Precipitation and averages of the minimum (squares) and maximum (circles) temperatures during the experimental period (EP, blank symbols), in comparison with the historical averages (HA, 1998-2015, black symbols) for the city of Ponta Grossa/PR (Source: SIMEPAR)



In 2006, three tree species, eucalyptus (*Eucalyptus dunnii* Maiden), pink pepper (*Schinus terebinthifolius* Raddi) and silver oak (*Grevillea robusta* A. Cunn ex R. Br.) were planted in single rows, maintaining 3 m spacing between successive trees and 14 m distance between the tree rows, following the 14 x 3 m arrangement. The tree lines were planned transverse to the direction of the slope of the terrain to lessen the surface runoff of rainwater. The layout predominantly faced the Northeast-Southwest direction.

From 2010, corn and soybean crops were cultivated alternately in the summer, adopting the no-till system. However, in the winter, black oat (*Avena strigosa* Schreb) cv. IAPAR 61 plus annual ryegrass (*Lolium multiflorum* Lam.) Cv. FEPAGRO São Gabriel were grown for both soil cover and beef-cattle grazing, in sowing densities of 45 kg ha^{-1} and 15 kg ha^{-1}, respectively. During the 2013 winter, 400 kg ha^{-1} of commercial formula 4-30-10 (NPK) was applied. Urea was applied approximately 40 days after the pasture was sown, using 90 kg N ha^{-1} or 180 kg N ha^{-1}, resulting in the evaluation of two nitrogen fertilization rates. Alves (2002) confirmed the highest number of responses in terms of the annual dry matter (DM) production with black oat (IAPAR 61), in doses ranging from 150 and 225 kg ha^{-1} of N. Therefore, in the current work, optimal N doses (i.e. 180 kg N ha^{-1}) and limiting (i.e. 90 kg N ha^{-1}) were selected. In early 2013, the trees were chopped down to decrease the initial stand (238 trees ha^{-1}) in 1/3 (158 trees ha^{-1}). The pink pepper trees were cut due to the animals damaging them (PORFÍRIO-DA-SILVA *et al*., 2012).

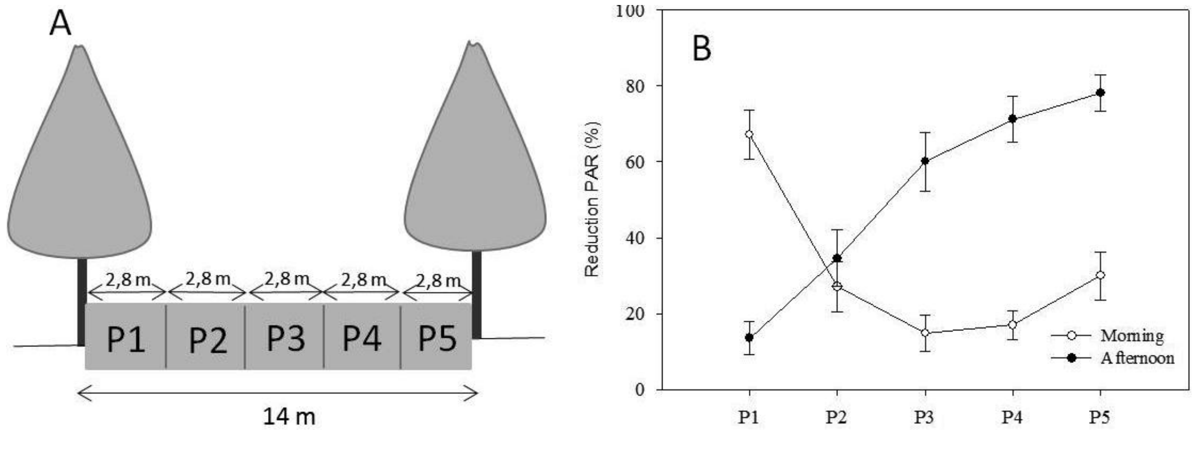
During the maize cultivation, the trees at breast height (DBH) measured 32.5 cm in diameter and 19.4 m in total height (Ht) for eucalyptus and DBH of 17.1 cm and Ht of 11.4 m for the silver oak.

On November 11, 2013, the corn variety IPR 164 was sown under the no-tillage system beneath the residual straw from the winter pasture. Maintaining 0.80 m spacing between the maize lines and sowing 6.0 seeds per linear meter produced an initial plant population of 75,000 ha^{-1}. After applying 400 kg ha^{-1} of NPK as the base fertilization in the 10-30-30 formulation, cover fertilization was done at 41 days post planting, using a single dose of 270 kg ha^{-1} of urea in both systems.

The randomized block, in an incomplete factorial scheme (2x2x5), was adopted as the experimental design. The treatments included two doses each of nitrogen fertilization and ICLS (which implied, with and without trees) involving three replicates per treatment, for a total of 12 plots, each being 0.99 ± 0.231 ha. In the six tree system plots, five positions were also included between two tree rows, namely: P3, the central position between two tree rows; P1 and P5, positions adjacent to the rows; and P2 and P4, the intermediate positions, as evident in Figure 2. Further, Figure 2 shows the distinct percent reduction of photosynthetically active radiation (PAR) in each of these positions. As the pasture phase ended, which was just prior to sowing the corn, this characterization was done using two ceptometers (AccuPAR LP-80, Decagon Equipment Co, Pullman, WA). One ceptometer was positioned in a site under full sunlight, while the other was placed under the treetops. Between 9 and 10:30 four evaluations were done, and another four were taken between 13:30 and 15:00, according to the position in each of the six wooded plots. The drop in the PAR was calculated from the difference between the two values recorded by the ceptometers. The decreased PAR in the tree system was 41 ± 2.41% on average.

The corn for silage was harvested between March 7 and 15, 2014, when the plots were at the ideal silage

Figure 2 - The sampling positions between the tree rows in the integrated crop-livestock system (A) and the percentage of photosynthetically active radiation (PAR) in each position at different shifts



point (in the R5 phenological phase). In the tree system, five samples per plot were collected, with one sample from each position between the tree rows (Figure 2), and a single sample was randomly selected per plot in the treeless system. For each sample, all plants found within two linear 5 m lines, with 0.80 m spacing, in a total area of 8 m², at 30 cm height from the ground, were chopped down. At harvest time, the green mass yield was determined by weighing the plants. Next, the plants were grinded separately in a forage harvester coupled to the tractor, homogenized and then placed in 36 mini-PVC experimental storage silos. Each silo was 0.30 m in height and 0.11 m in diameter, provided with a Bunsen type valve to enable the fermented gases to escape. Using a wooden plunger all the samples were compacted.

The mini silos were opened after 32 days and 5 cm of silage at the top and bottom were discarded. A portion of the fresh sample was used to determine the pH according to the method of Silva and Queiroz (2002), utilizing the digital potentiometer (three readings in each of the three subsamples). The remainder was first oven-dried at 65ºC for 72 hours and then weighed to assess the dry mass (DM) content, to determine the silage yield (SY) in kg DM ha^{-1}. The samples were then dried and ground in a "Willey" mill provided with a 1.0 mm mesh, for laboratory analysis in the future. Adopting the methods described by Silva and Queiroz (2002) the levels of DM, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and mineral matter (MM) were analyzed. The percentage of hemicellulose was calculated by the difference in the NDF and ADF values. The total digestible nutrients (TDN) were estimated according to equation 1 proposed by Chandler (1990).

$$\% \, TDN = 105.2 - 0.68 \, x\% \, NDF \qquad (1)$$

At 176 days post sowing, the corn was harvested to assess the grain yield, by cutting down the plants in the 5 m of maize line, very close to the soil. In the tree system, five samples were taken from each plot, with one sample from each position between the tree rows (Figure 2); in the treeless system only a single random sample was taken per plot. The following evaluations were recorded - final stand (number of plants found in one linear meter when the maize was ready for harvest); insertion height of the first tenon (distance between the plant base and insertion of the first tenon); number of grain rows per spike; number of grains per row; mass of 1000 grains, estimated by the count of 500 grains drawn from all the ears in the plot, and position between the grains, expressed in grams, corrected to 13% of the moisture content; harvest index, calculated by dividing the grain mass by the total plant mass; and grain yield (GY) from the accumulated grain of all the plants within a plot and / or position between the roots, corrected to 13% moisture and extrapolated to one hectare.

Analyses of variance were done to test the effect of block (GL = 2), N (GL = 1), system (presence or absence of trees, GL = 1) and position between the two tree rows (GL = 4), employing the Statgraphics Centurion XV program (2006). At first, all the interactions were included in the statistical model, barring only those with the block. All non-significant interactions were eliminated from the final model. The data were analyzed, identifying the block as the random effect and the others as the fixed effect. For the normality test, the hemicellulose, SY and GY data were transformed (square root and logarithm). In the event of a significant effect for any variable, the least significant difference (LSD) test was done.

RESULTS AND DISCUSSION

Regarding the parameters linked to silage quality, no significant differences were recorded either between the treatments or their interactions, for NDF, TDN and pH (Table 1).

Corn silage revealed an average pH of 3.76. Lugão *et al*. (2011) reported silages with pH ≤ 3.8 which are well classified, as they facilitate improved conservation of the silage fodder.

The ash content indicates the inorganic constituents present. Schmidt *et al*. (2015) reported that a silage content value exceeding 6% is indicative of some degree of soil contamination in the silo, apart from the proportional decrease in the energy levels of the silage. The DM value of the corn silage noted in the current study revealed a slight deviation due to the effect of the N doses (3.4 ± 0.12% and 3.7 ± 0.11% for 90 and 180 kg of N ha^{-1}, respectively), but always remained well below the level reported above.

Usually, the higher the quantity of grains in the silage, the more the energy content. Therefore, silages having greater grain content show a higher TDN percentage and thus, a higher potential for milk or meat yield. However, in this study, despite the variations observed between the treatments in terms of the amount of grains (Table 1), the TDN values (mean of 67.3%) of the silage remained unaffected. Mbewe and Hunter (1986) reported that the drop in the energy content due to the decreased quantity of grains can be offset by the heightened digestibility of the remaining plant parts, under conditions of luminous stress. These authors proposed that this type of raised digestibility in shaded plants is due to the translocation of the assimilates intended to move from the stalk to the grains remaining at the top. Therefore,

Table 1 - Summary of the variance analyses for dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, total digestible nutrients (TDN), mineral matter (MM), pH, silage productivity (SY), final stand (FS), height of the first spike (H), number of rows per spike, number of grains per row, harvest index (HI), 1000 grain mass and productivity (GY) in relation to systems (S) nitrogen rates (N), position between tree rows (P) and interactions

SV	S	N	P	N x S	N x P	CV (%)
DF	1	1	4	1	4	
DM	1,8^{ns}	8,7**	2,7#	14,1***	-^{ns}	7,1
CP	16,7***	8,11**	1,0^{ns}	7,1*	3,6*	12
NDF	2,5^{ns}	0,06^{ns}	1,8^{ns}	-^{ns}	-^{ns}	7,1
ADF	3,8$^{\#}$	0,06^{ns}	4,0*	-^{ns}	-^{ns}	8,3
Hemicellulose	0,3^{ns}	2,2^{ns}	0,3^{ns}	4,8*	-^{ns}	9,9
TDN	2,4^{ns}	0,1^{ns}	1,8^{ns}	-^{ns}	-^{ns}	3,8
MM	0,7^{ns}	3,3#	0,2^{ns}	-^{ns}	-^{ns}	14,5
pH	0,6^{ns}	0,1^{ns}	1,1^{ns}	-^{ns}	-^{ns}	1,3
SY	45,2***	1,3^{ns}	1,0^{ns}	-^{ns}	-^{ns}	41
FS	0,8^{ns}	0,5^{ns}	0,9^{ns}	-^{ns}	-^{ns}	9,1
H	11,5**	0,4^{ns}	0,8^{ns}	-^{ns}	-^{ns}	14,2
Nº rows.spike^{-1}	3,7#	12,4**	0,8^{ns}	-^{ns}	-^{ns}	12,5
Nº grans.row^{-1}	13,6**	0,4^{ns}	0,7^{ns}	-^{ns}	-^{ns}	40
HI	5,5*	0,2^{ns}	0,6^{ns}	-^{ns}	-^{ns}	27
1000 grain mass	0,6^{ns}	0,0^{ns}	0,7^{ns}	-^{ns}	-^{ns}	7,6
GY	43,4***	0,2^{ns}	1,2^{ns}	4,2*	-^{ns}	47

SV - Sources of variation; DF - degrees of freedom; S - systems, without trees x with trees; N - doses of N, 90 x 180 kg of N ha^{-1}; P - position between the tree rows; CV - Coefficient of Variation; ns - not significant; #, *, **, ***, significant at 10, 5, 1 and 0.1% by the F test, respectively; -ns, Non-significant interactions were removed from the final model

an increase in the grain quantity in a given system may not have been enough to trigger a sizable increase in the TDN content when the whole plant (silage) is taken into consideration, because the plant biomass may have exerted a diluting influence on the silage TDN value. Besides, by keeping the cutting height (30 cm) identical in both systems, but including some variations in the plant height between the systems (observe the height of the insertion of the first spike), some differences may have occurred in the quantity of senescent material contained in the samples, reducing the influence of the increase in grain quantity on the energetic value of the silage.

With reference to the mean fiber content of the silage, Schmidt *et al*. (2005) assessed the bromatological variability of the corn silage in 109 sites situated in the main dairy basins across Brazil. The NDF and ADF values found were 52.5 ± 5.4% and 26.3 ± 4.1%, respectively, which were less than the findings of this study (54.1 ± 0.64% and 29.8 ± 0.41%, respectively). Velho *et al.* (2007) stated that the silage NDF contents below 50% encouraged greater consumption by animals, because the lower this value in the food, the higher the fermentation rate, and the faster the animal rumen gets emptied. Although the NDF values stayed constant among the treatments under evaluation, significant differences in terms of the ADF levels (Table 1) were observed. A higher ADF content was reported in the treeless system (31.4 ± 1.0%) when compared with that of the tree system (29.5 ± 0.44%). This finding was ascribed to the larger leaf area in shaded plants, because these leaves are high in protein and low in fiber (PONTES *et al*., 2016). This morphological change is the strategy employed by those plants experiencing light restriction, to raise their capacity to intercept the incident radiation (PONTES *et al*., 2015). The ADF content also revealed variations due to the position of the plants in relation to the tree rows (Table 2). As the current study was performed under conditions of natural shading, with the trees being planted in accordance with the curves of the terrain, the incidence of PAR for the crop canopy below the plane of the tree canopy is low, but interspersed with periods of higher incidence of sunlight. This implies that these plants experience periods of higher or lower luminosity throughout the day (Figure 2). The temporal radiation pattern (more shade during the mornings or afternoons)

Table 2 - Effect of the position between the tree rows on dry matter (DM) and acid detergent fiber (ADF) and the influence of the interaction between the nitrogen rates and position between the rows of trees on the crude protein (CP) content of the corn silage (*Zea mays*), variety IPR 164

Position between tree rows	ADF (%)	DM (%)	CP (%)	
			90 kg N ha^{-1}	180 kg N ha^{-1}
P1	28,35 ± 1,19 bc	30,38 ±1,85 a	8,9 ± 0,37 a	7,4 ± 0,95 a
P2	27,40 ± 1,44 c	30,02 ±2,13 a	7,5 ± 0,13 b	7,7 ± 0,33 a
P3	29,70 ± 2,14 abc	29,36 ±1,14 ab	7,9 ± 0,27 b	8,7 ± 0,12 a
P4	30,03 ± 2,48 ab	28,61 ±0,80 ab	8,1 ± 0,12 ab	7,7 ± 0,38 a
P5	31,97 ± 2,20 a	27,62 ± 1,90 b	7,5 ± 0,32 b	8,7 ± 0,37 a

Averages (± standard deviation of the means) followed by different letters in the column, for each variable, differ by the LSD test. Positions between the tree rows: P3, central position between two rows; P1 and P5, positions adjacent to the rows; and P2 and P4: intermediate positions

changes can result in some variations in certain plant parameters (SELLARO; PACÍN; CASAL, 2012).

The current study anticipated similar results between the P1 and P5 positions, that is, between the positions closest to the trees, by escalating the competition for light, water and nutrients, and producing a parabolic type of response pattern, as reported by Newman, Bennett and Wu (1998). However, as evident in Table 2, significant differences were noted between these positions, for both ADF and DM. Therefore, the well-defined light patterns at such positions (i.e., different shades of diurnal periods) seemed to be more decisive in the bromatological composition of the plants than did the competition for water and nutrients. The actual competition for nutrients between the trees and intercropping (corn) may have been negligible, as fertilizations were performed annually in both systems. Besides, the rainfall values (Figure 1) during the experimental period were normally higher than the historical average for the area.

With respect to the hemicellulose content, a remarkable reduction was evident in the tree system compared to the treeless one, for the lowest N dosage (Table 3). This N dose also induced a drop in the DM content of the treeless system (27.7 ± 0.63%), below the range believed to be ideal for the silage, from 30 to 35%, according to Lugão *et al.* (2011). These authors reported that, at this range, the plant reveals an improvement in the relationship between the high DM production, high starch concentration and low fiber component, offering an acceptable fermentation profile in the ensiled material, which raises the consumption by the animals. Silages low in DM content support *Clostridium* fermentation and effluent release, showing a decline in its nutritional value. Silages high in DM, on the other hand, are more porous with greater susceptibility to aerobic deterioration and fungal and yeast development (LUGÃO *et al*., 2011).

Each system revealed a distinct effect of the N doses on the DM content, with significance observed only in the treeless system (Table 3). In the tree system, irrespective of the N dose, the DM content was a little less than the ideal (Table 3), although harvesting was performed at the same phenological stage as that of the treeless one. The results indicated that the corn silage plants needed to be harvested at a later date to achieve the ideal DM content at harvest time, which would contribute to raising the silage quality. A slowing down in the plant maturity and / or components of the corn plant due to shading, for example, have been reported in other studies (MBEWE; HUNTER, 1986).

In the treeless system, the CP content of the silage rose dramatically when the N dose was increased, on par with the tree system (Table 3). This was an expected result caused by the increase in the soil N through fertilization, even in the crop prior to maize. In general, in the literature, higher CP percentages were reported for the shaded plants (PONTES *et al*., 2016), which have been ascribed to a boost in the N concentration in the plant or an enhanced level of mineralization in the soil organic matter beneath the trees, increasing the N supply for the plants to absorb (WILSON *et al*., 1990). Besides, Hirose and Bazzaz (1998) emphasize that the higher CP concentration reflects an increase in the efficiency of light use, minimizing the efficiency of N usage. Thus, in the woody ICLS, the decrease in the fibrous fraction of the plant (ADF and hemicellulose) and corresponding rise in the protein fraction enhance the silage quality.

Notable interactions were also observed between the N dose and position between the tree rows (Table 2), as well as for the CP content of the silage, with a mean reading of 7.79 ± 0.16%. According to evaluations by Paziani *et al*. (2009) the bromatological characteristics of corn silage, showed CP values between 6.7 and 9.4%. Slight variations in terms of row position showed up in the

Table 3 - The effect of the interaction between the nitrogen doses (90 and 180 kg N ha^{-1}) and type of system (with and without trees) for dry matter (DM), hemicellulose, and crude protein (CP) of corn silage (*Zea mays*), variety IPR 164), and grain yield (GY)

	No trees	With trees
	DM (%)	
90 kg N ha^{-1}	32,66 ± 2,18 Aa	28,91 ± 1,60 Ba
180 kg N ha^{-1}	27,72 ± 1,09 Ab	29,49 ± 2,05 Aa
	Hemicellulose (%)	
90 kg N ha^{-1}	26,43 ± 1,88 Aa	23,76 ± 3,07 Ba
180 kg N ha^{-1}	23,03 ± 0,67 Aa	24,57 ± 1,64 Aa
	CP (%)	
90 kg N ha^{-1}	5,93 ± 0,45 Ab	7,98 ± 0,66 Ba
180 kg N ha^{-1}	7,60 ± 0,31 Aa	8,03 ± 0,93 Aa
	GY (kg ha^{-1})	
90 kg N ha^{-1}	5.459 ± 988,7 Aa	3.252 ± 291,2 Ba
180 kg N ha^{-1}	6.857 ± 311,6 Aa	2.547 ± 170,4 Ba

Averages (± standard deviation of the means) followed by different letters, lower case letters in the column and upper case in the line, differ by the LSD test

CP content, when 90 kg of N ha^{-1} (Table 2), i.e., between 7.5 and 8.9%, was added within the range mentioned above.

Compared with the treeless system, the SY value was considerably lower in the tree system (Table 4). This effect was also noted in the GY, which dropped by 53% in the tree system compared with the treeless system (Table 4). The potential corn yield (number of leaves and ears that would eventually produce) is evident in the V3 stage (MAGALHÃES *et al*., 2002). Therefore, the restriction of solar energy available for the corn plants at this stage acted as the determinant for the findings recorded. It is notable that the GY in the tree system was extrapolated to hectares to facilitate a comparison with the results recorded under full exposure to the sun, when the maize productivity per se was analyzed. However, Porfírio-da-Silva *et al*. (2015) reported in their study performed in the same experimental area, that corn occupied 71% of the area, with the remaining 29% being taken up by the trees. Thus, the real maize yield achieved in 1 ha of this association of corn plus trees would be 5,373 kg of silage and 2,058 kg of grains. The rest of the 29% of the region would be wood-producing.

The decline in GY in the tree system occurred, along with the fewer number of rows per spike, lesser number of grains per spike, smaller plants and a drop in the harvest index (Table 4). Although slight variations were noted in the number of rows per spike in response to the N rates (13 ± 0.27 and 11 ± 0.35 for 90 and 180 kg N ha^{-1}, respectively), these variations were not

Table 4 - Effect of the integrated crop-livestock system (with and without trees) on the characteristics of the yield in maize (*Zea mays*) variety IPR 164. HI, harvest index; SY, silage productivity; GY, grain yield. Averages ± standard deviation of the mean

	No trees	With trees
Height of the first spike (cm)	113,7 ± 8,15	96,2 ± 1,99
Nº rows.$spike^{-1}$	13,2 ± 0,31	12,1 ± 0,29
Nº grans.row^{-1}	16,8 ± 1,8	10,3 ± 0,69
HI	0,35 ± 0,03	0,27 ± 0,01
SY (kg ha^{-1})	15.754 ± 774,5	7.568 ± 370,5
GY (kg ha^{-1})	6.158 ± 559,1	2.899 ± 178,2

observed in the GY values. Apart from this, neither the final stand (6.0 ± 0.09 plants m^{-1}), nor the weight of 1000 grains (338 ± 4.31 g), was significantly affected by any of the factors investigated.

However, it is noteworthy that in both systems, the corn GY values were below 8,158 kg ha^{-1}, as recorded in the State of Paraná, for the crop year 2013/14, according to the SEAB data (2014). One significant fact is that most maize producing regions in Brazil utilize hybrid seeds (PORFÍRIO-DA-SILVA *et al*., 2015), as they are more productive than the variety material. However, as the aim of this study was to determine the effect of the treatments, it does not extend its scope to include the maximum productive potential of the crop in the region.

The appreciable interaction between the systems and N doses for GY (Table 1) revealed wider divergences between the systems for the higher N dose when compared with the lower one (Table 3). These differences reflected the residual effect of the nitrogen fertilization in winter, probably because of the effect of the fertilization on the quantity of pasture residue, as reported by Assmann *et al*. (2003).

The position between the tree rows exerted no observable effect on any of the parameters assessed at the harvest time (Table 1). Seven years post tree planting, at 14 m distance, the shading value was 41%. As for the C_4 species, even slight reductions in the light level influenced the photosynthetic rate, lowering the productivity, as the C_4 plants became saturated by light under conditions approaching full sunlight (REYNOLDS *et al*., 2006). However, as the maize culture is crucially important and the aim is to encourage the use of woody ICLS in the Brazilian subtropics, this type of crop should not be rejected for use in these systems. In the tree system, the poor maize productivity emphasizes the necessity for more exhaustive and meticulous management of the tree component, for instance, by reducing the tree density, which can be achieved by thinning the trees and / or cutting down whole trees rows in the system. In terms of tree thinning, one of the species could be harvested (eg. silver oak) prior to the 7 years, for the yield of fine wood. Removal of entire rows would widen the distance from 14 to 28 m between successive rows. Therefore, the challenge is to lower the degree of competition with the trees to sustainable levels of yield losses in maize.

CONCLUSIONS

1. Corn silage in the woody system revealed higher quality, showing increase in the CP and decrease in the fiber content;
2. The variable ‘position between the tree rows’ influenced a few of the silage quality parameters (ADF, DM and CP). However, these differences did not induce a more intense competition for resources with the trees in the positions nearest to the trees;
3. A residual influence of the nitrogen fertilization during winter was visible on silage quality parameters and corn grain production. It is therefore, evident that fertilization in the winter enhances the nitrogen nutrition in maize;
4. Due to their association with trees the silage productivity and maize grains showed significant decrease (~ 52%) seven years after they were planted in an initial 14 x 3 m arrangement.

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