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Forage Yield and Silage Quality of Intercropped Maize+Soybean With Different Relative Maturity Cycle

Vanderson Vieira Batista[1], Paulo Fernando Adami[1], Laercio Ricardo Sartor[1], Magali Floriano Da Silveira[1], André Brugnara Soares[2], Karine Fuschter Oligini[2], Diego Kwiecinski[1], Michael Luiz Ferreira[1], Douglas Camana[1], Cleverson Luiz Giacomel[1] & Amanda Cassu da Fonseca[1]

[1] Technologic University of Paraná, Dois Vizinhos, Paraná, Brazil

[2] Technologic University of Paraná, Pato Branco, Paraná, Brazil

Correspondence: Vanderson Vieira Batista, Technologic University of Paraná, Dois Vizinhos, PR, Brazil. Tel: 55-46-999-000-618. E-mail: vandersonvbatista@hotmail.com

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Abstract

The success of maize+soybean intercrop depends on the correct synchronism between species phenological stages at the silage point. Due to it, the experiment was carried out to evaluate maize+soybean intercrop forage yield and silage quality using crops with different maturity cycle combination. The experiment used a randomized complete block design with a 2 × 3 factorial scheme. Treatments consisted of two maize hybrids (1: P1630YHR-early cycle and 2: middle cycle P30F53VYHR) and two soybean cultivars (P95R51-maturity cycle of 5.1; TMG7062-maturity cycle of 6.2) and one control represented by maize monocrop. Silage harvesting was performed when maize had reached 2/3 milk line stage. Intercropping soybean into maize did not affect its biomass yield. Both soybean cultivars present compatible cycles for ensiling together with maize hybrids, since they were in phenological stages from R5.3 to R7 by the time maize was at its optimum stage for ensiling. There was interaction between species for the soybean biomass yield. Maize hybrid P30F53 produced higher biomass yield than P1630 what also resulted in higher amount of total crude protein yield. Intercrop P1630-P95R51 produced 458 Kg ha^{-1} of crude protein more than maize monocrop. Maize+soybean intercropping system results in higher silage crude protein percentage and yield per area (Kg of CP ha^{-1}).

Keywords: acid detergent fiber, animal feed, crude protein, dry mass, forage yield

1. Introduction

Maize silage is an important source of feed, particularly in the Brazilian dairy industry. The important traits of maize silage include high yield and high metabolisable energy, although, it has low protein content (Millner et al., 2005). In the other hand, soybean (*Glycine max* (L.) Merr.) is an important high-quality protein source for human and animal nutrition. It is mainly grown for grain and oil production, however, research have been showing its potential to be intercropped with maize (grow both species together at the same time and the same piece of land) (Sánchez et al., 2010).

Indeed, although not practiced in Brazil, maize+soybean intercrop is becoming more and more popular worldwide. Previous studies have documented that maize+soybean intercrop systems result in better environmental sources use efficiency for plant growth and thus stable yields when compared to monocrop system due to interspecific complementarily, facilitation and competition (Li et al., 2013; Latati et al., 2016).

Many studies have been reporting that intercropping soybean into maize did not affected maize biomass yield, showing similar or even higher values, what also resulted in silage with higher crude protein content (Oliveira et al. 2016; Sánchez et al., 2010; Stella et al., 2016). Higher radiation use efficiency (RUE) (Liu et al., 2017; Gao et al., 2010; Baghdadi et al., 2016) and better soil use (Baghdadi et al., 2016; Yang et al., 2017) of intercrop versus monocrop support these results and turn out in better land equivalent ratio (LER) (Gao et al., 2010; Martin et al., 1998).

Most studies on intercropping have focused on its resource utilization (water, light, nutrients) (Liu et al., 2017), and plant arrangement (density, number or rows) (Sánchez et al., 2016), however, the determination of an optimum plant maturity cycle between maize and soybean and its yield potential is a major agronomic goal in intercrop systems.

The selection of an appropriate maturity cultivar of soybean is important for the success of the intercrop. Earlier maturing varieties may have set seeds and their leaves will be senescing by the time maize is at its optimum stage for ensiling, while, late maturing cultivars may not have grain filled, what may reduce its crude protein contribution for the silage. According to Leonel et al. (2008), soybean should be in R7 stage at the moment maize is ready to be ensilaging.

Furthermore, these cultivars are influenced by the environment (soil conditions, latitude, altitude, etc.) and must be adapted to the region where it is going to be used, and present compatible cycles with maize. It was hypothesize that the presence of soybean as intercrop with maize will positively influence plant biomass yield and silage quality in relation to maize monocrop. Moreover, it was expected to find higher biomass yield for the maize hybrid with longer cycle, which also would fit better with longer soybean maturity cycle.

The objective of this research was to test two cultivars of maize and soybean with different maturity cycles to determine which is the best arrangement between these two species when grown as intercrops to produce high-quality silage.

2. Material and Methods

2.1 Study Area

Field experiment was carried out (2016/2017 summer growing season) at the Federal Technologic University of Paraná (UTFPR), Agricultural Research Station (25º41′33″ S and 53º05′36″ W with an average altitude of 540 m and a maximum slope of 3%) southern of Brazil. According to the Köppen classification, the climate is Cfa (Alvares et al., 2013).

Soil at the experimental site is classified as a Clayey Oxisol. Chemical properties of the experimental soil area were determined before the start of this study in the 0.0-0.1 and 0.1-0.2 m soil layer, with the following results: pH($CaCl_2$) 5.6 and 5.5; organic matter (OM) 46.2 and 30.8 g kg^{-1}; P (Mehlich1) 26.5 and 19.7 mg dm^{-3}; K 84.1 and 35.2 mg dm^{-3}, cation exchange capacity of 9.7 and 8.8 cmol$_c$ dm^{-3} and base saturation 71.5 and 66.6 % respectively.

2.2 Experimental Design

This experiment was conducted from September 2, 2016 to February 22, 2017. The experiment used a randomized complete block design with a 2 × 3 factorial scheme. Treatments consisted of two maize hybrids (1: P1630YHR-early cycle and 2: middle cycle P30F53VYHR) and soybean cultivars (1: P95R51-relative maturity 5.1; 2: TMG7062-relative maturity 6.2 and 3: without soybean represented by maize monocrop) resulting in six treatments in the combination of these factors.

Treatment combinations were assigned to a split plot design in a randomized complete block with four replications. Corn hybrids were randomly assigned to the main plots while the soybean cultivars were randomly allocated to the subplots. Crops were sown as sole maize (M-2 hybrids) and four arrangements of maize and soybean intercropping 1 row maize to 1 row soybean. Intercropped maize was 60 cm from maize to maize and 30 cm from maize to soybean. The experimental plot size was of 60 m^2 (3 m × 20 m).

Both maize and soybean varieties were resistant to herbicide glyphosate (RR2). Soybean cultivars have great branch potential and indeterminate growth habit. Moreover, TMG7062-IPRO Intacta RR2 PROTM has been genetically modified and express a endotoxin that allows the soybean plant to protect itself against the main caterpillars species (PROTM) and tolerance to *Phakosphera pakirizi,* a rust disease, having also a longer cycle (125 to 135 days to relative maturity-RM) (Tropical Breeding and Genetics, 2017) than the P95R51 (cycle of 115 to 125 days to RM). Corn hybrids (single-cross hybrid) used in the study stands out with high productive potential and are highly responsive to management. Are considered excellent options for grain and silage production and have a recommended seed rate positioning of 65,000 to 70,000 plants ha^{-1} (P30F53) and 70,000 to 80,000 plants ha^{-1} (P1630) (Dupont Pioneer, 2017). Maize seeds were treated with imidacloprid (2.6 g a.i. Kg^{-1} seed) and thiodicarb (7.9 g a.i. Kg^{-1} seed).

2.3 Experiment Management, Sample Collection and Measurement

Black oat (*Avena strigosa*) was used as prior crop and it was desiccated with glyphosate [(1.100 g ha^{-1} of active ingredient (ai)] 21 days before intercrop establishment. On 09/02/2016, intercrop of maize+soybean was sown simultaneously with the aid of a precision planter with seed disc distribution configured with smooth cuts disk, fertilizer plow rod type and seed furrow double disc type set at 30 cm from each other in a pantograph system. A

New Holland® tractor, model TT3840, 4 × 2 with a maximum power of 41 kW (55 hp) at 2,400 rpm with wheel tires was used to pull the seed drill at a constant speed of 4 km h^{-1}. Maize seed discs had 28 holes, while soybean seed discs had 90 holes (90/28 = 3.2 soybean seed to each maize seed). Seed drill regulation was set up to sow 70.000 maize seeds ha^{-1} (4.2 seeds linear m^{-1}) and soybean seed stand was a consequence (225.000 seeds ha^{-1}) of it.

Mineral fertilization in the maize planting furrow consisted of 11 and 80 kg ha^{-1} of N and P2O5, respectively (366 kg ha^{-1} of N-P_2O_5-K_2O fertilizer mixture 03-22-00). Potassium was broadcast using potassium chloride (KCl with 60% of K_2O) at185 Kg ha^{-1} at the sowing day. Nitrogen was applied as urea (45% of N) at the rate of 180 kg of N ha^{-1}. Half of the N required dosage was applied two weeks after sowing (09/19/2016) and the remaining half was applied six weeks after sowing (10/14/2016), all by manually side placement along the rows. Weed control was achieved by applying glyphosate on September 23 and October 08 at a rate of 1.400 and 1.200 g ha^{-1} of a.i respectively.

Fungicide application was done at maize VT stage (pre-silking) with a systemic fungicide of ready mixture containing *Protioconazol* (175 g L^{-1}) + *Trifloxistrobina* (150 g L^{-1}) at a dose of 72 + 61 g. i. a ha^{-1}. Along with the fungicide, vegetable oil was added at a dose of 0.5 L ha^{-1} and spray volume of 150 L ha^{-1}. Fungicide was applied with a self-propelled sprayer.

Corn and soybean intercrops were harvested at the same time considering 1/3 of kernel milk line to black layer maturity, which happened 109 and 116 days after its emergence respectively for hybrid P1630 and P30F53. At that point, phenological stage of soybean cultivars was determinated. The evaluations were performed in 10 randomized plants by experimental unit, in a visual way, being considered as the stage of the crop, the one in which the majority of the plants were found.

At harvest time, final stand of maize (FSM) and soybean plants (FSS) (plants ha^{-1}) were determined, counting the number of corn and soybean plants from each EU, being the values extrapolated to hectare.

Sample area considered the experimental unit two central rows (1 of corn and 1 of soybean) 5 m long, totaling a sample area of 6 m^2. Plants were harvested by hand cutting the plants at 25 cm above the soil surface. They were weighed to determine maize (MGBY) and soybean green (SGBY) biomass yield. Then, plant samples of both crops of each experimental unit (EU) were ground separately on a forage harvester coupled to a tractor with an average particle size of 0.5 to 1.5 cm. In addition, whole plant samples were weight fresh and sub-samples (300 g) were placed in paper bags, weighed and oven-dried at 65 °C for at least 72 hours until constant weight to determinate its dry matter content. Forage DM yield was calculated from the fresh and dry weights of respective components listed above to determinate maize and soybean dry matter yield (MDMY and SDMY) and it sum resulted in the total dry matter yield (TDMY).

Total fresh and dry matter forage yield was calculated by adding maize and soybean values and data is showed in kg ha^{-1}. Moreover, dry matter per plant of maize (DMPM) and soybean (DMPS) (g) were determined dividing the plant total dry matter by its population. Furthermore, the percentage of soybean dry matter in the silage (PSS) was determined by the formula PSS = SDMY × 100/TDMY.

Samples of corn and soybean plants that had previously been collected and ground separately were grouped into the corresponding experimental units. Amount of maize and soybean were taken, respecting the proportion of the field biomass production between maize and soybean. This biomass was mixed for total homogenization and samples of 3 kg was packed compactly into Laboratory silos made of PVC pipes, measuring 100 mm in diameter, 600mm in length, with average density of 600 kg m^{-3}. The silos were sealed at the time of ensiling, with PVC caps fitted with 'Bunsen' type valves. The silos were opened after 60 days of the ensiling.

Upon the opening of the silos, the material was homogenized and extracted for further analysis. At the time, determination of pH was carried out using a pH meter in accordance with the methodology described by Silva & Queiroz (2002). Samples collected (300 g) after the opening of the silos were placed in paper bags, weighed and oven-dried at 55 °C for at least 72 hours until constant weight to determinate its dry matter content. The pre-dried samples were ground in a 'Willey' type mill with a 1mm mesh sieve, and the samples taken to the Bromatological Analysis Laboratory of the UTFPR.

Further analysis of dry matter, ashes (%) (Silva & Queiroz, 2002), neutral detergent fiber (NDF), acid detergent fiber (ADF) (%) were determinated by the methodology described in the Ankon (2009) manual. Silage crude protein (SCP) (g kg^{-1}) analyzes were performed by quantifying the N present in the samples, with the total N being determined in Kjeldhal semi-micro steam distillation methodology Tedesco et al. (1995). By multiplying SCP values by TDMY data, total crude protein yield (TCPY) (Kg ha^{-1}) production of the crops was determined.

2.4 Statistical Analysis

The data obtained was subjected to analysis of variance through the SISVAR 5.6 software (Ferreira, 2008), and when it presented significance for the ‘F’ test, mean was compared through the Tukey test at a 5% probability. Soybean cultivars phenological stages are described along the text.

3. Results and Discussion

3.1 Weather Conditions

Total precipitation of 551 mm observed from September 2 to December 31 was well distributed along the experimental period, being September the period of lower rain (55 mm along the month), although, maize plants germinate well and showed good initial plant development. According to Aguilar and López-Bellido (1996), maize hybrids of medium-cycle requires 400 to 700 mm of water in its complete cycle when grown for grain. By that, it is inferred that rainfall was sufficient for the good development of the plants in the experimental period. Thus, maximum and minimum temperature recorded during the field study period were 27.4 and 16.9 °C, respectively (Figure 1).

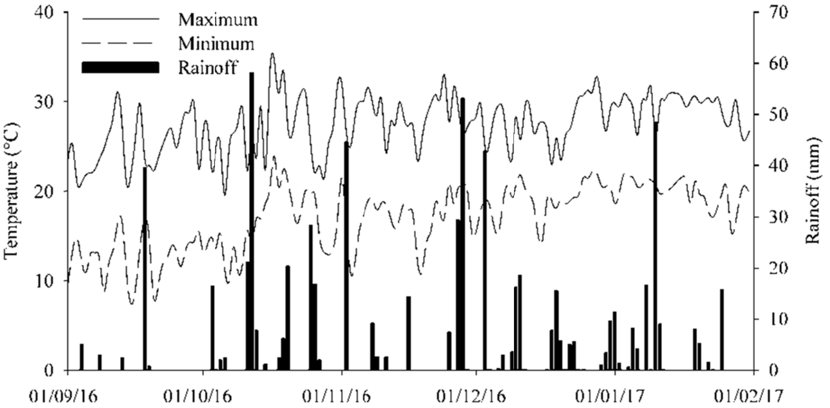

Figure 1. Maximum, minimum temperature and rainfall. UTFPR, Dois Vizinhos, Paraná, Brazil (2018)

3.2 Phenological Stages of Soybean Cultivars

By that time, soybean TMG7062 had reached the phenological stage R5.3 (26 to 50% of grain filling), and soybean cultivar P95R51 had reached phenological stage R6 (full grain in one of the four upper nodes on the main stem) for the P1630 maize hybrid. For the P30F53 hybrid, TMG7062 and P95R51 had reached the phenological stage R6 and R7 (beginning of maturation—a pod with mature staining on the main stem) respectively.

The advance of reproductive stage changes the nutritional value of whole-plant soybean silage increasing crude protein as grain filling occurs (Dias et al., 2010). Evangelista et al. (2003) emphasize that when determining the correct time to harvest soybean for silage, it is necessary to combine grain filling stage and leaf retention to reach best silage quality and yield. In this context, Keplin (2004) reports that when silage is performed before R5 and latter than R7 stage, there is a reduction in the percentage of soybean crude protein. Moreover, Leonel et al. (2008) also reported that the right phenological stage of soybean plants to obtain silage with better quality is R7.

Evaluating soybean dry matter accumulation along phenological stages, Piana at al. (2017a) reported that soybean cultivars (CD 2610 IPRO and CD 2611 IPRO) reached the highest rate of mass increment 95 and 97 days after its emergence, respectively, in stage R5.5 (75 to 100% grain filling). Moreover, Teodoro et al. (2015) points out that the highest rate of soybean dry mass accumulation occurs at the R6 stage.

Regarding to the soybean plant nitrogen content, Piana et al. (2017b) report that 80 days after its emergence, grains represent the soybean most important component and that grain N content increases up to 100 days after its emergence, remaining stable until the end of the cycle. The researchers point out that there are variations in the amount of biomass and nitrogen content in soybean plants throughout its cycle, but in general, the maximum accumulation occurs between R5 to R7 phenological stages.

In this context, it is possible to infer that both evaluated soybean cultivars present compatible cycles for ensiling together with maize hybrids, since they were in stages from R5.3 to R7, being at or very near to the point of maximum accumulation of dry mass and nitrogen content of the plant. Thus, when selecting a soybean cultivar for intercropping with corn, the cultivars that yield the highest in monocrop can be assumed to yield the highest when intercropped. Moreover, optimally higher biomass yields for later maturing soybean varieties seem to be the major factor contributing to higher protein yields in intercrops.

3.3 Analysis of Variance (ANOVA)

Table 1 shows the mean square values for the variables analyzed, with the respective level of significance.

Table 1. Mean square values of corn hybrids and soybean cultivars with distinct cycles, grown in a intercrop for silage. UTFPR, Dois Vizinhos, Paraná, Brazil (2018)

	Df	FEM	MGBY	MDMY	
Replications	3	6,743,174.994450^{ns}	7,009,634.500000^{ns}	2,194,401.375000^{ns}	
Maize (M)	1	32,851,306.840017*	2.23085027^{e}+0009**	127,471,113.375000**	
Soybean (S)	2	787,057.925937^{ns}	8,088,148.166667^{ns}	3,401,042.625000 ^{ns}	
M x S	2	3,145,908.728204^{ns}	8,334,133.166667^{ns}	2,026,003.875000 ^{ns}	
Residue	15	6,871,222.111693	16,051,283.933333	2,085,276.741667	
	Df	FES	SGBY	SDMY	
Replications	3	399,117,654.850256^{ns}	955,049.708333^{ns}	36,118.597222^{ns}	
Maize (M)	1	6,386,986.470150 ^{ns}	28,512,220.041667**	2,810,557.041667**	
Soybean (S)	2	7.01727310^{e}+0010**	45,761,127.125000**	3,894,682.541667**	
M x S	2	54,006,041.232050 ^{ns}	7,633,318.791667**	703,052.541667**	
Residue	15	174,892,788.123006	436,521.108333	52.937.263889	
	Df	TGBY	TDMY	DMPM	
Replications	3	12,731,268.930556^{ns}	1,894,426.486111^{ns}	145.428537^{ns}	
Maize (M)	1	1.77213439^{e}+0009**	90,889,876.041667**	21,835.871637**	
Soybean (S)	2	21,474,300.791667^{ns}	476,637.125000 ^{ns}	908.259784 ^{ns}	
M x S	2	28,474,482.791667^{ns}	4,731,442.541667 ^{ns}	908.259784^{ns}	
Residue	15	18,225,363.863889	2,059,108.052778	616.399444	
	Df	DMPS	PSS	pH	Ashes
Replications	3	0.543033^{ns}	1.120937^{ns}	0.003966^{ns}	28.568840^{ns}
Maize (M)	1	113.804904**	100.833106**	0.045503**	69.524998^{ns}
Soybean (S)	2	148.583366**	109.586117**	0.009528^{ns}	8.368570^{ns}
M x S	2	28.494542**	25.288467**	0.000023^{ns}	23.412140^{ns}
Residue	15	2.593874	1.495155	0.003387	14.053020
	Df	NDF	ADF	SCP	TCPY
Replications	3	36.392415^{ns}	10.986911^{ns}	10.622777^{ns}	16,759.593698^{ns}
Maize (M)	1	7.927826^{ns}	0.504151^{ns}	201.313646*	398,046.298089**
Soybean (S)	2	3.174360^{ns}	4.594612^{ns}	361.224159**	157,350.545446*
M x S	2	48.599259^{ns}	19.348340^{ns}	104.061314*	99,501.550493^{ns}
Residue	15	30.410155	9.273851	23.457967	31,127.183099

Note. * Significant at the $p \leq 0.05$ level. ** Significant at the $p \leq 0.01$ level. ^{NS} Nonsignificant at the $p > 0.05$ level. FEM = Final stand of maize plants; MGBY = maize green biomass yield; MDMY = maize dry matter yield; FES = Final stand of soybean plants; SGBY = soybean green biomass yield; SDMY = soybean dry matter yield; TGBY = total green biomass yield; TDMY = total dry matter yield (maize+soybean); DMPM = dry matter per plant of maize; DMPS = dry matter per plant of soybean; PSS = percentage of soybean dry matter in the silage; pH = potential hydrogen; ashes; NDF = neutral detergent fiber; ADF = acid detergent fiber; SCP = Silage crude protein and total crude protein yield (TCPY).

It was noticed by the analysis of variance (ANOVA) ($p \leq 0.05$), significant interactions between maize hybrids and soybean cultivars to the: soybean green and dry matter yield (GSBY and SDMY), dry matter per soybean plant (DMPS), percentage of soybean into the dry matter biomass in silage (PSS) and silage total crude protein silage yield (kg ha^{-1}) (TCP) (Table 1).

There was effect of maize hybrids to the final stand of maize plants (FSM), maize green and dry matter biomass yield (MGBY and MDMY), total green and dry matter biomass yield (TGBY and TDMY), dry mass per maize plant (DMPM), silage potential hydrogen (pH) and total crude protein (TCPY). Similarly, the use of soybean cultivars with different maturity cycles ad an influence on the final stand of soybean plants (FSS) and on the total crude protein yield (CPY), when comparing the factor alone (Table 1). For the variables ashes (%), neutral detergent fiber (NDF), acid detergent fiber (ADF) (%), no significance was observed for the evaluated factors ($p \leq 0.05$) (Table 1). There were also no differences between the blocks evaluated for any of the variables (Table 1).

3.4 Plant Stand and Maize Biomass Yield

On Table 2 it is possible to observe maize yield components (FSM, MGBY, MDMY and DMPM). Interestingly, the P30F53 was observed to be more productivity than P1630 for all these variables.

Table 2. Stand of plants and yield components of maize hybrids with distinct cycles intercropped with soybean for ensiling. UTFPR, Dois Vizinhos, Paraná, Brazil (2018)

Maize/Soybean	Final stand of maize (FEM) (plants ha^{-1})				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	63,690	64,285	63,690	63,888 b	4.02
P30F53	67,083	65,238	66,364	66,228 a	
Mean	65,386	64,761	65,027	65,058	
Maize/Soybean	**Maize Green biomass yield (MGBY) (Kg ha^{-1})**				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	46,062	48,957	47,261	47,427 b	6.68
P30F53	65,780	66,016	68,332	66,709 a	
Mean	55,921	57,487	57,797	57,068	
Maize/Soybean	**Maize dry matter yield (MDMY) (Kg ha^{-1})**				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	16,353	16,526	16,650	16,510 b	7.71
P30F53	19,899	21,262	22,196	21,119 a	
Mean	18,126	18,894	19,423	18,814	
Maize/Soybean	**Dry matter per plant of maize (DMPM) (g)**				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	257.27	257.78	261.35	258.80 b	8.03
P30F53	297.02	326.05	334.32	319.13 a	
Mean	277.14	291.92	297.83	288.96	

Note. Mean values followed by the different lower case letter in the column, differ by Tukey test 5%. CV = Coefficient of variation.

Corn hybrid P30F53 with medium-maturity cycle showed greater green biomass and dry matter yield compared to hybrid P1630 with early-maturity cycle (difference of 19.282 and 4.609 Kg ha^{-1}, respectively). Vieira et al. (2016) and Assis et al. (2014) also reported differences in the biomass accumulation potential for maize, being the medium-maturity hybrids higher productive. One concern for production of short-season maize hybrids is that there is less time for leaf area production and for interception of photosynthetically active radiation (PAR) (Edwards et al., 2005).

Moreover, difference observed between hybrids may be associated with a greater susceptibility of P1630 to diseases such as *Phaeosphaeria maydis* and *Helminthosporium turcicum*. In this context, any reduction in leaf area or season-long light interception would likely result in decreased yield potential

Despite hybrid P30F53 had higher plant final stand (2,340 plants ha^{-1}) than hybrid P1630, it is believed that this fact did not influence the results of biomass yield, since P1630 showed lower values of DMPM (61 g), evidencing that its plants had lower yield potential.

Maize biomass yield (silage) in the southern of Brazil typically produces between 40 to 50 t ha^{-1} of green material (Vieira et al., 2011). In this context, it was noticed that, even in the early cycle hybrid, yield is similar to what farmers have reported, although, it could be better. Higher plant population (mean final population: 63.888 plants ha^{-1}), better *Bt* technology as offered today (LYH versus YH) and better disease management might allow higher yields. Moreover, early corn material allow earlier harvest and consequently anticipate second summer crop sowing, reducing frost risk and allowing higher yield to the productive system.

Intercropping soybean into maize did not affected maize biomass yield (Table 2). Similar results were reported by Alvarenga et al. (1998). Furthermore, Martin et al. (1998) studding the effect of soybean cultivars on maize-soybean intercrop biomass reported that none of them resulted in significantly lower biomass yields than the maize monocrop. Moreover, at the late soybean variety, land equivalent ratios of the intercrop shoot biomass yield revealed advantages of intercrops over monocrop of 21%. Moreover, according to Sánchez et al. (2010), maize-soybean intercrop produced DM yields similar to those of monocropped maize due to higher maize yields in border rows adjacent to soybean.

Although, Oliveira et al. (1986) reported lower maize yield due to interspecific competition. In this way, good soil fertility associated with mineral fertilization, good crop management and wheater conditions, may have contributed to the development of the crop and, consequently, contributing to high biomass yields.

3.5 Plant Stand and Soybean Biomass Yield

It is observed on Table 3, that both soybean cultivars (TMG7062 or P95R51) showed lower biomass values when intercropped with maize P30F53. Taller plants, greater leaf area and higher biomass accumulation of the hybrid P30F53 (Table 2), possibly contributes to the shading of the soybean crop and, consequently, to the lower potential biomass accumulation of the soybean cultivars. Moreover, nowadays, the greatest challenge of Brazilian soybean farmers is a rust disease (*Phakopsora pakirizi*), that causes early fall of leaves and consequently lower productive potential. Thus, the disease inoculum pressure increase from December to January due to good climatic condition, what affect soybean shoot biomass yield when intercropped with maize P30F53.

Table 3. Final stand of plants and its yield components of soybean cultivars with distinct relative maturity intercropped with maize for silage. UTFPR, Dois Vizinhos, Paraná, Brazil (2018)

Maize/Soybean	Final stand of soybean (FSS) (plants ha^{-1})				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	161,666	161,071	0.00	107,579	13.48
P30F53	169,333	157,499	0.00	108,611	
Mean	164,999 A	159,285 A	0.00 B	108,095	

Maize/Soybean	Soybean green biomass yield (SGBY) (Kg ha^{-1})				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	6,108 Aa	4,897 Aa	0.00 Ba	3,668	28.05
P30F53	3,340 Ab	1,124 Bb	0.00 Ba	1,488	
Mean	4,724	3,010	0.00	2,578	

Maize/Soybean	Soybean dry matter yield (SDMY) (Kg ha^{-1})				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	1,886.00 Aa	1,438.00 Ba	0.00 Ca	1,108.00	29.24
P30F53	845.00 Ab	425.75 Bb	0.00 Ca	423.58	
Mean	1,365.50	931.88	0.00	765.79	

Maize/Soybean	Dry matter per plant of Soybean (DMPS) (g)				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	11.76 Aa	9.00 Ba	0.00 Ca	6.92	31.65
P30F53	5.08 Ab	2.61 ABb	0.00 Ba	2.56	
Mean	8.42	5.80	0.00	4.74	

Note. Mean values followed by the different uppercase letter in the row and lowercase in the column, differ by Tukey test 5%. CV = Coefficient of variation.

It can be noticed in Table 3 that soybean green biomass yield (SGBY) was similar between cultivars for the P1630 hybrid. For the hybrid P30F53, cultivar TMG7062 stands out with 2.216 kg ha^{-1} more than P95R51.

Regarding to the dry matter yield, independent of the used maize hybrid, cultivar TMG7062 showed higher values than P95R51. Relative to the soybean weight per plant (DMPS), TMG7062 (11.76 g) showed plants heavier than P95R51 (9 g) at the P1630. For the P30F53, both cultivars presented similar values (Table 3).

These results show that between soybean cultivar, TMG7062 presents a higher productive potential of biomass in relation to P95R51, being more indicated for the intercrop system. Inox® technology which is a tolerance to rust (*Phakopsora pakirizi*) present on TMG7062 helped this cultivar to support disease pressure and reduce plants defoliation. Thus, shorter cycle of P95R51 stimulated its defoliation by the time maize was ensiled.

Sánchez et al. (2010) reported that maize+soybean intercropping caused a 62 to 70% decrease in soybean DM yield in relation to its monocrop. However, according to Gao et al. (2010), soybean plants can tolerate shade produced by maize plants in intercropped systems, and the author uses the land equivalent ratio to support his theory. Comparing maize monocrop with three rows of soybean alternated with one row of maize, land equivalent ratio for the intercrop was of 1.65. Moreover, the authors conclude that maize+soybean intercropping usually had greater radiation use efficiency (RUE) than sole cropping, which may account for the yield advantage of intercropping. Thus, (Liu et al., 2017), showed that photosynthetically active radiation (PAR) and radiation use efficiency (RUE) of intercropping systems (maize+soybean) were all higher than those of monocrop.

3.6 Total Biomass Yield (Maize+Soybean)

Table 4 shows the effect of maize hybrids on TGBY and TDMY. It is noticed that P30F53 showed higher biomass yield (17.186 and 3.892 kg ha^{-1} of green and dry mass) than P1630.

Table 4. Total green biomass and dry matter yield of soybean cultivars intercropped with maize hybrids, both of distinct relative maturity groups. UTFPR, Dois Vizinhos, Paraná, Brazil (2018)

Maize/Soybean	Total green biomass yield (maize+soybean) (TGBY) (Kg ha^{-1})				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	52,170	53,855	47,261	51,095 b	6.97
P30F53	69,121	67,391	68,332	68,281 a	
Mean	60,646	60,623	57,797	59,688	

Maize/Soybean	Total dry matter yield (maize+soybean) (TDMY) (Kg ha^{-1})				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	18,239	18,064	16,650	17,651 b	7.27
P30F53	20,745	21,688	22,196	21,543 a	
Mean	19,492	19,876	19,423	19,597	

Note. Mean values followed by the different uppercase letter in the row and lowercase in the different column, differ by Tukey test 5%. CV = Coefficient of variation.

Soybean intercropped with maize P1630 tends to increase biomass yield. Lower final plant population (63.880 plants ha^{-1}), early relative maturity associated with lower leaf area index (LAI) and lower plants height allowed higher PAR and RUE to the soybean cultivars. In the other hand, P30F53 had higher plant population (66.228 plants ha^{-1}) and taller plants, with greater LAI, what reduced the amount of light intercepted by soybean and its contribution to the total biomass production. Seems that in intercrop systems, it is necessary to reach an equilibrium between maize plant population and row arrangements aiming to allow soybean development and biomass accumulation.

Experiment mean green and dry matter biomass results (59.688 and 19.597 kg ha^{-1} respectively) are higher than regional values reported in other studies (Vieira et al., 2011, 2016; Assis et al., 2014), showing that intercropping maize with soybean for silage presents a great potential as a system to be used by farmers. Furthermore, Oliveira et al. (1986) reported that maize-soybean intercropping resulted in higher DM yield in relation to the monocrop. Also, intercropping systems improved land use efficiency, once relative total yield (RTY) values of intercropping were higher than that of monocrop maize and soybean (Baghdadi et al., 2016).

Yield advantages from intercropping are often attributed to complementation between component crops in the mixture, resulting in a better total use of resources rather than growing crops separately. Furthermore, this complementation may be a result from both above and below-ground interactions between associated species (Latati et al., 2016).

Together these results provide important insights about maize+soybean intercrop, although, further studies need to be carried out, in order to identify the most efficient plant/row arrangement and population to be used to maximize intercrop yield and system adoption. Thus, nowadays, *Phakopsora pakirizi* disease management may also be a challenge in intercrop system, especially for maize hybrids with longer cycle.

3.7 Bromatological Traits of Maize+Soybean Silage

Table 5 shows the interaction between the evaluated factors for PSS. It was observed higher values of PSS at the silage with maize P1630, except for the monocrop (without soybean). Cultivar TMG7062 showed higher PSS than P95R51 (10.42 and 7.90% respectively), when intercropped with hybrid P1630. However when intercropped with P30F53, it is observed that only the cultivar TMG7062 differs statistically from the treatment without soybean.

Table 5. Chemical-bromatological traits of silage from maize+soybean intercrop with different relativity maturity cycle. UTFPR, Dois Vizinhos, Paraná, Brazil (2018)

Maize/Soybean	Percentage of dry mass of soybean in silage (PSS) (%)				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	10.42 Aa	7.90 Ba	0.00 Ca	6.11	29.50
P30F53	4.07 Ab	1.95 ABb	0.00 Ba	2.01	
Mean	7,25	4.93	0.00	4.06	

Maize/Soybean	Potential hydrogen (pH)				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	4.47	4.46	4.41	4.45 a	1.34
P30F53	4.39	4.37	4.32	4.36 b	
Mean	4.43	4.42	4.37	4.41	

Maize/Soybean	Ashes (%)				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	3.93	3.44	3.59	3.65	10.62
P30F53	3.94	4.13	3.89	3.99	
Mean	3.94	3.79	3.74	3.82	

Maize/Soybean	Neutral detergent fiber (NDF) (%)				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	36.14	41.97	37.27	38.46	14.36
P30F53	40.87	37.49	40.46	39.61	
Mean	38.50	39.73	38.86	39.03	

Maize/Soybean	Acid detergent fiber (AFB) (%)				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	18.16	21.58	17.22	18.99	16.16
P30F53	19.89	18.30	19.64	19.28	
Mean	19.03	19.94	1843	19,13	

Maize/Soybean	Silage crude protein (SCP) (g Kg^{-1})				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	104.02 Aa	107.94 Aa	89.95 Ba	100.63	4.72
P30F53	100.35 Aa	94.11 ABb	90.07 Ba	94.84	
Mean	102.18	101.02	90.01	97.74	

Maize/Soybean	Total crude protein yield (TCPY) (Kg ha^{-1})				
	TMG7062	P95R51	Without soy	Mean	CV (%)
P1630	1,900	1,952	1,494	1,782 b	8.87
P30F53	2,076	2,039	2,004	2,040 a	
Mean	1,988 A	1,995 A	1,749 B	1,911	

Note. Mean values followed by the different uppercase letter in the row and lowercase in the column, differ by Tukey test 5%. CV = Coefficient of variation.

According to Stella et al. (2016), the amount of soybean in silage is an important factor that must be taken into account, since it can affect quality of silage. The lower PSS reported for the P95R51 intercropped with maize P30F53 is mainly explained by plant defoliation due to rust disease.

Regarding to potential hydrogenous (pH), values ranged from 4.36 and 4.45 for the P30F53 and P1630 respectively. Thus, although the silage presented different percentages of soybean in its composition, no effects of the legume on the pH of the silage were observed (Table 5). According to Kung and Shaver (2001), the final silage pH indicates the quality of the fermentation process and should be low enough (appropriate range from 3.8 to 4.2) to inhibit the growth of undesirable bacteria, such as those of the genus *Clostridium*.

The amount of ashes, NDF and ADF of silage were not influenced by the evaluated treatments, presenting average values of 3.82, 39.03 and 19.13% respectively (Table 5). Results corroborate with those observed by Sánchez et al. (2010) which only found lower fiber content, at the treatments with more than 10% of soybean into the silage.

According to Sánchez et al. (2010), soybean forage fiber concentration varied according to its phenological stage. Soybean cultivar harvested at phase R3 (beginning pod) presented NDF values equal to those of maize and higher ADF concentrations. In the other hand, when cultivar was harvested at phase R7 (beginning maturity), forage quality was better than maize, with lower NDF concentration and similar ADF values.

Martin et al. (1998) studding the effect of soybean cultivars on maize-soybean intercrop biomass reported that under intercropping, only the late soybean cultivars produced significantly higher protein yields than the maize monocrop. Intercrop shoot protein yield revealed yield advantages of intercrops over monocrop of 10%. According to the authors, soybean with longer maturity cycle increased silage crude protein without affecting intercrop biomass yield and this result was attributed to higher percentage of leaves and minimal pods shattering at the time of intercrop silage harvest.

There was interaction between maize hybrids and soybean cultivars to the silage crude protein (Table 5). Silage from P1630 + TMG7062/P95R51 intercrop resulted in higher amount of crude protein (104.02 and 107.94 g Kg^{-1}, respectively) when compared to the maize monocrop (without soybean) (89.95 g Kg^{-1}). In the same way, silage from P30F53 + TMG7062 intercrop showed higher CP values (100.35 g Kg^{-1}) than the maize monocrop (90.07 g Kg^{-1}).

It is possible to infer that there is a close relation for SCP values with maize and soybean dry matter yield (Table 2 and 3). Treatments with lower maize biomass yield (P1630) allowed higher soybean development and yield which contributed to higher SCP in relation to maize monocrop. However, when maize biomass yield increased, as the case of hybrid P30F53, the soybean biomass reduced and only the cultivar TMG7062 presented the potential to differentiate from the treatment without soybean. These results show that the addition of soybean biomass to maize silage can increase the crude protein content of the silage, although, higher soybean biomass than observed is desired.

Pauli et al. (2017) evaluated maize silage crude protein content from 10 properties located near the experimental site and reported crude protein values from 54.9 to 91.0 g Kg^{-1}, being these values lower than those observed in the present study. According to Sánchez et al. (2010), crude protein content in maize+soybean silage from intercrops was 16 to 22 g kg^{-1} greater than in forage from monocropped maize.

When comparing maize hybrids, it is possible to observe that P30F53 produced higher amount of total crude protein than P1630, especially at the treatment without soybean, where this difference reaches 510 Kg ha^{-1} of crude protein. This difference was attenuated by the presence of soybean in the treatment with P1630, where intercrop with P95R51 produced 458 Kg ha^{-1} of crude protein more than maize monocrop. Increase silage protein content is important once it allows feed cost reduction and higher profit once crude protein derived from soybean meal is much more expansive (may cost to the Brazilian farmers up to US$ 2.00 per crude protein kilogram) than crude protein derived forage production (may cost to the Brazilian farmers up to US$ 0.50 per crude protein kilogram).

This higher productive potential of TCPY of the hybrid P30F53 is related to its higher values of biomass yield (Table 2). For the P1630 hybrid, maize+soybean intercropping system results in higher crude protein yield in the silage and per area, collaborating with other studies (Oliveira et al., 2016; Sánchez et al., 2010; Stella et al., 2016).

From the standpoint of chemical composition, the soybean plant can be added up to 50% in maize ensilage, resulting in improvements to the final product (Stella et al., 2016). According to Belel et al. (2014), improved forage production for agricultural industry is a key factor for current agricultural production, evidencing the need for studies in this area.

Although not widely practiced in Brazil, maize+soybean intercrop for silage appears to be an excellent environmentally sustainable method of producing high-quality silage. The results found in the present study corroborated with a number of other data already mentioned in the literature and further evidence the positive effects of maize+soybean intercrop system. Studies evaluating the crops intercropping system need to be carried out periodically, as the market for soybean cultivars and maize hybrids is constantly changing, with the use of new materials and the use of different technologies, aiming to assess and to identify better cultivars, plant arrangements, potential of fertilization reduction, etc. With that, maize+soyben intercrop may became more usual among farmers, once he already has the whole structure (seeds access, weed RR technology among crops, seeder and mechanical harvester adapted for the system) to adopt the system.

4. Conclusion

Intercropping soybean into maize did not affected maize biomass yield.

Soybean cultivars presented relative maturity phenological stages ranging from R5.3 to R7 by the time maize was at its optimum stage for ensiling showing to be compatible with the evaluated maize hybrids.

Maize hybrids of medium-maturity cycle as P30F53 presents a higher productive potential for ensiling, in relation to the early-maturity cycle P1630, resulting in higher total crude protein yield per area.

Soybean cultivar TMG7062 presents greater biomass yield than cultivar P95R51.

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