UNIVERSIDADE TECNOLÓGICA FEDERAL DO PARANÁ
PROGRAMA DE PÓS-GRADUAÇÃO EM AGROECOSSISTEMAS

VANDERSON VIEIRA BATISTA

CULTIVO CONSORCIADO DE MILHO E SOJA

DISSERTAÇÃO

DOIS VIZINHOS - PR
2019

VANDERSON VIEIRA BATISTA

CULTIVO CONSORCIADO DE MILHO E SOJA

Dissertação apresentada ao Programa de Pós-Graduação em Agroecossistemas da Universidade Tecnológica Federal do Paraná, Campus Dois Vizinhos, como requisito parcial para obtenção do título de Mestre em Agroecossistemas - Área de Concentração: Culturas Anuais em Sistemas Integrados de Produção.

Orientador: Prof. Dr. Paulo Fernando Adami

DOIS VIZINHOS - PR

2019

B333c Batista, Vanderson Vieira.
Cultivo consorciado de milho e soja. / Vanderson Vieira Batista – Dois Vizinhos, 2019.
59 f.:il.

Orientadora: Profº Dr. Paulo Fernando Adami.
Dissertação (Mestrado) - Universidade Tecnológica Federal do Paraná, Programa de Pós-Graduação em Agroecossistemas, Dois Vizinhos, 2019.
Bibliografia p.57-58.

1. Milho - cultivo. 2. Soja - cultivo. 3. Cultivo consorciado. I. Adami, Paulo Fernando, orient. II. Universidade Tecnológica Federal do Paraná – Dois Vizinhos. III. Título

CDD: 664.762

Ficha catalográfica elaborada por Keli Rodrigues do Amaral Benin CRB: 9/1559

Biblioteca da UTFPR-Dois Vizinhos

Ministério da Educação
Universidade Tecnológica Federal do Paraná
Câmpus Dois Vizinhos
Diretoria de Pesquisa e Pós-Graduação
Programa de Pós-Graduação em Agroecossistemas

UTFPR
UNIVERSIDADE TECNOLÓGICA FEDERAL DO PARANÁ

TERMO DE APROVAÇÃO

Título da Dissertação n° 28

Cultivo Consorciado de Milho e Soja

Vanderson Vieira Batista

Dissertação apresentada às quatorze horas do dia onze de fevereiro de dois mil e dezenove, como requisito parcial para obtenção do título de MESTRE EM AGROECOSSISTEMAS, Linha de Pesquisa – Manejo e Conservação de Agroecossistemas, Programa de Pós-Graduação em Agroecossistemas (Área de Concentração: Agroecossistemas), Universidade Tecnológica Federal do Paraná, Câmpus Dois Vizinhos. O candidato foi arguido pela Banca Examinadora composta pelos professores abaixo assinados. Após deliberação, a Banca Examinadora considerou o trabalho ....APROVADO....................

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Dedico este trabalho...

A Deus, verdadeira fonte de sabedoria.

A meus queridos pais, os quais sempre incentivaram e priorizaram a educação de seus filhos.

AGRADECIMENTOS

Primeiramente, agradeço a Deus pelo dom da vida. Obrigado por me iluminar e guiar, por me conceder saúde, fé e perseverança para não desistir e assim concluir mais está etapa de minha vida.

À minha família, em especial minha esposa Leticia Camila da Rosa e meus pais Valdir Santana Batista e Elenir da Silva Vieira Batista, os quais foram “alicerceis” durante esta caminhada, e a minhas irmãs Eliana e Eloisa Viera Batista, pelo apoio prestado.

Ao professor e orientador Paulo Fernando Adami, pela paciência, atenção e pelos ensinamentos na elaboração deste trabalho. Saiba que é uma imensa honra tê-lo como orientador.

Aos amigos e colegas, obrigado pela ajuda e pela cumplicidade adquirida ao longo desta caminhada.

A CAPES e a UTFPR, pela concessão de bolsa e apoio para realização do mestrado.

Enfim, quero deixar aqui expresso os meus mais sinceros agradecimentos a todos que de alguma forma contribuíram na realização deste trabalho.

A todos vocês o meu sincero muito obrigado.

“Há um ditado chinês que diz que, se dois homens vêm por uma estrada, cada um carregando um pão, ao se encontrarem, eles trocam os pães; cada um vai embora com um. Porém, se dois homens vêm andando por uma estrada, cada um carregando uma ideia, ao se encontrarem, trocam as ideias; cada um vai embora com duas. Quem sabe, é esse mesmo o sentido do nosso fazer: repartir ideias para todos terem pão...” (Mario Sergio Cortella).

BATISTA, Vanderson Vieira. Cultivo consorciado de milho e soja. 59 f. Dissertação (Mestrado em Agroecossistemas) – Programa de Pós-Graduação em Agroecossistemas (Área de Concentração: Culturas Anuais em Sistemas Integrados de Produção), Universidade Tecnológica Federal do Paraná. Dois Vizinhos, 2019.

RESUMO: O cultivo consorciado de milho e soja não é nenhuma novidade, entretanto a evolução das tecnologias/cultivares exige que informações sobre o tema sejam atualizadas. Além disso, o sucesso do cultivo consorciado de milho e soja depende do sincronismo correto entre os estádios fenológicos das espécies (momento da silagem) e do arranjo de plantas/linhas utilizado. Sendo assim, o presente trabalho teve por objetivo avaliar a produção de forragem e a qualidade da silagem de consórcio de milho e soja, com cultivares de diferentes ciclo de maturação (experimento 1) e verificar a influência de diferentes arranjos entre linhas a produção de forragem, qualidade de silagem e rendimento de grãos de milho em consórcio, comparando com o cultivo de milho em monocultura (experimento 2). Ambos os estudos foram conduzidos na Universidade Tecnológica Federal do Paraná, Campus Dois Vizinhos – PR, Brasil, em delineamento de blocos ao acaso com 4 repetições. O experimento 1 foi conduzido durante a safra 2016/17, com esquema fatorial 2 × 3. Os fatores consistiram de dois híbridos de milho (1: P1630YHR - ciclo precoce e 2: ciclo médio P30F53VYHR) e duas cultivares de soja (P95R51 - ciclo de maturação de 5,1; TMG7062 - ciclo de maturação de 6,2) e um tratamento controle, representado por milho em monocultura. Já o experimento 2, avaliou oito arranjos entre milho e soja (número de linhas e espaçamentos) em consórcio mais um tratamento com milho em monocultura. A colheita dos matérias para silagem foi realizado quando o milho se encontrava com 2/3 do grão já preenchido de amido, e a colheita para determinação do rendimento de grãos (estudo 2) foi realizada com aproximadamente 20% de umidade. Aplicou-se análise variância e quando se observou efeito significativo, teste de comparação de médias (Tukey). Para o estudo 2, comparou-se o tratamento de milho em monocultura com os sistemas de consórcio pelo teste t. A análise de dados foi realizada com o auxílio do software Sisvar 5.6. Para o primeiro estudo, observou-se que ao consorciar a soja com o milho, o rendimento de biomassa para silagem não é afetado. Também, constatou-se que ambas as cultivares de soja apresentam ciclos compatíveis para ensilagem com os híbridos de milho, uma vez que se encontravam em estágios fenológicos de R5.3 a R7 no ponto de ensilagem do milho. O híbrido de milho P30F53 produziu maior quantidade de biomassa que o P1630, o que também resultou em maior produtividade de proteína bruta (2.040 Kg ha^{-1}). O consórcio P1630+P95R51, produziu 458 kg ha^{-1} de proteína bruta a mais que o cultivo de P1630 em monocultura. Quanto ao segundo experimento, a produtividade de biomassa de milho foi similar entre os arranjos, entretanto alguns arranjos apresentaram menor produtividade quando comparado com o milho em monocultura (3.000 kg ha^{-1}, aproximadamente). Todavia, não foi observado diferenças entre os diferentes arranjos avaliados e o cultivo de milho em monocultura, para a produtividade total de biomassa. Averiguou-se que o maior rendimento de biomassa de soja, proporciona aumento da quantidade de proteína bruta da silagem e consequentemente por unidade de área. A massa de mil grãos e a produtividade de grãos por planta e por área foi afetada em alguns arranjos do consórcio milho e soja. Observa-se que a utilização de duas linhas de milho e duas linhas de soja (2M + 2S-30 cm) e/ou quatro linhas de milho + quatro linhas de soja (4M + 4S-30 cm), apresentam maior rendimento de proteína bruta por área associada ao rendimento de grãos de milho semelhante ao cultivo de milho em monocultura. Considerando os dados de ambos os experimentos, confirma-se que a soja cultivada em consórcio com o milho apresenta potencial para elevar o teor proteína bruta da silagem.

Palavras-chave: *Glicine max*, *Zea mays*, silagem, proteína bruta, produtividade de grãos.

BATISTA, Vanderson Vieira. Intercrop between maize and soybean. 59 f. Dissertation (Master in Agroecosystems) - Postgraduate Program in Agroecosystems (Area of Concentration: Annual Crops in Integrated Production Systems), Technologic University of Paraná, Dois Vizinhos, 2019.

ABSTRACT: The intercropping of corn and soybean is not new, however, the evolution of technologies/cultivars requires subject update. In addition, the success of corn and soybean intercropping depends on a synchrony between the phenological stages at silage timing of the species and its plant/row arrangement used. The objective of this study was to evaluate the forage production and its silage quality of corn and soybean intercrop using cultivars with different maturation cycles (experiment 1) and to verify the influence of different maize and soybean intercrop row arrangements in the forage production, silage quality and maize grain yield compared with a monocrop maize cultivation (experiment 2). Both studies were carried out at the Technologic University of Paraná, Campus of Dois Vizinhos - PR, Brazil in a randomized block design with 4 replications. Experiment 1 was carried out along 2016/17 harvest season, in a randomized block design with a 2 × 3 factorial scheme. Factors consisted of two maize hybrids (1: P1630YHR - early cycle and 2: medium cycle P30F53VYHR) and two soybean cultivars (P95R51 and TMG7062- with maturation cycle group of 5.1 and 6.2 respectively) and a control treatment, represented by maize monocrop. Thus, experiment 2 evaluated eight arrangements between maize and soybean intercrop (number and distance between rows), plus a treatment with maize in monocrop. Silage was harvested when maize reached 2/3 of the grain filled with starch, and maize grain harvest (study 2) with approximately 20% moisture. An analysis of variance was applied and when a significant effect was observed, a comparison test of means (Tukey) was performed. For experiment 2, treatment of maize monocrop was compared with the intercrop arrangements by the t-test. Data analysis was performed with the help of Sisvar 5.6 software. It was noticed at the first experiment that maize and soybean intercrop does not affect silage biomass yield. It was also noticed that both soybean cultivars presented compatible cycles for ensiling with maize hybrids, once they were in phenological stages from R5,3 to R7 at the maize silage right time. Maize hybrid P30F53 produced higher amounts of biomass than P1630, which also resulted in a higher amount of crude protein per hectare. The P1630 + P95R51 intercrop produced 458 kg ha^{-1} of crude protein over maize monocrop. At the second experiment, it was reported that corn biomass yield among different arrangements were similar, although, some arrangements showed lower biomass (about 3,000 kg ha^{-1}) when compared to corn monocrop. However, there were no differences among the evaluated arrangements and maize monocrop for total biomass yield. It has been found that crude protein in the silage and consequently per unit area increases as soybean biomass increases. Maize thousand grain weight and grain yield per plant and per area were affected in some of the maize and soybean intercropped arrangements. It was noticed that the arrangement with two maize rows + two soybean rows (2M + 2S-30 cm) and/or four maize rows + four soybean rows (4M + 4S-30 cm) showed higher crude protein yield (kg ha^{-1}) associated with similar maize grain yield of monocrop treatment. Based on data from both experiments, it is confirmed that soybean intercropped with maize has the potential to raise silage crude protein content and yield.

Key words: *Glicine max, Zea mays,* silage, crude protein, grain yield.

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INTRODUÇÃO GERAL

O Brasil destaca-se mundialmente na produção e exportação de grãos, com ênfase para as culturas da soja (*Glicine max*) e do milho (*Zea mays*). Segundo dados da Companhia Nacional do Abastecimento (CONAB, 2018), foram produzidos no Brasil na safra 2017/2018, 119.281,7 mil toneladas de grãos de soja, em uma área cultivada de 35.149,2 mil ha^{-1}. Ainda segundo a CONAB, estima-se que para a safra 2018/2019, estes valores sejam semelhantes a safra anterior. Quanto a cultura do milho, foram produzidos no Brasil 81.356,7 mil toneladas de grãos do cereal na safra 2017/2018, produção está que deve aumentar em 2018/2019 (CONAB, 2018).

Além do cultivo para produção de grãos, a cultura do milho destaca-se como uma das principais plantas cultivadas para a confecção de silagem. Segundo Nussio et al. (2001), o milho destaca-se no processo de ensilagem por apresentar elevado acúmulo de massa por área, além da biomassa apresentar boa fermentação microbiana e baixo poder tampão, proporcionando uma silagem com aproximadamente 7,7% de proteína bruta.

Apesar da soja e o milho serem as principais culturas agrícolas brasileiras, estas não são cultivadas em consórcio no Brasil. Entretanto, estudos das décadas de 70,80,90, apontam efeitos positivos na consorciação das culturas (VIEIRA e BEN, 1984; OLIVEIRA et al., 1988; ALVARENGA et al., 1998; LEMPP et al., 2000).

Vieira e Ben (1984) descrevem algumas vantagens do sistema consorciado milho e soja em relação ao monocultivo, como: controle da erosão, melhor aproveitamento da luz e dos nutrientes, estabilidade da produção e maior produção e renda por área. Também, Alvarenga et al. (1998) estudaram o cultivo consorciado de milho e soja e concluíram que a soja não afeta a produtividade de grãos da cultura do milho. Porém, os pesquisadores relataram que a soja em consórcio apresenta maior acamamento e menor rendimento produtivo de grãos, em relação ao monocultivo.

Já Oliveira et al. (1988) avaliaram cultivares de milho e soja em consórcio para obtenção de forragem, e concluíram que no sistema consorciado, ambas as culturas são afetadas pela competição, sendo mais intensa para a leguminosa. Entretanto destacam que apesar de ocorrer redução da produção da massa seca do milho em consórcio, esta é 5,4% superior em relação à relatada em monocultivo de milho.

Além disto, quando destinado a produção de silagem, o sistema consorciado de milho e soja proporciona maior produtividade de proteína bruta por área (OLIVEIRA et al. 1988;

LEMPP et al., 2000). Entretanto, os pesquisadores destacam que este efeito pode ser variado em função dos arranjo de plantas/linhas utilizado no sistema, pois este fator interfere diretamente no número de plantas por área da leguminosa, consequentemente no acúmulo de massa verde a ser ensilada e nos teores de proteína bruta da silagem.

Cabe destacar, que em outros países, são encontrados estudos recentes sobre o cultivo consorciado de milho e soja (HE et al., 2012; REN et al., 2016; BAGHDADI et al., 2016), e que assim como os estudos antigos encontrados na literatura nacional (VIEIRA e BEN, 1984; OLIVEIRA et al., 1988; ALVARENGA et al., 1998), estes também, em sua maioria, relatam efeitos positivos do sistema de consórcio milho e soja, em relação ao milho em monocultivo.

Segundo He et al. (2012), que avaliaram o microclima sobre o solo na lavoura de milho e soja cultivados em consórcio em Yunnan (China), ocorre melhor aproveitamento da luz solar, neste sistema de cultivo. Também, o desenvolvimento radicular, o aproveitamento da água e o rendimento de grãos são influenciados em função de diferentes arranjos utilizados no consórcio milho e soja, e são melhores em relação ao monocultivo (REN et al., 2016). Segundo estes autores, ao ser utilizado consórcio milho-soja, ocorre aumento do comprimento das raízes das plantas, explorando um volume maior de solo, otimizando o uso dos recursos hídricos no perfil do solo, proporcionando assim incremento no rendimento.

Já Baghdadi et al. (2016) destacam que os sistemas consorciados melhoraram a eficiência do uso da terra em relação ao sistema com cultivo único de milho. Os pesquisadores da Malásia, também observaram que ao utilizar arranjos com 100% de milho de plantas de milho, 75:25 de milho e soja e 50:50, não ocorre redução significativa no rendimento total de silagem.

Quanto ao rendimento e qualidade de silagem, Sánchez et al. (2010) concluíram em seus experimentos conduzidos no México, que o consórcio de milho + soja proporciona aumento da qualidade da silagem em termos de proteína bruta por quilograma de silagem e por unidade de área, sem diminuir o rendimento de massa seca em relação ao milho em monocultivo.

Apesar destas evidencias positivas do cultivo consorciado de milho e soja, está técnica não é difundida no meio rural, possivelmente pelo fato de ser um sistema mais complexo. Percebe-se vários questionamentos sobre o tema: Como implantar? Qual material utilizar? Qual arranjo de plantas utilizar? É viável cultivar milho e soja em consórcio? Esta viabilidade ocorre somente quando o destino for silagem, ou também no viés grãos? Como é o desenvolvimento das culturas? Qual o melhor ciclo de maturação da soja para cultivo em consórcio quando o objetivo for silagem e grãos? Sendo assim, o presente trabalho buscou responder estes questionamentos.

Problemática de pesquisa

Apesar das evidencias positivas do cultivo consorciado de milho e soja apresentados nos estudos brasileiros e em outros países, está técnica de cultivo não se difundiu nas lavouras brasileiras. Um dos motivos, possivelmente está relacionado a maior complexibilidade do sistema, o qual exigir maior quantidade de mão de obra (VIEIRA e BEN, 1984). Segundo os pesquisadores, o sistema de cultivo consorciado milho e soja apresenta maior demanda de mão de obra para o manejo de plantas daninhas, sendo uma técnica mais recomendada para a agricultura familiar.

Atualmente, à presença da tecnologia Roundup Ready® (RR), incorporada tanto na cultura do milho como na soja, o manejo das plantas daninhas nas lavouras consorciadas de milho e soja é facilitado, acelerando o manejo e reduzindo a quantidade de mão de obra, viabilizando assim o cultivo em grandes áreas.

Destaca-se ainda que a agricultura brasileira passou por um processo de grandes transformações entre as décadas de 70,80,90, até os dias atuais. Neste período, ocorreu uma transição na agricultura brasileira, passando de uma agricultura de pequena escala, com utilização de insumos locais e pouco maquinário agrícola, para uma agricultura de grande escala, moderna, altamente dependente de insumos externos, com utilização de sementes híbridas, cultivares transgênicas e emprego de adubos e defensivos químicos (GALVÃO et al., 2014).

Diante destas transformações ocorridas na agricultura nos últimos anos e a falta de estudos atualizados no Brasil sobre o cultivo consorciado de milho e soja, torna-se fundamental investigações cientificas sobre o tema, justificando assim a realização do estudo.

Ainda, para que o consórcio tenha sucesso, tomadas de decisões, como a escolha do híbrido e/ou cultivar a ser implantada o e arranjos de plantas utilizados, necessitam ser entendidos. Segundo Belel et al. (2014), existem áreas críticas para a consorciação de leguminosas com milho, uma vez que pode ocorrer interferência sobre a produtividade de ambas culturas.

A escolha de híbridos para produção de silagem deve ser baseada principalmente no potencial de produção de matéria seca (NUSSIO et al., 2001). No entanto, em virtude da diversidade do potencial de produção dos materiais disponíveis atualmente no mercado e da grande dispersão entre variáveis agronômicas e qualitativas, ressalta-se também, a importância de informações sobre a qualidade bromatologica dos materiais a serem utilizados na ensilagem.

Para possibilitar maior produção de massa e maior valor proteico da silagem no consórcio milho e soja, os materiais utilizados devem ser adaptados à região e apresentar ciclos compatíveis (OLIVEIRA et al., 1986). Segundo Leonel et al. (2008), é possível a utilização de soja cultivada em consórcio para produção de silagens, desde que a leguminosa seja colhida no estádio R7. Já Sánchez et al. (2010) destacam que a alta proporção de vagens de soja preenchidas no momento da ensilagem, aumenta a quantidade de proteína bruta da silagem.

Também, faz-se necessário manejar o estande e arranjo de plantas a fim de permitir o crescimento e acúmulo de biomassa da soja a tal ponto que esta biomassa contribua para a melhoria da qualidade da silagem (proteína bruta), sem afetar a produtividade total e o rendimento do milho. Nesse sentido, parte-se da hipótese de que quanto maior a produção de biomassa da soja, menor a produção de biomassa e grãos do milho e que este efeito pode variar conforme o arranjo de plantas utilizado.

Ainda, quando o viés do consórcio for para silagem, o possível menor acúmulo de biomassa do milho pode ser contrabalanceado pelo aumento do teor de proteína bruta da silagem. Porém, quando o milho tiver o viés grão, pode ser que o efeito da soja não compense o cultivo consorciado. Alms (2015) constatou que a produtividade de grãos do milho reduz em média 30% quando há presença de 37 plantas m^2 de soja voluntária. Sendo assim, a interação entre os ciclos dos híbridos de milho e cultivares de soja, além do arranjo de plantas a ser utilizado, necessitam ser entendidos para garantir o sucesso esperado do cultivo consorciado de milho e soja.

Objetivos Gerais e específicos

O presente trabalho tem por objetivo avaliar parâmetros produtivos e qualitativos no cultivo consorciado de milho e soja.

O primeiro experimento (artigo 1 - Forage yield and silage quality of intercropped maize+soybean with different relative maturity cycle), teve por objetivo avaliar híbridos de milho e cultivares de soja com diferentes de diferentes ciclos, para identificar qual a melhor combinação entre estas duas espécies a ser utilizada para a produtividade e qualidade de silagem.

O segundo experimento (artigo 2: Row arrangements of maize and soybean intercrop on silage quality and grain yield), foi desenvolvido com objetivo de verificar os efeitos de diferentes arranjos de linhas no cultivo consorciado milho e soja, resultam sobre a produção de biomassa e qualidade da silagem, além de inferir sobre o potencial de rendimento de grãos da cultura do milho, comparando os sistemas de consórcios ao cultivo de milho em monocultura.

METODOLOGIA DA PESQUISA

Experimento 1

Conduziu-se o experimento a campo durante a safra de verão 2016/2017, na Estação de Ensino e Pesquisa da Universidade Tecnológica Federal do Paraná (UTFPR), situada 25º41′33″ S e 53º05′36″ W. A região apresenta altitude média de 540, com inclinação máxima de 3% e clima é Cfa (ALVARES et al., 2013).

A área experimental apresenta solo classificado como Latossolo Vermelho Distroférrico (BHERING et al., 2008). As propriedades químicas do solo foram determinadas antes da implantação do estudo, nas camadas de 0-10 e 10-20 cm, apresentando os seguintes valores: pH ($CaCl_2$) 5,6 e 5,5; matéria orgânica (MO) 46,2 e 30,8 g kg^{-1}; P (Mehlich1) 26,5 e 19,7 mg dm^{-3}; K 84,1 e 35,2 mg dm^{-3}, capacidade de troca cátions de 9,7 e 8,8 $cmol_c$ dm^{-3} e saturação de base de 71,5 e 66,6%, respectivamente.

Utilizou-se delineamento experimental de blocos ao acaso, com parcelas subdivididas, em esquema fatorial 2 × 3. Os fatores consistiram em dois híbridos de milho (1: P1630YHR – ciclo superprecoce e 2: P30F53VYHR – ciclo precoce) e cultivares de soja (1: P95R51 – grupo de maturação 5,1; 2: TMG7062 – grupo de maturação 6,2 e 3: sem soja, representada por milho monocultura), resultado em seis tratamentos. Os híbridos de milho foram distribuídos nas parcelas principais, enquanto as cultivares de soja foram inseridas nas subparcelas.

As culturas foram semeadas simultaneamente, com espaçamento de 60 cm entre linhas de milho. Nos tratamentos consorciados, a soja foi semeada na entre linha do milho, resultando em espaçamento de 60 cm entre linhas de soja e 30 cm entre linhas de soja – milho (Figura 1). As parcelas experimentais foram implantadas com 60 m^2 (3 m × 20 m).

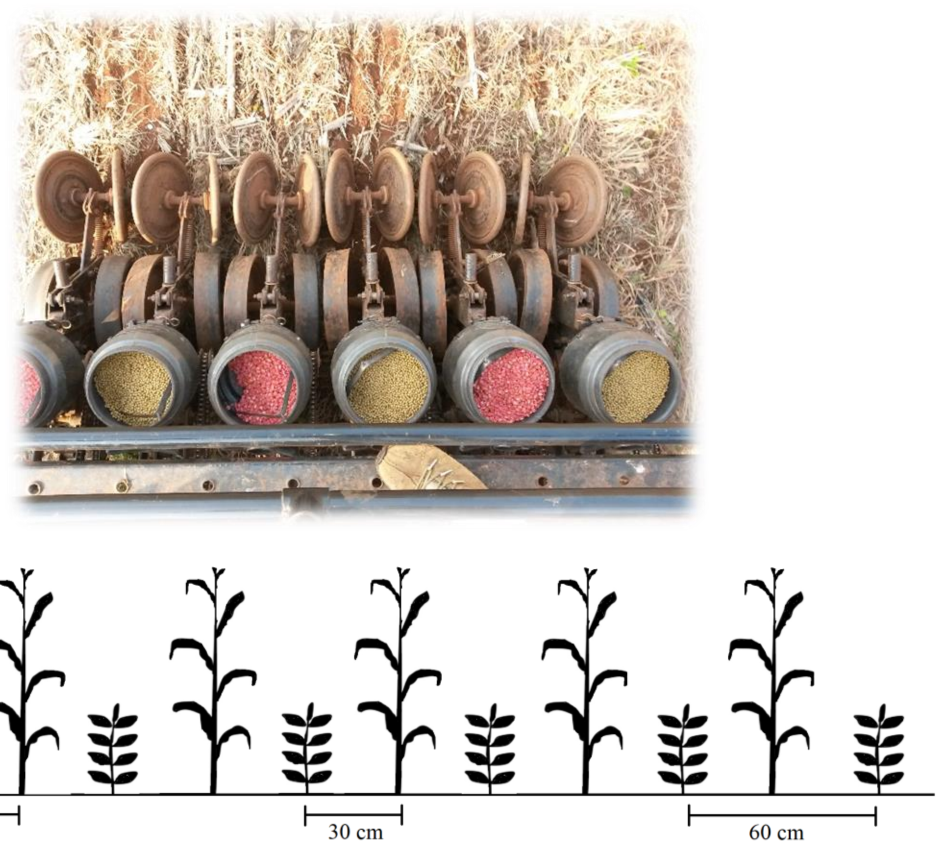

Figura 3. Distribuição das linhas no cultivo consorciado de milho e soja. UTFPR, Dois Vizinhos - PR, 2019

Ambos os matérias de milho e soja utilizados no estudo eram resistentes ao herbicida glifosato (RR2). As cultivares de soja possuem potencial de ramificação e hábito de crescimento indeterminado. Além disso, TMG7062-IPRO Intacta RR2 PROTM foi geneticamente modificada e expressava toxinas, protegendo as plantas das principais espécies de lagartas (PROTM), além de apresentar tolerância à ferrugem (*Phakosphera pakirizi*), possuindo um ciclo de 125 a 135 dias (TROPICAL BREEDING AND GENETICS, 2017). Já a cultivar P95R51 apresenta ciclo de 115 a 125 dias.

Os híbridos de milho (híbridos simples) utilizados no estudo se destacam pelo alto potencial produtivo, sendo altamente responsivos ao manejo. São considerados excelentes opções para a produção de grãos e silagem e têm um posicionamento recomendado com taxa de sementes de 65.000 a 70.000 plantas ha^{-1} (P30F53) e 70.000 a 80.000 plantas ha^{-1} (P1630) (DUPONT PIONEER, 2017). As sementes de milho foram tratadas com imidacloprid (2,6 g i.a. Kg^{-1} semente) e thiodicarb (7,9 g i.a. Kg^{-1}).

O experimento foi implantado em semeadura direta sobre área contendo aveia-preta (*Avena strigosa*) durante a período de inverno, a qual foi dessecada com glyphosate [(1,100 g ha^{-1} de ingrediente ativo (i.a.)] 21 dias antes da semeadura. As culturas foram semeadas em 02/09/2016, simultaneamente, com o auxílio de uma semeadora-adubadora de precisão, acoplada a um trator. Os discos de semente de milho possuiam 28 furos, enquanto os discos de semente de soja 90 furos (90/28 = 3,2 sementes de soja para cada semente de milho). A semeadura foi ajustada para implantar 70.000 sementes ha^{-1} de milho (4,2 sementes lineares m^{-1}) e a quantidade de sementes de soja foi consequência (225.000 sementes ha^{-1}).

A adubação mineral no sulco do milho consistiu de 11 e 80 kg ha^{-1} de N e P_2O_5, respectivamente (366 Kg ha^{-1} de mistura de fertilizantes N-P_2O_5-K_2O 03-22-00). O potássio foi distribuído em cobertura utilizando cloreto de potássio (KCl com 60% de K_2O) a 185 Kg ha^{-1} no dia da semeadura. O fornecimento de N (180 Kg ha^{-1}) foi realizado de forma manual, a lanço e em cobertura, divididos em duas aplicações (90 Kg ha^{-1} cada), sendo a primeira realizada em 19/09/2016, e a outra, seis semanas após a semeadura. O controle de plantas daninhas foi realizado com a aplicação do glyphosate em 23 de setembro e 08 de outubro, com uma taxa de 1.400 e 1.200 g ha^{-1} de i,a. respectivamente.

A aplicação de fungicida foi realizada no estádio de milho VT (pré-silagem) com fungicida sistêmico contendo mistura *Protioconazol* (175 g L^{-1}) + *Trifloxistrobina* (150 g L^{-1}) na dose de 72 + 61 g i.a. ha^{-1}. Juntamente com o fungicida, foi adicionado óleo vegetal na dose de 0,5 L ha^{-1} e volume de calda de 150 L ha^{-1}. O fungicida foi aplicado com um pulverizador autopropelido.

As plantas de milho e soja foram colhidas na mesma época, considerando 1/3 da linha de leite do grão, o que ocorreu 109 e 116 dias após a emergência, respectivamente para o híbrido P1630 e P30F53. Nesse ponto, foi determinado o estádio fenológico das cultivares de soja. As avaliações foram realizadas em 10 plantas por unidade experimental, de forma visual, sendo considerada o estádio da cultura no qual a maioria das plantas se encontrava. Nesta época também foram determinados o estande final de plantas de milho e soja (plantas ha^{-1}), contando-se o número de plantas de cada cultura presentes nas unidades experimentais, sendo os valores extrapolados para hectare.

Como área de amostragem (AA), considerou-se duas linhas centrais (uma de milho e uma de soja) com cinco m de comprimento, totalizando uma área amostral de seis m^2, de cada a unidade experimental. As plantas destas áreas foram colhidas manualmente, cortando-as a 25 cm acima da superfície do solo. Estas foram pesadas para determinar a produtividade de biomassa verde de milho e de soja. Em seguida, amostras de plantas de ambas as culturas foram moídas separadamente em uma ensiladeira de forragem acoplada a um trator, com tamanho médio de partícula de 0,5 a 1,5 cm. Uma subamostra de 300 g de biomassa verde de cada AA e de cada cultura, foram inseridas em sacos de papel, pesadas e secas em estufa com 65 °C até atingir massa constante para determinar o seu teor de massa seca. A porcentagem de umidade das culturas foi calculada a partir da diferença dos pesos fresco e seco dos respectivos componentes listados anteriormente.

O rendimento total de forragem fresca e seca foi calculado pela soma dos valores de biomassa de milho e soja, sendo os dados apresentados em Kg ha^{-1}. Além disso, foi determinado a produção de forragem por planta de milho e soja (g), dividindo a produtividade total de biomassa da cultura pela população de plantas. Também foi estimada a porcentagem de matéria seca de soja na silagem.

Amostras de plantas de milho e soja que haviam sido previamente coletadas e moídas separadamente, foram agrupadas nas respectivos unidades experimentais. Esta biomassa foi misturada para homogeneização e uma amostra de 3 kg foi inserida, compactamente com densidade média de 600 kg m^{-3}, em silos de laboratoriais, feitos de tubos de PVC "microsilos" (Figura 2), medindo 100 mm de diâmetro, 600 mm de comprimento. Os microsilos foram selados no momento da ensilagem, com tampas de PVC.

Figura 4. Microsilos para armazenamento de silagem. UTFPR, Dois Vizinhos - PR, 2019

Após 60 dias da ensilagem, os silos foram abertos. Na abertura dos silos, o material foi homogeneizado e extraído para posterior análise. Na ocasião, foi determinado o pH da silagem, utilizando um medidor de pH de acordo com a metodologia descrita por Silva & Queiroz (2002).

Também, foram coletadas amostras de silagem (300 g), as quais foram colocadas em sacos de papel, pesadas e secas em estufa a 55 °C até que atingisse massa constante para determinação do teor de matéria seca da silagem. As amostras secas foram trituradas em moinho de facas tipo "Willey", com peneira de tamanho de 1 mm e as amostras encaminhadas ao Laboratório de Análises Bromatológicas da UTFPR.

No laboratório, avaliou-se a matéria mineral (%) (SILVA & QUEIROZ, 2002), fibra em detergente neutro (FDN) e fibra em detergente ácido (FDA) pela metodologia descrita no manual de Ankon (2009). As análises de proteína bruta da silagem (g Kg^{-1}) foram realizadas quantificando-se o N presente nas amostras, sendo o N total determinado na metodologia de micro-destilação a vapor Kjeldhal Tedesco et al. (1995). Multiplicando os valores de proteína bruta da silagem, pelos dados produtividade total de biomassa (massa seca para ensilagem), obteve-se a produtividade total de proteína bruta por unidade de área (Kg ha^{-1}).

Os dados foram submetidos a análise de variância no software Sisvar 5.6 (FERREIRA, 2008), e constando efeito significativo, aplicou-se teste de comparação de media (Tukey a 5% de probabilidade).

Experimento 2

O experimento 2 foi conduzido a campo durante a safra de verão 2017/2018, na Estação de Ensino e Pesquisa da Universidade Tecnológica Federal do Paraná-UTFPR, (25º41′33″ S e 53º05′36 ″O). A área apresenta altitude média de 540 m acima do nível do mar, com inclinação máxima de 3%, clima Cfa (ALVARES et al., 2013) e precipitação média anual de 2.048 mm (IAPAR et al., 2018), os quais são distribuídos ao longo do ano.

O solo da área experimental é classificado como Latossolo Vermelho Distroférrico (BHERING et al., 2008). As propriedades químicas do solo foram pré-determinadas antes da implantação das culturas, nas camadas de 0-10 cm e 10-20 cm, sendo constatado os seguintes valores: pH: 5,4 e 5,3, matéria orgânica 44,23 e 29,48 g dm^{-3}, fosforo 36,65 e 29,19 mg dm^{-3}, potássio 0,28 e 0,10 $cmol_c$ dm^{-3}, acidez potencial (H+Al) 2,95 e 3,18 $cmol_c$ dm^{-3}, Ca de 4,4 e 3,8 $cmol_c$ dm^{-3}, Mg de 1,5 e 1,6 $cmol_c$ dm^{-3} e saturação de base de 67,7 e 63,4%, respectivamente.

Foi utilizado delineamento de blocos ao acaso, com nove tratamentos e quatro repetições. Os tratamentos foram representados por diferentes arranjos de linhas entre milho + soja cultivados em consórcio e um tratamento com cultivo de milho em monocultura (Figura 3). Os arranjos avaliados foram: 1 – uma linha de milho + uma linha de soja com espaçamento de 30 cm entre linha (1M+1S-30), 2 – duas linhas de milho + duas linhas de soja com espaçamento de 30 cm entre linha (2M+2S-30), 3 – três linhas de milho + três linhas de soja com espaçamento de 30 cm entre linha (3M+3S-30), 4 – quatro linhas de milho + quatro linhas de soja com espaçamento de 30 cm entre linha (4M+4S-30), 5 – uma linha de milho + duas linhas de soja com espaçamento de 30 cm entre linha (1M+2S-30), 6 – duas linhas de milho + uma linha de soja com espaçamento de 30 cm entre linha (2M+1S-30), 7 – uma linha de milho + uma linha de soja com espaçamento de 45 cm entre linha (1M+1S-45), 8 – duas linhas de milho + duas linhas de soja com espaçamento de 30 cm entre linha (2M+2S-45) e 9 – milho em monocultura com 60 cm entre linhas (M-60).

O tamanho das parcelas experimentais foi de 72 m^2 (3,6 m de largura x 20 m de comprimento). Estas parcelas foram divididas em duas (3,6 × 10 m) sendo uma para determinar a produção de silagem e a outra o rendimento de grãos. As avaliações foram realizadas nas unidades de observação (UO), composta pelas linhas centrais de cada unidade experimental, com 5 metros de comprimento. Como os números de linhas de cada tratamento eram diferentes, as UO foram constituídas por 6 m^2 para os tratamentos 4M+4S-30 e M-60 e 9 m^2 para os demais tratamentos.

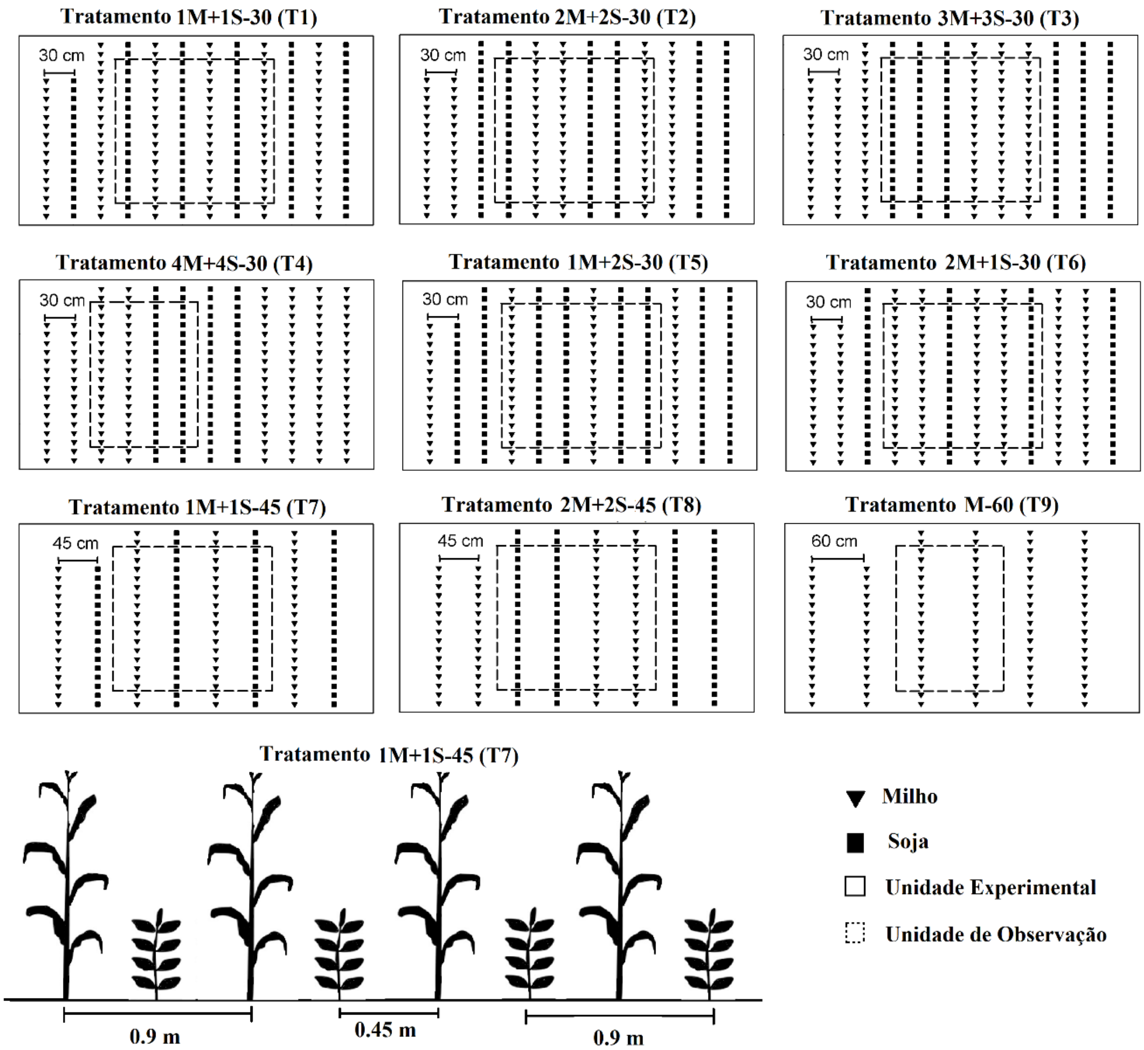

Figura 5. Arranjos de linhas avaliados no cultivo consorciado de milho e soja. UTFPR, Dois Vizinhos - PR, 2019

Utilizou-se na condução do experimento, o híbrido de milho 2B533 o qual é recomendado tanto para a produção de silagem quanto de grãos. Apresenta plantas de tamanho médio, alta produtividade de grãos, apresenta alta participação de grãos na matéria seca, altos valores de nutrientes digestíveis totais (NDT), alta digestibilidade e baixa quantidade de fibra em detergente neutro (FDN) e é recomendada para silagem de plantas inteiras, silagem de grãos ou produção de grãos (DOW AGROSCIENCES, 2018).

Quanto a soja, utilizou-se a cultivar TMG7062-IPRO Intacta RR2 PROTM, a qual é geneticamente modificada apresentando endotoxina que permite que a planta se proteja contra as principais espécies de lagartas (PROTM). Apresenta ainda tolerância à *Phakosphera pakirizi* (ferrugem), com ciclo de maturação 6.2, o que representa 125 a 135 dias para maturação. Possui recomendação de taxa de semeadura de 220 a 240 mil sementes ha^{-1} (TROPICAL BREEDING AND GENETICS, 2017). Além disso, a soja é resistente ao glifosato, facilitando o controle de plantas daninhas aos agricultores.

Aveia preta (*Avena strigosa*) foi utilizada como cultura antecessora (cobertura no inverno) ao experimento. A aveia foi dessecada com glifosato (1.080 g i.a. ha^{-1}) 30 dias antes do estabelecimento dos arranjos. O consórcio de milho e soja foi semeado simultaneamente no dia 2 de outubro de 2017, com o auxílio de uma semeadora de precisão. O espaçamento entre linhas foi configurado inicialmente para 30 cm e depois alterado para implantação dos tratamentos com 45 cm. É importante ressaltar que a maioria dos agricultores usa 45 cm entre as linhas de cultivo, embora o espaçamento das linhas das semeadoras seja facilmente ajustável e possa ser realizado pelos agricultores.

A regulagem de da semeadura foi estabelecido para densidade de 62 mil sementes de milho ha^{-1}, resultando em estande de sementes de soja como consequência. Os discos de sementes de milho possuíam 28 furos, enquanto os discos de sementes de soja possuíam 100 furos (uma relação de 3,57 sementes de soja para cada semente de milho semeada).

Além disso, como os arranjos apresentaram diferentes espaçamentos entre as linhas de milho, a densidade de semeadura da soja alterou entre os arranjos avaliados, sendo de 110.714 sementes ha^{-1} (9,96 sementes metro linear) para o arranjo 2M+1S-30; 221.429 sementes ha^{-1} (13,29 sementes metro linear) para os arranjos 1M+1S-30, 2M+2S-30, 3M+3S-30, 4M+4S-30, 1M+1S-45 e 2M+2S-45; 442.857 sementes ha^{-1} (19,29 sementes metro linear) para o arranjo 2M+1S-30.

Na semeadura, foi realizada adubação para ambas as espécies adicionando 450 kg ha^{-1} de fertilizante químico 5-20-10 (22,5 N – 90,0 P_2O_2 – 45,0 K_2O). O nitrogênio (N) foi aplicado utilizando ureia (45% de N) na dose de 180 kg N de ha^{-1}. Metade da dose de N foi aplicada em V4 (três semanas após a semeadura) e a outra metade em V8, distribuindo o nutriente em cobertura, manualmente a lanço.

Inseticida *imidacloprid* + *beta-cyfluthrin* na dose de 1 L ha^{-1} foi aplicada, logo após a emergência do milho para controle do percevejo (*Dichelops melacanthus*). O controle de plantas daninhas foi obtido pela aplicação de glyphosate (1,2 g a.i. ha^{-1}) quando o milho encontrava-se em estádio V3. A aplicação de fungicida foi realizada no estádio do milho R2 com uma mistura sistêmica pronta contendo *estrobilurina* + *pirazol carboxamida* a uma dose comercial de 300 g ha^{-1}. Juntamente com o fungicida, foi adicionado óleo vegetal na dose de 0,5 L ha^{-1} e pulverizado com 160 L ha^{-1} aplicado com pulverizador autopropelido.

As avaliações iniciaram-se no ponto de ensilagem do milho aos 120 dias após a emergência. Nesse momento, a cultivar de soja encontrava-se no estádio fenológico R5,5. Determinou-se o estande de plantas de milho e soja (plantas ha^{-1}), contando-se o número de plantas presentes em cada UO e extrapolando o valor para hectare. Também, avaliou-se o número de vagens por planta de soja em dez plantas aleatórias por UO.

Dez plantas de milho por UO foram avaliadas para determinar o diâmetro do caule entre o segundo e terceiro nó com o auxílio de um paquímetro, altura da inserção da espiga, ou seja distância entre o nível do solo e a inserção da espiga principal de milho e altura de planta - distância do solo até o ponto mais distante das plantas, sendo os valores expressos em centímetros. Os valores médios obtidos, para cada variável em cada OU, foram considerados para a análise estatística dos dados.

Plantas contidas nas UO foram colhidas manualmente, cortando-as 25 cm acima do solo. Elas foram pesadas para determinar a produção de biomassa verde de milho e soja. Em seguida, amostras de plantas de ambas as culturas de cada OU, foram moídas separadamente em uma ensiladeira acoplada a um trator, com tamanho médio de partícula de 0,5 a 1,5 cm. Amostras frescas foram pesadas (300 g) e colocadas em sacos de papel, os quais foram levados a estufa com 65 °C até atingir massa constante, para determinar a porcentagem de matéria seca. A produtividade de forragem (massa seca) foi determinada a partir dos pesos frescos e secos dos respectivos componentes listados acima. Somando a produtividade de forragem de milho e soja, obteve-se a produtividade total de forragem (Kg ha^{-1}).

As amostras de plantas de milho e soja que haviam sido previamente coletadas e moídas separadamente, foram agrupadas nas respectivos unidades experimentais. Esta biomassa foi misturada para homogeneização total e uma amostra de 3 kg do material resultante, foi adicionado compactamente em silos de laboratório feitos de tubos de PVC, medindo 100 mm de diâmetro, 600 mm de comprimento, com densidade média de 600 kg m^{-3}. Os silos foram selados no momento da ensilagem, com tampas de PVC equipadas com válvulas do tipo "Bunsen". Os silos foram abertos após 60 dias de ensilagem.

Após a abertura dos silos, a silagem foi homogeneizada e determinado o seu pH, utilizando um medidor de pH de acordo com a metodologia descrita por Silva e Queiroz (2002). Coletou-se 300 g de silagem após a abertura dos silos, massa está inserida em sacos de papel, pesadas e secas a estufa a 65 °C até atingir massa constante. As amostras secas foram moídas em moinho de facas tipo 'Wiley' com peneira de 1 mm e o material resultante encaminhado ao Laboratório de Análises Bromatológicas da UTFPR.

Em laboratório foi aferido a matéria seca e matéria mineral da silagem (%) (SILVA & QUEIROZ, 2002), fibra em detergente neutro (FDN) e fibra em detergente ácido (FDA) pela metodologia descrita no manual Ankon (2009). Para estimar os nutrientes digestíveis totais (NDT), foi utilizado a equação matemática NDT = 87,84 - (0,7 × FDA).

A proteína bruta da silagem (g kg^{-1}) foi estimada pela quantificação do N presente nas amostras, multiplicando pelo fator de correção 6,25. O N total determinado na metodologia de micro-destilação a vapor Kjeldhal (TEDESCO et al., 1995). Também, multiplicando os valores de proteína bruta por produtividade de biomassa seca, determinou-se o rendimento de proteína bruta de silagem total (Kg ha^{-1}).

As parcelas destinadas a colheita de grãos, foram avaliadas em 3 de março de 2018 (152 dias após a semeadura) quando os grãos encontravam-se com umidade média de 22%. Para determinar os componentes do rendimento do milho, 10 espigas por parcela foram avaliadas quanto ao número de grãos por fileira (grão menor que ½ grão normal não foi considerado) e o número de fileiras por espiga. Também, multiplicando nas respectivas espigas, o número de grãos por fileira pelo número de fileira, determinou-se o número de grãos por espiga. Além disso, a massa de mil grãos foi avaliada pela contagem manual de 5 amostras de 100 grãos, os quais foram pesados e corrigidos a umidade para 13% (via cálculo). Para as análises estatísticas dos dados, utilizou-se os valores médios observados em cada UO.

A produtividade de milho foi avaliada colhendo as espigas presentes nas UO, as quais passaram por um batedor de cereais para a obtenção dos grãos. A massa de grãos obtida foi pesada em balança de precisão, sendo a umidade ajustada para 13% e o valor extrapolado para hectares (Kg ha^{-1}). Também, determinou-se a produtividade de grãos por planta, dividindo os valores de produtividade de grãos pelos dados de população de milho.

Para os arranjos em consórcio, os dados foram submetidos à análise de variância (Anova), e quando constatado significância ($P<0,05$), as médias foram comparada pelo teste de Skot Knott. Os tratamentos consorciados foram comparados com os dados de monocultura de milho (M-60) através do teste de contraste "t". Para análise dos dados, foi utilizado o software Sisvar 5.6 (FERREIRA, 2008).

Journal of Agricultural Science; Vol. 10, No. 12; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

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

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Received: August 15, 2018 Accepted: September 16, 2018 Online Published: November 15, 2018

doi:10.5539/jas.v10n12p249 URL: https://doi.org/10.5539/jas.v10n12p249

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).

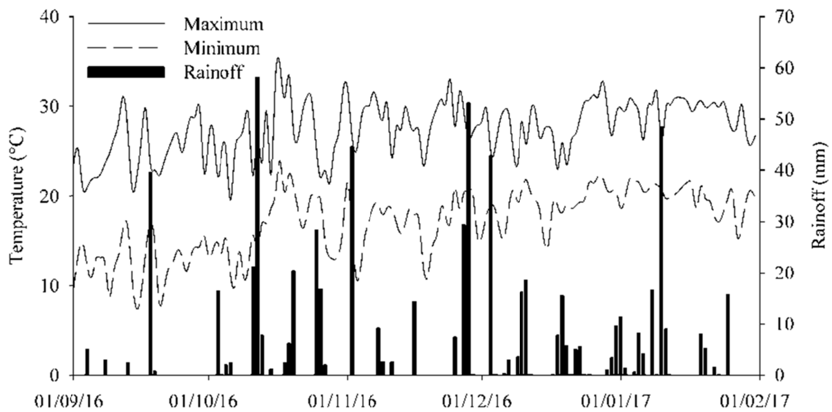

Figure 1. Maximum, minimum temperature and rainfall. UTFPR, Dois Vizinhos, Paraná, Brazil (2018)

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	
P30F53	67,083	65,238	66,364	66,228 a	4.02
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	
P30F53	65,780	66,016	68,332	66,709 a	6.68
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	
P30F53	19,899	21,262	22,196	21,119 a	7.71
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	
P30F53	297.02	326.05	334.32	319.13 a	8.03
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	
P30F53	4.07 Ab	1.95 ABb	0.00 Ba	2.01	29.50
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	
P30F53	4.39	4.37	4.32	4.36 b	1.34
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	
P30F53	3.94	4.13	3.89	3.99	10.62
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	
P30F53	40.87	37.49	40.46	39.61	14.36
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	
P30F53	19.89	18.30	19.64	19.28	16.16
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	
P30F53	100.35 Aa	94.11 ABb	90.07 Ba	94.84	4.72
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	
P30F53	2,076	2,039	2,004	2,040 a	8.87
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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Journal of Agricultural Science; Vol. 11, No. 2; 2019
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Row Arrangements of Maize and Soybean Intercrop on Silage Quality and Grain Yield

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Received: October 13, 2018 Accepted: November 14, 2018 Online Published: January 15, 2019

doi:10.5539/jas.v11n2p286 URL: https://doi.org/10.5539/jas.v11n2p286

Abstract

The success of maize + soybean intercrop depends on the plant arrangement. An experiment was carried out to evaluate different row arrangements on intercrop forage yield, silage quality and maize grain yield in relation to maize as a sole crop. The experiment was set up with a randomized complete block design with eight row arrangements between maize and Soybean. Maize biomass yield among crop arrangements were similar, although, lower than the maize sole crop. On the other hand, these treatments showed higher soybean biomass yield, which in turn increased silage crude protein and crude protein yield per unit area. Maize thousand grain weight, grain yield per plant and per area was affected by the intercrop arrangements. The use of two corn rows + two soybean rows (2M+2S-30 cm) and four corn rows + four soybean rows (4M+4S-30 cm) showed higher crude protein yield per area associated with similar maize grain yield in relation to the sole maize crop. In conclusion, alternating four maize rows with four soybean rows was the optimum row ratio in maize + soybean intercrop, though this needs to be further confirmed by more trials.

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

1. Introduction

Maize and soybean are the most common grain crops in Brazil. Maize is the most used forage crop worldwide due to its many advantages such as high dry matter yield, high energy content, consistent-palatable feed, reduced total feed cost, rapid harvest and storability potential (Lempp et al., 2000), although, its low crude protein content may play a limitation on its use (Lempp et al., 2000; Evangelista et al., 2005; Oliveira et al., 2017).

Soybean also appears to be an option due to its great adaptability, yield potential and its high crude protein content (Kananji et al., 2013); Although fresh forage yield from soybean is low compared to maize, one of the major limitations to increase the use of soybeans for silage is the fact that when ensiled alone, it shows a bad fermentation process. It's use as intercrop with maize may improve soybean silage fermentation process as the soluble carbohydrate content and the higher maize DM content contribute to a good fermentation process.

Therefore, soybean intercropped with maize may be an option for improving silage quality (Lempp et al., 2000; Sánches et al., 2010; Batista et al., 2017) with the addition of nitrogen-rich soybean. According to Stella et al. (2016), maize silage presents 73 g kg^{-1} of crude protein and this value increased to 105 and 136 g kg^{-1} with the addition of 25 and 50% of soybean biomass into the silage, respectively. In this way, the use of soybean silage represents an alternative for increasing the protein content of the diet, thereby reducing production costs through reduced need for supplementation with protein concentrate.

Although not usually adopted in Brazil, maize + soybean intercrop may prove to be a more environmentally friendly sustainable method of producing silage and grain than the common maize monocrop system, due to better resources uses (Ren et al., 2016; Latati et al., 2016). There are many studies that shows greater land equivalent ratio (LER) of maize + soybean intercrop (Gao et al., 2010; Martin et al., 1998) in relation to conventional crop systems which gives a great incentive to intercrop adoption. Greater LER is mainly explained by 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) through the stimulation of legume biological N_2 fixation of intercrop versus monocrop.

Among intercrop management, crop row arrangement may be of greater significance as it affects the competitive dynamics between intercropped species and determines the yield of cereal-legume intercrops. In this sense, it is assumed that the higher the biomass production of soybean, the lower the grain yield of maize and vice versa, and that this effect may vary according to the arrangement of plants.

Also, when the objective of intercropping is for silage, the possible lower accumulation of maize biomass can be counterbalanced by the increase of the crude protein content of the silage. However, when maize is grown for grain, interspecific competition may affect yield potential to a point where it is not interesting to adopt this system. In fact, there is little data available and it is not usual to see farmers growing maize + soybean intercrop to harvest maize grain. Most of research shows that the yield of maize is reduced when intercropped with other species (Borghi & Crusciol, 2007; Pereira et al., 2011; Silva et al., 2015). Being more specific, Alms (2015) studying the effect of voluntary soybean over maize reported grain yield losses around 30% with 37 plants m^2 of soybeans.

Considering all these facts, the aim of this study was to determine the effects of maize + soybean intercrop row arrangement on (1) biomass production and silage quality, (2) maize grain yield potential, and (3) intercrops yield compared to maize monocrop, as maize and soybean are the two most important crops in Brazil.

2. Material and Methods

2.1 Study Area

Field experiment was carried out (2017/2018 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 above sea level and a maximum slope of 3%. According to the Köppen classification, the climate is Cfa (Alvares et al., 2013). Mean average rainfall is of 2,048 mm per year (IAPAR et al., 2018), which is well distributed along the year. The temperature and precipitation data observed during the study are shown in Figure 1.

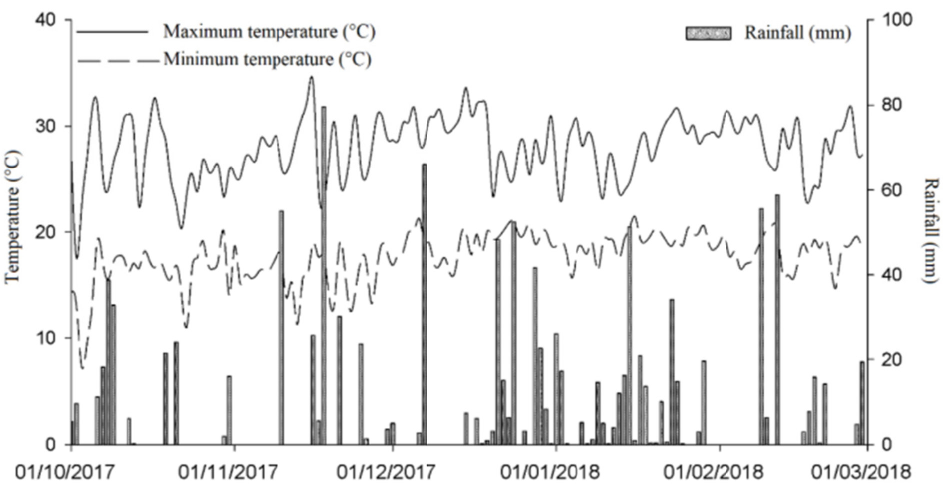

Figure 1. Maximum and minimum temperature (°C) and rainfall (mm) recorded by the INMET weather station of Dois Vizinhos-PR, during the experimental period

Source: INMET (2018).

Soil at the experimental site is classified as a Clayey Oxisol (Bhering et al., 2008). Soil chemical properties of the experimental site were determined in the 0.0-0.1 and 0.1-0.2 m layer, and the values are shown in Table 1.

Table 1. Soil chemical analysis of the experimental site. UTFPR, Dois Vizinhos-PR, Brazil (2018)

Soil depth (m)	pH	OM	P	K	H+Al	Ca	Mg	V
	$CaCl_2$	g dm^{-3}	mg dm^{-3}	------------------	$cmol_c$ dm^{-3}	-----------------		%
0-0.1	5.40	44.23	36.65	0.28	2.95	4.40	1.50	67.69
0.1-0.2	5.30	29.48	29.19	0.10	3.18	3.80	1.60	63.36

Note. OM = Organic matter; V = base saturation.

2.2 Experimental Design

Experiment used a randomized complete block design with 9 treatments and four replications. Treatments were represented by different rows arrangements between maize + soybean intercrop and maize grown as a sole crop, as shown in Figure 2.

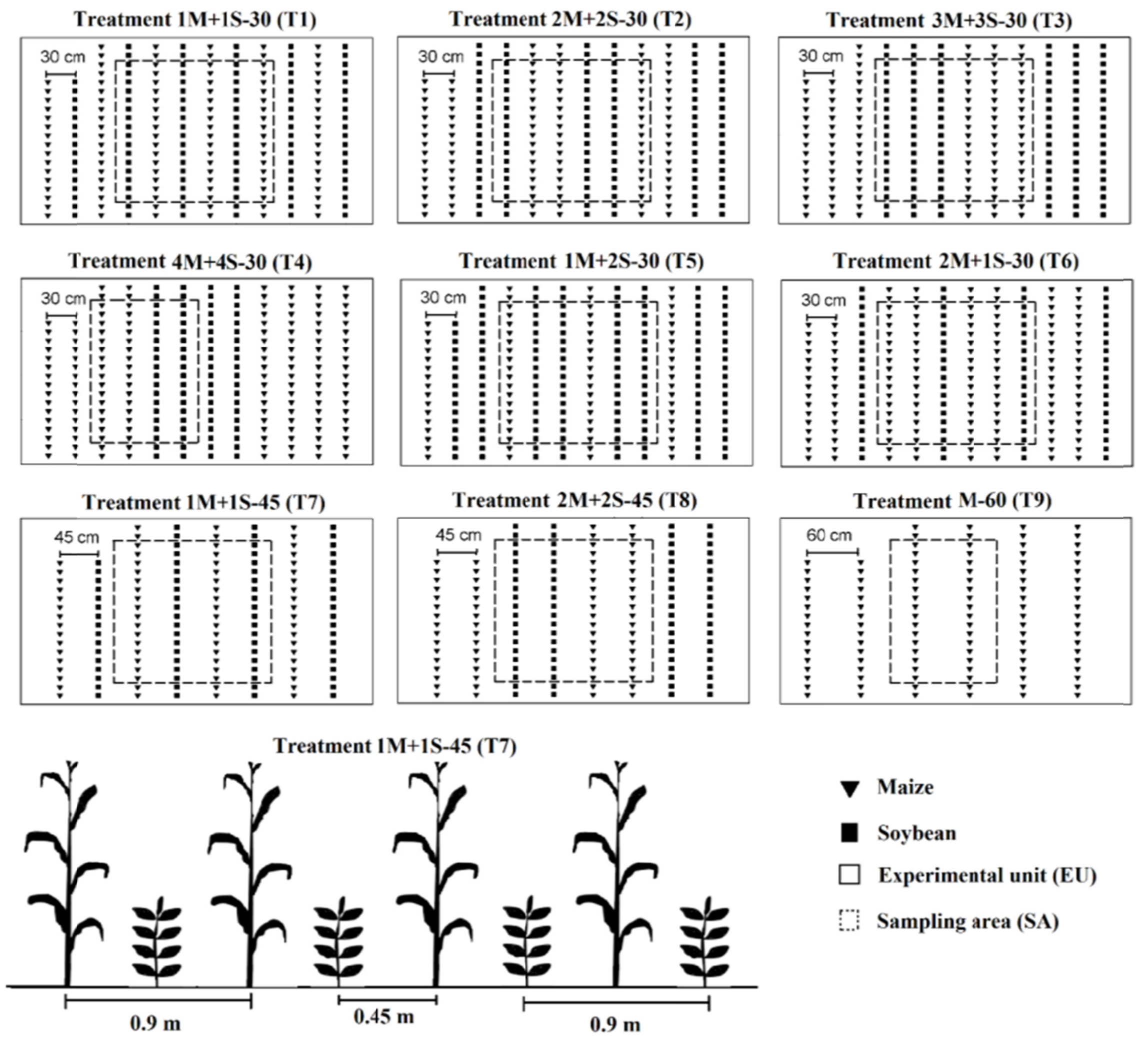

Figure 2. Maize + soybean intercrop row arrangement (treatments). UTFPR, Dois Vizinhos - PR, Brazil (2018). As an example, treatment 1 is represented by 1 row of maize + 1 row of soybean spaced 30 cm between rows and so on to the other treatments. Treatment 9 is represented by maize monocrop with spacing of 60 cm between rows (M-60)

The experimental plot size was of 72 m^2 (3.6 m wide × 20 m long). From the main plots, half of it (3.6 × 10 m) was used to determine silage yield and other half, its grain yield.

Evaluations were carried out in the experimental unit (EU) considering a sampling area (SA), which was composed of the central rows of each EU, 5 meters long (Figure 2). As the numbers of treatments rows were different, the SA were constituted by 6 m^2 for the treatments 4M+4S-30 and M-60, and 9 m^2 for the other treatments (Figure 2).

2.3 Maize and Soybean Materials

Maize hybrid 2B533 is recommended both for silage and grain production. It presents medium-sized plants, high grain yield, progressively responds to technology, presents high grain participation in dry matter, high total digestible nutrients (TDN), high digestibility and low neutral detergent fiber (NDF) and is recommended for whole plant or wet grain silage or grain product (Dow Agrosciences, 2018).

Soybean cultivar TMG7062-IPRO Intacta RR2 PROTM has been genetically modified and expresses 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 maturity cycle classified as 6.2 which represents 125 to 135 days to relative maturity - RM) and seeding rate recommendation of 220 to 240 thousand seed ha^{-1} (Tropical Breeding and Genetics, 2017). Moreover, glyphosate-resistant soybean as a weed management tool has provided farmers with the opportunity and flexibility to manage a broad spectrum of weeds.

2.4 Experiment Management

Black oat (*Avena strigosa*) was used as prior crop and it was desiccated with glyphosate (1.080 g ha^{-1} of active ingredient) 30 days before intercrop establishment. Maize + soybean intercrop was sown simultaneously on October 2nd 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 in a pantograph system. Row spacing was first configured to 30 cm and then changed to 45 cm to set up the treatments. It is important to highlight that most of farmers use 45 cm between crop rows, although, seeder rows spacing is easily adjustable and can be done by farmers.

Seed drill regulation was set up to sow 62,000 maize seeds ha^{-1} and soybean seed stand was a consequence of it. Maize seed discs had 28 holes, while soybean seed discs had 100 holes (a relation of 3.57 soybean seed to each maize seed sown).

Also, because the arrangements characterize different spacings between maize rows, soybean sowing density changed among the evaluated arrangements, as shown in Table 2.

Table 2. Distance between rows and seed distribution in maize + soybean intercropping in different row arrangements. UTFPR, Dois Vizinhos-PR, Brazil (2018)

Treatments (arrangements)	Distance between rows (cm)		Total of seeds			
			Maize		Soybean	
	Maize	Soybean	Linear meter	ha^{-1}	Linear meter	ha^{-1}
1M+1S-30	60	60	3.72	62,000	13.29	221.429
2M+2S-30	60	60	3.72	62,000	13.29	221.429
3M+3S-30	60	60	3.72	62,000	13.29	221.429
4M+4S-30	60	60	3.72	62,000	13.29	221.429
1M+2S-30	90	45	5.58	62,000	19.93	442.857
2M+1S-30	45	90	2.79	62,000	9.96	110.714
1M+1S-45	90	90	5.58	62,000	19.93	221.429
2M+2S-45	90	90	5.58	62,000	19.93	221.429
M-60	60	-	3.72	62,000	-	-

At sowing, fertilization was done for both species adding 450 kg ha^{-1}, of chemical fertilizer 5-20-10 (N-P_2O_2-K_2O). Nitrogen (N) was applied as urea (45% of N) at the rate of 180 kg N of ha^{-1}. Half of the N dose was applied at V4 (three weeks after sowing) and the remaining half at V8, all by side placement manually along the rows. Insecticide *imidacloprid* + *beta-cyfluthrin* at the dose of 1 L ha^{-1} was applied, shortly after maize emergence to control stink bug (*Dichelops melacanthus*). Weed control was achieved by applying *glyphosate* (1.2 g a.i.ha^{-1}) on maize at V3 stage. Fungicide application was done at maize R2 stage with a systemic ready mixture product containing *estrobilurina* + *pirazol carboxamida* at a commercial dose of 300 g ha^{-1}. Along with the fungicide, vegetable oil was added at a dose of 0.5 L ha^{-1} and spray volume of 160 L ha^{-1} applied with a self-propelled sprayer.

2.5 Evaluations

2.5.1 Stand of Plants and Morphological Characteristics of Crops

Maize (MPS) and soybean (SPS) plants stand were determined at the maize ensiling point (01/30/2018-120 days after its emergency), by counting the number of plants present in each EU and extrapolating to hectare (plants ha^{-1}).

Soybean number of pods per plant (NPP) were evaluated in ten randomized plants per EU. Also, ten maize plants per plot were evaluated for determining the stem diameter (SD-between the second and third nodes with the aid of a caliper), spike height insertion (SHI - distance between soil level and the insertion of the main maize spike) plant height (PH - distance from the soil to the most distant point of the plants, and the values were obtained with a tape measure) being the values expressed in centimeters. The mean values obtained at each EU were considered for the data analysis.

2.5.2 Crop Dry Mass and Silage Biomass Yield

Silage harvesting was performed when maize had reached 2/3 milk line stage, which happened 120 days after its emergence. At that point, soybean cultivar was at the 5.5 phenological stage.

Plants from the SA were harvested by hand cutting the plant 25 cm above the soil surface. They were weighed to determine maize (MGBY) and soybean (SGBY) green biomass yield. Then, plant samples of both crops of each SA 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 weighed 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 determine its dry matter content.

Forage DM yield was calculated from the fresh and dry weights of respective components listed above to determine maize and soybean dry matter yield (MDMY and SDMY) and its sum resulted in the total dry matter yield (TDMY = MDMY + SDMY) (Kg ha^{-1}).

2.5.3 Silage Chemical-Bromatological Traits and Digestibility

Samples of maize 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, relating to 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 100mm 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 ensiling.

Upon the opening of the silos, the material was homogenized and extracted for further analysis. At the time, pH determination was carried out using a pH meter in accordance with the methodology described by Silva and Queiroz (2002). Samples collected (300 g) after opening the silos were placed in paper bags, weighed and oven-dried at 55 °C for at least 72 hours until constant weight to determine its dry matter content. The pre-dried samples were ground in a 'Wiley' type mill with a 1 mm 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 determined by the methodology described in the Ankon (2009) manual. TDN = 87.84 – (0.7 × ADF) was used to estimate the total digestible nutrients (TDN). Silage crude protein (SCP) (g kg^{-1}) analysis was 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 each silage component dry matter yield and from its sum, total silage crude protein yield (TCPY) (Kg ha^{-1}) was determined.

2.5.4 Maize Grain Yield Components and Total Yield

Grain harvesting was carried out on March 3, 2018 (152 days after sowing) with mean moisture of 22%. To determine maize yield components, 10 cobs per plot were evaluated to determine the number of grains per row (NGR-grain smaller than ½ normal grain was not considered) and the number of rows (NR) per cob. In addition, the weight of thousand grains was assessed by manual counting 5 samples of 100 grains, weighing and corrected for moisture content of 13%, with extrapolation to thousand-grain weight. Number of grain per spike (NGE), was determined considering the NGR and NR (NGE = NGR × NR). For the statistical analyzes, the mean values observed in each SA were used.

Maize yield was assessed by harvesting the spikes of the SA and passing them through a stationary small-plot maize sheller. Maize grain yields were adjusted to a moisture content of 13 g kg^{-1}. Grain yield per plant was also evaluated by dividing total yield to the maize population.

2.6 Statistical Analysis

All data were submitted to analysis of variance (Anova), and when it presented significance ($P < 0.05$), mean was compared through the Tukey test. Intercrop results were compared with the maize monocrop data through the contrast "t" test. For analysis of data, Sisvar 5.6 (Ferreira, 2008) software was used.

3. Results and Discussion

3.1 Stand de Plants and Features Morphological Traits

Final stand of maize plants (FMP) was not influenced by the different row arrangements (treatments), showing a mean of 58,159 plants ha^{-1} (Table 3). This result supports the data, since the objective was to have a similar maize population for all the evaluated treatments. Batista et al. (2018) reported a difference of 9.1% between sowing density (60,000 seeds ha^{-1}) and the mean of the final population (54,513 plants ha^{-1}), which was higher than that observed in the present study (62,000 ha^{-1}-58,159 plants ha^{-1}). These results, combined with the analysis of the "t" test, show that soybean intercropped with maize did not affect FMP values, since maize monocrop showed similar FMP when compared to the intercropping treatments (Table 3).

Table 3. Final plant population and morphological traits of maize + soybean intercrop at the plant row arrangements. UTFPR, Dois Vizinhos-PR, Brazil (2018)

Treatments (arrangements)	FMP	FSP	SD	SHI	MPH	NPSP
1M+1S-30	60,000.00^{ns}	139,166.70 b	2.35 a^{ns}	134.20 a*	266.75 a^{ns}	10.25 b
2M+2S-30	56,250.00^{ns}	118,750.00 b	2.30 a^{ns}	136.00 a*	268.15 a^{ns}	14.85 b
3M+3S-30	58,611.11^{ns}	125,277.80 b	2.15 b*	127.33 b^{ns}	259.38 b^{ns}	15.03 b
4M+4S-30	57,083.33^{ns}	117,083.30 b	2.26 a*	125.48 b^{ns}	257.70 b^{ns}	29.63 a
1M+2S-30	56,111.11^{ns}	241,111.10 a	2.12 b*	132.70 a*	267.35 a^{ns}	11.35 b
2M+1S-30	60,000.00^{ns}	82,222.22 c	2.22 a*	134.00 a*	266.75 a^{ns}	8.15 b
1M+1S-45	59,444.44^{ns}	159,086.10 b	2.06 b*	136.15 a*	268.28 a^{ns}	12.65 b
2M+2S-45	57,777.78^{ns}	141,944.40 b	2.03 b*	122.18 b^{ns}	252.63 b^{ns}	13.60 b
Mean	58,159.72	140,580.20	2.18	131.00	263.37	14.44
P	0.6360	0.0000	0.0063	0.0165	0.0372	0.0001
CV	6.34	16.30	5.41	4.54	2.80	22.18
M-60	57,500.00	**	2.43	124.13	258.70	**

Note. ANOVA: $P > 0.05$ = not significant; $0.05 \geq P \geq 0.01$ = significant at 5%; $P < 0.01$ = significant at 1%. Tukey Test: In each column, averages followed by different lowercase letter differ by the Tukey test in 5% of probability. Test T: ^{ns} = Nonsignificant; * = Significant at the $p \leq 0.05$ level; ** = The 0 (zero) values to the M-60, test T is not applied. FSC = final stand of maize plants (plants ha^{-1}); FSP = final stand of soybean plants (plants ha^{-1}); SD = stem diameter (cm); SHI = spike height insertion (cm); MPH = maize plant height (cm); NPSP = Number of pods per soybean plant.

Final stand of soybean plants (FSS) was a consequence of maize seeding rate, resulting in higher values to the 1M+2S-30 (241,111 plants ha^{-1}) and lower values to the 2M+1S-30 (82,222 plants ha^{-1}) arrangement, with intermediate values to the other arrangements (Table 3).

There was a great difference between sowing density (Table 2) and the FSP values (Table 3), at the 1M+2S-30 treatment, which ranged from 442,857 to 241,111 plants ha^{-1}, with a reduction of 45.8%. Lempp et al. (2000) point out that one of the difficulties in maize + soybean intercrops is to obtain a high number of soybean plants per linear meter. Liu et al. (2017) emphasize in their studies that in maize + soybean intercrop, soybean crop is the most affected species due to maize competition potential, requiring good arrangement of plants/rows/density to reach system success, otherwise, soybean may show low dry mass accumulation. Moreover, higher density of plant per linear meter may result in self-thinning process, where plants with lower vigor die. In this context, the use of soybean seed disc with a lower number of holes (64 as an example) may be an option to reduce seed expenses at the 1M+2S-30 treatment. It is worth commenting that usually, one of the problems/difficulties in adopting legumes is the seed cost, although, the cost of soybean seeds are very low once farmers can produce and use his own soybean seeds/grains in the corn intercrop.

Maize plants morphological traits (SD, SHI, MPH) differed among treatments, where the arrangements 1M+1S-30, 2M+2S-30, 4M+4S-30 and 2M+1S-30 showed ticker stem diameter (SD) and the arrangements 1M+1S-30, 2M+2S-30, 1M+2S-30, 2M+1S-30 and 1M+1S-45 stood out with greater SHI and MPH. It was also noticed that most of the arrangements (1M+1S-30, 2M+2S-30, 1M+2S-30, 2M+1S-30 and 1M+1S-45) showed higher spike insertion height when compared to the maize monocrop, although, final maize plant height was similar between arrangements (Table 3).

Paz et al. (2017) did not observe interference in the maize spike insertion and plant height when cultivated with different legumes as intercrops. Santos et al. (2017) also reported similar values of spike insertion and plant height, for the maize intercropped with fodder. Stacciarini et al. (2010) and Ferreira et al. (2015) observed that row spacing and plant density affect intercrop competition and may influence stem diameter in maize crop, but with no effect on plant height and spike insertion height. Taller plants represent better development as a result of lower intercrop interference, or in other words, row arrangements with taller plants fits better for intercrop systems.

Maize plant morphological differences among row arrangements and/or in relation to the maize monocrop reported in Table 3 do not present a standard, although, lower row spacing and higher plant density per linear meter tends to increase plant competition and as a morphological change, plants tend to grow higher. This fact explains part of the differences noticed among arrangements.

Regarding the number of pods per plant, 4M+4S-30 arrangement stood out with 29.6 pods per plant, differing over other treatments (Table 3). This trait is important as soybean grain may increase the fodder quality. Since most of the protein in the soybean plant will have been translocated to the seeds at harvest, the higher number of soybean pods may increase silage protein concentration. Soybeans contains about 17 to 18% of oil and 35 to 37% of crude protein of high biological value, with a composition in essential amino acids favorable to animal feed and therefore is a good alternative protein feed (Mendes et al., 2004). It is possible to infer that greater distance between rows is advantageous as this arrangement allowed better photosynthetic radiation incident on the soybean plants, allowing a greater pod number. According to Liu et al. (2017), the lack of photosynthetic radiation intercepted by the soybean crop in maize + soybean intercrop, results in a significant reduction in plant development and pods differentiation.

3.2 Crops Silage Biomass, Dry Mass and Biomass Yield

Silage dry mass is a very important parameter as it directly affects silage fermentation (Cruz et al., 2001). Regarding to the dry mass of the crops (MSDM=Maize silage dry mass and SSDM=Soybean silage dry mass) at the time of ensiling, a statistical difference was observed in both crops (Table 4). Data analysis divided the MDM of the arrangements into two groups, the first with higher values formed by treatments 1M+1S-30, 2M+2S-30, 4M+4S-30, 1M+1S-45 and 2M+2S-45 and the second with lower values composed of 3M+3S-30, 1M+2S-30 and 2M+1S-30. When compared to the maize monocrop, there were no differences to the maize silage dry mass (Table 4). As for the MDM, the evaluated arrangements were also divided into two groups for the SDM, with the highest values obtained in the 2M+2S-30, 4M+4S-30, 2M+1S-30 and 2M+2S-45 (Table 4).

Table 4. Crops silage biomass dry mass and silage biomass dry matter yield at the maize + soybean intercrop row arrangements. UTFPR, Dois Vizinhos-PR, Brazil (2018)

Treatments (arrangements)	MSDM	SSDM	SBY	MBY	TBY
1M+1S-30	35.41 a^{ns}	23.27 b	1,773.78 b	22,267.33^{ns}	24,041.11^{ns}
2M+2S-30	35.90 a^{ns}	25.23 a	2,564.87 a	22,318.78^{ns}	24,883.65^{ns}
3M+3S-30	33.90 b^{ns}	24.26 b	2,203.39 b	20,461.90*	22,665.27^{ns}
4M+4S-30	37.43 a^{ns}	26.14 a	3,045.35 a	21,948.45^{ns}	24,993.79^{ns}
1M+2S-30	33.03 b^{ns}	23.22 b	2,742.61 a	20,187.63*	22,930.25^{ns}
2M+1S-30	33.22 b^{ns}	26.57 a	1,354.60 c	20,787.93^{ns}	22,142.53^{ns}
1M+1S-45	35.86 a^{ns}	23.23 b	1,796.17 b	21,348.88^{ns}	23,145.05^{ns}
2M+2S-45	37.69 a^{ns}	26.97 a	2,701.51 a	21,624.57^{ns}	24,326.09^{ns}
Mean	35.30	24.86	2,272.79	21,368.18	23,640.97
P	0.0081	0.0014	0.0000	0.5925	0.2896
CV	5.31	5.69	14.61	8.53	7.89
M-60	35.55	**	**	23,239.37	23,239.37

Note. ANOVA: $P > 0.05$ = not significant; $0.05 \geq P \geq 0.01$ = significant at 5%; $P < 0.01$ = significant at 1%. Tukey Test: In each column, averages followed by different lowercase letter differ in 5% of probability. Test T: ^{ns} = Nonsignificant; * = Significant at the $p \leq 0.05$ level; ** = The 0 (zero) values to the M-60, test T is not applied. MSDM = Maize dry mass (%); SDM = Soybean dry mass (%); SBY = Soybean biomass yield (kg dry matter ha^{-1}); MBY = Maize biomass yield (kg dry matter ha^{-1}); TBY = Total biomass yield (kg dry matter ha^{-1}).

Dry matter loss and silage fermentation quality are directly related to the forage DM content at harvesting time. There was no difference to the maize silage dry mass (%) with a mean value of 35.3% with lower and higher DM value of 33 and 37%. According to Savoie and Jofriet (2003), silage DM content is the main driver to predict effluent losses and that effluent is prevented in most cases at DM content greater than 35%. Intercrop row arrangements of 4M+4S-30 and 2M+2S-45 showed higher DM content for both maize and soybean. Closer maize plants at the 2 row maize and 4 rows aside may have affected species competition and light quality that may increase plant senescence and DM content in this treatment (Table 4).

It is worth to comment that in Brazil, there are many farmers that grow maize at 90 cm row spacing. In this case, a soybean row between maize may bring along some advantages to the system, such as land and natural resource use efficiency. According to Ren et al. (2016), land equivalent ratios (LER) of 0.84-1.35 indicated resource complementarity in most of the studied intercrops (maize + soybean). Complementarity was directly affected by changes in plant densities; the greatest LER were observed in 2 rows maize and 2 rows soybean intercrops at low density (45 thousand maize plant ha^{-1}). Although, intercrops did not result in greater dry matter production than those of the higher producing maize sole crop (90 thousand maize plant ha^{-1}) at any of the harvest indicating that maize had the growth advantage over soybean.

Salvagiotti et al. (2008) reported in a review article that biological N_2 fixation (BNF) from soybean ranged from 0 up to 337 kg N ha^{-1} and on average 50-60% of soybean N demand originates from BNF. Zimmer et al. (2016) reported soybean grain and protein yield per hectare of 2,455 and 965 kg ha^{-1} (average from 2011 to 2013) with an average protein content of 386 g kg^{-1}. These results highlight the soybean potential as a silage specie to be intercropped with maize. Moreover, effective inoculation with *Bradyrhizobium* strains increased grain yield, protein content and protein yield by up to 57%, 26% and 99%, respectively and the percentage of nitrogen derived from air (Ndfa) ranged between 40% and 57%.

Martin et al. (1998), evaluating different soybean maturing cultivars reported similar biomass yield between maize + soybean intercrops and maize monocrop. Furthermore, to the late soybean cultivar (was still green enough to be harvested with minimal pod shattering), land equivalent ratios revealed yield advantages of intercrops over monocrops of 21% and 10% for the shoot biomass and shoot protein yield, respectively. These aspects highlight the importance and viability of maize and soybean intercrop.

Soybean DM content ranged from 23 to 26%. Low DM contents of soybeans may reflect lower quality of fermentation and stabilization of the silage process. According to Undersander et al. (2007) standing soybean forage at the R3 to R4 stage was generally at about 80% moisture and needed to be mowed and wilted to dry down to 65% moisture for ensiling. Another way to improve soybean silage fermentation process, is to intercrop it with maize, once the soluble carbohydrate content and the higher DM content contribute to the good fermentation process. Moreover, soybean (R3 stage) forage quality was similar to alfalfa haylage (Undersander et al., 2007).

Soybean silage harvested at the R2 and R4 stages showed various degrees of mold, with unpleasant odor and a dark green color tending black. The optimum time to harvest soybeans for silage is when seeds completely fill the pods and the lower leaves of the plant are just beginning to turn yellow (just before R7). At this point the field has achieved maximum dry matter yield and is beginning to decrease in moisture content. Soybeans harvested later will have higher oil content which reduces their ensiling characteristics (mixing grass at ensiling will help later harvested soybeans) (Undersander et al., 2007). At the experiment, soybean at the maize silage point was at the R5 stage.

Intercropped maize had a strong competitive effect on the growth of soybean at 2M+1S-30. A yield advantage in intercropping is achieved only when the component crops do not compete for the same resources in the same time and space. In the present study, the sharing of light by the component crops was important for improved utilization of resources, resulting in higher soybean yield of the intercropping system 2M+2S-30; 4M+4S-30; 1M+2S-30 and 2M+2M-30. Prasad and Brook (2005) reported that intercropping increased the total amount of radiation intercepted due to rapid establishment of ground cover by the combined canopies of the component crops.

Ren et al. (2016) reported greater Land Equivalent Ratio (LER) of maize in relation to soybean in the M2S2 and M4S2 intercrop, whereas the M2S4 intercrop had a higher partial LER for soybean than for maize. Thus, maize was dominant in the M2S2 and M4S2 cropping systems. These results are similar to the ones observed at this study. Plant density and relative frequency thus determined the relative yield contributions of maize and soybean in the intercrops.

To the maize dry matter biomass yield (MBY), there was no statistical differences between the evaluated arrangements, showing a mean value of 21,368 kg ha^{-1}. When compared to the maize sole crop (23,368 kg ha^{-1}), treatment 3M+3S-30 and 1M+2S-30 showed lower values (20,461 and 20,187 kg ha^{-1}, respectively) (Table 4).

Total dry biomass yield did not differ between the evaluated arrangements, with a mean value of 23,640 kg ha^{-1}. Maize monocrop also showed similar value (23,239 kg ha^{-1}) to the intercropped arrangement (Table 4).

Batista et al. (2017) evaluating maize + soybean intercrop (1M+1S) reported similar biomass yield among intercrop and maize monocrop. Sánchez et al. (2010) reported that maize plants at border rows showed higher dry mass biomass, which turns out in similar yield of maize monocrop.

Research has indicated that the addition of soybean biomass to maize silage increases the crude protein content of the silage (Lempp et al., 2000). In this context, it is suggested that intercropping of maize + soybean considers the arrangements where higher soybean biomass occurs.

3.3 Bromatological Traits of Maize+Soybean Silage

There were differences among soybean biomass percentage in the total silage biomass. For most of the arrangements, soybean contributed with more than 10% of the total biomass, although, treatments 1M+1S-30, 2M+1S-30 and 1M+1S-45 showed lower values (Table 5). Results resemble those reported by Sánchez et al. (2010) in a two-year study.

Table 5. Bromatological traits of maize+soybean silage grown under different row arrangements. UTFPR, Dois Vizinhos-PR, Brazil (2018)

Treatments	PSS	pH	Ashes	NDF	ADF	TDN	SCP	TCPY
1M+1S-30	7.40 b	4.40^{ns}	4.02^{ns}	36.14^{ns}	21.64^{ns}	72.69^{ns}	92.00^{ns}	2,209.39 b^{ns}
2M+2S-30	10.32 a	4.38^{ns}	4.50^{ns}	39.30^{ns}	21.81^{ns}	72.57^{ns}	95.82*	2,382.35 a*
3M+3S-30	9.83 a	4.40^{ns}	4.25^{ns}	38.68^{ns}	19.89^{ns}	73.91^{ns}	95.28^{ns}	2,155.57 b^{ns}
4M+4S-30	12.20 a	4.46*	4.32^{ns}	38.83^{ns}	18.50^{ns}	74.88^{ns}	102.87*	2,563.53 a*
1M+2S-30	11.97 a	4.41^{ns}	4.40^{ns}	41.64^{ns}	20.17^{ns}	73.72^{ns}	96.58*	2,213.83 b^{ns}
2M+1S-30	6.14 b	4.39^{ns}	3.78^{ns}	38.38^{ns}	20.30^{ns}	73.63^{ns}	89.05^{ns}	1,963.45 b^{ns}
1M+1S-45	7.76 b	4.38^{ns}	4,22^{ns}	37.45^{ns}	18.79^{ns}	74.69^{ns}	91.69^{ns}	2.122,61 b^{ns}
2M+2S-45	11.09 a	4.43^{ns}	4,24^{ns}	36.25^{ns}	19.06^{ns}	74.50^{ns}	98.99*	2.409,41 a*
Mean	9.59	4.41	4.22	38.34	20.02	73.83	95.28	2.25252
P	0.0000	0.2801	0.9300	0.6074	0.7735	0.7735	0.3539	0.0292
CV	14.53	1.16	18.54	10.50	16.35	3.10	8.53	10.11
M-60	**	4.36	4.16	34.47	17.37	75.68	84.17	1,957.36

Note. ANOVA: $P > 0.05$ = not significant; $0.05 \geq P \geq 0.01$ = significant at 5%; $P < 0.01$ = significant at 1%. Tukey Test: In each column, averages followed by different lowercase letter differ in 5% of probability. Test T: ^{ns} = Nonsignificant; * = Significant at the $p \leq 0.05$ level; ** = The 0 (zero) values to the M-60, test T is not applied. Percentage of dry mass of soybean in silage (PSS) (%), Potential hydrogen (pH), Ashes (%), Neutral detergent fiber (NDF) (%), Acid detergent fiber (ADF) (%), Total digestible nutrients (TDN) (%), Silage crude protein (SCP) (g Kg^{-1}), Total crude protein yield (TCPY) (Kg ha^{-1}).

Percentage of dry mass of soybean in silage (PSS) increased as soybean biomass increased. Thus, according to Stella et al. (2016) it may increase the quality of the silage.

Silage fermentation and the resulting pH primarily suppress the growth of other anaerobic microorganisms, pH being a good silage quality parameter. The growth of yeasts and other spoilage (aerobic) microorganisms may occur when silage pH reaches values higher than 4.5 (Muck, 2010). Maize+soybean silage showed pH values below 4.5, what suggests good silage fermentation and storage potential, even with soybean values reaching 12% of total biomass. Maize monocrop pH values were lower than the 4M+4S-30 arrangement, which also showed the highest soybean dry matter biomass values (3,045 kg ha^{-1}) and PSS (12.2%) (Table 4).

Erdal et al. (2016) reported that the increase in the number of soybean rows in the intercropping systems results in an increased biomass of the legume, raising the pH values from 4.0 at the maize monocrop to 4.6 and 5.3 when using 3M:1S and 2M:2S respectively. According to the researchers, this increase of pH negatively influences the quality of silage. Even so, the authors reported that silage quality at 3M:1S was superior to maize monocrop in terms of crude protein (7.31%), neutral detergent fiber (42.56%), acid detergent fiber (25.81%), lactic acid (4.71%) and acetic acid (4.05%) concluding that 3M:1S row intercropped production system was a better alternative for silage than maize monocrop.

Regarding to the other silage traits such as ashes, neutral detergent fiber (NDF) (%), acid detergent fiber (ADF) (%), and total digestible nutrients (TDN), they were similar among row arrangement tested, collaborating with Sánchez et al. (2010) who studying different row arrangements in maize + soybean intercropped during two agricultural years reported similar values to these traits.

It is possible to observe that as the soybean share in the silage increases; the crude protein content of the silage also increases, improving silage quality. It is observed in Table 5 that some arrangements (2M+2S-30, 4M+4S-30, 1M+2S-30 and 2M+2S-45) presented higher SCP values than sole corn crop silage (M-60) (84.17 g Kg of silage), possibly explained by the fact that these arrangements showed higher percentage of soybean biomass. These results corroborate with other scientific investigations (Erdal et al., 2016; Sánchez et al., 2010; Stella et al., 2016).

Total crude protein yield (TCPY) is a consequence of the maize + soybean total biomass yield per area and its nitrogen content. These factors contributed to the arrangement of 2M+2S-30, 4M+4S-30 and 2M+2S-45, which showed TCPY values of 2,382, 2,563 and 2,409 kg ha^{-1}, differing from the other arrangements and sole corn crop (M-60) (Table 5). These data is important once silage energy and protein yield per area is more important than the total biomass yield per area.

According to Zhang et al. (2015), maize + soybean intercrop had significant advantage in yield, economy, land utilization ratio and reducing soil nitrate nitrogen (N) accumulation, as well as better residual effect on the subsequent wheat (*Triticum aestivum* L.) crop when compared to maize sole crop. Among the reason used to explain these better performances, the authors mentioned that intercropping systems increased relative biomass of intercropped maize, due to promoted photosynthetic efficiency of border rows and N utilization during symbiotic period.

Crude protein value varies according to maize and soybean meal prices, however, crude protein cost from grain (maize + soybean) usually is above 1 US$ per kg of protein. Considering the fact that the arrangements 4M+4S-30, 2M+2S-45, and 2M+2S-30, yielded 606, 452, and 425 kg CP ha^{-1} more than sole corn crop, it is possible to infer that these treatments resulted in higher economic gain per area. Furthermore, higher CP yield occurs mainly due to the soybean nitrogen biological fixation efficiency, what also turns out maize + soybean intercrop as a more sustainable way of production.

Furthermore, these results associated with the data reported in the literature serves as an incentive to maize + soybean intercrop adoption. However, it is important to observe which plant arrangement should be used, in such a way that they can associate a high accumulation of maize biomass, together with a high accumulation of soybean biomass (above 10% of silage dry mass), in order to add crude protein per kilogram of silage and increase crude protein yield by area.

3.4 Effect of Intercropping on Grain Yield

There was no significant difference between row arrangements in intercropping and maize sole crop to the number of rows (NR), number of grain per row (NGR), number of grain per spike (NGS) (Table 6). Results corroborate Paz et al. (2017), who reported similar number of rows and the number of grains per spike of sole crop and maize intercroped with different legumes (*Canavalia ensiformis* L., *Crotalaria juncea* L., *Stylozobium aterrimum* L., *Cajanus cajan* L., *Vigna unguiculata* L.).

Table 6. Effect of maize + soybean intercropping on grain yield. UTFPR, Dois Vizinhos-PR, Brasil (2018)

Treatments (arrangements)	NR	NGR	NGS	TWG	GY	GYPM
1M+1S-30	17.50^{ns}	36.10^{ns}	632.88^{ns}	362.78 b^{ns}	12,741.61^{ns}	212.47*
2M+2S-30	18.90^{ns}	38.70^{ns}	731.96^{ns}	390.32 a^{ns}	12,451.47^{ns}	221.09^{ns}
3M+3S-30	18.30^{ns}	37.30^{ns}	681.96^{ns}	362.95 b^{ns}	12,039.74^{ns}	204.89*
4M+4S-30	18.60^{ns}	37.15^{ns}	690.00^{ns}	372.79 a^{ns}	12,525.77^{ns}	219.94^{ns}
1M+2S-30	17.80^{ns}	37.50^{ns}	666.96^{ns}	378.36 a^{ns}	12,341.66^{ns}	219.88^{ns}
2M+1S-30	18.60^{ns}	37.05^{ns}	689.98^{ns}	372.44 a^{ns}	13,310.71^{ns}	221.95^{ns}
1M+1S-45	18.10^{ns}	35.25^{ns}	638.14^{ns}	348.38 b*	12,433.53^{ns}	209.15*
2M+2S-45	17.60^{ns}	36.90^{ns}	649.52^{ns}	367.05 b^{ns}	11,689.05*	202.32*
Mean	18.18	37.00	672.68	369.38	12,441.69	213.96
P	0.3070	0.5281	0.1919	0.0072	0.5760	0.1279
CV	5.00	5.78	7.79	3.47	8.43	5.41
M-60	18.50	38.25	705.28	379.04	13,208.56	229.95

Note. ANOVA: P > 0.05 = not significant; 0.05 ≥ P ≥ 0.01 = significant at 5%; P < 0.01 = significant at 1%. Tukey Test: In each column, averages followed by different lowercase letter differ in 5% of probability. Test T: ^{ns} = Nonsignificant; * = Significant at the p ≤ 0.05 level. Number of rows (NR), number of grain per row (NGR), number of grain per spike (NGS), thousand-grain weight (g) and grain yield (GY-kg ha^{-1}) and grain yield per plant maize (GYPM) (g).

According to Ren et al. (2016), plant density and sowing proportions significantly affected the interspecies dynamics of maize-soybean intercrops. A yield advantage in intercropping is achieved only when the component crops do not compete for the same resources in the same time and space. Maize was generally more growth efficient for biomass accumulation than soybean during the growth period and maize leaf area index increased as its density increased. However, stronger competitive effects of intercropped soybean on the growth of maize were observed as the proportion of soybean seed was increased at low maize cropping density. In the present study, the sharing of light by the component crops was important for improved utilization of resources, resulting in higher productivity of the intercropping system.

In addition, soybean has a high efficiency in the use of atmospheric nitrogen via biological fixation (Hungria et al., 2001). Thus, it is thought that crops do not compete for N, a fact that can justify similar maize yield components between plant arrangements and maize monocrop.

Considering that soybean crop is of interest to the grower when cultivated for silage in intercropping system with maize, it is worth noting that the soybean crop received fertilized just as maize did which may allow lower competition between species. However, when maize is designed for grain production, the non-fertilization (P, K) of soybean could favor a lesser development of soybean plants, thus contributing with less competition with maize.

It is possible to observe in Table 6, that the statistical analysis divided the row arrangements in four groups regarding the TWG, demonstrating that the soybean cultivation may have an effect on the maize TWG. Despite differences between the arrangements, it was found that only the arrangement 1M+1S-45 (348 g) showed lower values of MMG in relation to M-60 (379 g). It is not possible to identify which factor contributed to the statistical difference between the values of TWG in the evaluated arrangements, requiring more research for this component.

There was similarity for grain yield (GY-kg ha^{-1}) and grain yield per plant (GYP) (g) between the evaluated arrangements, with a general average of 12.441 kg ha^{-1} and 213 g respectively (Table 6). Although, intercrop arrangement 2M+2S-45 yielded 1,519 kg ha^{-1} less grain than the maize monocrop (M-60). It is necessary to find a balance between soybean biomass yields and maize grain yield reduction as it is desired to increase soybean biomass to increase silage crude protein and in the other hand, it is wished to have maize grain yield maximized or soybean effect as low as possible, since its grain is the main energy source of maize silage.

Therefore, even though the statistical analysis does not indicate a difference between the evaluated arrangements, it can be inferred that there was crop competition between the different arrangements. Treatments with higher soybean forage yield and total forage production, as 2M+2S-30 cm, 4M+4S-30, 1M+2S-30 showed maize grain yield reduction of 757, 683 and 867 kg ha^{-1} or 5.7; 5.1 and 6.5% respectively in relation to the sole maize crop. It is important to highlight that the arrangement 2M+2S-45 yielded similar forage than arrangement mentioned before, but with higher effect over maize grain yield (Table 6) also noticeable by its lower grain yield per plant (GYP) in relation to maize monocrop.

Thus, crop arrangement 2M+1S-30 presented maize yield values numerically superior than maize monocrop and a soybean biomass yield of 1,354 kg ha^{-1}. Ren et al. (2016) reported that both maize and soybean produced slightly greater yield per plant in the intercrop treatment compared to the sole crop treatments and this fact was attributed to a significant water use advantage as a result of species complementary roots distribution. Interspecific interaction increases growth, nutrient uptake and yield of dominant species, but decreases growth and nutrient uptake of the subordinate species during the co-existence (Milkereit, 2016).

Further studies need to evaluate maize + soybean intercrop silage effect on animal yield potential. Thus, soybean intercropped with maize may have a positive impact on the next crop, and the measurement of this possible effect may offset maize grain yield reduction to a point where it is interesting to adopt the intercrop system. Moreover, intercrop under low nitrogen fertilization may show good yield results and might as well be evaluated.

4. Conclusion

Maize + soybean intercrop showed similar maize biomass yield among arrangements, however, 3M+3S-30 and 1M+2S-30 showed lower maize dry mass yield in relation to the sole maize crop, evidencing competition between the crops. Despite this difference, total biomass (corn + soybean) yield was similar among intercropping arrangements and these with sole maize crop. In the other hand, soybean biomass yield showed greater values at the 2M+2S-30, 4M+4S-30, 1M+2S-30 and 2M+2S-45 arrangements, which contributed with more than 10% of the total silage yield and also resulted in higher crude protein contents.

2M+2S-30 and 4M+4S-30 intercrop arrangements increased the silage crude protein percentage and its yield per area with similar grain yield to the sole maize crop.

Maize grain yield was lower at the 1M+1S-30, 3M+3S-30, 1M+1S-45 and 2M+2S-45 arrangements when compared to the other arrangements and with sole maize crop.

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Os resultados dos experimentos, confirmaram os resultados encontrados em outras investigações cientificas de que a soja apresenta potencial para elevar o teor de proteína bruta da silagem de milho, além do aumento da produtividade por unidade de área. Além disso, demostra que o cultivo consorciado destas culturas apresenta potencial para ser implantado nas lavouras comerciais, sendo uma técnica passível de ser utilizada pelos produtores rurais. Entretanto, o estudo também demonstra que o agricultor deve ter cuidado com o arranjo de plantas/linhas a ser utilizado, pois em alguns casos, a soja pode reduzir peso da massa de grãos e o potencial produtivo de grãos da cultura do milho.

Contudo para que a técnica se difunda e se viabilize, são necessários novos estudos os quais devem avaliar além dos fatores verificados no presente trabalho, fatores relacionados a variáveis de solo, plantas daninhas, adubação das plantas, viabilidade econômica, armazenamento e conservação da silagem ao longo do tempo e potencial de produção animal.

Quanto as cultivares de soja, desenvolvimento de matérias com maior porte e tolerantes/adaptados ao sombreamento, tornam-se características desejáveis nas cultivares a serem utilizados no sistema cultivo consorciado com milho.

Além disso, destaca-se aqui a necessidade de desenvolvimento de maquinário agrícola para facilitar a implantação, condução e colheita das plantas. Destaca-se a necessidade de semeadeiras na qual seja possível realizar a regulagem de semeadura das culturas de forma independente para que se consiga inserir as populações desejáveis e implemento de colheita para silagem, no qual seja possível regular a altura de corte.

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