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Research Article
Methods of Intercropping Cover Crops with Maize in Southern Brazil

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Abstract
Background and Objective: In the southern of Brazil, maize is mainly sowed between February and March as a second summer crop after soybean. After maize harvesting, the area undergoes a short fallow period (from July-September), favoring soil erosion and emergence of weeds. In this context, intercropping, cover crops with maize, can minimize these impacts, once after it's harvesting, these plants are already established in the system. The objective of this study was to evaluate the effect of different methods of cover crops establishment on the development and yield of maize as well as the biomass yield of the cover crop species. **Materials and Methods:** Experiment was carried out in a randomized complete block design, arranged in a 2×3 factorial scheme, with 4 replications. Factor A was represented by the cover crops (1-*Crotalaria spectabilis*, 2-*Urochloa ruziziensis*) and Factor B by the intercrop establishment methods (1-cover crops sowed in the inter-row at the maize sowing, 2-cover crops broadcast before maize sowing, 3-cover crops broadcast at the V6 maize phenological stage). **Results:** *Urochloa ruziziensis* showed higher dry mass yield in relation to *Crotalaria spectabilis*, reaching among establishment methods at the maize harvest time an average of 1,425 and 401 kg DM ha^{-1}, respectively. **Conclusion:** Maize yield was not influenced by cover crops species and methods of establishment. Maize presents a competitive advantage over cover species and cover crops intercropped at maize V6 phenological stage showed very low biomass production and due to it, it is not recommended. Further studies should evaluate intercrop at maize earlier phenological stages (V1 or V2).

Key words: *Crotalaria spectabilis*, *Urochloa ruziziensis*, biomass yield, maize as a second summer crop

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Maize (*Zea mays* L.) stands out in the Brazilian economy, being the second-largest grain cultivated in the country, behind only the soybean crop[1]. Grain production is used for domestic supply and export[2]. In addition, in most farms with livestock activities, maize is the most forage used to feed animals. Moreover, it is grown mainly alone, being its intercrop with other species a good opportunity to access better soil and weed management.

Brazilian maize production is divided into 2 crops, summer (first crop) and winter crop or second summer crop (off-season), which corresponds to 72% of the total maize produced in Brazil (69 million t), being the state of Paraná accounted for 18.5% of the amount produced in this period[1]. Maize second crop is grown in rainfed sowed between January and March, after the summer crop, which normally is soybean[3].

After harvesting 1st season corn for silage or grain at February, intercrop species can be used as forage or a cover crop but usually farmers prefer a cash crop, unless for those that study with farm livestock-system. When grown as a 2nd crop, there is an off-season period of approximately 60-80 days, until the new summer crop is seeded. Because it is a relatively short period of time, farmers end up leaving the area on fallow. According to Chieza *et al.*[4], the idea of having cover crops exclusively for biomass production in the fields does not motivate farmers because it does not bring immediate profit. Moreover, oat development after maize harvest (June/July) is not very good, reaching lower levels of biomass up to September, when new season starts and due to it, most areas remain of fallow. Although, this fallow period favors the weed infestations[5], leaving the soil unprotected and susceptible to erosion[6].

According to Hernani *et al.*[7], the intercropping between crops with different features can characterize a better use of light, nutrients and land use, resulting in numerous benefits for the cropping system. Cover crops play an important role in improving the physical, chemical and biological soil properties, which advantages may result in higher yields of subsequent crops[8,9].

In this context, intercropping cover species with maize grown as a second crop can minimize some problems and add many advantages to the production system, once after maize harvesting, crops will already be established, protecting the soil and suppressing weeds.

Studies seeking to understand the intercropping system have been conducted in Brazil. However, researches show that the system varies greatly depending on the cover species used[10] and the way intercrop is established[11], which may compromise the maize development due to competition and biomass accumulation of cover species and grain yield of the main crop[12]. In this away, for example, cover crop established at maize phenological stages of V3-V6 will for sure reduce plant competition but the question is if it will fail or succeeding as a cover crop.

It is worth noting that most studies involving intercropped maize are conducted in the first summer harvest season, with few studies in the second summer crop, thus requiring information on such cultivation. Given the context and aiming to understand the intercropping process with maize grown as a second summer crop, this study aimed to evaluate the consequences of different methods of intercropping of cover crops species on the development and grain yield of maize as well as the potential of biomass accumulation of these species in an intercropping system.

MATERIALS AND METHODS

Location and climatic conditions: The experiment was established on February 15th, 2018. The study was carried out on Teaching and Research Unit of Annual Crops at Federal Technological University of Paraná-UTFPR, campus of Dois Vizinhos-Paraná, Brazil (25°42'4'' latitude south e 53°5'43'' longitude west).

Experimental site has an average altitude of 540 m above sea level, with soil classified a Clayey Oxisol[13]. Predominant climate is subtropical humid (Cfa), with an annual average temperature of approximately 20°C[14] and rainfall between 1800 and 2000 mm/year spike[15]. Data for minimum and maximum temperature and rainfall registered during the study are shown in Fig. 1.

Experimental design: The experiment was laid out as a randomized complete block design, arranged in a 2×3 factorial scheme, with 4 replications, consisting of 6 treatments (24 experimental units-EU). The first factor was represented by the cover crops (1-*Crotalaria spectabilis*, 2-*Urochloa ruziziensis*) and the second factor by the intercrop establishments methods (1-cover crops sowed in the inter-row at the maize sowing (Fig. 2a, b), 2-cover crops broadcast before maize sowing (Fig. 2c, d), 3-cover crops broadcast at the V6 maize phenological stage) (Fig. 2e, f).

Cover cropping sowed at the inter-row or at V6 maize phenological stage were established considering a single

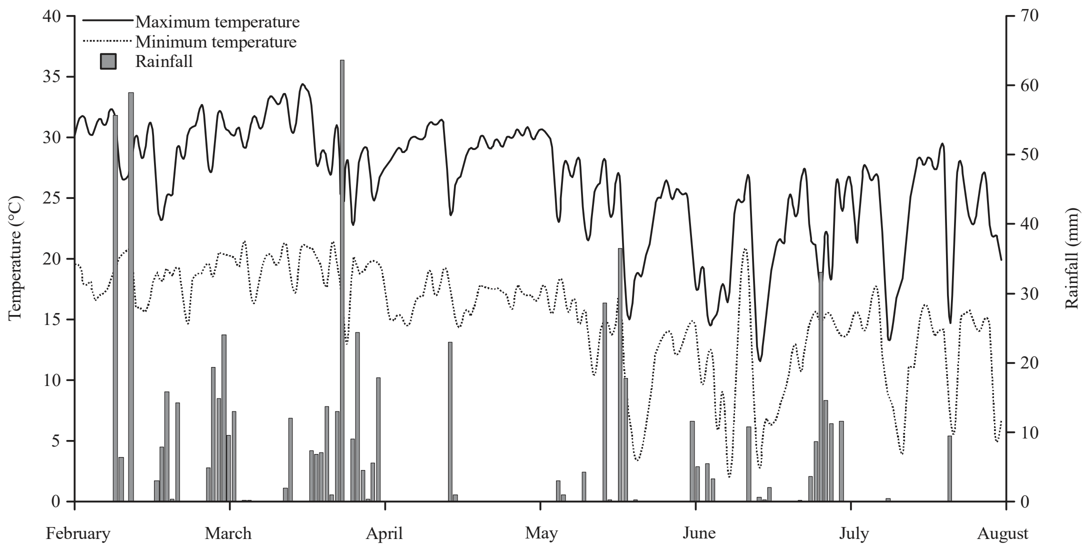

Fig. 1: Rainfall, maximum, minimum and average temperature (°C) during the maize growing period, (February up to August of 2018)
Source: INMET-meteorological station-campus of Dois Vizinhos[16]

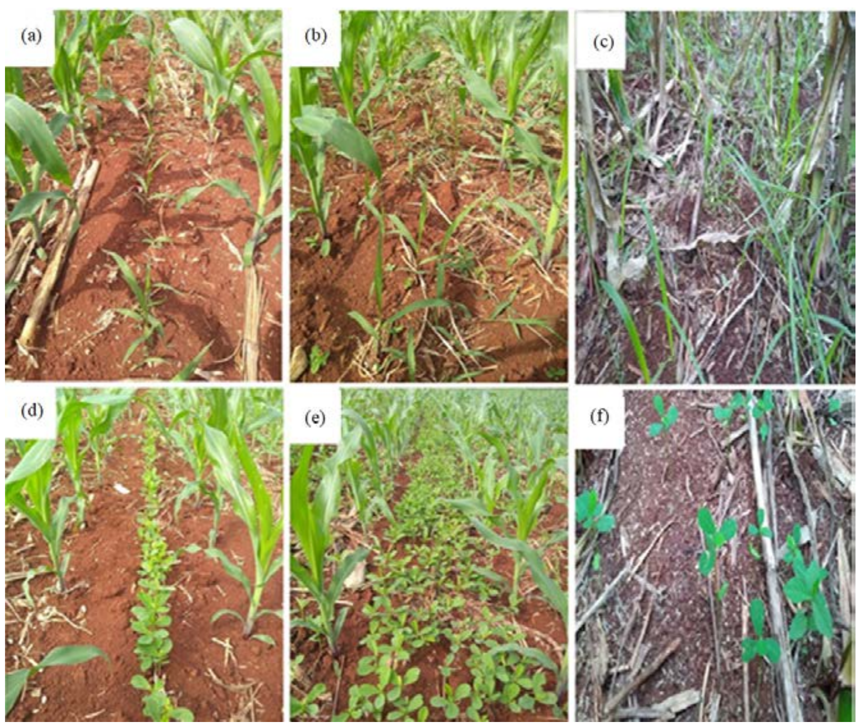

Fig. 2(a-f): (a, b) Cover crops sowed in the inter-row at the maize sowing, (c, d) Broadcast before maize sowing and (e, f) Broadcast at the V6 maize phenological stage, respectively with *U. ruziziensis* and *C. spectabilis*

operation, whether concurrently with maize sowing or urea application, respectively by adapting a seed spreader in front of the tractor.

The EUs consisted of 2.25 m wide (5 maize rows) and 10 m long, totaling 22.5 m^2 each. For the assessments, it was discarded the border rows and also one meter from each end, providing observation units (OU) of 10.8 m^2 (1.35 m wide x8 m long).

Experimental details: The prior crop was maize, used for silage production. In the conduction of the study, maize hybrid Pioneer 3380 HR was sown with the aid of a hydraulic multi-seeder winter/summer) coupled to the tractor. Spacing of 0.45 m between maize rows and a seed density of 60,000 seeds ha^{-1} (2.7 seeds/linspike meter) were set up.

For the implantation of the treatments with *U. ruziziensis*, 8 kg ha^{-1} of pelletized seeds were used for sowing in the maize row (treatment: inter-row) and 15 kg ha^{-1} for *C. spectabilis*. Considering the climatic risks and its influence on emergence rate and consequently, on cover crop stand, treatments with seeds broadcasted (broadcast before sowing and at the V6) had its sowing density increased by 30%, resulting in 10.4 and 19.5 kg of seeds ha^{-1} for *U. ruziziensis* and *C. spectabilis*, respectively.

Cover species were manually broadcast in the experimental units and after that, the maize sowing occurred. In the treatments called "inter-row", the cover species and maize were seeded simultaneously with the aid of multi-seeder with summer and winter kit, being the seeds of cover species inserted into the wheat box. A 45 cm row spacing between maize-maize was used, with 1 alternating row of cover species, resulting in 22.5 cm between rows of maize-cover crops. For the "broadcast at V6" treatment, when maize was at the V6 phenological stage, cover species was manually broadcast over the ground.

At maize sowing, in the furrow, 300 kg ha^{-1} of chemical fertilizer 5-20-15 (N-P_2O_5-K_2O) was applied. Also, when the maize was at V6 phenological stage, nitrogen fertilization (65 kg ha^{-1} of N) was applied with urea (45% N).

Experimental area was desiccated with glyphosate (1.44 kg i.a ha^{-1}) one day before the implementation of the treatments for weed control. It is noteworthy that in the case of the use of *C. spectabilis*, there are no selective herbicides that can be used to weed management on maize, except in the treatment where the species is established at stage V6. As a result, the experimental units were kept free from weed interference by hand weeding when maize plants were in V2-V4 phenological stage. Disease and insects were monitored and due to Bt technology, no fungicides or insecticides was applied during the experiment. Maize was harvest when grain moisture was around 25% (155 days after sowing), which is usually the stage that farmers harvest the maize off-season in the region.

Evaluations: Yield components of the cover species were evaluated at maize harvesting day, through the plant height and accumulation of green biomass and dry matter. In this same period, the maize spike height insertion and its yield components were evaluated.

Final height of cover species (m): It was obtained with a tape measure in 10 plants/experimental unit by the distance from the soil to the most distant point of the cover plants. The mean values obtained at each EU were considered for the data analysis.

Analysis of green and dry mass accumulation of cover crops (kg ha^{-1}): Plants were collected on the day of maize harvesting, cutting them above the soil surface, in a square area of 0.225 m^2. To determine the green biomass, the sample was weighed on a precision scale and the value extrapolated to hectare. Then, samples were taken to the oven with forced air circulation at 65°C until constant mass and weighed again. Based on the inlet and outlet mass values of the oven-dried samples, the dry matter was determined and the value related to the green mass, thus obtaining dry mass accumulation (kg ha^{-1}) of the cover species.

Spike insertion height (m): It was evaluated with a tape measure, considering the distance from the soil to the main spike insertion. Evaluations were performed in 10 plants/OU and for data analysis, we considered the observed mean value.

Yield components determination of maize: Determination of the final maize stand was obtained by counting the number of plants present in the EU and the value extrapolated to hectare (plants ha^{-1}). For the determination of maize grain yields, 30 random spikes were harvested from each EU, in plants with equidistant spacing (38±2 cm) between plants according to the established initial population. From these spikes, 10 were evaluated for the numbers of row and number of grains/row. For the statistical analysis, mean values observed were used. Also, by multiplying the average of number of rows by number of grains/row, we obtained the number of grains/spike.

Subsequently, the spikes were threshed with the aid of stationary small-plot maize sheller, attached to a tractor. Samples were weighed on a precision scale (1 g) and moisture content was measured by an electronic meter, being the values extrapolated to hectare (kg ha^{-1}), considering the moisture content of 13%.

From each sample, 1,000 grains were counted and weighed to obtain the values of thousand weight grain, corrected for moisture content of 13%. Grain yield/plant was also determined by dividing total yield to the maize population.

Statistical analysis: Data were tabulated and subjected to normality and homogeneity analysis and once the assumptions attended, analysis of variance (ANOVA) was used to verify if there was significant effect among treatments, using the F test at 5% probability ($p<0.05$). When there was significance, means were compared by Tukey test at 5% probability. For the analysis[17] of the data, Sisvar 5.6 software was used.

RESULTS

Table 1 showed that there was an interaction between the establishment methods and cover crop species assessed for the variables: plant height, green mass and dry mass of cover plants.

Cover crop height: Cover crop height, when established at maize stage V6 is reduced by approximately 80 and 65 cm for *C. spectabilis* and *U. ruziziensis*, respectively. *C. spectabilis* presented higher plant height when sown simultaneously with maize (inter-row and broadcast before maize sowing), however, when it is broadcast at V6 stage of maize, the cover crops have their development affected, a result observed by lower cover plant height (Table 2). Maize vegetative growth as a second summer crop is faster due to higher temperature from January and February. Plants close the inter-rows faster, shading the cover crop, affecting its development.

Green and dry mass accumulation of cover crops: Regarding the green and dry mass yield, there is a correlated behavior between the variables.

It can be seen from Table 2 that when sowing cover species in the inter-row and broadcast before maize sowing, *U. ruziziensis* has higher green and dry mass yield than *C. spectabilis*, however when sown at V6 stage of maize, they have similar mass accumulation.

C. spectabilis presented higher amount of dry mass when broadcast before maize sowing (700.00 kg ha^{-1}) compared to broadcast at V6 (44.44 kg ha^{-1}), while for *U. ruziziensis*, an accumulation of 2072.20 and 2144.44 was observed for treatments in the inter-row and broadcast before maize sowing, respectively, with no statistical difference between treatments. However, both were higher than broadcast at V6, which was observed mass accumulation of only 88.89 kg ha^{-1} (Table 2). Later establishment as at maize V6 would allow lower competition among species and also herbicide use to control weed (there is no post emergence selective herbicide to *C. spectabilis*), although, corn development impair cover crops developments and broadcast of cover crops at earlier maize stages should work better.

Table 1: Cover crop development in relation to the establishment method and species intercropped with maize

Variables	Plant height (m)	Green mass (kg ha^{-1})	Dry mass (kg ha^{-1})
C. spectabilis	0.58	2,814.80	401.85
U. ruziziensis	0.66	7,301.82	1,425.18
Inter-row	0.88	8,405.56	1,422.22
Broadcast before maize sowing	0.86	6,480.49	1,266.65
Broadcast at V6	0.13	288.89	66.67
p-value (CS)	0.0038*	0.0000*	0.0000*
p-value (EM)	0.0000*	0.0000*	0.0000*
p-value (CS×EM)	0.0192*	0.0013*	0.0000*
Means	0.62	5,058.31	918.51
CV (%)	9.57	21.57	25.12

*Respectively correspond to significant at 5% of probability ($p<0.05$), CV: Coefficient of variation

Table 2: Interaction between cover crops variables in relation to the establishment methods and cover species intercropped with maize

Variables	Inter-row	Broadcast before maize sowing	Broadcast at V6
Cover crops height (m)			
C. spectabilis	0.95^{Aa}	0.93^{Aa}	0.12^{Ab}
U. ruziziensis	0.81^{Ba}	0.80^{Ba}	0.15^{Ab}
Cover crops green mass (kg ha^{-1})			
C. spectabilis	3,211.08^{Ba}	5,144.44^{Ba}	88.89^{Ab}
U. ruziziensis	9,749.90^{Aa}	11,666.67^{Aa}	488.89^{Ab}
Cover crops dry mass (kg ha^{-1})			
C. spectabilis	461.11^{Bab}	700.00^{Ba}	44.44^{Ab}
U. ruziziensis	2,072.20^{Aa}	2,144.44^{Aa}	88.89^{Ab}

Means followed by different lowercase in the lines and uppercase in the columns, differ by the Tukey test in 5% of probability

Table 3: Maize variables in relation to the establishment method and cover species intercropped

Variables	Maize plant population (plants ha^{-1})	Spike insertion height (m)	Number of rows	Number of grain/row
Cover species (CS)				
C. spectabilis	59412.98	1.27	13.83^{a}	33.50
U. ruziziensis	58024.11	1.25	13.33^{b}	33.92
Establishments methods (EM)				
Inter-row	60184.58	1.23	13.00^{b}	33.62
Broadcast before maize sowing	58564.23	1.25	14.00^{a}	33.13
Broadcast at V6	57406.83	1.30	13.75^{a}	34.38
p-value (CS)	0.1964^{ns}	0.6124^{ns}	0.0077*	0.7467^{ns}
p-value (EM)	0.1171^{ns}	0.0742^{ns}	0.0003*	0.7252^{ns}
p-value (CS×EM)	0.0830^{ns}	0.2324^{ns}	0.0000*	0.7624^{ns}
Mean	58718.55	1.26	13.58	33.71
CV (%)	4.32	4.40	3.01	9.23

*Respectively correspond to significant at 5% of probability (p<0.05), ns: Not significant (p<0.05), CV: Coefficient of variation, Dois Vizinhos-Brazil, UTFPR, 2019

Table 4: Interaction between number of rows of maize in relation to the establishment method and cover species intercropping

Cover species	Inter-row	Broadcast before maize sowing	Broadcast at V6
C. spectabilis	14.00^{Aa}	14.00^{Aa}	13.50^{Aa}
U. ruziziensis	12.00^{Bb}	14.00^{Aa}	14.00^{Aa}

Means followed by different lowercase in the lines and uppercase in the columns, differ by the Tukey test in 5% of probability, Dois Vizinhos-Brazil, UTFPR, 2019

Table 5: Maize yield components in relation to the establishment methods and cover crops intercropped

Variables	Number of grain/spike	Thousand grain weight	Yield	Yield/plant
Cover species (CS)				
C. spectabilis	452.50	291.25	7,317.80	123.17
U. ruziziensis	463.33	294.25	7,520.72	129.61
Establishment methods (EM)				
Inter-row	437.25	288.00	7,510.15	124.79
Broadcast before maize sowing	463.75	297.63	7,075.92	120.82
Broadcast at V6	472.75	292.63	7,671.71	133.64
p-value (EC)	0.5665^{ns}	0.6642^{ns}	0.3689^{ns}	0.1712^{ns}
p-value (FE)	0.2919^{ns}	0.5246^{ns}	0.1010^{ns}	0.0998^{ns}
p-value (ECxFE)	0.1007^{ns}	0.6300^{ns}	0.0741^{ns}	0.5646^{ns}
Mean	457.92	292.75	7,419.26	124.79
CV (%)	9.92	5.69	7.27	8.73

ns: Not significant (p>0.05), CV: Coefficient of variation, Dois Vizinhos-Brazil, UTFPR, 2019

Spike insertion height and maize yield components: Table 3 presents data on spike insertion height and maize yield components. Only the number of rows presents interaction between factors.

It is observed in Table 4 that *C. spectabilis* did not affect the number of rows/spike of maize. However, *U. ruziziensis* established in the inter-row results in fewer rows of grains when comparing the establishment methods and cover species.

In addition to no interaction between the factors, no significant difference was observed when analyzing main effects for the variables plant population, spike insertion height and number of grains-row, with average values of 58718.55 plants ha^{-1}, spike insertion height of 1.26 m and 33.71 grains/row (Table 3).

Table 5 shows that there was no interaction between factors, nor significant statistical difference when analyzing main effects, to the number of grains/spike, thousand grain weight, grain yield and yield/plant of maize. It was reported mean values of 457.92 (grains/spike), 297.75 g (thousand grain weight), 7419.26 kg ha^{-1} (grain yield) and 124.79 g (yield/plant).

DISCUSSION

Height of the cover plants is important in the intercropping system as it can interfere with the mechanical harvesting process of maize. The highest height recorded for *C. spectabilis* in relation to *U. ruziziensis*, when sown together with maize, is related to the morphological characteristics of the species.

According to Sereia *et al.*[18], *U. ruziziensis* is the most commonly used cultivar for intercropping with maize as it has high tillering capacity and tendency to establish closer to the soil, associated with high biomass yield.

The difference in height of the cover plants, observed among the establishment forms (Table 1 and 2), is related to the sowing date and the suppression capacity imposed by maize. Implantation of the cover species together with maize sowing (inter-row and broadcast before maize sowing), favored that the cover crops exhibited greater height in relation to the broadcast at V6 stage of maize. It is noteworthy that the thermal sum in the months of January/February allows faster initial development of maize when grown as a second summer crop, which ends up increasing its ability to compete over plants in the intercrop.

Beyond cover plant height, green and dry mass accumulation better express its development and the difference among treatments. *U. ruziziensis* stood out in dry mass yield, accumulating more than 2,000 kg ha^{-1} in the treatments where it was established at maize sowing. It is worth mentioning that these values may double or triple until the next crop cultivation, depending on the weather conditions or the sowing period. These values are lower than those reported by Richart *et al.*[11], in experiments in northern Paraná-Brazil, which found that in simultaneous sowing of maize and *U. ruziziensis*, forage produces up to 3,555 kg ha^{-1} of dry mass.

It is important to highlight that it is necessary a balance between biomass production and competition, which may affect maize grain yield. Studies by Pariz *et al.*[12] reported that 2,500 kg ha^{-1} of dry mass biomass would already be satisfactory for the intercrop. The lower dry mass yield of *U. ruziziensis* observed in the present study, in relation to other scientific research, may be related to the spacing between maize rows used (45 cm), which provides advantages to maize compared to forage development in intercrop. Oliveira *et al.*[19] verified that with the reduction of the spacing row of maize, it causes a faster crop closure, suppressing the intermediate species by shading. This factor is even more important for a second summer crop, where the higher thermal sum accelerates maize development, resulting in greater competition potential.

Although these values of biomass accumulation are considered low, it is worth to comment that after the maize harvest, *U. ruziziensis* was already established in the area. Thus, there is no need for the farmer to perform new sowing of cover species in this off-season period until the sowing of the new summer crop. During this period, cover plant will continue to accumulate biomass, without the competition exerted by maize, bringing advantages to the production system such as soil protection against erosion and help in weed control. In addition, even if frost occurs at the end of July, the volume of biomass produced compensates for its use.

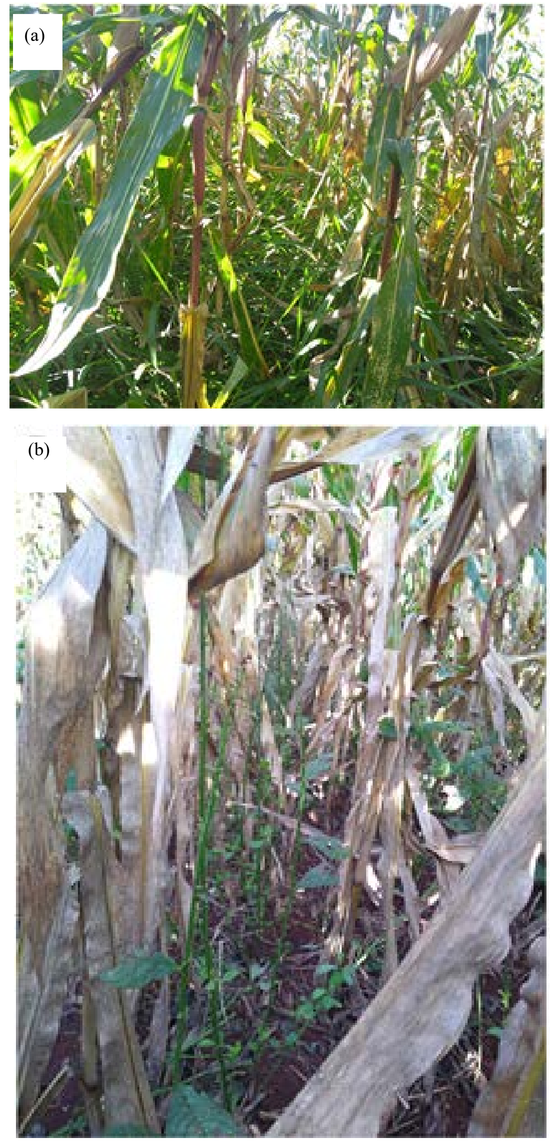

Fig. 3(a-b): Cover crops broadcast before maize sowing with (a) *U. ruziziensis* and (b) *C. spectabilis*
Dois Vizinhos-Brazil, 2018

The lower mass yield of *C. spectabilis* is related to cycle shortening and flowering stimulation due to the lower photoperiod[20] available at this time of the year and also due to the legume senescence observed at the time of maize harvesting, due to its faster cycle (Fig. 3b). *C. spectabilis* is characterized by low carbon/nitrogen ratio, with soluble substances that facilitate the action of microorganisms in its decomposition, thus causing faster release of nutrients to the soil[21].

Mechi *et al.*[22] points out that in conventional production systems, only the residue left by the crop is not enough to increase the levels of organic matter. For this reason, the cultivation of cover crops, with the sole purpose of biomass production is necessary.

The lowest biomass yield of the cover species is observed in the establishment at V6 stage of maize. This can be explained by the competition exerted by maize, since it was already established, having a greater capacity to uptake water and nutrients and shading its inter-rows. The use of reduced spacing (0.45 cm) in maize sowing exerting shading in the inter-row and the period of lowest rainfall observed in May (Fig. 1) are factors that contribute to lower biomass yield of the cover crops.

In addition, the rapid maize growth and development in off-season results in competitive advantages over cover crops. In the other hand, the smaller maize plant population used in the off-season allows a higher radiation incidence on the cover crops, especially after maize senescence and during the process of maize grain moisture content loss, which occurs very slow due to winter weather conditions (shorter days, lower temperature with most days cloudy and rainy), favoring a later biomass accumulation of the cover plants.

Another important maize trait to be noticed is its spike insertion height. There was no influence of the evaluated treatments over this trait, corroborating with Gitti *et al.*[23], who evaluated *Crotalarias* sp. intercropped with maize. High spike insertion height (>1.25 m) is a trait recommended when choosing the hybrid to be used in the intercropping system with other species as this feature can facilitate harvesting.

Average height of the cover plants obtained in the experiment was 0.62 cm (Table 1). Considering the spike insertion height average of 1.26 m, it is possible to infer that there was no interference in the mechanical harvesting process of the maize. Indeed, harvest was done by a mechanical maize harvester and there was no trouble processing maize grain.

Regarding to maize yield components, the observed change in number of rows/spike was also reported by Pariz *et al.*[12], in which the use of *U. ruziziensis* intercropped with maize, reduced the number of grain rows.

Number of rows is defined between V4-V8 phenological stages[24]. During the experiment, it occurred low rainfall in May which associated with inter-row forage competition (mainly for water and nutrients such as nitrogen) resulted in directly influences on the formation of this yield component.

Establishment forms and the intercropping cover species did not influence population of maize plants, possibly due to the fact maize presents faster initial development compared to the cover plants. Maize has a competitive advantage over cover species and has a faster establishment in the system[23].

For maize grain yield, Kappes *et al.*[10] also evaluated the maize second crop intercropping and reported satisfactory yields in 0.45 m row spacing when intercropped with *U. ruziziensis* broadcast sowed and *C. spectabilis* in the sowing row. Ikeda *et al.*[25] also verified in maize intercropping with *Urochloa* spp. cultivars that there was no influence on the maize yield components and grain yield.

Gitti *et al.*[23] evaluated establishment periods of intercropping *C. spectabilis* with maize and concluded that when performing simultaneous sowing of crops, in the inter-rows and at V4 or V7 stages, there is no influence on maize yield. However, Arf *et al.*[26] found in 2 year spike studies that maize intercropping with *U. ruziziensis* and/or *C. spectabilis* has lower yields, on average the intercropping provided an 11.2% reduction in maize grain yield compared to maize in monoculture. According to the researchers, this reduction in yield may occur due to competition between maize and species intercropped by space, light, water and nutrients.

It is believed that the similar values observed between treatments for plant population (maize) and number of grains/row (Table 3), number of grains/spike and thousand grain weight (Table 5) contributed to the maize yield (kg ha^{-1}/plant) did not present statistical difference between the evaluated treatments. Analyzing maize yield variable, the results showed that it is possible to use any treatment (cover species and establishment forms), since it does not interfere with the final maize yield, with no difference between treatments.

However, there is always a trade-off between yield components. Less row number may result in higher grain/row or thousand weight grain. There was a reduction of almost 500 kg ha^{-1} of maize grain yield when the cover species was broadcast before maize sowing. Disposition of random plants in this treatment generated competition with maize, a fact that is not seen when the cover species is sowed in the inter-row or broadcast at V6.

Average maize yield in this study was 7419 kg ha^{-1}, which is higher than the Brazilian (5732 kg ha^{-1}) and Paraná (5749 kg ha^{-1}) average, respectively[1]. Analyzing this study, we see that even in the intercropping system, the yield was higher than the country average. Moreover, treatment with cover crops broadcast at V6 showed very low biomass production, almost turning these treatment as a control (with no cover crops intercropped) showing low effects on maize grain yield.

Grain yield potential in the intercropping experiment was high, obtaining satisfactory yield for the off-season. In addition, intercropping cover crops can provide great benefits, making cultivation more sustainable and environmentally friendly, being necessary further dissemination of long-term benefits that comes from this productive system, in order to become a reality among farmers. Furthermore, new studies should evaluate under sowing at earlier stages of maize, such as V1- V2, since perhaps at this stage the cover plants can be established before the maize rows closure, making the intercropping system feasible.

CONCLUSION

Cover crops height and dry mass yield were influenced by establishment methods, being cover crops intercropped at maize V6 phenological stage not recommended. Dry mass yield was higher for *Urochloa ruziziensis* when sown simultaneously with maize and higher than *Crotalaria spectabilis*. Maize yield was not affect by different establishment methods and cover crops species.

SIGNIFICANCE STATEMENT

This study discovered the rapid canopy closure of maize grown as a 2nd summer crop impairs cover crops (*Urochloa ruziziensis* and *Crotalaria spectabilis*) development when intercropped at maize V6 phenological stage and seed broadcast at earlier stages is recommended. Moreover, results shows no effects for both studied cover crops and methods of intercrop over maize grain yield with further good biomass yields, which result in many benefits for the system (soil protection and weed suppression). These results are very important once most of farmers do not adopt this system afraid of interspecific competition risks and its effects on maize grain yield. Moreover, this study will help the researchers to go further in the studies aiming to reduce intercrop interspecific competition and improve its benefits through management.

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