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Effect of oat and brachiaria intercropped with off-season maize in the grain production and biomass of green manure

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This study aims to determine the ideal time of green manures deployment and assess what kind of green manure will produce a favorable quantity of mass for the farming without interfering in the maize production. The experiment was conducted in Toledo - PR in 2013. It was designed in randomized blocks, in a factorial scheme (2 × 3 + 1) with 4 replications; the first factor is the species of intercropped coverage (*Avena strigosa* and *Brachiairia ruziziensis*), the second factor is the time of implementation of green manures intercropped with maize according to the phenological stages of the crop (VE, V4 and V8), and the single maize is the control treatment. The evaluated parameters were: Diameter of the stem base, ear insertion height, diameter of the base, middle and apex of the ear, ear length, number of grains per row and number of rows per ear, 1000 grain weight and productivity, and in the green manure the dry matter production. The results showed that the use of intercropping system did not affect maize yield, as well as the time of implementation of green manure. The more delayed the sowing of brachiaria, the lower its dry matter production; on the other hand oats showed opposite results, because the later its seeding is performed, the better are the results, presenting their normal development cycle. So the most feasible kind of green manure to be used according to the dry matter production is *B. ruziziensis* in the first sowing season (VE), being a profitable and favorable system for soil cover, without affecting maize productivity.

Key words: *Zea mays*, *Brachiaria ruziziensis*, *Avena strigosa*, crop-livestock integration.

INTRODUCTION

To be enabled technically and economically, the direct planting system (DPS) must not be focused only as an alternative method of seeding and soil management. It needs to be treated as a production system, comprising an ordered complex of agricultural practices interrelated and interdependent that include, in addition to not soil disturbance, diversified crop rotation, the use of cover crops to build and maintain stubble on the land and, more

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recently, the crop-livestock integration (Muzilli, 2000). Therefore, for the consolidation and success of the DPS, it is of the uttermost importance the crop establishment for the production of stubble, in adequate amount for soil cover, which reveals a problem in warmer regions, because of the accelerated process of decomposition (Chioderoli et al., 2010).

The soil cover crops are important components in agricultural systems, since they improve the physical, chemical and biological soil conditions. The presence of stubble on the ground reduces soil erosion and reduces weed infestation (Conte, 2007; Flores, 2008; Souza et al., 2009). Thus, it is worth to reinforce the concern in producing high amounts of stubble in order to maintain the soil protected for a longer period of time. The green manure is one of the indicated techniques used to improve soil fertility, consisting in vegetable cultivation and incorporation or not of its green mass to the soil. The choice of the most suitable green manure for each situation is very important, because the characteristics of each species of plant and its productive potential of dry matter must be known (Emater, 2002).

As the maize crop has low soil coverage levels with stubble, favoring soil degradation and reducing crop yields, other forms of coverage are being studied, such as the intercropped system of production with green manures. The intercropping is a system in which in a same area two or more species are implanted, coexisting together, for all or part of its cycle, allowing increase in productivity (Portes et al., 2003). Recently the intercropping may also be known as "mixture" of maize with other grasses, inclusive in autumn-winter (Soares et al., 2000).

The intercropping of grain-producing crops and tropical forages is possible due to the difference of time and space, in the accumulation of biomass among species (Kluthcouski and Yokoyama, 2003). According to Jakelaitis et al. (2004), the existing competition between species can make the intercropping impracticable. However, the knowledge of the species behavior, in the competition for factors of production, is of great importance for successful pasture formation in the autumn-winter period and for the satisfactory production of grain-producing crops.

As one of the most cultivated forages in the Brazilian savanna, brachiaria has been used to compose the intercropping, especially with maize, without causing damage to grain production (Ceccon et al., 2005). The maize intercropping with brachiaria allows the maintenance of maize as an economic cash crop in the off-season and the brachiaria adds coverage to the system for producing mass after the maize harvest until the time of desiccation prior to the next crop sowing (Ceccon, 2007). Being often used as green manure, oat has great importance for agriculture and cattle raising, due to its resistance to drought, low incidence of pests and diseases, low cost and high forage production (Pitol, 1988). Amado et al. (1999) observed a greater supply of nitrogen to the maize when it was preceded by oat + vetch intercrop, which promoted increase in maize yield. However, black oat has no evidence intercropping with maize, being used mostly as preceding maize crop or soybeans (Lázaro et al., 2013) which highlights the importance of the work.

The off-season maize intercropped with green manure provides great amounts of stubble for soil cover and consequently greater benefits to crops. For the intercropping becomes profitable, knowing the ideal time of sowing green manure not to interfere with the productivity of the main crop is of the uttermost importance to maximize agricultural production. Thus, this study aims to determine the ideal time to the deployment of green manures and assess what kind of green manure will produce a favorable quantity of mass to the cultivation, along without interfering in maize production.

MATERIALS AND METHODS

The experiment was conducted in 2013 on a property with direct seeding in the soybean stubble, located in Dez de Maio, a district of Toledo city- PR, latitude 24°42'28.71 "S, longitude 53°54'34.70" W, at an altitude of 504 m. The climate in the region, according to Köppen classification is Cfa, mesothermal humid subtropical, with hot summers with a tendency of rainfall concentration, with an average temperature above 22°C, winters with little frequent frosts with average temperatures below 18° C, without defined dry season. The average rainfall in the region is 1800 mm per year (Rubel and Kottek, 2010). The soil of the area used is classified as clayey eutroferric Red Latosol (Embrapa, 2012).

The experimental design adopted was in randomized blocks in a factorial design (2×3+1) with four replications. The treatments consisted of two green manures, *Avena strigosa* and *Brachiaria ruziziensis*, and three sowing seasons of green manures with the presence of a control. The size of each plot was 9×10 meters, totaling 90 m², with 2520 m² of total plots of land. The plots were composed of 10 lines of maize, with the sampling being done with the six half lines, having a useful area of 23.4 m².

The green manures were sown in predetermined stages of maize, VE (emergence of maize), V4 (four fully developed leaves) and V8 (eight fully developed leaves), being arranged in the following treatments: T1: Control (single Maize); T2: Seeding of *Avena strigosa* between rows of maize in emergency; T3: Seeding of *Avena strigosa* between rows of maize in V4 stage; T4: Seeding of *Avena strigosa* between rows of maize in V8 stadium; T5: Sowing of *Brachiaria ruziziensis* between rows of maize in emergency; T6: Sowing of *Brachiaria ruziziensis* between rows of maize in V4 stage; T7: Sowing of *Brachiaria ruziziensis* between rows of maize in V8 stadium.

The off-season hybrid maize AG 9010 YG was used, with characteristic super precocity; it can flourish before possible droughts or frosts and hence ensuring the best yield. Furthermore, it has modern plant architecture, with upright leaves and lodging resistance, this way it allows higher density and uses smaller spacing between rows, increasing the plant population (Agroceres, 2013). The used green manure plants were both *Poaceae*, being black oat (*Avena strigosa*), Embrapa 29 Garoa, with 98% of purity and 80% of viable seeds and *Brachiaria ruziziensis* cv. Ruziziensis of the company Sementes Mega 100®, with 94.9% of purity and 80% of viable seeds with sowing density of 40 viable seeds and 15 to 20 viable seeds per meter, respectively.

Soil correction was used with 200 kg ha^{-1} NPK formulation 08-20-20. The maize sowing was done on February 2^{nd}, 2013 and the final population density of maize on the desired experiment was 59,000 plants ha^{-1}, with 5.3 plants m^{-1} linear, with space between rows of 0,9 m. The green manures of cover were sowed in a single row between the maize line. The control of weeds in pre-emergence was performed with the use of the herbicides glyphosate and atrazine. An application of insecticide made of imidacloprid + beta-cyfluthrin was held to control bugs in the maize at seven days after emergence (DAE). The application of nitrogen in 100 kg ha^{-1} was made when the maize crop was in V4 stage. The evaluation of the experiment occurred in the R7 stage of the maize, in other words, when the grains are already physiologically mature.

Among the evaluations, ten random plants were used within the useful area of the plot, collecting the stem base diameter data, ear insertion height, diameter of the base, middle and apex of the ear, ear length, number of kernels per row and number of rows per ear. As for the diameter of stem and ear parameters, evaluations were carried out with the aid of a digital caliper. For the parameters height of ear insertion and ear length, we used tape measure, measuring plant from the base to the ear height of stem node and measuring from base to apex of the ear, respectively. The parameters number of rows per ear and grains per row, the count was made individually.

After collecting the data from the above analysis, the harvest of the remaining useful area of the plot was held, when the maize was found in point of harvest, in other words, with 14% of humidity. Subsequently, the threshing of the material was performed, with the aid of a thresher coupled to the tractor. The threshed maize samples were submitted to weighing to determine the yield in kg ha^{-1}. Of these samples, 1000 seeds were counted to determine the weight of them. Both weight measurements were performed on precision scales.

For the green manures, it was held the collection of 2 linear meters (1.8 m^2) of green plant material, since the green manures were seeded in line. These materials were added in paper bags and then taken to air forced circulation stove for drying, at a temperature of 60°C for 72 h. The samples after being drought were weighed on a precision scale and the values were transformed for kg ha^{-1} of dry matter.

The data were submitted to variance analysis and when significant, they were compared using the Tukey averages test at 5% of significance, with the help of statistical program CoStat 6.4 (Cohort Software, 2003).

RESULTS AND DISCUSSION

The qualitative components of maize: stem diameter (SD) and ear insertion height (EIH) showed no significant differences ($p > 0.05$) showing that the covers and the sowing seasons of green manure did not influence the development of maize as shown in Table 1. Table 2 shows that ear mean diameter (EMD), ear length (EL), number of rows per ear (NRE), number of grains per row (NGR) and number of grains per ear (NGE) have no significant difference ($p > 0.05$). Green manures did not interfere with the development of the plant, but through competition among plants for nutrients, water and light, the 1000 grain weight (TGW) has achieved significant results ($p < 0.05$) as the type of coverage.

Similar results were found by Tsumanuma (2004) when studying the combination of three species of brachiarias (*Brachiaria decumbens*, *Brachiaria brizantha* and *Brachiaria ruziziensis*) being sown in two seasons (V0 and V4 stage of the maize). No statistical difference were found between treatments for the following variables: Plant height; leaf area index; diameter of the stem; leaf analysis; number of grain rows; number of grains per ear; 1000 grains weight and productivity.

Gimenes et al. (2010) observed that sowing *B. brizantha* after 15 days ensured larger stem diameter, 1000 grain weight and productivity, being indifferent statistically when compared to single maize cultivation, corroborating this work, in which the intercropping becomes feasible for the maize.

According to Table 3, the productivity of maize (PROD) showed significant differences ($p < 0.05$) only in blocks, which justifies the use of randomized blocks design (RBD), as well as the number of grains per row on Table 2. Batista et al. (2011) when assessing the simultaneous cultivation in a Red Ferric Latosol between rows of maize cv. DKB 390 with four forage species (*Brachiaria brizantha* cv. Marandu, *B. decumbens* cv. Basilik, *B. ruziziensis* cv. Comum and *Panicum maximum* cv. Tanzania), found that grain yield was not affected by the presence of intercropping.

As for the dry matter production of green manure, both the type of coverage and the implementation season had an effect on it significantly ($p < 0.05$). A meaningful interaction also occurred for the type of coverage x time (Table 3). The 1000 grain weight had influence according to the type of cover used in the winter maize intercropping, where the single maize (control) had the best result and in brachiaria coverage obtained the lowest mass. The sowing of the intercrops did not show significance ($p > 0.05$) on the 1000 grain weight (Table 4). The results coincide with Spader and Vidal (2000) who found that light interference caused by the intercropped plant affect the photosynthetic rate of the maize plant; thereby reducing the amount of starch stored in the grains and therefore reducing the mass of grains. Gimenes et al. (2008) obtained a reduction of the mass of the 1000 grains weight of maize when it was intercropped with brachiaria, pointing to this reduction the competition between plants and soil and climatic conditions during this period. In the case of Table 4, the weather conditions were favorable for maize crop (Figure 1).

The productivity of off-season maize intercropped did not show any significant differences ($p > 0.05$) between treatments (Table 5). One of these facts is that the maize hybrid used in the trial has high competitiveness with other plants. The productivity results obtained are in line with Crusciol and Borghi (2007) who observe that there was not significant reduction in maize cultivation for the single maize intercropped, commenting so, that intercropping maize with brachiaria can be performed due to time and space, being different the accumulation of biomass for the species.

The sowing time of the green manures had no

Table 1. Summary of the variance analysis of the qualitative components: stem diameter (SD) and ear insertion height (EIH). Toledo – PR, 2015.

Variance factors	M.S.	
	SD	EIH
Coverage	0.008^{ns}	5.255^{ns}
Season	0.004^{ns}	2.620^{ns}
Coverage x Season	0.004^{ns}	11.745^{ns}
Blocks	0.017^{ns}	31.594^{ns}
Average	cm	
	2.089	84.222
CV (%)	6.339	4.457

^{ns}, Non-significant.

Table 2. Summary of the variance analysis for the production components: Ear mean diameter (EMD), ear length (EL), number of rows per ear (NRE), number of grains per row (NGR), number of grains per ear (NGE) and thousand grain weight (TGW). Toledo – PR, 2015.

Variance factors	M.S.					
	EMD	EL	NRE	NGR	NGE	TGW
Coverage	0.017^{ns}	0.113^{ns}	0.463^{ns}	0.066^{ns}	672.335^{ns}	1,034.43*
Season	0.001^{ns}	0.005^{ns}	0.063^{ns}	0.303^{ns}	246.923^{ns}	25.926^{ns}
Coverage x Season	0.003^{ns}	0.105^{ns}	0.127^{ns}	1.027^{ns}	346.065^{ns}	35.516^{ns}
Blocks	2.79^{ns}	0.239^{ns}	0.341^{ns}	9.194*	884.925^{ns}	17.046^{ns}
Average	cm		n°		g	
	4.464	16.144	14.667	30.658	449.574	312.596
CV (%)	2.411	4.643	3.851	4.890	6.487	4.061

^{ns}, Non-significant; *, significant at 5%.

Table 3. Summary of variance analysis for grain productivity (PROD) and dry matter production of the intercropped covers (DM). Toledo – PR, 2015.

Variance factors	M.S.	
	PROD	DM
Coverage	123,473.320^{ns}	30,173,333.000*
Season	68,645.055^{ns}	4,154,533.300*
Coverage x Season	25,804.374^{ns}	6,547,866.7*
Blocks	279,214.910*	482,785.190^{ns}
Average	Kg ha^{-1}	
	5,480.836	1,300.000
CV (%)	4.733	34.161

^{ns}, Non-significant; *, significant at 5%.

significant influence ($p < 0.05$) on maize productivity, since its development is slower compared to maize's (Table 5). Even in the simultaneous sowing of both crops, the maize, for being a large-sized plant and with accelerated growth, excels in the light of the forage; in this way, maize productivity is not affected.

Batista et al. (2011) conclude that by having a slow growth, brachiaria even germinating along with maize cannot compete for water, light and nutrients and its development stagnates. The authors also relate that the forage only back receiving lot of light and water when the maize mature, which makes the dried leaves reduce shading and prevent the ingress of water. Pequeno (2006) conducted a similar experiment, using five arrangements of brachiaria sowing intercropped with maize, getting no significant results between treatments

Table 4. Thousand grain weight results (TGW) of the off-season maize intercropped with different green coverage at different times of deployment of the intercrop (phenological stages of maize). Toledo – PR, 2015.

Variance factors		**TGW (g)**
Coverage	Control	322.1[a]
	Oat	312.2[ab]
	Brachiaria	303.4[b]
Season	VE	314.3[a]
	V4	312.0[a]
	V8	311.5[a]
MSD		12.9

Averages followed by the same letter in the column, do not differ significantly at 5% in the Tukey test.

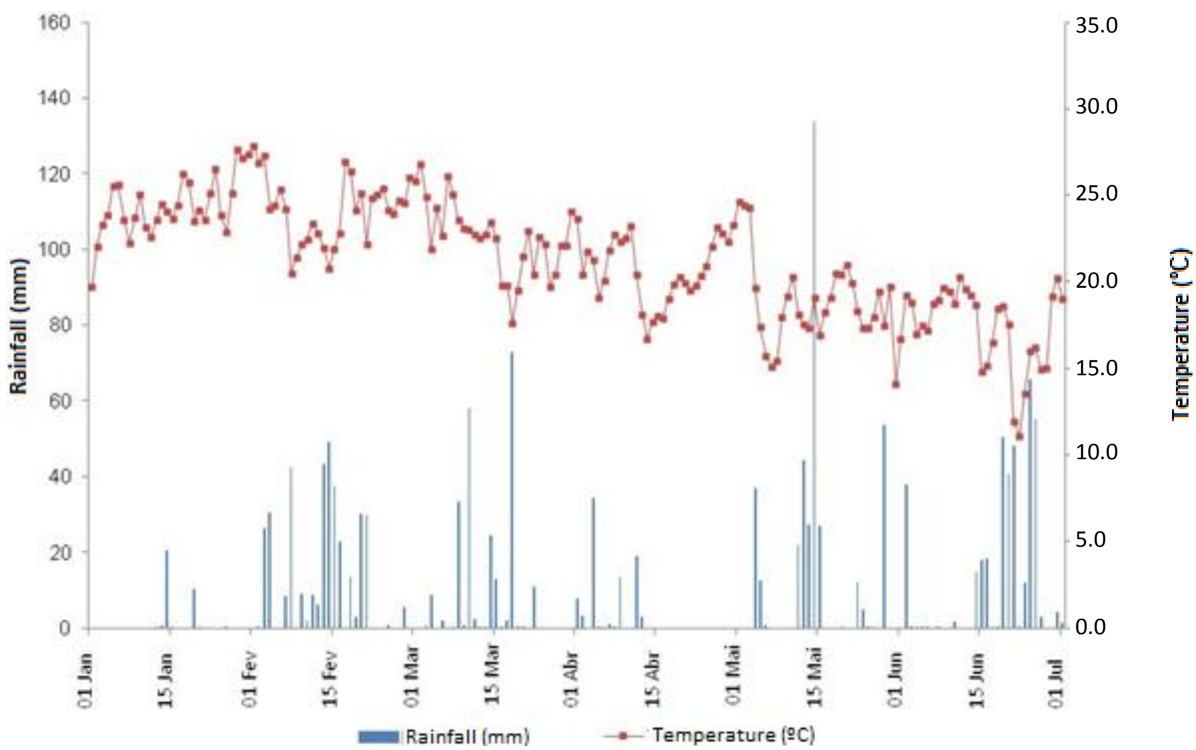

Figure 1. Weather conditions (Rainfall and Temperature) of the experimental period in 2013. Toledo - PR, 2015. Source: Weather Station from PUCPR - Campus Toledo.

($p > 0.05$), concluding economically that simultaneous sowing of brachiaria with maize is the most recommended, because it reduces the operating system in cultivation, thereby reducing costs.

Disagreeing with the results, Gimenes et al. (2008) obtained better production results in single maize compared to intercropped maize, but with acceptable loss levels. This proves the viability of maize intercropped system with forages for the low and medium population density, 10 and 15 plants per linear meter, respectively. Chioderoli et al. (2010) also achieved significant production results, both for the time of implementation of green manures and also for the type of coverage, concluding with their experiment that the most indicated green manure is *B. ruziziensis* sown at the time of the maize coverage (V4).

The dry matter produced by green manure had significant results ($p < 0.05$) as for the type of coverage and the time of their sowing (Table 6). The coverage that achieved greater dry matter production in conjunction

Table 5. Grain production of off-season maize (PROD) intercropped with different green coverage at different times of deployment of the intercrop (phonological stages of maize). Toledo – PR, 2015.

Variance factors		PROD (kg ha^{-1})
Coverage	Control	$5,594.1^{a}$
	Oat	$5,398.4^{a}$
	Brachiaria	$5,449.9^{a}$
Season	VE	$5,525.6^{a}$
	V4	$5,449.9^{a}$
	V8	$5,567.0^{a}$
MSD		264.5

Averages followed by the same letter in the column, do not differ significantly at 5% in the Tukey test.

Table 6. Dry matter production of oat and brachiaria depending on the sowing season. Toledo – PR, 2015.

Interaction		**Season**			**MSD**
		VE	**V4**	**V8**	
		Kg ha^{-1}			
Coverage	Control	0^{bA}	0^{bA}	0^{bA}	0
	Oat	580^{bB}	760^{bB}	$1,160^{aA}$	185.2
	Brachiaria	$5,100^{aA}$	$3,110^{aB}$	990^{aC}	1,412.0
MSD		946.2	1,473.5	351.6	

Averages followed by the same letters, lowercase in the columns and uppercase in the lines, do not differ between each other by Tukey test at 5% probability.

with the sowing time was brachiaria in VE stage of the maize. As for the sowing season, it can be observed that the maize had direct influence on the development of green manures, especially regarding the intercepted light intensity. Thus, the later the seeding is performed, in other words, the maize crop in a more advanced stage, the lower the brightness that the green manure will receive and obtaining smaller plant development and consequently, smaller amounts of biomass. Thereby, the sowing of green manure in VE's stage of maize showed better biomass production responses of brachiaria. These values are opposed to the culture of the oat, because the more delayed its implementation, it is found closer to its sowing, and consequently shows higher vegetative development.

The use of brachiaria intercropped with maize has shown good results, not reducing the production of maize grain and getting a good soil cover with dry matter of brachiaria as reported by Ceccon (2008). The same author also states that the presence of grasses does not affect the maize production, among them *B. ruziziensis* has stood out by presenting decumbent growth habit, the highest closure between lines and better soil cover.

Corroborating the results of this experiment, Resende (2008) conducted experiments with different population densities of brachiaria and noted that there were not very different results between the densities. This probably occurred due to large plastic capacity of this species in terms of vegetative growth, having low population but with greater number of tillers, offsetting the average density.

Richart et al. (2010) observed the different dry matter production responses of *B. ruziziensis* sown at different times intercropped with corn, obtaining values similar to those obtained in this experiment. The authors report that there was a declining production curve as the later sowing, in other words, simultaneous seeding resulted in higher dry matter production. Borghi et al. (2007) noted that the sowing time of brachiaria influences its dry matter production, and they explain this fact through the competition caused by maize with brachiaria. This occurs due to the interception of light radiation, which promotes physiological changes in the plant, as the photosynthetic metabolism. Thus, the plan anticipates its development cycle, reducing the production of leaves, stems and sheaths.

The oat has no evidence intercropping with maize, being used mostly as preceding crop to maize or soybeans (Lázaro et al., 2013). This is due to the fact that oat is very influenced by maize and also the planting of this species along with maize or even the V8 stage of it, is out of its sowing season. Thereby, oat will reduce its vegetative cycle and then start the reproduction and consequently, biomass production will be lower. The production of dry matter varied according to implementation time, as found by Pequeno (2006) with a difference of production between the seasons, which suggests the planting of cover crops to maize simultaneously, reducing the number of agricultural operations and, above all, achieving higher dry matter production.

Therefore, the later was the sowing of brachiaria, the lower was the production and such results corroborate Tsumanuma (2004), pointing out that late sowing affects in a bad way the initial development and the accumulation of dry matter by brachiaria, caused by water competition rate, nutrients and light, in which maize has high efficiency.

Conclusion

According to the results obtained through this study, it can be concluded that there was no interference in maize yield as for the intercropping with the covers, being a viable practice to the farmer. The coverage best suited for intercropping with maize is brachiaria sown V0 stage, because it presents a greater dry matter production at the end, providing a greater soil cover and a lower cost of production. As for the green coverage sowing season, both of them caused no decrease in productivity of maize; therefore, the first sowing season is the most profitable, because it provided greater development of brachiaria, resulting in a higher production of biomass and lower production costs.

Conflict of Interest

The authors have not declared any conflict of interest.

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