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WEEDS SUPPRESSION AND AGRONOMIC CHARACTERISTICS OF MAIZE CROP UNDER LEGUMINOUS CROP RESIDUES IN NO-TILLAGE SYSTEM

[SUPRESIÓN DE ARVENSES Y CARACTERÍSTICAS AGRONÓMICAS DE MAÍZ CULTIVADO SOBRE LOS RESIDUOS DE CULTIVO DE LEGUMINOSAS EN UN SISTEMA DE LABRANZA MÍNIMA]

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SUMMARY

This trial aimed at testing the leguminous *Mucuna deeringiana, Cajanus cajan and Stylosanthes capitata e macrocephala* before corn development and weeds incidence. The leguminous species were sown in October 2007 with a control treatment without legumes (fallow) in 4 x 5 m plots with five replications each, totaling 20 plots. At 90 days, plants were grazed and maize, 15 days after grazing, was planted on the wastes. The seedling emergence and plants growth were evaluated, besides the weeds incidence during culture development. At last, the experimental design was completely randomized and the means were compared by Scott-Knott at test 5 % of significance. The studied cover plants showed an efficient control over weeds and did not interfere in a negative way on the maize crop. Thus, it is an alternative to the integrated management of species concerning the green manure and crop rotation in no-tillage system for the Western region of Paraná.

Keywords: Green manure; *Mucuna deeringiana; Cajanus cajan; Stylosanthes capitata e macrocephala*; cover crop.

RESUMEN

Se examinó el efecto de las leguminosas *Mucuna deeringiana, Cajanus cajan y Stylosanthes capitata e macrocephala*, desarrolladas antes del cultivo del maíz, sobre la incidencia de especies invasoras. Las leguminosas fueron sembradas en octubre de 2007 con un testigo sin leguminosas (barbecho), en 20 parcelas de 4 x 5 m, con cinco repeticiones cada una. A los 90 días después de la siembra, las plantas fueron segadas y el maíz sembrado 15 días después sobre los residuos. La presencia de plántulas de maíz y el crecimiento de las mismas, además de la incidencia de arvenses durante el desarrollo del cultivo, fueron evaluados al inicio del cultivo y cada 30 días. El diseño experimental fue completamente al azar y los promedios de las variables fueron comparados por la prueba Scott-Knott con un 5% de significancia. Las plantas de cobertura estudiadas presentaron eficiente control de arvenses y no interfirieron de forma negativa sobre el cultivo del maíz, siendo una alternativa para el manejo integrado de especies en la práctica de abonos verdes y la rotación de cultivo en el sistema de siembra directa (sin labranza), para la región del Oeste del Paraná.

Palabras clave: Abono verde; *Mucuna deeringiana*; *Cajanus cajan*; *Stylosanthes capitata e macrocephala;* rotación de cultivos.

INTRODUCTION

Agriculture has undergone great changes and producers are always looking for monitoring trends and developments in technological and economic areas (Karam *et al*., 2008), with new and sustainable concepts as time passes by, in order to improve productivity and promote environmental performance. In this context, the no-tillage system associated with the practice of crop rotation and a capacity of producing wastes has been studied. Practices such as the addition of cover crops in this system provide benefits, which help in maintaining or improving the chemical, physical and biological soil conditions. As well as the control of weeds, diseases and pests, it is also an increase of nutrients to the next crop. The use of cover crops in soil has been a strategy to increase the agroecosystems sustainability, which also improves the economical crops, soil and environment. So, it comes as an economic, available and environmental sustainable alternative (Gamma-Rodriguês *et al*., 2007).

However, the interactions among cover crops and crops, especially when weed control is the main issue for both physical and allelopathic effects of cover crops, are poorly studied. This knowledge can assist in a suitable planning of crop rotation. Such practice may be important in controlling pests, diseases and weeds and as an alternative to manage soil fertility, due to its capacity to recycle nutrients from the topsoil and those which have percolated along horizons below it (Borkert *et al*., 2003).

The weed control is one of the main benefits of crop rotation, since some species occur and develop better in certain crops than others, due mainly to differences in cultural practices and vegetation cycles (Souza and Pires, 2002). Green manure is a renewable source of manuring as it makes the agricultural system sustainable. The leguminous plants make part of this system, mainly because they have better wastes, due to the fact that these plants fix nitrogen from the air and provide part of it to the next crop. Thus, the study of leguminous species is an alternative to reduce the intensive application of chemical fertilizers.

On the other hand leguminous and other species used as cover crop can release and add chemicals to the system. These substances, known as allelochemicals, can cause beneficial or detrimental effect on other species. This phenomenon is known as allelopathy (Rice, 1984) and is important to be observed when a cover crop is inserted, since there is a species-specific effect, which can inhibit both weeds and crop. The investigation of plants with allelopathic activity represents an alternative to the intensive application of pesticides on crops, as it reduces the environmental pollution.

The maize culture gives sustainability to the production systems, mainly through crop rotation (Conselho de Informações sobre Biotecnologia, 2007). As corn is a grain that asks for a high demand of nitrogen, there is a positive answer in its presence. It also has potential to be included in rotations with leguminous crops and can bring a positive impact on their productivity.

Hence, this paper aimed at analyzing leguminous cover crops as dwarf mucuna [*Mucuna deeringiana* (Bort.) Merr], stylosanthes (*Stylosanthes capitata* and *macrocephala*) and dwarf pigeonpea (*Cajanus cajan* L.), used as cover crops on emergence and development of maize (*Zea mays*) and weed species of broad and narrow leaves, especially morning-glory (*Ipomoea* spp.) arrowleaf sida (*Sida rhombifolia* L.) and beggarsticks (*Bidens pilosa*). It also aimed at generating and validating information that contributes to the agroecosystem sustainability and allows the incorporation of green manure in production units.

MATERIAL AND METHODS

The experiment was carried out in a farm, western Paraná, in the municipality of Braganey, whose geographic coordinates are 24°49'03" S latitude; 53°07'11" W longitude and 643 m of altitude, during 2007/2008 agricultural year. The soil is classified as Eutroferric Red Latosol, with average annual rainfall of 1,600 mm and average annual temperature of 20 °C. The studied area has been cropped under no-tillage system with soybean/wheat management for about ten years. Soil preparation occurred under minimum tillage (one chiseling + a leveling harrow), since soil was under compaction.

Campo Grande variety was used for stylosanthes seeds, given by Embrapa Beef Cattle, Campo Grande-MS. The seeds of dwarf mucuna and dwarf pigeonpea were acquired at Chopinzinho Seed Company in Chopinzinho city, Paraná. The leguminous were sown with approximately 20 seeds m^{-2} of dwarf mucuna, 50 seeds m^{-2} of dwarf pigeonpea and 70 seeds m^{-2} of stylosanthes. They were sown in an experimental area, in October, 2007, in plots of 4 x 5 m, with one meter between plots. The leguminous seeding was by throwing, incorporated into soil with a hoe, without fertilization.

There were four treatments, three leguminous and one control (fallow). The experimental design was completely randomized with five replications per treatment in the field. The products were sprayed with insecticide metamidafós (Tamaron ®) at a 600 mL ha^{-1} dose, on cover crops whenever necessary, especially to control *Diabrotica speciosa*, in a total of two pulverizations. In the early flowering stadium, the plants was cut down with a planter machine to cut down the remains, so that straw remained on the plot that corresponds to the treatment.

It was used the hybrid Pioneer 30R32 corn, traditional for cultivation during second harvest. Firstly, the seeds were submitted to germination tests in laboratory, with 92% of germination.

Sowing was with a rattle, on February, 03rd, 2008, on the leguminous remains, 15 days after cutting, in the chosen plots of a no-tillage system. The distance between rows was 80 cm, while six seeds per meter were used for density. Fertilization was 350 kg ha^{-1} urea in the seeding formula 10-20-20 (NPK) and 140 kg ha^{-1} in cover. The control received the same preparation as the other treatments, but its area remained under fallow (development of natural vegetation). The seedling emergence of corn was daily registered, starting at 5th day after sowing and going up to a constant number of seedlings, which occurred 20 days after sowing. According to these data, the emergence speed (ES), the emergence percentage (EM%) and the emergence speed index (ESI) were also determined.

The ES was calculated according to Edmond and Drapala (1958), they consider that the shortest treatment, in relation to seedling emergence, showed the highest emergence rate, therefore, a lower mean of ES:

$$ES = \frac{(N_1E_1) + (N_2E_2) + ... + (N_nE_n)}{E_1 + E_2 + ... + E_n}$$

where:
ES = emergence speed;
$E_1, E_2 ... E_N$ = number of normal seedlings, registered on the first count, the second count, (...) until the last one;
$N_1, N_2 ... N_N$ = number of days from sowing until the first, the second, (...) and the last count.

The results were expressed in number of days it takes the seedlings to emerge. The ESI was calculated according to Maguire (1962):

$$ESI = \frac{E_1}{N_1} + \frac{E_2}{N_2} + ... + \frac{E_n}{N_n}$$

where:

ESI = emergence speed index;
$E_1, E_2 ... E_N$ = number of normal seedlings registered on the first count, the second count, (...) until the last one;
$N_1, N_2 ... N_N$ = number of days from sowing until the first, the second, (...) and the last count.

The weed incidence was evaluated during maize development, at 30 and 60 days after sowing and at harvest. The survey of weed incidence consisted of four randomized samples per plot, with a randomized throwing of squares, using a 0.50 x 0.50 m metal frame, so that the internal area was 0.25 m^2.

The weeds found within the frame were counted and separated into broad and narrow leaves, plus the counting and specific identification of *B. pilosa* species as: morning-glory and arrowleaf sida. The identification was made according to Lorenzi (1994) and Kissmann (1997). Based on the averages of weeds per treatment, the percentage of reduction was calculated in relation to the control. The results were submitted to the analysis of variance and mean comparison was obtained by Scott-Knott test at 5% significance, according to SISVAR software (Ferreira, 2000).

RESULTS AND DISCUSSION

The evaluations of weed incidence during corn development were made for broad and narrow leaves, so that among the broadleaf species, *Bidens pilosa*, *Ipomoea* sp and *Sida rhombifolia* were identified.

The averages of weeds incidence are presented (Table 1) during corn development at 30 and 60 days after sowing only for broadleaf species and *Bidens pilosa*, since only they differed significantly.

It is observed that, at 30 days after corn sowing, the control showed the greatest number of weeds, for both broadleaf and *Bidens pilosa* (Table 1). It is also important to emphasize that the treatment with stylosanthes had the lowest number of broadleaf plants and *Bidens pilosa*, even though the treatment with the least amount of biomass had been left on soil. At 60 days after sowing, for broadleaf, the control has also shown a higher number of weeds when compared to the other treatments, although they have not differed among themselves. For *Bidens pilosa,* there was no significant difference among treatments, however, the control has shown the highest value of incidence.

In both evaluations, during corn development, the control had the greatest average number of weeds, which meant that the treatments with leguminous as *M. deeringiana, C. cajan* and S. *capitata* and *macrocephala* were efficient in controlling such species. Lorenzi (1984) stated that *Mucuna aterrina* has a strong and continuous inhibitory effect on *Cyperus rotundus* and *B. pilosa* and this action is possibly allelopathic. Weih *et al*. (2008) highlighted the possibility of using the allelopathic activity as an alternative to the application of chemical control for suppression of weeds in agroecosystems. Favero *et al*.

(2001) studied the changes in the population of spontaneous plants associated with leguminous cover crops, which are: *Canavalia ensiformis* DC, *Canavalia brasiliensis*, *aterrina Mucuna*, *Dolichos lablab* and *Cajanus cajan*. They concluded that *Canavalia brasiliensis*, followed by *Mucuna aterrina* and *Canavalia ensiformis* DC were the species with the highest biomass yield. *Mucuna aterrina* showed the greatest potential for soil coverage and weeds suppression.

In Table 2, there are significant results for the incidence of broadleaf plants and *Bidens pilosa* during corn harvest.

It is observed that for both broadleaf and *Bidens pilosa*, the control showed the highest number of weed species. These data of weed incidence indicate that the suppressive effect on weed community continues even after corn development. Calegari *et al*. (1992) stated that the important point is that cover crops let free of weeds not only at graze time, but that their wastes remain for longer, in order to prevent such infestation for the next crops. During the analysis of reduction percentage of weed incidence, in relation to the control by leguminous, it was observed that the greatest reduction was caused by *C. cajan*, followed by *M. deeringiana*, *S. capitata* and *macrocephala*, which showed very similar performances.

Table 1. Weeds incidence (plants m^{-2}) and reduction percentage of treatments in relation to control, during corn development in evaluations after 30 and 60 days of sowing. Braganey (PR), 2007/2008.

Evaluation	30 days			60 days		
Treatments	broadleaf	*B. pilosa*	reduction%	Broad-leaf	*B. pilosa*	reduction %
Control	265 a	185 a	0	83 a	11 a	0
M. deeringiana	80 b	40 b	69.8	33 b	4 a	60.2
Cajanus cajan	118 b	75 b	55.5	49 b	8 a	41.0
S.capitata and macrocephala	42 c	11 c	84.2	27 b	5 a	67.5
Coefficient of variance (%)	20.61	24.44	-	34.73	54.28	-
General Mean	126	78	-	48	7	-
F Values	17.77*	22.17*	-	3.15*	1.19*	-

Means followed by the same letter, in column, do not differ among themselves by Scott and Knott test at 5% probability. The presented data are obtained from the original observations, followed by letters obtained from the comparison of means with the transformation in $\sqrt{x+0,5}$.

Table 2. Weed incidence (plants m^{-2}) and reduction percentage of treatments in relation to the control at harvest of corn planted in crop residues of leguminous species. Braganey (PR), 2007/2008.

Treatments	broadleaf	*Bidens pilosa*	% reduction
control	316 a	255 a	0
M. deeringiana	114 b	77 b	63.9
Cajanus cajan	188 b	144 b	40.5
S.capitata e macrocephala	118 b	61 b	62.7
Coef. of Variation (%)	22.18	27.52	-
General Mean	184	134	-
F Values	6.40*	7.49*	-

Means followed by the same letter, in column, do not differ among themselves by Scott and Knott test at 5% probability. These data are results of original observations, followed by the letters obtained from the comparison of means with the transformation in $\sqrt{x+0,5}$.

In all analyses of weed incidence, during maize development, the control showed the highest average values for weeds in broadleaf and *Bidens pilosa* (Tables 1 and 2). This demonstrates that the studied leguminous species have suppressive effect on weed community and such effect may be due to chemical, physical or biological factors (Calegari, 1992; Favero, 2001). There are many studies that have been looked for weed control by cover crops (Fernandes *et al*, 1999, Mateus *et al*. 2004; Trezzi; Vidal, 2004; Tokura, Nobrega, 2005; Balbinot, Bialeski; Backes, 2005; Correia, Durigan; Klink, 2006; Piccolo, 2007), however, there are few records concerning the species studied in this work.

Tokura and Nóbrega (2006) evaluated the allelopathic potential of cover crops as *Triticum* spp, *Avena strigosa*, *Pennisetum glaucum*, *Raphanus sativus* and *Brassica napus* concerning weed development. The authors concluded that, from the studied species, *Brachiaria plantaginea* presented the greatest allelopathic potential and *Chenopodium ambrosioides* the lowest one.

In northern Greece, Dhima *et al*. (2009) carried out a trial regarding the mulch effects of some scented plants that were incorporated and used as green manure for the emergence and growth of weeds and maize. The studied species were: *Foeniculum vulgare, Pimpinela anisum, Ocimum basilicum, Coriander sativum, Coriandrum sativum, Mentha* L., among others. In the field, weed emergence was reduced from 11 to 83% when compared to the control. As in this experiment, corn emergence was not affected by any green manure (Table 3). Uchino *et al*. (2009) also concluded that weeds can be effectively controlled by planting cover crops, including their seed bank.

The values for emergence speed, final emergence percentage and emergence speed index of corn seedlings sowed on crop remains of *M. deeringiana*, *C. cajan* and *S. capitata macrocephala*, plus the control are shown in Table 3.

According to the analyses in Table 3, there was no statistic difference of treatments concerning: emergence speed (ES), emergence percentage (EM %) and emergence speed index (ESI) of corn seedlings that were under treatments with the studied leguminous species. However, when the ES values were analyzed, it is observed that the control presented the lowest value, i.e, the emergence speed of corn seedlings in the control was larger than in the other treatments. Therefore, even though seed corn of the control had emerged earlier, they showed the lowest emergence percentage (EM %) and consequently the smallest stand (number of plants m^{-2}) at the end of culture (Table 4), but they did not differ statistically among treatments.

According to Ramos *et al*. (2008), straw disposal on soil causes changes on chemical, physical and biological characteristics of soil environment and, depending on the species, the emergence and growth of plants can be affected. Among the changes caused by the waste deposition, Miyazawa *et al*. (2002) observed that for calcitic limestone mobility, applied on soil surface in columns of isolated PVC and with the addition of cover crops wastes, the association of its application with wastes have accelerated the transport of Ca and Mg in soil, among other effects.
According to Carvalho and Nakagawa (2000), the environment changes in which seeds are sown may cause problems or make easy their emergence, since this process depends on water and oxygen availability, in addition to room temperature.

Table 3. Mean values of emergence speed (ES), emergence percentage (EM %) and emergence speed index (ESI) of maize seedlings under treatments with leguminous cover crops and the control. Braganey (PR), 2007/2008.

Treatments	ES (days)	EM (%)	ESI (plants day^{-1})
Control	7.92 a	69 a	3.09 a
M. deeringiana	8.35 a	79 a	3.33 a
Cajanus cajan	8.30 a	72 a	2.99 a
S.capitata and macrocephala	8.34 a	72 a	3.01 a
Coef. of variation (%)	7.33	11.38	19.16
General Mean	8.22	72.95	3.10
F Values	0.59^{ns}	0.31^{ns}	0.34^{ns}

Means followed by the same letter, on the column, do not differ among themselves by Scott and Knott test at 5% probability. The data for emergency % are obtained from the original observations followed by the letters obtained from the comparison of means with the transformation in $\sqrt{x}$.

Table 4. Maize productivity and relative percentage among the treatments with leguminous wastes. Braganey (PR), 2007/2008.

Treatments	Productivity (kg ha^{-1})	Costs (R$)*	Stand (21 days)	relative Production %
Control	4777 a	1600	21 a	100
M. deeringiana	4956 a	1660	24 a	104
C. cajan	4831 a	1610	22 a	101
S.capitata e macrocephala	4418 a	1480	22 a	92
Coef. of variation (%)	13.47	-	22.63	-
General Mean	4746	-	22.36	-
F Values	0.65^{ns}	-	0.28^{ns}	-

Means followed by the same letter in column do not differ among themselves by Scott and Knott test at 5% probability.
* 60 kg bags

Rosa *et al*. (2009), at 60 days after maize sowing, observed that there was a significant difference among treatments with dwarf mucuna and dwarf pigeonpea, which showed the greatest heights in relation to the stylosanthes.

The averages of maize productivity, grown on wastes of leguminous as *M. deeringiana*, *C. cajan* and *S. capitata* and *macrocephala* and the control are shown in Table 4.

The maize productivity was not affected by submission to treatment, so, there was no significant difference. However, there is a numeric lower productivity when corn was grown after stylosanthes. This answer is confirmed in percentage when compared to the control, where *S. capitata* and *macrocephala* was the only treatment in which there was an 8% reduction in productivity in relation to the control (Table 4). Both *C. cajan* and *M. deeringiana* showed an increase in productivity of 1 and 4%, respectively, when compared to the control.

According to the IBGE, 18,745,355 tons of corn were harvested from second harvest in Brazil (IBGE, 2009). In the 2007/2008 second harvest, Paraná received 5,489.330 tons of production in an area of 1,512.078 hectares, which corresponds to almost 3,630 kg ha^{-1}, according to data from the Department of Agriculture and Supply of Paraná (SEAB, 2008). These data show that maize productivity, in this experiment, was above the average in Paraná (Table 4).

The 60 kg bag ranged from R$ 28.00 in December, 2007 to R$ 17.00 in December, 2008 (CONAB, 2009). In June, the price paid to producers by a 60 kg bag was around R$ 20.17 (SEAB, 2009). So, taking into account the production costs (Table 4), it was observed that treatment with *M. deeringiana* showed a gain of R$ 60.00, while *C. cajan* received R$ 10.00 per hectare when compared to the control.
On the other hand, the treatment with *S. capitata* and *macrocephala* decreased in R$ 120.00 per hectare. These differences must be considered by the producer at the moment he chooses a cover crop. In a similar study, Bertin *et al*. (2005) studied cover crops in pre-harvest to maize under no-tillage system. So, when it was planted just after *Crotalaria*, it showed higher production of grains. The *Crotalaria* is a leguminous, as well as the cover crops studied in this work.

In studies of crop rotation and succession with leguminous as *Crotalaria juncea*, the result of corn productivity was 8,362 kilograms ha^{-1}. While for the maize succession, it was 6,806 kilograms ha^{-1} (Penteado, 2007). This corroborates the benefits of using cover crops. Braz *et al*. (2006), in the Brazilian Midwestern region, studied about cover crops as *Brachiaria*; corn + *Brachiaria*; *Cajanus cajan, Pennisetum, Panicum maximum, Sorghum bicolor* and *Stylosanthes,* in wheat culture. They found out that the highest productivities of wheat were when it was grown after the leguminous, as pigeonpea and stylosanthes. The authors also highlighted that the use of leguminous has as advantage the right available nutrients to the next cultures, due to the fast decomposition of wastes.

Suzuki & Alves (2004) analyzed the grain productivity, influenced by soil tillage and cover crops as *atterrimum, Pennisetum americanum, Crotalaria juncea* and *Cajanus cajan* and observed that, when *Pennisetum americanum* was used as cover crop, the no-tillage system gave better response for maize grain yield when compared to the conventional tillage. The cover crops, according to each tillage system, did not show any difference for grain yield of maize.

Carvalho *et al*. (2004) studied soybean grown after green manures under no-tillage and conventional systems, in a soil from Midwest. Among the green manures, there were *Cajanus cajan* and *Mucuna*. The authors concluded that the green manure management during springtime has no effect on soybean productivity in succession, just as it was registered in the present trial, where there was no difference in maize productivity.

In studies that concern about nitrogen supply by leguminous in springtime for maize in succession in the systems of minimum and conventional tillage, Cereta *et al*. (1994) observed that all leguminous have been effective as a nitrogen source for maize, which also provided higher productivity than weeds up to 70%. Among the studied species, *Cajanus cajan* contributed, on average, with 10.7 kg ha^{-1} of nitrogen to corn. Heinrichs *et al*. (2005) found out a higher productivity of corn, 20% higher than the control, when it was grown after *Canavalia ensiformes* L.. But, corn yield was not influenced by the consortium with other green manures, including, dwarf mucuna, dwarf pigeonpea and *Crotalaria juncea* L. sp.

In general, some considerations were possible to be observed in the field about the leguminous plants. The stylosanthes had some difficult in their initial development, mainly due to wheat invasion, which acted out as weed species, providing further invasion by other species. When the cover was established, there were few weeds in the plots, so it is a potential green manure, because it had an efficient weed control, which asks for further researches. The dwarf mucuna and dwarf pigeonpea showed some adaptability in the region of this experiment, so they can be used as cover crops.

The use of green manure during the summer or in spring ensures that crop rotation can be carried out correctly and this guarantees the benefits of using green manure. So, the crop rotation is a fundamental action to guarantee some no-tillage system viability.

Studies regarding the use of crop rotation in Southern region must be stimulated to help the producer on planning at medium and long term, as well as to improve conditions and maintain the soil cover and thus a sustainable no-tillage system, with positive economic consequences for rural producers. It is noteworthy that the most consistent results are obtained through a continuous supply of organic matter to soil at medium and long term, in order to make possible the maintenance or recovery of its fertility.

CONCLUSION

Leguminous plants as green manure did not affect the development of cultivated species and have negative influence on weed community, offering an alternative to the integrated management of species in the green manuring practice and crop rotation under no-tillage system, based on the studied conditions.

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