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Soybean growth and yield after single tillage and species mixture of cover plants¹

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ABSTRACT

The use of cover crops is important for the agricultural crop and soil management in order to improve the system and, consequently, to increase yield. Therefore, the present study analyzed the effect of crop residues of black oat (*Avena strigosa* Schreb.) (BO) and a cocktail (CO) of BO, forage turnip (*Raphanus sativus* L.) (FT) and common vetch (*Vicia sativa* L.) (V) on the emergence speed index (ESI), seedling emergence speed (SES) plant height and soybean yield in different intervals between cover crop desiccation with glyphosate 480 (3 L ha⁻¹) and BRS 232 cultivar sowing. Plots of 5 x 2.5 m with 1 m of border received four treatments with BO cover crops and four with CO as well as a control for each cover crop, at random, with five replications. The plots were desiccated in intervals of 1, 10, 20 and 30 days before soybean seeding. The harvest was manual while yield was adjusted to 13% of moisture content. The experimental design was completely randomized with splitplots and means compared by the Scott and Knott test at 5% of significance. The results showed that CO of cover crops can be recommended for soybean to obtain a more vigorous seedling emergence, from 10 days after cover crop desiccation.

Key words: no-tillage system, crop rotation, *Glycine max* (L.) Merr.

RESUMO

Crescimento e produtividade de soja após cultivo solteiro e coquetel de plantas de cobertura

A adequação da cobertura vegetal à cultura agrícola e ao manejo de solo é importante para obtenção de melhorias do sistema e, conseqüentemente, de maior produtividade. Nesse contexto, este estudo analisou a interferência de restos vegetais de aveia preta (*Avena strigosa* Schreb.) (AP) e coquetel de aveia preta, nabo forrageiro (*Raphanus sativus* L.) e ervilhaca-comum (*Vicia sativa* L.) (CO) no índice de velocidade de emergência (IVE), velocidade de emergência (VE) de plântulas, altura de plantas e produtividade da cultura da soja em intervalos diferenciados entre dessecação da cobertura vegetal com glifosato 480 (3L ha⁻¹) e semeadura da cultivar BRS 232. Parcelas de 5 m x 2,5 m, com 1 m de bordadura, receberam quatro tratamentos com cobertura AP, quatro para CO e uma testemunha para cada cobertura, ao acaso, com cinco repetições. A dessecação foi nos intervalos de 1, 10, 20 e 30 dias anteriores à semeadura da soja. A colheita foi manual e a produtividade, ajustada para 13% de teor de água. O delineamento experimental foi inteiramente casualizado, em esquema de parcelas subdivididas, teste de Scott e Knott a 5% de probabilidade. Pelos resultados obtidos pode-se recomendar a utilização do coquetel de coberturas na cultura da soja a fim de proporcionar emergência de plântulas mais vigorosas. A semeadura da soja é recomendada a partir de 10 dias após a dessecação da cobertura vegetal.

Palavras-chave: plantio direto, rotação de cultura, *Glycine max* (L.) Merr.

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INTRODUCTION

Highest efficiency, with improvements on the productive capacity of the soil requires planning for the crops to be grown, considering species of high biomass production with potential for soil mulching, cultivated either in the cocktail or single form, with commercial crops (Embrapa, 2004).

The mulching process is an ecological and economic alternative for soil management, bringing balance to the chemical, physical and biological properties that compose the soil-plant system (Rufato *et al.*, 2006). With the expansion of soybean crop, the no-tillage system and the establishment of winter crops for soil mulching are techniques that emphasize the recovery and improvement of productivity (Silva *et al.*, 1997). However, the success of this system depends on the interval existent between the mulch desiccation and the sowing (Timossi *et al.*, 2005).

Leaf chlorosis and decrease in plant development (which can affect productivity) have been commonly observed in areas covered with a great mass of mulches, where the seed sowing is carried in intervals very near to the desiccation (Constantin & Oliveira, 2005). Therefore, the choice and the correct management are determinant in the formation and recovery of the mulch and the resulting benefits (Pires *et al.*, 2008).

The fast and uniform emergence of healthy seedlings in open field is important for the establishing of uniform stands, which will provide a faster spread of mulches and, depending on the crop, higher competitiveness against weeds (Lima, 1997).

Fast emerging seedlings are able to compete more efficiently for environment resources (Fleck *et al.*, 2002). Theoretically, strong seedlings have advantage to become a high plant (Flores *et al.*, 2002). Stronger seeds generate seedlings with higher growth indices due to their capacity of transformation and supplying reserves in the storage tissues and the higher incorporation of tissues by the embryonic axis. The growth of seedlings can be evaluated by the measurement of the mean length of normal seedlings and it is considered that samples with higher mean values are the strongest ones (Dan *et al.*, 1987).

Among probable effects promoted by the deposition of a straw layer, provided by the soil mulch, the allelopathy represents the influence of one individual over another (Rice, 1984). This influence can be positive or negative, through the effects of the biomolecules produced by a plant and released into the environment, either in the aqueous phase of the soil or substratum, gaseous substances released into the environment, or by decomposition and leaching. Thus, the germinating process and the development of other plant species

change affecting the constitution of the natural ecosystems and crops (Perez *et al.*, 1998). Plant wastes in the soil surface interfere with humidity, luminosity and soil temperature – the main factors in controlling dormancy and the germinating process (Correia & Rezende, 2002).

Therefore, the aim of this study was to analyze a probable effect of plant wastes on the following mulches: black single oat and black cocktail oat, forage turnip and common vetch in initial development, growth and productivity of soybean crop, considering different intervals between the mulch desiccation and the crop sowing.

MATERIAL AND METHODS

Description of the experimental area

The experiment was set in the agricultural year of 2006/07, in Braganey, in western Paraná, with the geographical coordinates 24°54'08"S of latitude and 53°07'15" W of longitude, at 643 m. The experimental area had a 4-year history of no-tillage system, with soybean and corn in the summer, and black oat in the winter. The soil is classified as an eutrophic Red Latosol, with an annual rainfall average of 1.600mm, and an annual average temperature of 20°C (Cavaglione *et al.*, 2000).

Pre-sowing management and crop management

Soil preparation, implantation of mulches and the crop, all occurred under the no-tillage system. Initially, a desiccation of plant wastes in the area was carried out using the herbicide 480 glyphosphate (1.44 L ha⁻¹ of the active ingredient, 3L ha⁻¹ of commercial product). Twenty days after the desiccation, the vegetal mulches were sown (08/12/2006), namely: black oat (50 kg ha⁻¹) in a single system, and black oat (30 kg ha⁻¹), forage turnip (8 kg ha⁻¹) and common vetch (15 kg ha⁻¹) as cocktail, with a 0.15 m spacing between lines, a control without mulching, only with the spontaneous species (fallow).

The desiccation of the plots with mulches was also carried out with 480 glyphosphate (1.44 L ha⁻¹ of the active ingredient) in intervals of one, ten, twenty and thirty days, before the soybean sowing (11/15/2006). Next, plots of 5 x 2.5 m, with a 1 m border between them and thirteen sowing lines were all lined off, with a 0.45 m spacing among them and 14 soybean seeds per meter. The plot useful area was 12.5 m², and eight sowing lines were used for the evaluation.

The sowing was carried out with a Metasa planter, in the time recommended for the region. A 2-20-20NPK formulation was applied in the furrow at the rate of 300 kg ha⁻¹, as recommended by the soil analysis. The semi-precocious cultivar BRS 232, indicated for the State of Paraná (Embrapa, 2006), and previously subjected to a

germination test in laboratory, resulting in a 90% rate of germination was used in the experiment. Four treatments were established for the black oat mulch in single system, and four treatments for the cocktail with one control for each cover, randomly distributed, with five replications per treatment.

Evaluations

After sowing of the soybean crop, the emergence velocity index (EVI), emergence velocity (ES), plant height and yield were evaluated, as follows:

ESI: count of emerged plants in the useful lines of each plot, according to the agronomical criteria of emergence, that is, the presence of essential structures so the seedling is able to continue development (Brasil, 2009). The evaluation started from the fourth day up to the stabilization of the number of emerged seedlings, which happened around 20 days (Nakagawa, 1999).

$$ESI = \frac{E_1}{N_1} + \frac{E_2}{N_2} + \dots + \frac{E_N}{N_N}$$

Where:

ESI = emergence speed index.

$E_1, E_2 \dots E_N$ = number of normal seedlings recorded in the first, second, (...) up to the last count.

$N_1, N_2 \dots N_N$ = number of sowing days up to the first, the second, (...) up to the last count.

ES: data used to evaluate the ES were the same used in the ESI evaluation. ES was calculated according to Edmond & Drapala (1958), considering the treatment with the lowest mean the one that took fewer days for the emergence of seedlings from the soil, therefore considered the one with the highest ES:

$$ES = \frac{(N_1 E_1) + (N_2 E_2) + \dots (N_n E_n)}{E_1 + E_2 + \dots E_n}$$

Where:

ES = emergence velocity.

$E_1, E_2 \dots E_N$ = number of normal seedlings recorded in the first, second, (...) up to the last count.

$N_1, N_2 \dots N_N$ = number of sowing days up to the first, the second, (...), up to the last count.

The results were expressed in the number of days that the seedlings took to emerge from the soil.

Plant height: the aerial part was measured considering the distance from the soil up to the apical meristem in the main stem, of ten soybean seedlings, randomly chosen within the useful area of each plot, for each treatment and the control. The evaluations were carried out at monthly intervals, starting from 30 days after the sowing. The results were expressed in cm.

Yield: a manual harvest of each plot was carried out after maturation, by pulling the plants off the useful lines. Plants were spread on a canvas and hit with a stick to release the seeds and were cleaned by manual waving in sieves. The selected seeds were packed, identified and taken to the laboratory so that the yield could be determined by weighing the seeds of each plot and transformed into kg ha^{-1} . Then, all the values were adjusted for 13% water content.

Experimental design

The experiment was arranged in a completely randomized design, using a split-plot in time and four treatments for the black oat, four treatments for cocktail and a single control for each mulch, with five replications for each treatment. The main factors – the mulches (vegetal cover) – were placed in the plots. They were, then, divided in subplots, in which the secondary factors were distributed, that is, the intervals between desiccation (1, 10, 20 and 30 days) and sowing (Banzatto & Kronka, 1992).

Data on yield did not show normality and were transformed into \sqrt{x} (Banzatto & Kronka, 1992). The results were subjected to a analysis of variance, and the means were compared by the Scot-Knott test at 5% probability. The classification of the values for the coefficient of variation (CV) was according to Pimentel Gomes (2000).

RESULTS AND DISCUSSION

The highest emergence speed index (ESI) was recorded for the treatment with the mulch cocktail, indicating that it was beneficial to the ESI of the soybean crop (Table 1).

For the intervals between desiccation and sowing (IDS), the highest ESIs were at 10, 20 and 30 days after the desiccation, differing from the control and from the day 1 IDS, which had the lowest ESI, also differing from the control. Laboratory-based studies performed by Nóbrega *et al.* (2009), showed a negative influence of ryegrass, black oat and black oat cocktail, common vetch and forage turnip mulching on the emergence and ESI percentage of soybean seedlings. However, the authors did not found significant difference between the single mulches and the cocktail.

The results for ES (Table 2) showed a behavior similar to those obtained for the ESI. The soybean sowed on day 1 after the desiccation demanded a higher amount of days for emergence. That may due to the higher concentration of constitutive substances of the cover crops with allelopathic potential, without discarding, though, the possibility of the residual effect of the herbicide used. Days 10, 20 and 30 IDSs

presented a lower amount of days to the soybean mean seedling emergence when compared with the control and with the day 1 IDS, which also differed between each other (Table 2).

The lower the values obtained by the ES formula are, the higher the seed physiological potential (Edmond & Drapala, 1958). That result allowed the inference that Days 10, 20 and 30 IDSs favored seed germination when compared with the control and to the day 1 IDS, which differed from each other. These data confirmed the results obtained by the ESI test (Table 1).

Bortolini & Fortes (2005) reported a decrease in the ES of soybean seeds exposed to the black oat aqueous extract, in laboratory-based experiments. Similar results were observed in this study, in which there was an alteration in the ES of the soybean seedlings subjected to black oat and black oat cocktail, common vetch and forage turnip mulching with day 1 IDS.

Timossi *et al.* (2005) reported an increase in the average amount of days to the soybean seedlings emergence, when the mulching desiccation was performed at seven and zero days before the crop sowing; thus, corroborating the findings of the present study.

Table 3 shows that at 30 and 60 days after the sowing (DAS), the day 1 IDS differed from the control and from the other treatments, with lower plant height. At 90 DAS, it was observed higher values for plant height in the 20 and 30 days IDSs. At 120 DAS, the day 30 IDS had higher plant height and was not statistically different from days 10 and 20 IDSs (Table 3).

Table 1. Unfolding of means of the mulching parameters and interval between desiccation and sowing (IDS) for the emergence speed index (ESI) of soybean seedlings

Mulch	ESI	IDS	ESI
Black Oat	2.56 a	control	2.52 b
Cocktail	2.64 b	1 day	1.98 a
		10 days	2.87 c
		20 days	2.74 c
		30 days	2.89 c

Means followed by the same letter, in the column, are not significantly different by the Scott-Knott test at 5% probability.

Table 2. Means of the intervals between desiccation and sowing (IDS) for emergence velocity (ES) of soybean seedlings cultivated under mulching

IDS	ES (Average days to emergence)
Control	10.5 b
1 day	11.8 c
10 days	9.3 a
20 days	9.7 a
30 days	9.7 a

Means followed by the same letter, in the column, are not significantly different by the Scott-Knott test at 5% probability.

According to Merotto Júnior *et al.* (1999), the plants with late emergence can have lower growth in the aerial part and in the root system, and, as a result, a lower capacity of quantitative competition for water, light and nutrients.

Souza Filho & Alves (2002) discussed that the plant height is one of the criteria usually evaluated in the determination of the presence of an allelopathic agent. These authors, by quoting Williamson & Weidenhamer (1990), emphasized that a little flow of allelochemicals in the soil may interfere in plant height. Menezes *et al.* (1994) observed allelopathic substances in black oat exudations, which were capable of inhibiting the development of crops; they suggested a longer interval between the desiccation and sowing management, in order to decrease the depressive allelopathic effects.

From the first (30 DAS) to the last evaluation (120 DAS), the mulches, after the 10 days IDS, provided a greater plant height in relation to the control. That may have occurred due to the protection of the soil, provided by the mulches, or yet, by the supply of organic matter.

The results observed agree with those reported by Constantin & Oliveira (2005), who emphasized the attention with the interval between the mulching desiccation and the crop sowing. Findings from areas with a great mulching mass, with sowing performed a few days after the desiccation, show a decrease in the plant development, which may affect the productivity. Rice (1984) discussed that the allelopathic effects detected on the growth of a plant, by an allelochemical originated from crop residues, depend, among other factors, on the residue age, that is, on the stage of decomposition in which the plant that donated the residues was.

According to Silva *et al.* (2006), plant height is the parameter that determines the degree of development of the crop and has a positive correlation with yield, which may demonstrate that they are more productive, probably because they are under less stress during their development and accumulate higher amounts of reserves.

Table 3. Unfolding of means of the intervals between desiccation and sowing (IDS) for soybean plant height (cm) evaluated at 30, 60, 90 and 120 days after sowing (DAS)

IDS	DAS			
	30	60	90	120
Witness	17.3 b	73.9 b	75.7 a	75.0 a
1 day	15.3 a	69.7 a	76.7 a	73.6 a
10 days	18.3 b	75.1 b	76.8 a	76.2 b
20 days	18.4 b	75.9 b	79.9 b	76.7 b
30 days	18.4 b	75.4 b	78.8 b	78.6 b

Means followed by the same letter, in the column, are not significantly different by the Scott-Knott test at 5% probability.

Yield means did not differ between the black oat and cocktail mulches. The mean IDS shows a lower productivity for the soybean sowed 1 day after the cocktail desiccation handling (Table 4).

In the unfolding of means for IDS, in the black oat mulching, showed lower productivities in days 1 and 30 IDS, which differed from the control and from the other treatments. Day 10 IDS had the highest yield (Table 4).

In a similar study, Neves *et al.* (1999) did not observe any variation in the corn yield for days 1 and 13 IDS using black oat mulching. However, Constantin *et al.* (2009) reported results that resembled those found in this study, with a decrease in the soybean yield under the BO burn down system and single desiccation seven days before the sowing when compared to the sequential management system.

The unfolding of means for IDS, in the cocktail, there was a higher yield in the control and in the day 30 IDS; the day 1 IDS showed lower yield and was not statistically different from days 10 and 20 IDS, indicating that these mulches, after a few days of desiccation, interfere with the soybean crop yield.

Nevertheless, Rizzardi *et al.* (2003) reported a reduction in the soybean yield for the day 30 IDS due to the interference of weed species that begin to compete with the crop.

Comparing the yields of 3.030 kg ha⁻¹ for the soybean crop in Paraná (IBGE, 2008) and of 2.755 kg ha⁻¹ for Brazil (CEPEA, 2008), with the ones obtained in this work, it is found that the yield data gathered in this study is within the standards considered normal for the region.

One can observe that the average results for productivity presented the same behavior as the results obtained for ESI, ES and plant height. Higher productivities were verified from the 10 days IDS, what was also verified for the other parameters analyzed.

Table 4. Unfolding of means of the parameters mulching and interval between desiccation and sowing (IDS) for the soybean yield (kg ha⁻¹) obtained from cover crops and intervals differentiated between desiccation and sowing (IDS)

IDS	Mulching		
	Black Oat	Cocktail	Means
Witness	3062 Ab	3062 Ab	3062 b
1 day	2686 Aa	2618 Aa	2652 a
10 days	3102 Bb	2646 Aa	2874 b
20 days	3079 Ab	2731 Aa	2905 b
30 days	2828 Aa	2980 Ab	2904 b
Averages	2951 A	2808 A	

Means followed by the same small letter in the column and capital letters in the row are not significantly different by the Scott-Knott test at 5% probability. The presented data are obtained from the original observations, followed by the letters from the comparison of means transformed into \sqrt{x} .

CONCLUSIONS

The emergence speed index (ESI) for the soybean culture was benefited from the mulching cocktail, providing the emergence of vigorous seedlings.

The sowing of soybean is recommended ten days after mulching desiccation (10 days IDS), enabling the achievement of vigorous plants of greater size.

Sowing soon after the mulching desiccation (one day interval between desiccation and sowing) interferes negatively in the ESI, ES, plant height and the soybean yield.

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