Research, Society and Development, v. 11, n. 3, e52311326401, 2022
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i3.26401

Phytomass decomposition of cover crops subjected to mechanical management and soybean yield

Decomposição da fitomassa de plantas de cobertura submetidas a manejo mecânico e produtividade da soja

Descomposición de la biomasa de cultivos de cobertura bajo manejo mecánico y rendimiento de soja

Received: 02/01/2022 | Reviewed: 02/22/2022 | Accept: 02/25/2022 | Published: 03/06/2022

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Abstract
The research had as objective to evaluate the crops residues decomposition of cover crops mechanically managed and its effect on the soybean yield cultivated in succession. The design used was randomized blocks in a factorial arrangement (5 x 2), subdivided over time, with four replications, consisting of five soil covers (black oats, turnip, turnip + oats, common vetch and fallow) and two forms of species management (knife-roller and shredder). The six collection times (0, 20, 40, 60, 80 and 110 days after management- DAM) were the subplots. The straw decomposition time was evaluated using the litter bags method. At 110 DAM, the covers that showed the greatest decomposition were vetch and fallow (91 and 90%) as well as the shortest half-life-T½ (31 and 33), evidencing their low soil protection. The cover that remained the most was black oats (35%) being a good option to keep the soil

covered. In the first 60 DAM, the shredder accelerated the dry matter decomposition by 40% and presented a lower T½ (45). The cover crops cultivation and its management before soybean cultivation did not influence grain yield.
Keywords: Collection seasons; Soil protection; Shredder.

Resumo
A pesquisa teve como objetivo avaliar a decomposição dos resíduos culturais de plantas de cobertura manejadas mecanicamente e seu efeito na produtividade da soja cultivada em sucessão. O delineamento utilizado foi de blocos casualizados em arranjo fatorial (5 x 2), subdividido no tempo, com quatro repetições, sendo constituído de cinco coberturas de solo (aveia preta, nabo forrageiro, nabo+aveia, ervilhaca comum e pousio) e duas formas de manejo das espécies (rolo-faca e triturador). As seis épocas de coletas (0, 20, 40, 60, 80 e 110 dias após o manejo-DAM) foram as subparcelas. O tempo de decomposição da palhada foi avaliado pelo método das bolsas de decomposição (litter bags). Aos 110 DAM, as coberturas que apresentaram maiores decomposições foram a ervilhaca e pousio (91 e 90%) assim como os menores tempo de meia vida-T½ (31 e 33) evidencia sua baixa proteção do solo. A cobertura que mais permaneceu foi aveia preta (35%) sendo uma boa opção para manter o solo coberto. Nos primeiros 60 DAM, o triturador acelerou em 40% a decomposição da matéria seca e apresentou menor T½ (45). O cultivo das plantas de cobertura e seu manejo antecedente a cultura da soja não influenciou na produtividade de grãos.
Palavras-chave: Épocas de coleta; Proteção do solo; Triturador de plantas.

Resumen
La investigación tuvo como objetivo evaluar la descomposición de los residuos de cultivos de cultivos de cobertura manejados mecánicamente y su efecto sobre el rendimiento de la soja cultivada en sucesión. El diseño utilizado fue de bloques al azar en arreglo factorial (5 x 2), subdivididos en el tiempo, con cuatro repeticiones, compuesto por cinco coberturas de suelo (avena negra, rábano forrajero, rábano + avena, arveja común y barbecho) y dos formas de manejo de especies. (rodillo de cuchillas y trituradora). Los seis tiempos de recolección (0, 20, 40, 60, 80 y 110 días después de la gestión del-DAM) fueron las subparcelas. El tiempo de descomposición de la paja se evaluó mediante el método de las bolsas de arena. A 110 DAM, las coberturas que mostraron la mayor descomposición fueron la arveja y el barbecho (91 y 90%) así como la vida media más corta-T½ tiempo (31 y 33) mostrando su baja protección del suelo. La cobertura que más se mantuvo fue la de avena negra (35%) siendo una buena opción para mantener el suelo cubierto. En los primeros 60 DAM, la trituradora aceleró la descomposición de la materia seca en un 40% y tuvo una T½ (45) más baja. El cultivo de cultivos de cobertura y su manejo previo al cultivo de soja no influyó en el rendimiento de grano.
Palabras clave: Temporadas de colección; Protección del suelo; Trituradora de plantas.

1. Introduction

Soybean (*Glycine Max*) is a widely disseminated crop due to its broad use in different segments and plays an important role in the Brazilian economy. It is used for the production of animal protein and in human food, consolidating this agro-industrial chain, being also an alternative for the manufacture of biofuels (Conab, 2017).

The adoption of conservation practices, such 9as the no-tillage system (NTS) and the use of cover crops, are the way to perform adequate soil management. These practices aim at a good development of the successor crop and are indispensable for the cultivation system to become sustainable (Seidel et al., 2015).

One of the requirements for the success of no-tillage is a good straw formation on the soil surface, becoming a key factor for its maintenance and consolidation. In this context, the use of cover crops in the off-season with the objective of maintaining soil cover, nutrient cycling and increasing organic matter content is an excellent alternative for increasing the quality of the production system (Pariz et al., 2011).

The choice of cover crops species to be cultivated is fundamental for the NTS maintenance. They must have a phytomass production with good quantity and quality, and provide efficient soil cover (Araujo et al., 2015).

The rate of plant residues decomposition is an important variable in nutrient cycling and determines the length of time that residues remain on the soil surface. This rate is influenced by the carbon/nitrogen ratio (C/N) of the plant used, the volume of phytomass production and its management that associated with climatic conditions may favor the activity of the decomposing microorganisms and, hence, the plant material degradation. At the end of the decomposition, nutrients will be made available for the crops in succession and may contribute to the increase in yield (Teixeira et al., 2012).

Another factor that can influence the degradation process of plant material on the soil is the way of management of these cover crops. Generally, management is performed by mechanical equipment such as knife-roller, shredders, rotor mowers and harrows (Conceição et al., 2017).

The type of equipment used to manage the cover crops can directly influence the rate of straw decomposition, as it interferes in the form of contact of the residues with the soil, especially in function of the particles size provided by the equipment and its location at the soil (surface or incorporated) (Costa et al., 2014).

Thus, there are still few studies concerning the dynamics of the phytomass supply of cover crops on the soil as well as their decomposition process due to the different mechanical equipment and the influence of these factors on the crop yield in succession. This highlights the need to intensify work in this area, especially under no-tillage conditions.

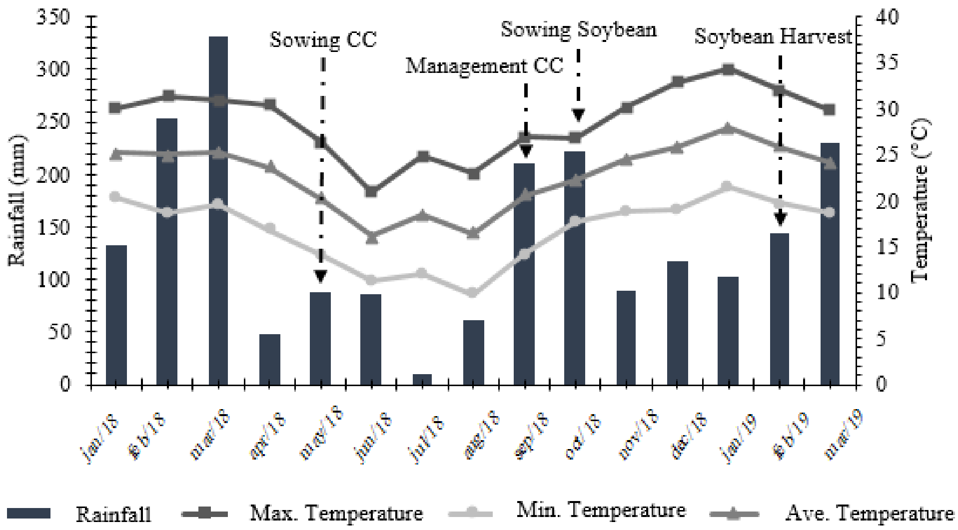
The objective of this work was to evaluate the crops residues decomposition from fall/winter cover crops managed with two pieces of equipment, the knife-roller and the shredder (triton) and its effect on the soybean yield cultivated in succession.

2. Methodology

The experiment was carried out in the agricultural year 2018/2019, at Experimental Station Professor Alcibíades Luiz Orlando, located in the municipality of Entre Rios do Oeste-PR, belonging to Universidade Estadual do Oeste do Paraná [Western Paraná State University - Marechal Cândido Rondon *Campus* (UNIOESTE/MCR). The geographical coordinates are -24º40’32,66” South latitude and -54º16’50,46” West longitude, and an altitude of 244 m.

According to the climate classification of Köppen, the climate of the region is humid subtropical mesothermal type (Cfa), with hot summers, average temperatures above 22 ºC and winters with average temperatures below 18 ºC and an annual average rainfall of 1600-1800 millimeters (Caviglione et al.,2000). The meteorological data for the experiment period (Figure 1).

Figure 1. Rainfall and average temperature, with maximum and minimum, during the experiment period (January/2018 to February/2019).



CC: Cover crops. Source: Weather Station of Santa Helena -PR (2018). Source: Authors.

The soil of the experimental area is classified as Red Nitosol eutroferric, (LVef), very sandy texture, with soft slopes relief (Santos et al., 2013).

The experimental design was randomized blocks (DBC) in a factorial arrangement (5 x 2), subdivided in time, with four replications, consisting of five soil covers: One *Poaceae* family (black oats- *Avena strigosa* S.), one *Fabaceae* family (common vetch- *Vicia sativa* L.), one *Brassicaceae* family (forage turnip-*Raphanus sativus*), intercropping of *Poaceae* + *Brassicaceae* (turnip+oats) family and area in fallow, and two pieces of equipment which were used for the cover crops management: knife-roller and plants shredder. The litter bags collection times (0, 20, 40, 60, 80 and 110 days after DAM management) were the subplots.

The same experimental design and number of replications previously mentioned was used to evaluate the agronomic and soybean yield components.

Each experimental plot presented 5.0 m width x 13.0 m length, totaling an area of 65 m^2. The plot useful area was calculated by discarding 1 m from each end and 0.50 m from each side, totaling 44.0 m^2.

The implementation of winter crops was mechanically performed with a multiple seed drill SEMEATO line, model SHM 11/13, on May 24th of 2018. 60 kg ha^{-1} of black oats BRS 139; 60 kg ha^{-1} of common vetch; 9 kg ha^{-1} of forage turnip IPR 116; 4 and 30 kg ha^{-1} of turnip+oats were used, respectively. 186 kg ha^{-1} of the 10-15-15 (N, P_2O_5 and K_2O) formulation was applied. The spacing between lines was 0.50 m for common vetches and forage turnip and 0.17 m for black oats single and oats+turnip.

Regarding the phytosanitary treatment, there was no need to apply herbicides, insecticides and/or fungicides. After 120 days of sowing, the cover crops were managed with shredder model Triton 1.800, cutting width 1.8 m, with 24 knives, weight 795 kg and knife-roller model Kohler number 08/4753, number of knives 10, distance between knives 0.25 m, working width 2.02 m. The cover crops management plants occurred 120 days after sowing.

The evaluation of the straw decomposition rate was performed using the litter bags method (Kliemann et al., 2006). These were made of nylon with dimensions 0.30 x 0.30 m (0.09 m^2). After the plants management, a portion of this fresh material was collected and 130 g was weighted, which was stored in each bag. This value was defined based on the size of the litter bags and taking into account the average values of green mass (t ha^{-1}) of the crops.

The bags dully identified were randomly distributed in each experimental plot in direct contact with the soil surface and to avoid their displacement, by wind, rain and etc., they were fastened by a metal shaft.

In each plot, 5 litter bags were distributed on the soil surface. They were removed at 20, 40, 60, 80 and 110 days after the cover crops management, and 1 bag per plot was collected (4 per treatment) to evaluate the remaining straw and determine the decomposition time during the 110-day period. A total of 200 litter bags were collected.

To determine the initial plant mass in time 0, soon after mechanical management, a square of metal equivalent to 0,24 m^2 was randomly cast. The material contained in the interior was collected and stored in Kraft paper packaging, two samples were performed in the useful area of each plot. In the Soil Physics laboratory of UNIOESTE/MCR, the samples were weighed to determine the green mass, then placed in the forced air ventilation oven at 65ºC until reaching a constant mass, to estimate the amount of initial dry mass, the results are expressed in kg ha^{-1}.

Within the time limit stipulated for each collection, the litter bags were collected and taken to the laboratory. Afterward, the plant material was cleaned in a sieve, for the elimination of the adhering soil, in bags of paper of known mass, and led to the forced air circulation oven at 65 °C, where it remained until reaching constant mass. After dried they were weighed on scale. The remaining dry matter was then obtained and by comparing the initial dry weight and the weight obtained at each collection date, it was possible to evaluate the mass loss through decomposition during the evaluation periods.

Based on the results obtained, the straw decomposition rates were determined using the simple negative exponential mathematical model used by Thomas and Asakawa (1993):

$$X= Xo.e^{-kt}$$

Where:

X= quantity of dry matter after a period of time t, in days;

$X_{0=}$ quantity of dry matter at the beginning of decomposition;

k=decomposition constant;

t=period of time in days.

Based on the values of the decomposition constant (k) of the dry matter, the half-life time ($T^{½}$=0,693/k) was calculated, which represents the period of time necessary for 50% of the dry matter to be decomposed.

Soybean sowing was carried out mechanically in a no-tillage system on October 16th of 2018, about one month after the cover crops management. Cultivar NIDERA (NA) 5909 RG was used, with spacing of 0.50 m between lines, being distributed approximately 14 seeds/linear meter. For the base fertilization, 310 kg ha^{-1} of the commercial formulation was used 02-20-18 (N, P_2O5 and K_2O) 8% Ca and 4% S, 0.3% Berg oil.

During the crop development, there was the appearance of insect pests such as soybean Caterpillar (*Anticarsia gemmatalis*), looper caterpillar (*Pseudoplusia includens*), brown stink (*Euschistus heros*) and cucurbit beetle (*Diabetes speciosa*) and its chemical control was carried out according to technical recommendations for the crop.

The number of plants was evaluated in three replications, considering the amount of plants/m^{-1} and then extrapolating the values to the hectare.

The evaluation of the agronomic components: Plant height and first pod insertion was carried out in ten plants of the useful area of each plot when they were at stage R_8. With the aid of a ruler graduated in centimeters, the distance from the plant collar to the apical end of the main stem and the plant collar was measured to the first pod insertion, respectively.

The number of pods was determined by quantifying all pods with grains, calculating the average of pods per plant.

The average number of grains per plant was calculated by multiplying the average value of the number of grains per pods by the number of pods found per plant.

For the evaluation of the thousand grain weight, eight sub-samples of 100 grains were separated, according to the requirements established by the seed analysis rule (Brazil, 2009), whose masses were determined on a precision scale and corrected considering the water content of 13%.

Yield was estimated (kg ha^{-1}) based on crop yield components.

Data were tabulated and analyzed for normality (Shapiro-Wilk) and homogeneity of variance (Hartley), respectively, in order to verify compliance with the requirements for the use of variance analysis (ANOVA). Then, the data were submitted to AVA considering a significance level of 5% probability of error for the F test

For the collection times data (remaining dry matter), when the analysis of variance presented significance, these were adjusted to the non-linear regression equation with exponential decay, since this way it is possible to explain the behavior of the biological data, having taken into account, for the choice of the model, the significance and magnitude of the coefficients of determination. The mathematical equations and figure were obtained using the SigmaPlot® 12.0 Software.

For qualitative factors, when significant, the Tukey test was applied at the level of 5% probability of error for comparison of means, using the statistical software Sisvar (Ferreira, 2011).

3. Results and Discussion

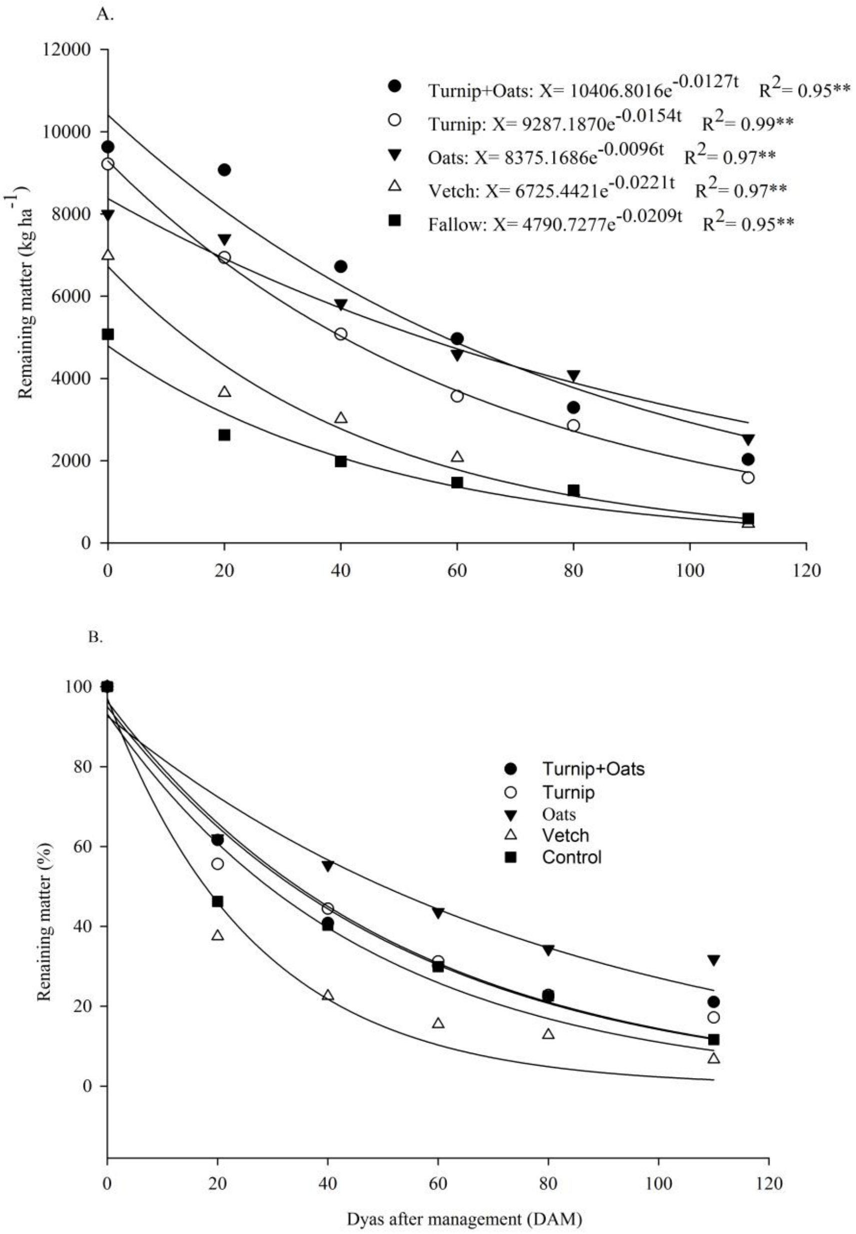
Significant interaction was observed between decomposition time (0, 20, 40, 60, 80, and 110 days after DAM management) and cover crops (turnip+oats, turnip, oats, vetch and fallow) ($p<0.01$) and between decomposition and management time (knife-roller and shredder) ($p<0.05$), for the remaining dry matter variable.

When analyzing the decomposition kinetics of crops residues, a similar pattern is observed, with a progressive exponential decrease in phytomass over the whole evaluated period (0-110 days).

The covers that produced the least initial dry matter were: vetch and fallow (6725.44 and 4790.72 kg ha^{-1}, respectively), as well as they underwent decomposition more quickly. At the end of the period (110 DAM), the initial dry mass was reduced by 91% (6133.95 kg ha^{-1}) and 90% (4309.94 kg ha -1) respectively (Figure 2A), with only 9% (591.49 kg ha^{-1}) and 10% (480.79 kg ha $^{-1}$) of their phytomass on the soil (Figure 2B).

This loss of MS observed in the fallow area can be explained by the predominance of spontaneous species (the most abundant family was *Asteracea*: Black jack -*Bidens pilosa* and common sowthistle-*Sonchus oleraceus*) that associated with low dry mass production (when compared to the other covers), eventually presented rapid decomposition. On the other hand, common vetches belonging to *Fabaceae family* and have a low C/N ratio (around 18), which favored its accelerated decomposition.

Figure 2. Dry matter formed (0 days) and remaining (remaining periods) in kg ha^{-1} (Figure A) and % (Figure B) of cover crops over the evaluated period (0-110 days).



** (p<0.01). Source: Authors.

These results are in agreement with those obtained by Ziech et al., (2015), where at 122 days after the deposition of the litter bags on the soil (the agricultural year 2011/2012), it was found that the common vetches showed only 20% (472 kg ha^{-1}) of the residues in cover. This evidenced the low potential of soil protection over time by leguminous crops grown in monocultures.

The plants of the leguminous family (*Fabaceae*), due to exhibiting a lower C/N ratio (<25) and low lignin content, have a higher availability of nutrients in a short time. This lower C/N ratio favors rapid decomposition, releasing N to the soil, leaving part of the nutrient to the crops since the beginning of its development (Brancalião et al., 2015; Seidel et al.,2016).

At 110 days after management, the following phytomass permanence scale was recorded on the soil: Oats (35%) > turnip+ oats (25%) > turnip (18%) > fallow (10%) > vetch (9%) (Figure 2B). At the end of the experiment (110 DAM), single oats and turnip+oats were the covers that left the highest remaining phytomass amounts, 2913.25 and 2573.99 kg ha^{-1} respectively.

Oats have a large capacity to cover the soil for a longer period of time, mainly due to the slow degradation of its material. This lower degradation may be associated, among other factors, with its composition and high C/N ratio (around 37). Thus, the presence of crops residues on the soil surface preserves it against the impact of the rain drop, reducing the risk of erosion and maintaining moisture. It also increases the supply of organic matter, favors the development of biota and the cycling of nutrients and, consequently, improves the physical and chemical quality of the soil (Mattei et al., 2018).

Ziech et al., (2015), found during the evaluated period (122 days) that black oats were of the species that presented the highest maintenance, with about 41% - (1.242 kg ha^{-1}) of remaining MS in soil cover.

Maintaining an effective amount of crops residues (straw) on the soil surface is a fundamental aspect of conservation management systems. It contributes among other factors with adequate erosion control, which is considered one of the main problems of agricultural areas in Brazil and in the world (Alban et al., 2017).

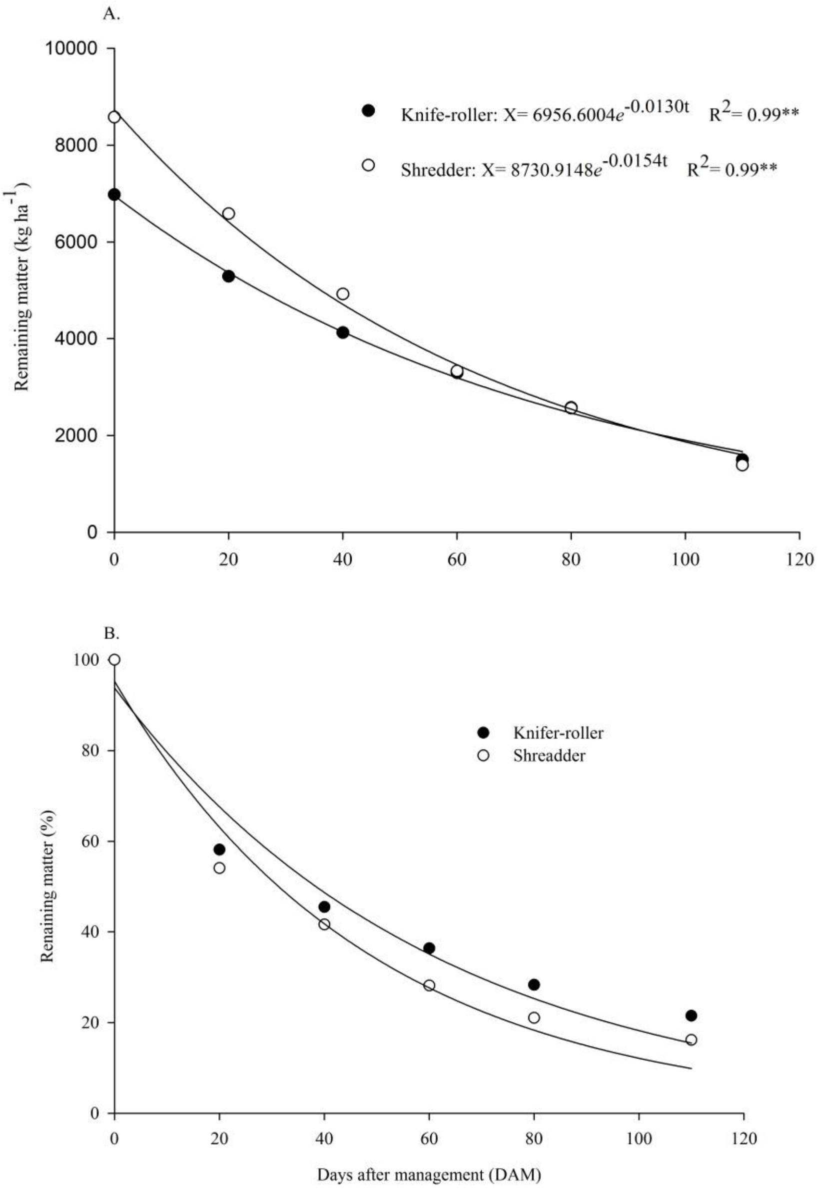
The presence of oats in intercropping with turnip reduced the rate of decomposition of crops residues compared to turnip in monocultures. Thus, the intercropping decomposition curve was at an intermediate level to that observed in single oats and turnip, and this aspect favored the greater permanence of the phytomass produced in the intercropping at the end of the evaluated period.

The intercropping, in addition to protecting the soil by providing the residues maintenance on its surface, present potential addition of nutrients to the system and its supply to subsequent crops, through the decomposition and nutrient cycling process (Ziech et al., 2015).

Figure 3 shows the result of the decomposition of cover crops over time as a function of the equipment used in their management. It is possible to verify that the initial remaining dry matter of the plants managed with the shredder was 8730.91 kg ha^{-1}; therefore, 25% higher than that observed with the knife-roller (6956.60 kg ha^{-1}) (Figure 3A). Probably, the shredder provided vegetation fragmentation and thus, there was also the thicker layers formation of dry mass on the soil, which directly influenced the initial DM difference.

At the first 60 DAM, the highest daily decomposition rate (DDT) of the plant material managed with the crusher and knife-roller was verified, reaching values of 88 and 63 kg MS/ha/day respectively (Figure 3A). In this period, the shredder accelerated the dry matter decomposition compared to the knife-roller by 40%. This is because the shredder fosters cutting of the supply material, reducing its size. While the knife-roller performs the mechanical lodging of the plant material.

Figure 3. Dry matter formed (0 days) and remaining (remaining periods) in kg ha^{-1} (Figure A) and % (Figure B) of cover crops managed with knife-roller and shredder in the evaluated period (0-110 days).



** (p<0.01). Source: Authors.

The dry mass fragmentation provided greater exposure (greater specific area) to the microorganisms that associated with the climatic effects of rainfalls and temperature observed at 60 days, favored the soil microbiota and thus a more accelerated decomposition of the plant material managed. Nor can one ignore the importance of mesofauna activity in an initial phase of the material physical degradation, exposing greater contact surface to microbial biomass attack (Alvarenga et al., 2001).

In addition, it should be borne in mind that the leaves are the first structures to be degraded by soil edaphic fauna and this may also be associated with rapid phytomass decomposition in the first two months after the plants management.

Similar results were obtained by Costa et al., (2014), who evaluating the *U. brizantha* and *U. ruziziensis* straw decomposition as a function of different managements (rotor mowers, straw shredder, knife-roller and whole plant), verified that the biomass decomposition in the management carried out with the shredder was more accelerated compared to the others.

According to Alban et al., (2017), the shredders of crops remains fragment the vegetation and distribute the material more evenly over the area and associated with the crop (C/N ratio) and the region (high temperatures and high humidity), may accelerate the straw decomposition and leave the soil uncovered. However, with this equipment, it is possible to perform fragmentation of more lignified stems or excessive covers and prevent them from causing obstruction or straw accumulation of implements used for further sowing.

After approximately 60 days, it was possible to observe that the decomposition curves of the residues managed with the shredder and knife-roller presented similar patterns in the decomposition kinetics, where their effects in terms of the amount of remaining dry matter were close (Figures 3A and 3B).

It is known that the microbial biomass action decreases rapidly after the consumption of the most labile fraction of the phytomass (part more easily decomposable), which may justify the residues slow decomposition after this period (Aragon, 2015). In addition, climatic factors may also have been preponderant in this process, since after this period, lower rainfall rates and temperature increase which occurred between November and December, were obtained (Figure 1). Such behaviors prove that local climatic conditions have a decisive influence on soil microbial biomass that acts in the decomposition of this straw, which changes the rate of decomposition and increases the life-time of plants residues.

At the end of the evaluations (110 days), 19 and 24% (1611.02 and 1664.78 kg ha^{-1}) remained on the plants phytomass managed with the knife-roller and shredder, respectively, and the knife-roller provided the permanence of 5% of dry matter on the soil more than the shredder (Figure 3B).

As for the half-life time ($T^{½}$) (Table 1) for the residues decomposition, it was observed that half of the plant phytomass originating from the area with black oats had decomposed at 72 days. It is also worth noting that the value of the decomposition constant (k) for this crop was the lowest (0.01), which directly influences the increase of the $T^{½}$ value, thus resulting in the material slower decomposition process.

The slower straw decomposition is due to the higher proportion of lignified material (stems) and the high ratio C/N (> 30) of black oats (Silva et al., 2012), which characterizes it as a plant of high persistence. Beneficial result because it preserves more residue on the soil, contributing to moisture maintenance and protection against the erosive effect, and spontaneous plant suppression (Favorato et al., 2014).

Acosta et al., (2014), upon studying the decomposition of cover crops phytomass, observed that the half-life time of black oats was on average 236 days, and approximately 80% of the material is considered recalcitrant compartment, that is, with slower and more difficult decomposition.

The lowest $T^{½}$ was obtained by common vetch at 31 days, therefore, its decomposition was twice as fast as that observed in black oats (72 days), that is, in the first month of evaluation, half of all the material had already decomposed. Fallow plants also presented low half-life at 33 days.

For these covers, the k values were the highest, being 0.02 for vetches and 0.02 for fallow, therefore, it can be inferred that the straw decomposition of these coverings was more rapid than the others, which reinforces the fact that they present an accelerated loss of their materials in a short time. That is, the decomposition constant is inversely proportional to $T^{½}$, because when its value is higher, $T^{½}$ is lower.

These results were similar to those found by Teixeira et al., (2012), where the lowest $T^{1/2}$ was obtained in the area with spontaneous vegetation (composed predominantly of leguminous plants), this behavior was related to the species composition, which presented a C/N ratio of 11, the lowest among the plants studied and thus favoring a more accelerated decomposition of plants residues.

The intercropping (turnip+oats) and the turnip in monoculture presented close $T^{½}$ (55 and 45 days, respectively). These values are intermediate to those found in vetches and oatmeal.

Table 1. Parameters of adjusted models ($X= XO.E^{-kt}$) to the remaining dry matter values, half-life time (T½)

COVERS	X_0 (1)	k (2)	$T^{1/2}$ (3) days
Turnip+Oats	10406.80	0.01	55
Forage turnip	9287.19	0.02	45
Black oats	8375.17	0.01	72
Common vetch	6725.44	0.02	31
Fallow	4790.73	0.02	33
MANAGEMENT	X_0 (1)	k (2)	$T^{1/2}$ (3) days
Knife-roller	6956.60	0.01	53
Shredder	8730.91	0.02	45

(1) Initial quantity (kg ha^{-1}); (2) Decomposition constant; (3) Half-life time. Source: Authors.

Acosta et al., (2014) evaluating the decomposition dynamics as a function of the amount of residues supplied to soil by winter cover crops used in the NTS in the southern region of Brazil, it was found that the decomposition of half of the vetch, forage turnip and black oats residues occurred at around 1,6, 3,5 and 5,5 months, respectively, above what was found in this study.

The covers managed with knife-roller showed higher t½ than the shrudder (53 and 45, respectively), and the decomposition of the material managed with the first equipment occurred more gradually than the second, and this may have been one of the factors that contributed to greater permanence of the remaining straw managed with a knife-roller at the end of the evaluation (figure 3).

Table 2 shows the average results for agronomic and yield components of soybean crop sown in succession to cover crops. Based on the results obtained, a significant effect was observed only for the covers ($p<0.01$) on the different components, indicating that the use of certain plants will be reflected in the soybean agronomic traits.

For the number of plants per hectare (NP) and thousand-grain weight (TGW) of soybean, the covers did not influence significantly. The number of plants in the present study was in the range from 312.499 to 350.833 plants ha^{-1}, and variations in the plant population were acceptable for soybean crop from 200.000 to 500.000 ha^{-1}. Similar results were obtained by Mottin (2016), where the final population of soybean plants did not undergo significant concerning the families and species of cover crops studied.

When the soybean plant height (PH) was analyzed, the highest values of this variable were found in the plots that had previously vetch (69.56 cm), oats (68.9 cm) and fallow (68.07 cm), and these covers were statistically higher than the others, but they did not differ among themselves.

The plots that had been cultivated with vetch provided, on average, the highest first pod insertion height (FPIH), of soybean (12.62 cm), but did not differ statistically from the others, except for the intercropping (turnip+oats), which presented lower HFPI (9.83 cm).

For the number of pods and grains per plant (NPP and NGP), it can be observed that the soybean cultivated in the plots that were composed of oats presented the highest average values (62.00 and 144.00, respectively), when compared to the rest of the covers, being also statistically higher than the turnip and turnip+oats, not differing from the others.

Based on the results, it was possible to observe that in the plots composed of monocropping turnip and oats+ turnip, it achieved the lowest performance on the soybean agronomic treats: PH (57.90 and 58.98 cm), FPIH (10.43 and 9.83 cm), NPP (40 and 39 cm) and NGP (95 and 91cm). These results may be related in part to the time of the covers management, since this occurred late, which caused the turnip resowing, and thus, an initial competition between the soybean and the cover, which consequently affected the summer crop components.

Table 2. Average results for the number of plants (NP), plant height (PH), first pod insertion height (FPIH), number of pods per plant (NPP), number of grains per plant (NGP), thousand-grain weight (TGW) and soybean yield, due to the cultivation in succession to winter cover crops, 2018/2019 harvest.

Cover crops	NP	HP	FPIH	NPP	NGP	TGW	Yield
	---(ha)---	--------(cm)--------				----(g)----	-----(kg ha^{-1})----
Turnip+Oats	350.833^{ns}	58.98 b	9.83 b	39.00 b	91.00 c	160.20^{ns}	3828.94^{ns}
Turnip	312.499	57.90 b	10.43 ab	40.00 b	95.00 bc	160.10	3489.49
Oats	338.333	68.90 a	11.16 ab	62.00 a	144.00 a	141.04	3693.67
Vetch	320.833	69.56 a	12.62 a	57.00 ab	134.00 ab	157.47	3465.68
Fallow	333.333	68.07 a	11.73 ab	53.00 ab	123.00 abc	148.86	3488.08
DMS	64741.61	4.42	2.74	17.72	41.88	26.35	468.06
CV %	13.38	4.69	16.83	24.15	24.4	11.75	8. 92

^{ns}not significant by F test ($p<0.05$); MSD: Minimum Significant Difference; CV: Coefficient of Variation. Means followed by the same lowercase letter in the column do not differ by Tukey's test, at 5% probability of error. Source: Authors.

The soybean estimated yield was not influenced by the previous crops. However, soybean sown after the intercropping of turnip+oats and vetch presented the highest and lowest values in magnitude, around 3828.94 and 3465.68 kg ha^{-1}. The data indicate that all these cover crops can be included, without loss in yield, in a succession system with the soybean crop, since the grain yield showed no difference. These results are corroborated by Sanchez et al., (2014), who did not find significant differences for soybean cultivation in succession to different cover crops.

4. Conclusions

Common vetch and fallow presented higher decompositions and lower $T^{½}$ of their residues, which evidences their low soil protection to erosive processes. Black oats and turnip+ oats intercropping obtained a higher permanence on the soil as well as $T^{½}$, being a good option to keep the soil covered longer and assuring better quality in the no-tillage system.

The cover crops management with the shredder resulted in a higher daily decomposition in the 60-day period and the management with a knife-roller may have gains mainly by reducing initial weeds and soil temperature, as well as protection to erosion processes.

The cover crops cultivation and their management previous to the soybean did not influence this crop yield.

Acknowlegements

To Universidade Estadual do Oeste do Paraná Campus Marechal Cândido Rondon (Unioeste/MCR) and the Graduate Studies Program in Agronomy (PPGA), for the opportunity to conduct the course. To the *Conselho de Aperfeiçoamento de Pessoal de Nivel Superior* [Coordination for the Improvement of Higher Education Personnel/ (CAPES), for providing the research grant and financing. To the Group of Soil and Agroecology Studies (GESA), professors and students for their support and contributions in the study construction and development.

Reference

Acosta, J. A. A., Amado, T. J. C., Silva, L. S., Santi, A., & Weber, M. A. (2014). Decomposição da fitomassa de plantas de cobertura e liberação de nitrogênio em função da quantidade de resíduos aportada ao solo sob Sistema Plantio Direto. *Ciência Rural*, 44(5), 801-809.

Alban, A. A. *Mecanização Agrícola*. (2017). In: Mazaro, S. M., Challiol, M. A., Alban, A. A., & Zorzzi, I. C (Org.). Sistema de produção Soja Orgânica. Porto Alegre: Editora Cinco Continentes, 97-128.

Alvarenga, R. C., Cabezas, W. A. L., Cruz, J. C., & Santana, D. P. (2001). Plantas de cobertura de solo para sistema Plantio Direto. *Informe Agropecuário*, 22, 25-36.

Aragão, J. I. O. (2015). *Plantas de cobertura e dinâmica do carbono orgânico do solo nas condições edafoclimáticas do Recôncavo da Bahia*. 2015. 68 f. Dissertação -Universidade Federal do Recôncavo da Bahia. Bahia.

Araújo, L. S., Cunha, P. C. R., Silveira, P. M., Netto, M. S., & Oliveira, F. C. (2015). Potencial de cobertura do solo e supressão de tiririca (C*yperus rotundus*) por resíduos culturais de plantas de cobertura. *Revista Ceres*, 62(5), 483-488. http://dx.doi.org/10.1590/0034-737X201562050009.

Brancalião, S. R., Aguiar, A. T. E., Brancalião, E. M., Limonta, C. R., Rossi, C. E., **&** Cristovão, N. N. (2015). Produtividade e composição dos grãos de soja após o aporte de nitrogênio com o uso de culturas de cobertura em sistema de semeadura direta. *Nucleus*, 12(1), 69-73.http://dx.doi.org/10.37378/1982.2278.1001.

Brasil. (2009). *Regras para análise de sementes*. Brasília: Secretaria de Defesa Agropecuária, 395.

Caviglione, J. H., Kiihl, L. R. B., Caramori, P.H., & Oliveira, D. (2000). Cartas Climáticas do Paraná. Londrina: Instituto agronômico do Paraná.

Conceição, P. C., Calegari, A., & Hojo, R. H. (2017). Plantas de cobertura e rotação de culturas. In: Mazaro, S. M., Challiol, M. A., Alban, A. A., & Zorzzi, I. C (Org.). Sistema de produção Soja Orgânica. Porto Alegre: Editora Cinco Continentes, 129-166.

Costa, N. R., Andreotti, M., Fernandes, J. C., Cavasano, F. A., Ulian, N. de. A., Pariz, C. M., & Santos, F. G. dos. (2014). Acúmulo de nutrientes e decomposição da palhada de braquiárias em função do manejo de corte e produção do milho em sucessão. *Revista Brasileira de Ciências Agrárias*, 9(2), 166-173. DOI:10.5039/agraria.v9i2a3380.

Favorato, L. F., Galvão, J. C. C., Souza, J. L., Guarçoni, R. C., Souza, C. M., & Cunha, D. N. (2014). Population density and weed infestation in organic no-tillage corn cropping system under different soil covers. *Planta Daninha*, 32(4), 739-746. http://dx.doi.org/10.1590/S0100-83582014000400008.

Ferreira, D. F. Sisvar: a computer statistical analysis system. (2011). *Ciência e Agrotecnologia*, 35 (6), 1039-1042. http://dx.doi.org/10.1590/S1413-70542011000600001.

Kliemann, H. J., Braz, A. J. B. P., & Silveira, P. M. (2019). Taxa de composição de resíduos de espécies de cobertura em Latossolo Vermelho Distroférrico. *Pesquisa Agropecuária Tropical*, 36(1), 21-28.

Mattei, E., Rabello, P. S. R. de., Rampim, L., Egewarth, J. F., Rego, C. A. R. de. M., Piano, J. T., & Herrera, J. L. de. Remaining straw and release of nutrients from oat managed in integrated crop-livestock. (2018). *Bioscience Journal*, 34(1), 2006-2015. https://doi.org/10.14393/BJ-v34n6a2018-42036.

Mottin, M. C. (2016*). Efeito de plantas de cobertura cultivadas no inverno nas propriedades físicas do solo e na produtividade de soja e milho em sucessão*. 2016. 65 f. Dissertação- Universidade Estadual do Oeste do Paraná. Paraná.

Pariz, C. M., Andreotti, M., Buzetti, S., Bergamaschine, F. A., Ulian, N. A., Furlan, L. C., Meirelles, P. R. L., & Cavasano, F. A. (2011). Straw decomposition of nitrogen-fertilized grasses intercropped with irrigated maize in an integrated crop livestock system. *Revista Brasileira de Ciência do Solo*, 35(6), 2029-2037. http://dx.doi.org/10.1590/S0100-06832011000600019.

Sanchez, E., Maggi, M. F., Genú, A. M., & Müller, M. M. L. (2014). Propriedades físicas do solo e produtividade de soja em sucessão a plantas de cobertura de inverno. *Magistra*, 26(3), 266-275.

Santos, H. G., Almeida, J. A., Oliveira, J. B., Lumbreras, J. F., Anjos, L. H. C. dos., Coelho, M. R., Jacomine, P. K. T., Cunha, T. J. F., & Oliveira, V. A. de. (2013). Sistema Brasileiro de Classificação de Solos. 3.ed. Brasília, DF, EMBRAPA, 353.

Seidel, E. P., Mattias, V., Mattei, E., & Corbari, F. (2015). Produção de matéria seca e propriedades físicas do solo na consorciação milho e braquiária. *Scientia Agraria Paranaensis*, 14(1), 18-24. https://doi.org/10.18188/sap.v14i1.8226.

Seidel, E. P., & Mottin, M. C. Plantas de cobertura ou adubo verde na agricultura orgânica. (2016). In: Seidel, E.P., Mello, E. C. T. de Zambom, M. A (Org.). Sustentabilidade agropecuária em sistemas agroecológicos e orgânicos de produção. Marechal Cândido Rondon-PR: Unioeste, 161-169.

Teixeira, C.M., Loss, A., Pereira, M.G., & Pimentel, C. (2012). Decomposição e ciclagem de nutrientes dos resíduos de quatro plantas de cobertura do solo. *Idesia*, 30(1), 55-64. http://dx.doi.org/10.4067/S0718-34292012000100007.

Thomas, R. J., & Asakawa, N. M. (1993). Decomposition of leaf litter from tropical forage grasses and legumes. *Soil Biology and Biochemistry*, 25(10), 1351-1361. https://doi.org/10.1016/0038-0717(93)90050-L.

Ziech, A. R. D., Conceição, P. C., Luchese, A. V., Balin, N. M., Candiotto, G., & Garmus, T. G. (2015). Proteção do solo por plantas de cobertura de ciclo hibernal na região Sul do Brasil. *Pesquisa Agropecuária Brasileira*, 50(5), 374-382. http://dx.doi.org/10.1590/S0100-204X2015000500004.