Journal of Experimental Agriculture International

40(6): 1-9, 2019; Article no.JEAI.51454
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

No-till System as an Alternative for Soil Conservation Aiming at Sustainability in Tobacco Production

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Authors' contributions

This work was carried out in collaboration among all authors. Authors FTB, CBM, CJM and CAS conducted the experiment, wrote the first draft of the manuscript, discussed the results, correct and improve the writing of the manuscript in English versions. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/v40i630384
Editor(s):
(1) Dr. Rusu Teodor, Professor, Department of Technical and Soil Sciences, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.
Reviewers:
(1) Nyong Princely Awazi, University of Dschang, Cameroon.
(2) Nicholas Ogot, International Centre of Insect Physiology and Ecology, Kenya.
Complete Peer review History: http://www.sdiarticle4.com/review-history/51454

Original Research Article

Received 10 July 2019
Accepted 11 September 2019
Published 23 September 2019

ABSTRACT

Aims: Tobacco cultivation is important in the income composition of family farmers. The use of soil cover plants is a practice that plays an important role in keeping the soil covered and reducing the effects of water erosion and improving the physical, chemical and biological conditions of the soil. The objective of this study was to evaluate the benefits of using different species for soil covering preceding the production of tobacco in the no-tillage system.
Place and Duration of Study: Two experiments were conducted in Jaguari-RS, in the years 2015 and 2016.
Methodology: The treatments were different species of soil cover crops, preceding the cultivation of tobacco (*nicotine tabacum*) as described: Black oat (*Avena strigosa*); Common Vetch (*Vicia sativa* L.); Consortium of Black Oat + vetch and white lupine (*Albus* L.). For both experiments, the experimental units consisted of plots of 3.5 x 3 m, comprising an area of 10.5 m^2. The plant growth, production of the dry mass and decomposition of crop residues, of the cover crops, as well as weed infestation and tobacco yield were evaluated.

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Results: Among the winter cover crops, black oats and white lupine stood out, as they showed fast growth and higher dry mass production, resulting in higher tobacco yield. These cover crops showed the most promising, combining the benefits to soil conservation and the sustainability of the production system.
Conclusion: In this study it was observed that the treatments with cover crops that presented the highest dry mass production were the same ones that provided the highest tobacco yield, making it possible to affirm that there is a positive relation between the production of the dry mass of precedent crop with tobacco yield.

Keywords: Green manure; soil conservation; water erosion; nicotine tabacum.

1. INTRODUCTION

The cultivation of tobacco has a significant importance in Brazil, involving around 150 thousand family farms, where it accounts for approximately half of the overall income of these families [1]. Brazil has second-ranked in the world production of Leaf tobacco, and has been the leader in exports since 1993 [2].

According to the secretariat of State for Agriculture and Supply, the Brazilian leadership is due to the excellent quality of tobacco and guarantee of supply, which increases the competitiveness of the Brazilian product in the international market.

In Brazil, the Rio Grande do Sul, Santa Catarina and Paraná states, respond for 95% of national production, with 705,930 ton produced in 298,230 hectares, during the 2017 season [2].The concentration of production in the southern region is due to the exceptional climatic and soil conditions, the tradition of the European descendant people in cultivating tobacco and mainly to the high profitability that the crop provides in small tobacco-producing farms [3].

The small family-based property allows the establishment of several systems of production integration with Agro industries, highlighting the tobacco growing [4]. The tobacco-producing properties are characterized by the intensive uses of natural resources, most of which are located in marginal areas with shallow and stony soils lying in wavy and steep relief [5].

The main problems encountered in areas cultivated with tobacco are related to inadequate use of the soil, associated with the conventional tillage system performed by most farmers. This practice incorporates organic residues, leaving the soil exposed to the impact of the raindrop and the daily temperature oscillations, which may deforest the soil [6]. This practice also increase the risk of soil degradation caused by erosion, as if high rainfall volumes occur when the soil is unprotected after its cultivation, large losses of soil, organic matter, nutrients, fertilizers, among others, may occur. Therefore, the reduction of soil quality and yield [7].

The physical properties of the surface and subsurface are affected by the form of soil cultivation and interfere in its structure, density and porosity, which modify the infiltration capacity and susceptibility to erosion [8]. Soil tillage aims to modify the superficial structure, which favors aeration, greater water absorption, and weed control. Usually, tobacco farmers revolve the soil before planting, to incorporate the nitrogen (N) applied and to provide better root-soil contact during the initial stages of the plant. However, it causes alteration in the arable structure leaving the soil unprotected favoring the soil erosion by water [8].

With this, there is a loss of particles and impoverishment of the soil decreasing the productive potential, increasing the cost of production. The leaching of fertilizers and contaminants of the crop can reach water flows contributing to eutrophication and environmental contamination. According to Silva [9], he recommends the conservationist practices of minimum cultivation and mainly of no-tillage as better management for soil and water conservation, and this system can be used in large as well as in small properties.

In the no-tillage system, the absence of the soil tillage maintains chemical and structural attributes of the soil; it favors the increment of organic matter and leads to a slow reconsolidation of the soil, approaching to natural levels, with a more uniform distribution of In-depth pores [10]. The use of cover crops and soil recovery are rarely used and are hardly part of the management and rotation by tobacco producers [8]. Soil cover is one of the most interfering factors in the erosive process. The surface straw acts as a natural barrier to meteorological factors, reduces the effects of erosion and improves the physical and chemical conditions, increases the stability of the aggregates and the rate of water infiltration in the soil [11].

Sowing of soil cover crops, preceding the planting of tobacco, is essential to implement the no-tillage system. The tobacco culture needs adequate technology and management that facilitates the cultivation in a conservationist form, but the limited adoption of conservationist management of water and soil in the tobacco crop is mainly due to a little research and technological diffusion geared towards these farmers.

Intending to maintain this sustainable productive chain, with emphasis on soil conservation practices, this study aimed to evaluate the benefits of using different species of soil cover crops in the production of tobacco in a No-tillage system. Also, it intends to stimulate the change in the system of tobacco cultivation, from conventional preparation to the conservationist system, as a way to reduce environmental impacts, and to increase the levels of productivity of the tobacco crop.

2. METHODOLOGY

2.1 Study Area

The experiments were implemented in the Jaguari city, a typical region of the Central depression of Rio Grande do Sul, during the 2015 and 2016 seasons. The site soil belongs to the mapping unit São Pedro, classified as red Argissol [12], sandstone substrate (Paleudalf). This unit is characterized by soils with a sandy, friable, and well-drained surface texture. These soils are acidic, with low to medium base saturation, poor in organic matter and most nutrients. The São Pedro unit covers the regions of the Central depression and part of the Rio Grande do Sul campaign, covering an area of 6,675 km^2, representing approximately 2,48% of the state area [13]. The climate of the region is of the type Cfa that is, subtropical humid without a drought, according to the climatic classification of Köeppen. The average annual precipitation is 1,561 mm.

The experimental design was randomized blocks with four replications. Each experimental unit consisted of plots of 3.5 x 3 m, totaling an area of 10.5 m^2 each, and 168 m^2 in total. The treatments consisted of different species of winter cover crops, legumes, and grasses, preceding the cultivation of tobacco (*Nicotiana tabacum*) as described: T1-Black Oat (*Avena strigosa*); T2-Vetch (*Vicia sativa* L.); T3-Consortium of Black Oat + vetch; T4-White lupine (*Albus* L.).

2.2 Sampling and Data Collection

In May of each year, the cover crops were sowed, no-till, maintaining the already constructed ridges, using the following densities: 70 kg ha^{-1} of black oat seed, 70 kg ha^{-1} of vetch seed, 250 kg ha^{-1} of lupine and 30 kg ha^{-1} of black oat + 50 kg ha^{-1} of Vetch in the Consortium [14]. According to soil analysis, the cover fertilization was made when the plants were at the beginning of the tillering. 50 kg ha^{-1} of N in the treatments with black oat and 20 kg ha^{-1} of N in the Black Oat + Vetch Consortium were applied, having urea as source [15].

In both experiments, the velocity of soil covering, the decomposition of the residues and weed infestation during the development of the cover crops were evaluated weekly, through the square diagonal method using a Center Plumb [16].

The evaluation of dry mass production of the treatments were performed when the crops were in full bloom. A 0.25 m² model was used to assist in the collection of samples of green Mass that were randomly performed in the plots. After being collected, the samples were oven-dried at 65ºC until it reached a constant mass. After drying, the samples were weighed and dry mass production was estimated.

The production of tobacco seedlings was carried out in a low tunnel greenhouse, using plastic trays with 250 cells, suspended in a small blade of fertilized water. The tobacco seeding was carried out in July. During the seedling development, management practices such as pruning the seedlings and the application of chemical products were performed to maintain sanity until the transplant was performed. In the preparation of the area, for the implantation of the tobacco seedlings, pre-emergent herbicides were applied for weed control, Sulfentrazone, 0.5 L ha^{-1} and Clomazone, 2 L ha^{-1}, according to technical recommendations and product shortage Chemical.

The fertilization used followed the technical recommendation for the tobacco culture, according to the interpretation of the Soil Analysis report, and the cover fertilization was applied without soil disturbance [15]. The basal fertilization was performed on the surface of the ridge. The transplant of the tobacco seedlings occurred when the soil and climate were in perfect condition. The plant density used was 20,000 plants ha^{-1}. For tobacco plants express their yield potential, topping was performed at the beginning According to Souza Cruz [17], this cultural tract consists of the elimination of the floral bud, keeping the plants with a satisfactory amount of leaves for good productivity. Shortly after the removal of the floral bud, Flumetralin was applied to control auxiliary bud growth.

The beginning of the harvest occurred when the leaves presented a certain degree of maturity. In the case of Virginia tobacco, maturity is not uniformly given. It starts from the bottom and goes to the top of the plant. First, the leaves near the bottom were harvested (first leaves of the plant) and, as the other leaves matted, were harvested the semi meeiras located in the low half-foot of the plant, the meeiras located at the top half foot of the plant and lastly the tips on the high Half-foot of the plant [17]. The whole experimental plot was harvested, but only the central plants were destined for yield measurement. After harvesting, the leaves corresponding to each treatment were separated and placed to the greenhouse, with temperature and humidity controlled, where they went through the process of curing and drying. After curing, the tobacco samples were weighed for production determination.

2.3 Data Analysis

The biomass and yield data observed were analyzed using the software Sisvar, for analysis of variance and, when significant, the averages were compared by the Tukey test at $P < 0,05$ of error.

3. RESULTS AND DISCUSSION

Fast growth is a desirable feature in cover crops because it results in faster soil covering, avoiding exposure to erosion, as well as suppressing the development of weeds. In 2015 (Fig. 1 A), black Oat was the crop that stood out, with rapid growth, reaching 100% of soil cover at 63 days after sowing (DAS). The lupine reached 100% coverage at 70 DAS and the combination of Black Oat + Vetch at 77 DAS. The treatment with Vetch was the only one that by the end of the evaluation period did not fully cover the soil, presenting 77% of soil coverage.

In 2016 (Fig. 1 B), the cover crops showed slower growth compared to the previous year. The crops that stood out were the lupine that reached 100% of soil cover at 84 DAS and Black oat that reached 100% of coverage at 91 DAS. As in 2015, the combination of black Oat + Vetch and Vetch were the treatments that showed the slowest development, not fully covering the soil until the end of observations. These results indicate that the white lupine and black oat are the best options when it is desired to quickly cover the soil and, when the length of the cover crop is shorter until the tobacco implantation.

According to Cremonez et al. [18], the lupine is employed in the field as a protection cover against erosion, due to its high production of biomass, acting as a plant destined to conservation management systems. Conforming to Filho et al. [19], Black Oat has a large tillering capacity and develops well in infertile soil, and it is used to protect and quickly cover the soil with good biomass production, which may be intercropped with grass species or Legumes. The Vetch is an option when the length of the cover crop purpose is greater. This is justified by the slower initial growth and a longer cycle of Vetch [20]. The highest dry mass production of the cover crops in 2015 was obtained in the treatments with black oat, black oat + vetch and lupine, respectively (Fig. 2). The treatment with vetch produced a lower amount of dry matter.

In 2016, the highest dry mass production was obtained in the treatments with lupine, and black oat (Fig. 2). Again, Vetch was the culture that produced the smallest amount of dry mass. These results corroborate with Alvarenga, et al. [21] that with an experiment conducted in Santa Maria-RS, found values of dry mass production for black Oat, lupine, and vetch of 4.3 tha^{-1}, 4.8 tha^{-1} and 2.5 tha^{-1} respectively. According to Monegat [14], the competitive ability of oat is higher due to its rusticity and aggressiveness in relation to Vetch, besides presenting the ability of tillering.

The amount of dry mass of winter cover crops, present on the soil surface after the tobacco transplantation, was higher in the treatment with black Oat, followed by the combination of Black Oat + Vetch and lupine, respectively. In the treatment with vetch, the presence of residues was lower (Fig. 3). It is important to highlight that the cover crops were managed with herbicide 25 and 15 days before tobacco transplanting, in 2015 and 2016, respectively.

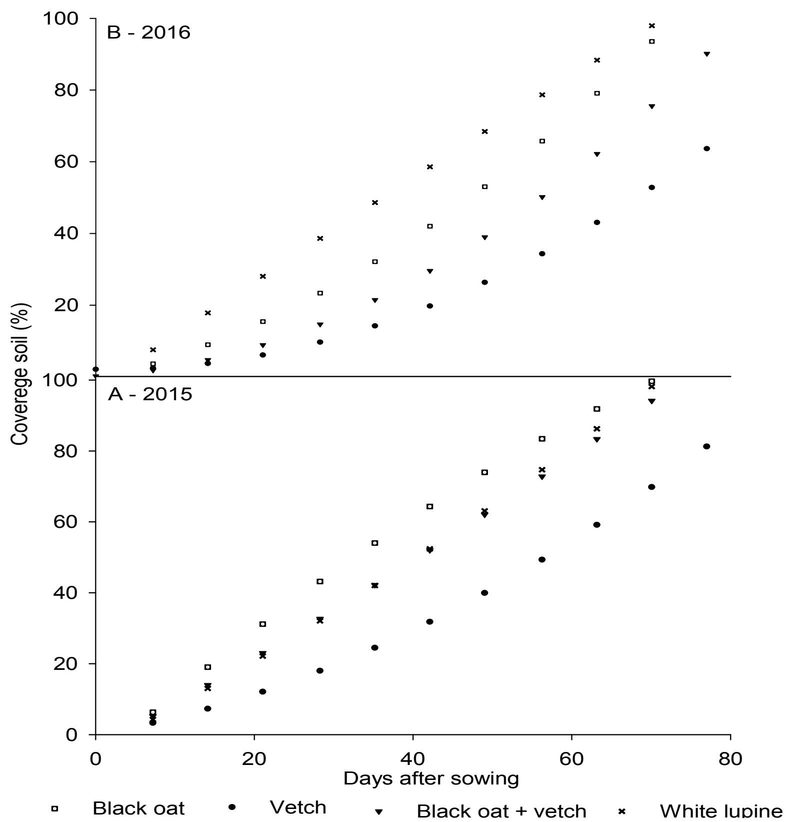

Fig. 1. Percentage of soil cover of the winter cover plants, used in the Years 2015 (A) and 2016 (B)

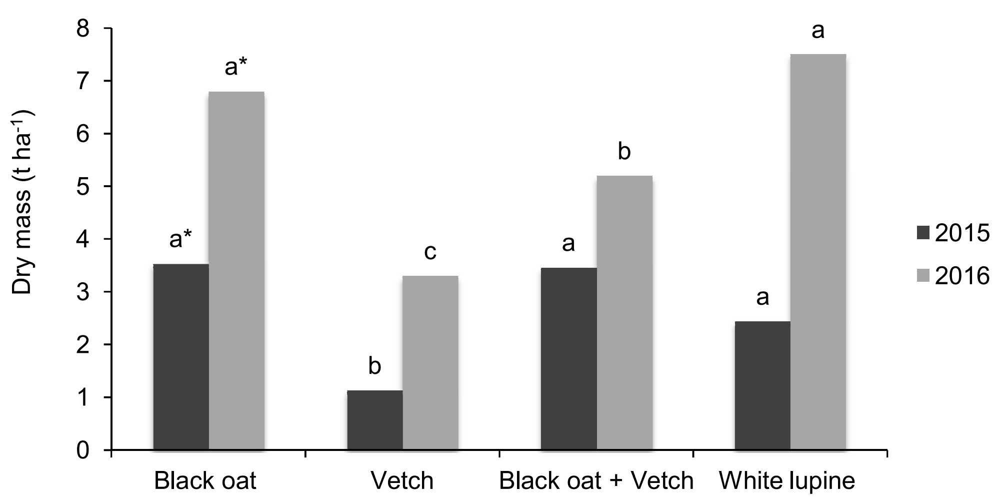

Fig. 2. Dry mass of the winter cover crops in the years 2015 and 2016
*The averages followed by the same letter do not differ significantly, at a * P < 0,05 by the Tukey test*

The results are similar to those found by Crusciol et al. [22] when they determined the remaining dry mass rate of black oat at 13, 35 and 53 days after management, respectively, 72.2%; 56% and 33.6% of the initial quantity of the dry mass-produced. According to Acosta et al. [23], the highest N content and the lowest C/N ratio in the Vetch provides a higher residue decomposition rate. Moreover, the dry mass production of Vetch was lower (Fig. 2). This lower dry mass production combined with rapid decomposition resulted in a lower amount of dry mass remaining on the soil (Fig. 3 A and B).

In the No-tillage system, to control erosion, it is recommended to maintain a high amount of residual biomass that protect the soil surface for the longest possible period. According to Da Ros and Aita [24], generally, grasses have a high C/N ratio of biomass and in this context, the decomposition process of oat residues is limited by the N available, with temporary immobilization of N by soil microorganisms. Leguminous are of faster decomposition as their C/N ratio is lower. Similar results were found by Aita and Giacomini [25], where the presence of oat combined with vetch reduced the decomposition rate of the crop residues in relation to only vetch. Thus, the decomposition curves of the two treatments involving intercropping between Oat and Vetch were located at an intermediate level to that observed in the treatments with these two species.

Weed infestation during the tobacco crop development cycle was higher in the treatment with Vetch (Fig. 4). Among the treatments analyzed, black oat and lupine showed lower weed infestation. Possibly, this is due to the production of the dry mass of the different cover crops. The presence of a layer of straw on the soil surface plays a key role in weed control, limiting the passage of light, creating difficulties for the seed germination, and creating

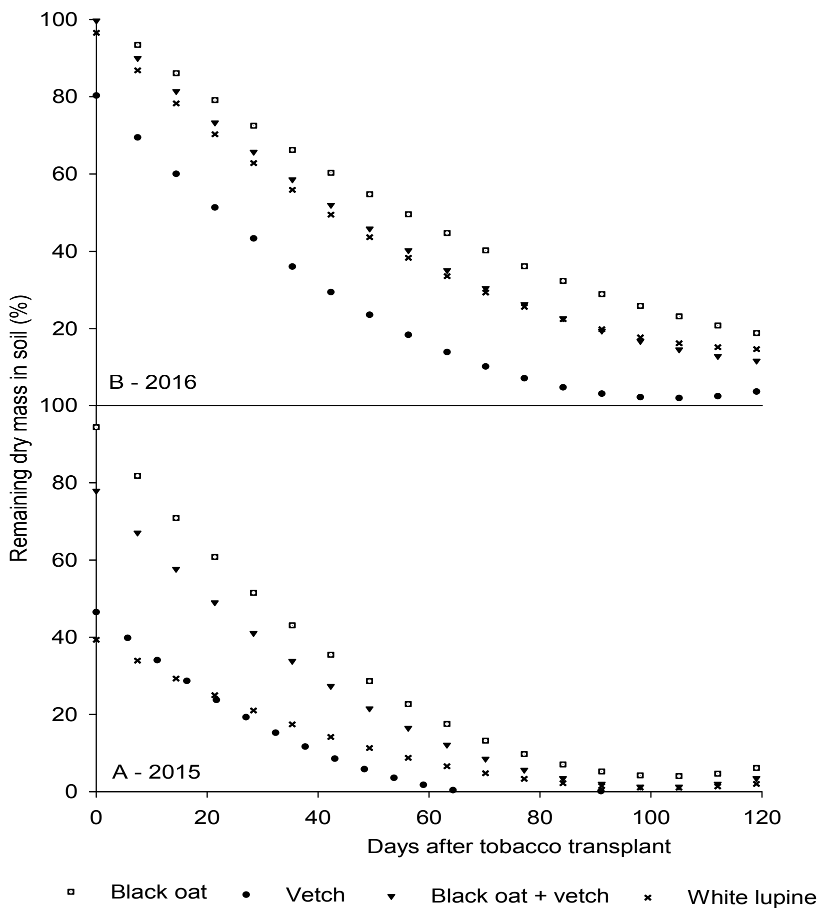

Fig. 3. Remaining dry matter of soil cover crops after tobacco transplantation in the Years 2015 (A) and 2016 (B)

a physical barrier, hindering the initial growth of weed seedlings [26].

According to Borges et al. [27], another possibility is the allelopathic effects arising from the decomposition of the biomass or exudation of the roots, which release substances that will exert some type of inhibitory effect on the seeds, preventing germination. In plants, the allelopathic effect may interfere in some developmental processes, in such a way that growth is delayed or paralyzed, and in some cases, the death of the plant occurs. According to Fontaneli et al. [28], Black Oat has a high positive allelopathic effect in many weeds.

The highest tobacco yield (Fig. 5) was obtained in the treatments with lupine and black oat as cover crops preceding the tobacco in the two years studied. The treatments with Vetch and Black Oat + Vetch combined showed lower tobacco productivity.

The amount of N accumulated in the aboveground biomass of cover crops may influence the yield of the following crop, mainly when leguminous crops are used as cover [29]. According to Cremonez et al. [18], Lupin provides improvements in the physical conditions of the soil and promotes the symbiotic nitrogen fixation, through the bacteria present on the

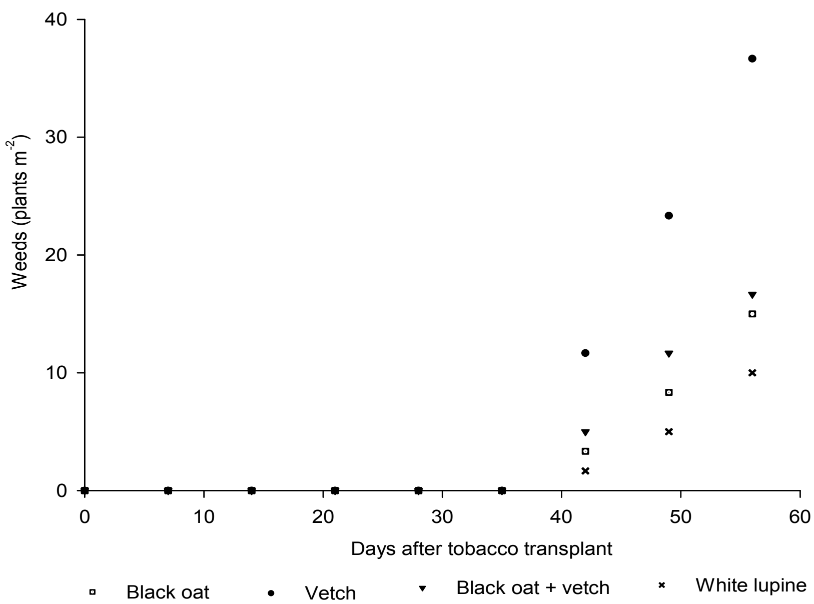

Fig. 4. Invasive plants present in the soil after tobacco transplantation in the year 2016

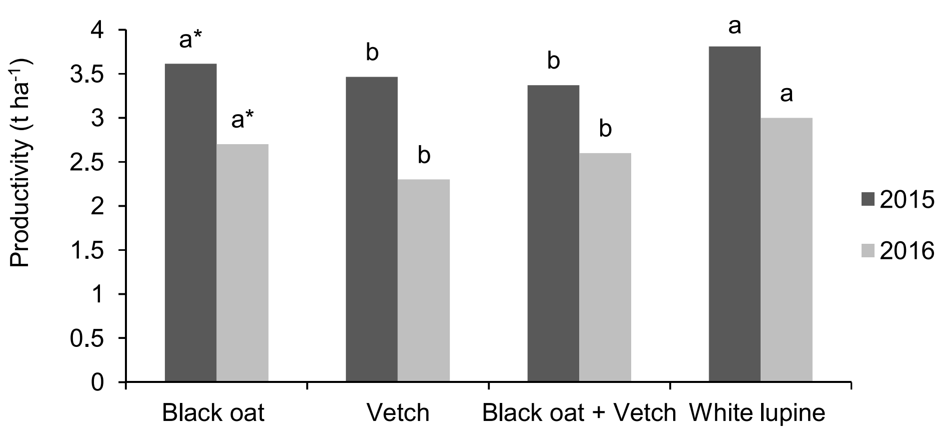

Fig. 5. Yield of tobacco cultivated after different winter cover crops
*The averages followed by the same letter do not differ significantly, at a * P < 0,05 by the Tukey test*

nodules, which can contribute with the equivalent of 90-100 kg ha^{-1} year^{-1} of N. The black oat, according to Carvalho [30], with the advent of no-tillage, became fundamental in crop rotation and straw formation, with good carbon/nitrogen ratio (C/N).

In this study it was observed that the treatments with cover crops that presented the highest dry mass production were the same ones that presented the highest tobacco yield, allowing to affirm that there is a positive relation between the dry mass production of the antecedent culture with tobacco yield. As a practical implications of this study it is stated that it is possible to produce tobacco in no-tillage system using the aforementioned crops as an alternative in the crop rotation system and thus reduce soil degradation.

4. CONCLUSION

The best results for soil conservation and tobacco yield were obtained with the use of Black oat and white lupine as winter cover crops.

It is possible to produce tobacco in a no-tillage system. For this, it is recommended to use crops of rapid growth and high dry mass production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/51454