Use of grass and leguminous species as winter mulching in organic no-tillage system of lettuce crop[1]

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10.1590/0034-737X202370020007

ABSTRACT

The no-tillage system for vegetables is an environmentally and economically suitable alternative, particularly for organic crops. However, further studies are needed using other plant species and under different growing conditions. This research aimed to evaluate the influence of different winter soil covers on lettuce development and yield under no-tillage system in an organic cultivation area. The experiment was arranged in a randomized block design with five treatments and six replications. The treatments used were three soil covers in the organic no-tillage system and two systems without cover crops and with soil tillage, one organic and the other conventional. The grass *Avena strigosa* (L.), the leguminous *Lupinus albus* (L.), and the intercropping of both species were used. The number of leaves per plant, stem length and diameter, head diameter, fresh and dry weight of plants, fresh weight of leaves and stem and Soil Plant Analysis Development (SPAD) index were evaluated. The use of leguminous straw is recommended for winter cultivation of lettuce in an organic no-tillage system. Black oat straw, single or intercropped, impaired the development and productivity of lettuce in the organic no-tillage system in winter cultivation.

Keywords: *Avena strigosa*; *Lupinus albus*; organic farming.

INTRODUCTION

Farms under organic cropping or agroecological transition phase should be considered as an agroecosystem which depends on the biological interactions of the environment and the soil (Resende *et al.*, 2016). Under these conditions, the use of management practices such as green manure and no-tillage system are essential to this crop system.

The no-tillage system of vegetables is an environmentally and economically suitable alternative on conventional cultivation (Almeida *et al.*, 2020). Furthermore, it may contribute to an increase in the organic matter content of the soil, increases the efficiency of water use due to the presence of mulch, and may contributes to the reduction of production costs (Tivelli *et al.*, 2010). The cultivation of vegetables using no-tillage on straw cover crops (as mulching) has been encouraged aiming at the sustainability of natural resources in agricultural systems. Researches have been carried out to increase the sustainability of vegetable crops such as coriander, green onions, lettuce, and others (Araújo Neto *et al.*, 2010; Tavella *et al.*, 2010; Hirata *et al.*, 2014).

There is a great potential for the contribution of green manure practices and the no-tillage system for the culti-

Submitted on July 16th, 2021 and accepted on June 29th, 2022.
[1] Project funded by CNPQ.
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vation of lettuce in agroecological management systems. Studies indicate that green manures associated to no-tillage system promoted an increase in fresh mass production and plant growth. However, new studies need to be carried out aiming to consolidate these results, as well as the use of other plant species and under different growing conditions (Girardello *et al.*, 2017). These studies are important for the consolidation of these kind of technologies that may allow ecologically adequate management, particularly to small family farmers. This research aimed to evaluate the influence of different winter soil covers on lettuce development and yield under no-tillage system in an organic cultivation area.

MATERIAL AND METHODS

This work was carried out at the Agroecology Reference Unit (ARU), INCAPER in the municipality of Domingos Martins, Espírito Santo state, Brazil (20°22'16.91"S and 41°03'41.83"W, 950 m altitude). This is a highland region with the following characteristics: from 26.7 to 27.8 ºC average maximum temperatures in the warmer; from 8.5 to 9.4 **ºC** average minimum temperatures in the cooler months; 1,800 mm annual average rainfall.

The total area of this ARU (2.5 ha) has been cultivated under organic management system since 1990. This area was divided into 15 permanent field plots where horticulture experiments have been carried out. The main focus of research in this ARU from 1990 to 2000 was mainly on the development of technologies for management of organic compound in soils and crops. From the 2001 to the 2010, researches on organic systems planning and technologies in soil management were focused. This information is long-lasting technologies due to the cumulative effects of several years of cultivation.

This research was carried out in a 720 m² area (plot 05) that is on no-tillage system since 2009. This plot was divided into subplots, physically isolated by concrete slabs buried at 0.40 m depth where successive cultivations have been done using summer and winter covering plants as well as intercropping them. The evaluated species were black oats, cabbage, crotalaria, eggplant, green corn, maize, and white lupine mulching.

The experiment was carried out from July to October 2019 using a randomized block design with five treatments and six replications, totaling 30 experimental plots. Each plot had 24.0 m² (6.0 x 4.0 m) with useful area of 16.0 m². The treatments were composed of three soil coverings under organic no-tillage system (G - organic no-tillage system with grass straw; L - organic no-tillage system with leguminous straw; G + L - organic no-tillage system intercropping grass and leguminous), and two systems without covering and with tillage system, one organic and the other conventional (OS - organic system without straw; CS - conventional system without straw). Black oats (*Avena strigosa*) as the grass species, and white lupine (*Lupinus albus*) as the leguminous species were used to cover the soil.

The soil is classified dystrophic clayey Oxisol (Embrapa, 2018). An initial chemical characterization of the soil was performed at the depth of 0-20 cm (Table 1).

Both plants used to cover the soil were sown on July 02nd, 2019 in single and intercropped crops, and spaced 0.33 m between rows. *Avena strigosa* was sown at the density of 60 kg ha-1, and *L. albus* at 85 kg ha^{-1} when in single crop. Sowing densities were reduced by a half part in the intercropped treatments due to planting them in alternate rows. Irrigation and weeding were carried out on the cover crops as needed.

The cover crops were managed 82 days after sowing (flowering) using the triton implement coupled to a tractor. Organic compost fertilizer was used at a dose of 1.5 kg m^{-2} (dry matter) spread over the soil in all experimental plots under organic management. The organic compost had N, P, K, Ca and Mg; 2.8, 0.7, 5.0, 3.3 and 0.5 dag kg^{-1}, respectively; Zn, Fe, Mn, Cu and B: 151.4, 13014, 455.3, 45.3 and 9 mg.dm^{-3}; OC: 18.4 dag.kg^{-1}; and C/N: 6.5. No supplemental topdressing for the plots under organic cultivation was carried out in order to measure the effect of N provided by the mulching of the cover crops. In plots with conventional cultivation and without soil cover, fertilization was carried out with only 800 kg ha^{-1} of the N-P-K formulated 04-14-08.

The transplantation of the lettuce seedlings was carried out after the management of the cover crops. The Wanda® variety of loose curly leaves and spacing of 0.30 m between rows and 0.30 m between plants were used. Weeds were manually removed from all plots 20 days after transplanting (DAT). Indirect measurement of chlorophyll content was performed 30 days after transplant. was used in ten sheets per experimental plot with the aid of the OPTI-Sciences® model CCM-200 device. The post-harvest evaluation of the lettuce plants was carried out at 50 DAT using 12 useful plants from each plot. This harvest was carried out during the morning in order to obtain plants with the same potential hydration. The number of leaves per plant (leaves greater than 15 mm in length), stem length and diameter (cm), head diameter (cm), fresh and dry weight (g per plant) and fresh weight of leaves and stem (g per plant) were evaluated.

A matrix with the means of the variables was elaborated to evaluate the similarity between the fertilization systems. Subsequently, a dendrogram was constructed using the Mean Euclidean distance to measure consistencies between two points and the complete link hierarchical clustering method.

Data were subjected to analysis of variance, and the means were compared by the Scott-Knott test ($p < 0.05$) using the statistical program R (R Core Team, 2019).

RESULTS AND DISCUSSION

Differences were observed for the characteristics fresh weight, number of leaves and head diameter. When cultivated in G and G + L lettuce plants showed smaller number of leaves and head diameter. Fresh weight was negatively influenced in the **G**, where the production was 19% lower than the general average (Table 2).

Table 1: Means of the chemical characteristics of the soil before the implementation of the experiment

Attributes	G	L	G + L	OS	CS
SpH H_2O	6.9	6.8	6.9	6.8	5.4
P (mg dm^{-3})	870.9	975.8	1076.0	971.4	145.3
K (mg dm^{-3})	623.0	445.4	463.0	387.0	197.0
Ca ($cmol_c$ dm^{-3})	13.2	13.4	14.2	14.6	5.5
Mg ($cmol_c$ dm^{-3})	3.4	3.5	3.7	3.4	0.8
Al ($cmol_c$ dm^{-3})	0.0	0.0	0.0	0.0	0.1
H+Al ($cmol_c$ dm^{-3})	1.7	1.7	1.7	1.6	4.5
SB ($cmol_c$ dm^{-3})	17.8	18.4	19.3	18.6	6.8
t ($cmol_c$ dm^{-3})	17.8	18.4	19.3	18.6	6.9
T ($cmol_c$ dm^{-3})	19.5	20.1	21.0	20.8	11.3
MO (dag kg^{-1})	5.1	5.4	5.5	5.1	3.6
Zn (mg dm^{-3})	33.1	43.0	45.4	45.7	12.9
V (%)	91.2	91.3	92.0	92.3	60.3
Fe (mg dm^{-3})	60.6	57.0	56.4	58.0	134.4
Mn (mg dm^{-3})	96.6	102.5	104.7	102.0	82.7
Cu (mg dm^{-3})	2.1	1.83	1.74	2.0	5.3
B (mg dm^{-3})	0.6	0.4	0.5	0.6	0.3

G – organic no-tillage system with grass straw; L – organic no-tillage system with leguminous straw; G + L – organic no-tillage system with grass + leguminous straws; CS – conventional system without straw; OS – organic system without straw.

Table 2: Mean fresh weight, number of leaves and head diameter of Wanda lettuce plants grown in no-tillage system on different winter cover crops

Treatment	Fresh weight per plant (g)	Number of leaves per plant	Head diameter (cm)
CS	338.08 a[1]	34.88 a	37.44 a
OS	328.75 a	32.50 a	38.17 a
G	242.25 b	29.51 b	33.39 b
L	321.25 a	32.41 a	38.45 a
G + L	292.75 a	29.71 b	35.67 b
Mean	302.24	31.80	36.62
CV (%)	16.07	7.65	6.64

[1]Means followed by the same letter in the columns do not differ by the Scott-Knott test ($p < 0.05$). CS – conventional system without straw; OS – organic system without straw; G – organic no-tillage system with grass straw; L – organic no-tillage system with leguminous straw; G + L – organic no-tillage system with grass + leguminous straws.

This result may be related to the high C/N ratio of black oat straw (> 30:1). This relationship provides a decrease in the availability of N in the soil due to microbial immobilization during the process of plant decomposition of the straw (Brito *et al.*, 2019). Therefore, a lack of N in the initial phase of crop establishment may be occurred. N is the nutrient that promotes the highest yield in lettuce crop, as well as the average head weight (Zhou *et al*, 2021).

The advantage of intercropping leguminous with non-leguminous plants is related to the decrease in N release after green manure management in relation to the single leguminous (Arf *et al.*, 2018). This intercropping can improve the synchrony between the release of N and the need for the crop in succession. The leguminous plant decomposes faster, and grass plant provide a more lasting and persistent mulch which favors the structuring of the soil and better control of weeds (Aita *et al.*, 2014; Crespo *et al.*, 2020).

Although there is an advantage in the intercropping between leguminous and non-leguminous plants. In the present work it was observed that the intercropping treatment between black oats and white lupine negatively influenced most of the characteristics evaluated for lettuce crop. This fact may be explained by the short crop cycle of lettuce (50 days) which does not provide synchrony between the nutrient release and plant demand (Aita *et al.*, 2014).

Favarato *et al.* (2020) evaluated the decomposition and nutrient release of black oat, white lupine and intercropping straw of both species and observed release of 22, 42 and 26 kg ha^{-1} of N, respectively, 10 days after straw management. At that time, the first top dressing is done in the lettuce crop and this proves the non-synchrony of N release according to the crop demand.

Straws composed of grass plant had a negative influence on the values of fresh weight of leaves and stem, as well as stem diameter and length (Table 3 and 4). A similar behavior was observed for the characteristics leaf number and fresh plant weight values. Differences were also observed to SPAD index with the highest values observed in the treatment with a conventional system where mineral fertilizer were used (Table 3). This result may be related to the fact that mineral fertilizers are considered a source of nutrients readily assimilable by plants. Its high solubility, particularly for N may have provided higher levels of N in leaves, and consequently higher SPAD index (Dunn *et al.*, 2018).

Table 3: Means of the characteristics of fresh weight of leaves and fresh weight of stem of Wanda lettuce plants grown in no-tillage system on different winter cover crops

Treatment	Fresh weight of leaves (g)	Fresh weight of stem (g)
CS	301.00 a[1]	37.08 a
OS	290.17 a	38.58 a
G	214.92 b	27.33 b
L	280.75 a	40.50 a
G + L	254.92 b	37.83 a
Mean	268.35	36.27
CV (%)	15.53	18.21

[1]Means followed by the same letter in the columns do not differ by the Scott-Knott test ($p < 0.05$). CS – conventional system without straw; OS – organic system without straw; G – organic no-tillage system with grass straw; L – organic no-tillage system with leguminous straw; G + L – organic no-tillage system with grass + leguminous straws.

Table 4: Means of the characteristics stem diameter, stem length and SPAD index of Wanda lettuce plants grown in no-tillage system on different winter cover crops

Treatment	Stem diameter (cm)	Stem length (cm)	SPAD
CS	2.88 a[1]	8.65 a	17.52 a
OS	2.64 a	7.96 a	15.98 b
G	2.25 b	6.75 b	15.71 b
L	2.59 a	9.00 a	15.71 b
G + L	2.36 b	8.87 a	15.81 b
Mean	2.54	8.24	16.14
CV (%)	10.89	20.54	6.84

[1]Means followed by the same letter in the columns do not differ by the Scott-Knott test ($p < 0.05$). CS – conventional system without straw; OS – organic system without straw; G – organic no-tillage system with grass straw; L – organic no-tillage system with leguminous straw; G + L – organic no-tillage system with grass + leguminous straws.

On the other hand, the SPAD index values were similar for all treatments fertilized with organic compost and lower than CS. This result can be directly related to the degree of decomposition and mineralization of the organic fertilizer. This affects the availability of nutrients for plants, particularly those with short cycles such as lettuce which can have an immediate or residual effect (Peixoto Filho *et al.*, 2013; Ziech *et al.*, 2014).

Ziech *et al.* (2014) studied the residual effect of organic fertilization in successive lettuce crops in the same area and they observed better production results with the use of organic fertilizers only during the second cycle of cultivation. Lorensini *et al.* (2014) studied the mineralization of N from a mineral (polymer coated urea) source and of organic compost, observed that n release from mineral source occurred up to 38 days after application and at organic source reached 141 days.

Three homogeneous groups may be observed in the dendogram (Figure 1). Group A: constituted by the conventional system; group B: formed by organic systems without straw, organic no-tillage system with leguminous straw and organic no-tillage system with grass straw + legume; and group C: formed by the organic no-tillage system with grass straw. The characteristics that most contributed to the construction of the dendrogram were the SPAD index (40%), number of leaves per plant (30%), head diameter (20%) and fresh weight per plant (10%). The other characteristics evaluated did not contribute to the observed results.

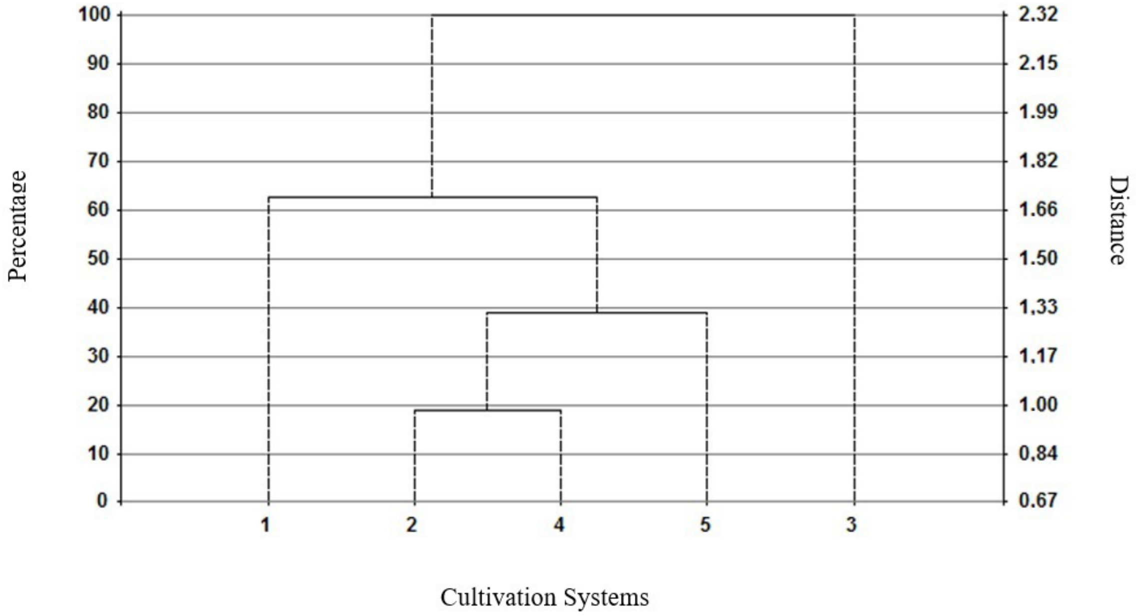

Figure 1: Dendrogram obtained from five growing systems for lettuce. 1 – Conventional system without straw; 2 – Organic system without straw; 3 – Organic no-tillage system with grass straw; 4 – Organic no-tillage system with legume straw; 5 – Organic no-tillage system with grass + legume straw.

The distinction between the groups observed may be related to the dynamic system of N in the soil in each management. For the group formed by the CS treatment, this distinction may be related to the fact that the application of the fertilizer mineral in this treatment is considered a source of easily assimilated nutrients.

The differentiation of the C group formed by the G treatment may be related to the characteristics of the black oat straw. This species has a high C/N ratio. Soil mineral nitrogen is immobilized by the microorganisms that need it for the synthesis of their cellular compounds, eventually disappearing from the soil during the period of maximum growth of the microbial community (Acosta *et al.*, 2014). During this period, depending on the nutritional requirements of the crop, its growth and development may be affected, due to the temporary shortage of mineral nitrogen in the soil.

CONCLUSIONS

The use of leguminous straw is recommended for winter cultivation of lettuce in an organic no-tillage system.

Black oat straw, single or intercropped, impaired the development and productivity of lettuce in the organic no-tillage system in winter cultivation.

ACKNOWLEDGEMENTS, FINANCIAL SUPPORT AND FULL DISCLOSURE

The authors would like to acknowledge the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financial support.

The authors thank the Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão (INCAPER) for the facilities to accomplish this research.

There is no conflict of interest for the publication.

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