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Revista Facultad Nacional de Agronomía

Effect of cover crops residues on crambe cultivation

UNIVERSIDAD NACIONAL DE COLOMBIA

Efecto de los residuos de cubierta vegetales en el cultivo de crambe

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ABSTRACT

Although the crambe is commercially exploited in Brazil, there is a demand for studies that allow the improvement of the techniques involved in its cultivation. Planting on residues of different species can provide greater vegetative and reproductive development. Thus, the objective of this work was to evaluate the vegetative and reproductive development of crambe cultivated on residue of different species, in succession to the cultivation of lettuce. The experimental design was a randomized block design, with six treatments containing the following cover crops residues: crotalaria (*Crotalaria juncea*), pigeon pea (*Cajanus cajan*), porcine bean (*Canavalia ensiformis*), millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*), besides a control treatment, with the use of spontaneous vegetation. At 49 days the vegetative development was evaluated by measuring plant height, stem diameter at the soil level, number of leaves, relative content of leaf chlorophyll, number of lateral branches, fresh and dry biomass of shoot. The productive variables were evaluated at 95 days after planting, obtaining the grain mass per plant, the hectoliter weight of the grains and estimating the productivity of each treatment, as well as its gross revenue. It was verified that the maintenance of residue of cover crops benefits the vegetative development of the crambe crop, without statistically altering grain yield. However, this technique results in an economic benefit, with the increase in gross revenue, being recommended during the fallow, to the detriment of the management of spontaneous plants.

Keywords:
Crambe abyssinica
Green manure
Edaphic microbiota
Nutrient cycling

RESUMEN

El cultivo de *Crambe abyssinica*, es explotado comercialmente en Brasil, así la importancia de desarrollar estudios que posibiliten el perfeccionamiento de las técnicas involucradas en su producción. La plantación sobre restos culturales de diferentes especies de cobertura puede aumentar el desarrollo vegetativo y productivo del crambe. Así, el objetivo de este trabajo fue evaluar el desarrollo vegetativo y reproductivo del crambe cultivado sobre restos culturales de diferentes especies, en sucesión al cultivo de lechuga crespa. El delineamiento experimental utilizado fue en bloques al azar. Los tratamientos correspondieron a restos culturales de plantas de cobertura, siendo estas: crotalária (*Crotalaria juncea*), frijol guandu (*Cajanus cajan*), frijol de porco (*Canavalia ensiformis*), milheto (*Pennisetum glaucum*) y sorgo (*Sorghum bicolor*), además de un tratamiento control, con uso de vegetación espontánea. A los 49 días se evaluó altura de planta, diámetro de tallo, número de hojas, contenido relativo de clorofila, número de ramas laterales, masa seca y fresca de la parte aérea. Las variables productivas se evaluaron a los 95 días después de la siembra, obteniendo la masa de granos por planta, el peso hectolitro de los granos. Posteriormente fue estimada la productividad de cada tratamiento y el ingreso bruto. Se verificó que mantener los restos culturales de plantas de cobertura beneficia el desarrollo vegetativo de la cultura de crambe y no altera la productividad de los granos. Esta técnica aumenta el beneficio económico del cultivo, siendo recomendada durante el barbecho, en detrimento del manejo de plantas espontáneas.

Palabras clave:
Crambe abyssinica
Fertilización verde
Microbiota edáfica
Ciclo de nutrientes

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The crambe (*Crambe abyssinica* Hochst) is a species belonging to the Brassicaceae family, which was introduced in Brazil as an oleaginous crop that can be used for the production of biodiesel, as forage (Rosetto *et al*., 2016), crop of second season and in rotation with others cultures (Panno and Prior, 2009). In addition to presenting drought stress tolerance, its economic efficiency is comparable to that of soybean (Ziolkowska, 2014). It is a plant with a short productive cycle (about 90 days) that presents high oil content (between 30% and 45%) (Pitol *et al*., 2010) and an average seed production of 1507 kg ha^{-1} (Jasper *et al*., 2010). In the United States of America, studies have shown that in addition to the potential as a raw material for the production of biofuel, oil extracted from crambe seeds can be used in the production of synthetic rubbers, plastic films, nylon, lubricant and other base products of erucic acid (Casey, 2009).

No-tillage system has been a viable practice for the production of different species with commercial interest, and for each species different responses regarding vegetative and reproductive development can be observed depending on the crop that precedes it. For the corn crop, it was verified that the succession to the crotalaria, under no-tillage system, increased the productivity and the profitability indexes (Kappes *et al*., 2015). For the bean crop, the predecessor crop with *Urochloa ruziziensis*, millet and pigeon pea provides better conditions for the development of the crop (Silveira *et al*., 2005; Mingotte *et al*., 2014). In this way, it is made explicit the importance of studies that make feasible the use of this practice in an effective way.

Species used as cover crops in no-tillage systems or as green fertilizers have different characteristics regarding the rate of decomposition and cycling of nutrients. Species that have a high C/N ratio, which gives their straw a high persistence capacity at the soil surface, provide physical protection to rainfall impact and maintenance of water and nutrients present in the soil, while nutrient cycling occurs slower compared to species with more tender tissues. These plants present a high rate of decomposition, not acting as a protection for the soil, but as a source of nutrients to the initial development of the crop (Floss, 2000).

For the crambe the best development of the plant was observed when the cultivation was carried out in succession to crotalaria (Bassegio *et al*., 2015). In this study, there were significant increases in the amount of dry matter produced in the aerial part of the plants, in the maintenance of the plant stand and in the grain yield of plants grown in succession to the crotalaria crop in relation to sorghum, millet, brachiaria and control treatment. The results are related to the ability of the crotalaria to fix the atmospheric nitrogen (Ferreira *et al*., 2011), which, when made available to crambe plants, favors its development, including the accumulation of dry matter (Silva-Neto *et al*., 2015; Calil *et al*., 2016).

Although the crambe is commercially exploited in Brazil, there is a demand for studies that allow the improvement of the techniques involved in its cultivation, as well as for other crops of commercial interest. The planting on the cover crops residues of other species represents a technique with potential for the improvement of the vegetative and reproductive development of this species. However, information about the use of different species as predecessor crops should be generated through empirical studies. Thus, the objective of this work was to evaluate the vegetative and reproductive development of crambe cultivated with cover crop residues of different species, in succession to the cultivation of crisp lettuce.

MATERIALS AND METHODS

The study was carried out in an experimental area located at the School of Agronomy of the Federal University of Goiás, in the city of Goiânia, Goiás. The following average climatic indicators were verified for the locality: annual precipitation of 1575 mm and average monthly temperature of 22.9 °C, predominance of Aw climate, characterized by tropical climate with rainy season between October and April and a period with precipitations below 100 mm monthly between May and September (Cardoso *et al*., 2014). Climatic records of air temperature and relative humidity, occurring during the conduction of the crambe crop, can be observed in Figure 1.

The soil was classified as RED LATOSOL (oxisol), following a methodology proposed by Embrapa (Santos *et al*., 2013). The chemical analysis of the soil before sowing of the cover crops showed, at depth of 0-0.2 m, levels of de Ca^{2+}: 2.0 $cmol_c\ dm^{-3}$, Mg^{2+}: 0.81 $cmol_c\ dm^{-3}$, K^+: 0.34 $cmol_c\ dm^{-3}$, P (Mehlich I): 3.5 mg dm^{-3}, organic matter: 7.0 g dm^{-3}, Al^{3+}: 0.0 $cmol_c\ dm^{-3}$, H+Al: 2.5 $cmol_c\ dm^{-3}$ and pH ($CaCl_2$): 4.6, CTC: 5.6 $cmol_c\ dm^{-3}$, V%: 55.7%, according to the

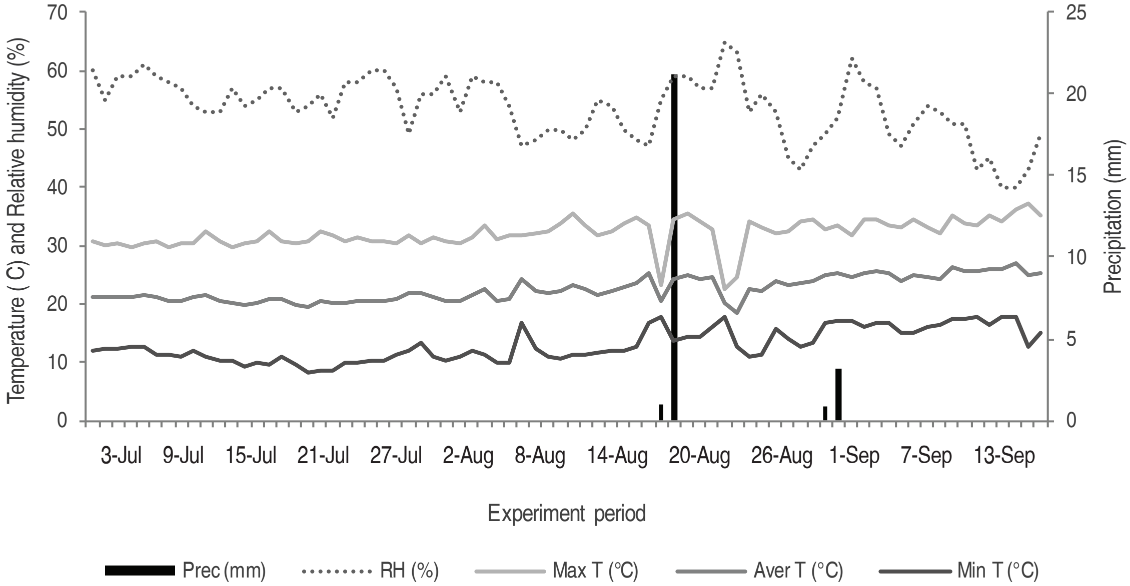

Figure 1. Climatic conditions of relative humidity, maximum, average and minimum temperature and precipitation during the period of conduction of the study.

procedures recommended from Donagemma *et al.* (2011). The granulometric analysis of the soil presented 48 g kg^{-1} of clay in the depth of 0-0.2 m following the procedures in Silva (2009).The experimental design was a randomized block design, with six treatments containing cover crop residues of the following cover crops: crotalaria (*Crotalaria juncea* L.), pigeonpea (*Cajanus cajan* (L.) Hunth), jack bean (*Canavalia ensiformis* (L.) DC.), millet (*Pennisetum glaucum* (L.) R. BR.) and sorghum (*Sorghum bicolor* (L.) Moench), besides a control treatment, with the use of spontaneous vegetation, with a predominance *Ipomoea quamoclit* L., *Bidens pilosa* L. and *Amaranthus viridis* L., with four replications. Each experimental plot had dimensions of 0.8 m x 1.20 m.

The cover crops were sown on December 08 of 2015, except for the spontaneous plants, which were naturally emerged by the seed bank itself in the plots corresponding to the control treatment. At 50 days after sowing the cover crops were desiccated with herbicide application (Glyphosate, 360 g L^{-1} of active ingredient) and at 22 days after application of the herbicide, a cut was made for the deposition of the straw on the soil. The straw was distributed over the area corresponding to the plots.

Prior to sowing of the crambe, cultivation of curly lettuce was carried out in a no-tillage system for 50 days. The crambe was sown on June 3 of 2016, in open furrows with a hoe, distant 25 cm between each other and with depth of three centimeters. The seeds were distributed in order to establish a final stand of 23 plants m^{-2}.

Irrigation was performed daily through hoses with drippers spaced 20 cm apart between the lines. Through this system was also applied the cover fertilization, applying 40 kg ha^{-1} of nitrogen and potassium, divided in the four weeks that followed the emergence of the plants. During crambe cultivation there was no necessity of pests control, diseases or spontaneous plants, justifying the non-use of agrochemicals for these purposes.

A first evaluation was performed 49 days after sowing, when the culture entered the reproductive stage. At this moment, the plant height parameters were evaluated, measuring since the lap of the plant until the apical end of the main branch with a ruler, stem diameter at the soil level with digital caliper (Metrotools, São Paulo, SP, Brazil), number of leaves, relative leaf chlorophyll content, by reading with a hand-held chlorophyll meter (CFL1030; Falker, Porto Alegre, RS, Brazil), number of lateral branches, fresh and dry biomass of aerial part. The shoot, root and total dry mass were measured in a digital scale (ML 600, Marte, São Paulo, SP, Brazil) after drying the plants in an oven at 65 °C until obtaining constant mass.

At 95 days after planting, the grains of three plants per plot were harvested. The humidity was adjusted to 13% to determine the grain mass per plant, the hectoliter weight of the grains and the productivity of each treatment. The gross revenue of each treatment for one hectare was also estimated. For this, was used the value of R$ 400.00, paid per ton of grain by the industry (Roscoe *et al*., 2010). Data were submitted to analysis of variance and compared by Tukey test at 5% probability.

RESULTS AND DISCUSSION

The averages obtained for of height, stem diameter, number of leaves and branches were 62.11 cm, 15.95 mm, 70.5 and 16.9, respectively. These results may be related to the good condition of the soil, even under the control treatment, due to the effect of the cover crops on the addition of organic matter to the soil, nutrient cycling, physical protection and soil conditioning by root distribution. Previous cultivation of the lettuce, in which cover fertilization was carried out, also improved the soil chemical conditions in the area. It was verified that, for the biometric variables of height, stem diameter, number of leaves and branches, there were no significant statistical differences (Table 1).

Table 1. Mean values of height, stem diameter, number of leaves and number of branches of crambe plants grown on residual of different cover crops.

Cover	Height cm	Stem diameter mm	Leaf number	Branch number
Control	52.71 a	12.98 a	65.25 a	15.33 a
C. cajan	56.96 a	14.89 a	65.08 a	15.92 a
C. ensiformis	58.08 a	14.55 a	87.42 a	18.17 a
P. glaucum	59.50 a	15.02 a	90.50 a	18.33 a
C. juncea	63.67 a	14.52 a	76.00 a	16.92 a
S. bicolor	65.17 a	15.59 a	89.67 a	17.75 a
CV%	25.51	21.92	28.67	16.46
MSD	18.17	3.87	27.17	3.37

Means values followed by the same lowercase letter in the columns do not differ from each other by the Tukey test at 5% probability.
CV = Coefficient of variation. MSD = Minimum significant difference.

For the relative contents of leaf chlorophyll, it was observed superiority of plants cultivated on the residues of crotalaria, followed by millet. However, treatment differed significantly only from the control (Table 2). This result is related to the better nutritional conditions of the plants, due to the qualities of the straw. Torres *et al.* (2005) observed that the crotalaria and millet crops accumulate large amounts of nitrogen, which is released after straw formation. According to Cazetta *et al.* (2005), millet is also viable in crops aiming at dry matter production, reaching more than 10 t ha^{-1}, contributing to improve soil physical conditions. In broccoli (*Brassica oleraceae*), Perin *et al.* (2004) observed that the presence of crotalaria increases the content and accumulation of N in the leaves and inflorescences, both in the absence and presence of N-fertilizer.

Studying the effect of the different plant species biomass presence on soil microbial biomass activity, Carneiro *et al*. (2008) observed that fallow development with spontaneous plant development, common practice in several regions, impairs the sustainability of the soil by causing detriments in the carbon of the microbial mass and in the organic carbon of the soil. On the other hand, the presence of the pigeon pea, *C. juncea*, niger and oats provided increases between 93% and 190% in the carbon of the microbial biomass. The presence of cover crop residues in the present study probably maintained high levels of organic carbon in the soil, thus favoring the development of crambe.

The microbial biomass of the soil has great importance as a catalyst for the decomposition process of the plant materials and, consequently, the cycling of the nutrients in the soil (Moreira and Siqueira, 2002). The mobilization of nutrients in the soil biomass itself leads to the rapid enrichment of soil nutritional reserves due to the short life of the microorganisms. Thus, in areas with residues that stimulates the increase of microbial biomass, higher are the rates of mineralization of the nutrients that compound the phytomass (Carneiro *et al*., 2008).

The sorghum residues provided greater accumulation of fresh and dry matter in crambe plants (Table 2). Possibly the answer is due to the physical barrier formed by sorghum straw on the soil surface, avoiding the excessive loss of water by evaporation, considering that the precipitation during the period that comprised the experiment was practically null and the average of relative humidity remained around 50% (Figure 1).

Residues from grasses present high potential for systems in which the presence of soil cover is desired. This is due to the slow decomposition of plant material (Mingotte *et al*., 2014), which also contributes to the control of weeds, through the physical suppression of development (Favero *et al*., 2001) and nutrient mineralization, such as Nitrogen, for periods up to 210 days after straw formation (Torres *et al*., 2005). The mulch management also promotes maintenance of soil moisture, improving water use efficiency, increasing crop productivity and greater weight gain of cabbage head (Carvalho *et al*., 2011).

Although the treatments containing residues of legume plants and spontaneous plants did not present the highest masses of dry or fresh matter but they also increased the accumulation of dry matter in relation to the fresh matter in crambe plants (Table 2). Again, this is due to the greater speed of decomposition of these species residues, making available the nutrients present in the tissues through the decomposition carried out by the edaphic microorganisms and later releasing these to the soil (Moreira and Siqueira, 2002).

Table 2. Average values of the relative content of chlorophyll (CRT), fresh and dry shoot mass and ratio between dry mass (DM) and fresh mass (FM) of crambe plants grown with different cover crops residues.

Cover	CRT SPAD	Fresh mass g	Dry mass g	Ratio DM/FM %
Control	37.43 b	168.01 d	17.13 c	10.31 ab
C. cajan	39.80 ab	172.84 cd	17.80 c	10.40 a
C. ensiformis	40.65 ab	212.50 bc	20.91 bc	9.91 ab
P. glaucum	41.17 ab	248.38 ab	21.72 b	9.00 c
C. juncea	41.58 a	213.09 bc	21.92 b	10.54 a
S. bicolor	40.79 ab	275.41 a	26.18 a	9.50b c
CV%	8.38	16.15	15.44	6.88
MSD	4.05	41.65	3.88	0.82

Means values followed by the same lowercase letter in the columns do not differ from each other by the Tukey test at 5% probability. CV = Coefficient of variation. MSD = Minimum significant difference.

The productive parameters were not affected by the cover crops residues. Average values of 236.47 g L^{-1} were obtained for the hectoliter weight of harvested grains, in addition to a mass of 41.77 g per plant and an estimated yield of 960.69 kg ha^{-1} (Table 3).

Despite the lack of statistical significance between the productivity, the estimated gross revenue for all treatments containing cover crops residues was higher than that obtained in the control treatment (Figure 2). This superiority reflected an increase of approximately 29.16%, 16.66%, 6.38%, 16.32% and 20.64% of the treatments containing residues of pigeon peas, porcine beans, millet, crotalaria and sorghum, respectively, on the gross revenue obtained with the cultivation of crambe on residual of spontaneous plants (US$ 101.62). Thus,

Table 3. Mean values of hectoliter weight, grain mass and grain yield of crambe plants grown with different cover crops residues.

Cover	Hectoliter weight g L^{-1}	Grains mass g $plant^{-1}$	Productivity kg ha^{-1}
Control	242.80 a	35.13 a	807.88 a
C. cajan	263.44 a	49.58 a	1140.44 a
C. ensiformis	233.64 a	42.15 a	969.39 a
P. glaucum	217.85 a	37.52 a	862.94 a
C. juncea	226.11 a	41.98 a	965.46 a
S. bicolor	234.99 a	44.26 a	1018.05 a
CV%	11.18	47.18	47.18
MSD	74.97	55.90	1285.66

Means values followed by the same lowercase letter in the columns do not differ from each other by the Tukey test at 5% probability.
CV = Coefficient of variation. MSD = Minimum significant difference.

although the treatments were not reflected in statistically significant differences for the variables related to the production, the planting of crambe in areas containing cover crops residues increases the monetary gains in addition to the benefits provided to the soil. In agreement with the results obtained by Carneiro *et al*. (2008), soil management with spontaneous plants is not recommended.

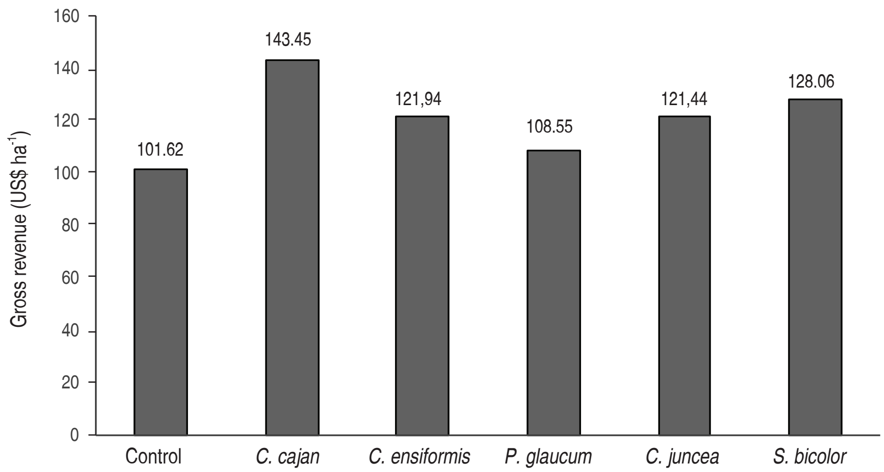

Figure 2. Gross revenue obtained with the crambe culture grown on residual of different cover crops.

CONCLUSIONS

The maintenance of cover crops residues (spontaneous plants, pigeon peas, porcine bean, millet, crotalaria and sorghum) benefits the vegetative development of the crambe crop.

The cultivation of the crambe with cover crops residues does not statistically alter the yield of grains. However, this technique results in economic benefit, with the increase in gross revenue. The use of cover crops during fallow is recommended to the detriment of the management of spontaneous plants.

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