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Effects of cover crops in the dynamics of organic matter and potassium in the soil and performance of common bean in the Brazilian Cerrado of Goiás State

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The effects of several cover crops on common bean cv. Pérola productivity cropped at Goiano – Ceres Campus (Brazil) and changes in soil organic matter and potassium were evaluated for one season. The experiment was based on a randomized complete blocks design encompassing four treatments (spontaneous vegetation, *Crotalaria spectabilis* L., *Mucuna aterrima* L. and *Pennisetum glaucum*) and four replications. Soil cover by cover crops was assessed 40 days after sowing (DAS). Manure was applied at 25 DAS at a rate of 250 kg ha^{-1} with a NPK formulation 20-00-20.Cover crops increased soil cover by approximately 170% when compared with the natural vegetation. Plant residues and manure also led to changes in the soil organic matter and potassium during the common bean growth cycle. Apparently, the *Mucuna aterrima* L. favored mostly the bean productivity and increased the organic matter and potassium in the soil.

Key words: Green manuring, manure, organic matter, *Phaseolus vulgaris,* potassium

INTRODUCTION

Cerrado soils present low organic matter (OM) rate due to fire, to the hot weather and, in some times of the year, to high humidity. Such conditions speed up OM decomposition. Besides, the adopted production strategies lead to significant physical, chemical and biological degradation increase in these soils and, consequently, to productivity reduction as well as to economic and environmental cost increase. Thus, Meschede et al. (2007) reported that it becomes mandatory to adopt conservationist handling systems, and that the main challenge lies on handling and on OM rate increase in the soil.

The use of cover crops becomes an excellent handling option in these soils. They may be incorporated to or used in coverage formation in tillage system (TS). Among the most used plants it is possible highlighting: millet, *Cajanus cajan*, *Canavalia ensiformes*, *Crotalaria* and *Mucuna*. Some of these plants produce more than 30 t

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ha^{-1} of fresh biomass.

The use of cover crops is associated with carbon (C) and nitrogen (N) mineralization, OM accumulation, nutrient cycling, invasive plant population's reduction, pest cycle rupture and with erosion reduction, therefore, improving the physical, chemical and biological properties of the soil.

Perin et al. (2004) reported that plant biomass production by *Crotalaria* was higher than that of spontaneous vegetation and millet. It also presented higher rates of accumulation of N and calcium (Ca), whereas millet and the invasive plants presented higher potassium (K) release.

According to Jesus et al. (2007), rice cultivation after leguminous crops resulted in larger foliar area, higher plant biomass and higher N concentration in the leaves. Silva et al. (2006) found that millet used as a cover crop increased native N absorption by corn, whereas *Crotalaria* led to higher grain production. Soratto et al. (2010) observed higher castor beans production in soil covered by straw from fallowing and millet combination. Duarte Júnior and Coelho (2008) got 37% increase in sugarcane production in TS using leguminous as cover crop when it was compared to the conventional system. The use of green manuring with leguminous also leads to changes in the succession dynamics of invasive plants (Favero et al., 2001).

Although the tillage system is widely adopted in the Brazilian Cerrado, this system prevails in soy, cotton and corn cultivation, whereas there is still lack of information on its use in rice and beans cultivation. Kluthcouski et al. (2000) reported that the bean plant culture presents better adaptability to the tillage system than corn and, mainly, than rice; and it may also reach high productivity rates. However, cultivation is compromised when soil presents physical impairments to radicular growth, low hybrid and nutrients availability in the soil (EMBRAPA, 2003).

With regards to bean, tillage system using adequate coverage leads to water saving when it is compared to other soil management. It also influences pods production and the number of grains per plant (Stone and Moreira, 2000). Arf et al. (1999) obtained higher bean plant productivity in treatments using black mucuma, lablab and corn plus black mucuma. According to Favero et al. (2001), black mucuma also has a great potential for soil covering and invasive plants' suppression.

The current study aims to evaluate the cover crop biomass production and straw effect before common bean plant cv. Pérola cultivation as well as changes in invasive plant population, and levels of OM and K levels in the soil.

MATERIALS AND METHODS

The study was conducted in the experimental area of IF Goiano – Ceres Campus (Brazil) during the 2010/2011 cropping season and was split in two stages: fresh and dry biomass production were assessed in the first stage, as well as the invasive plant suppression by cover crops *Crotalaria spectabilis* L., *Mucuna aterrima* L., *Pennisetum glaucum* L. and spontaneous vegetation; in the second stage, the straw effects of these species on bean plant cv. Pérola and on soil OM and K levels were assessed.

The experiment followed the randomized complete block design encompassing four treatments and four replications in 25 m² plots. The clayey soil in the experimental area is classified as red latosol (Oxisol) (EMBRAPA, 2006); the climate is humid tropical presenting a mean annual rainfall above 1.600 mm (SEPLAN, 2005, with rainy season from October to April and dry from May to September. Figure 1 shows the maximum and minimum mean temperatures and monthly rainfall during the experimental period.

The experimental design was in randomized blocks, with for treatments with four repetitions. The treatments were composed of tree cover crops (*C. spectabilis* L.; *M. aterrima* L. and *P. glaucum* L) and control, using the spontaneous vegetation.

Initially, the soil preparation consisted of one plowing operation and followed by two harrows. The result of the chemical analysis of the soil, there was the need of pH correction. Cover crop sowing was done at 0.4 m inter-row spacing to form stands holding 750,000, 205,000 and 175,000 of *C. spectabilis*, *P. glaucum* and *M. aterrima* plants per ha^{-1}, respectively.

Coverage of soil was determined at 40 DAS, according to method described by Alvarenga (1993). The harvest of cover crop aerial biomass was performed at flowering, at 72, 84, 94 and 97 DAS for *P. glaucum*, *C. spectabilis*, *M. aterrima* and spontaneous vegetation, respectively. The number of natural vegetation in the plots was determined and samples were collected to set fresh and dry biomass. The biomass accumulation in the cover crops was determined from four 0.25 m² samples for *M. aterrima* and spontaneous vegetation, and in plots containing *P. glaucum* and *C. spectabilis* four 0.5 m linear. The samples were kept for 72 h at 70°C in order to estimate the dry weight.

The aerial plant biomass was kept on the soil surface and at 106 DAS of cover crops the common bean (cv. Pérola) was sown in rows 0.5 m apart from each other, at a seeding rate of thirty seeds per meter. Manure was applied to 250 kg ha^{-1} of the 04-30-16 NPK formation. Thinning was performed to set a population of 250,000 plants per hectare at 16 DAS for beans. Besides thinning, the culture tracts consisted of manual invasive plant control at 16 DAS during the bean plant cycle, of three contact insecticide application and of the pyrethroid chemical group ingestion as well as of the active ingredient permethrin at 384 g.L^{-1} concentration, in dosage 0.13 L ha^{-1}, in tail 200 L ha^{-1} at 15, 33 and 50 DAS in bean, and one coverage manure using 250 kg ha^{-1} of the 20-00-20 formation, at 25 DAS bean.

When the common bean was at the R5 stage, at 91 DAS, the bean plants height (cm) was assessed as well as the number of pods per plant, the amount of seeds per pod and productivity (kg ha^{-1}), depending on cover crop material. The pods were maintained at 60°C for 72 h, and, subsequently, the weight of 100 seeds and grains productivity was determined.

Soil samples were collected from 0 to 20 cm soil depth after the cover crop harvest, which was done in a monthly basis, within a 120 day period of time after harvest cover crop. The OM and K contents in the soil were determined (EMBRAPA, 1997). Elements' dynamics was set by the following equation:

Dynamics (%) = {(OM or K contents at harvest – OM or K contents at the first stage) / OM or K contents at the first collection)} x 100

Results are presented in graphics in order to show the OM and K levels in the soil after harvesting the cover crops. Data of cover crop biomass and beans' productivity were subjected to variance analysis and means comparison was done by Scott-Knott's test at 5% probability level using the SAEG software version 9.1 (UFV, 2007).

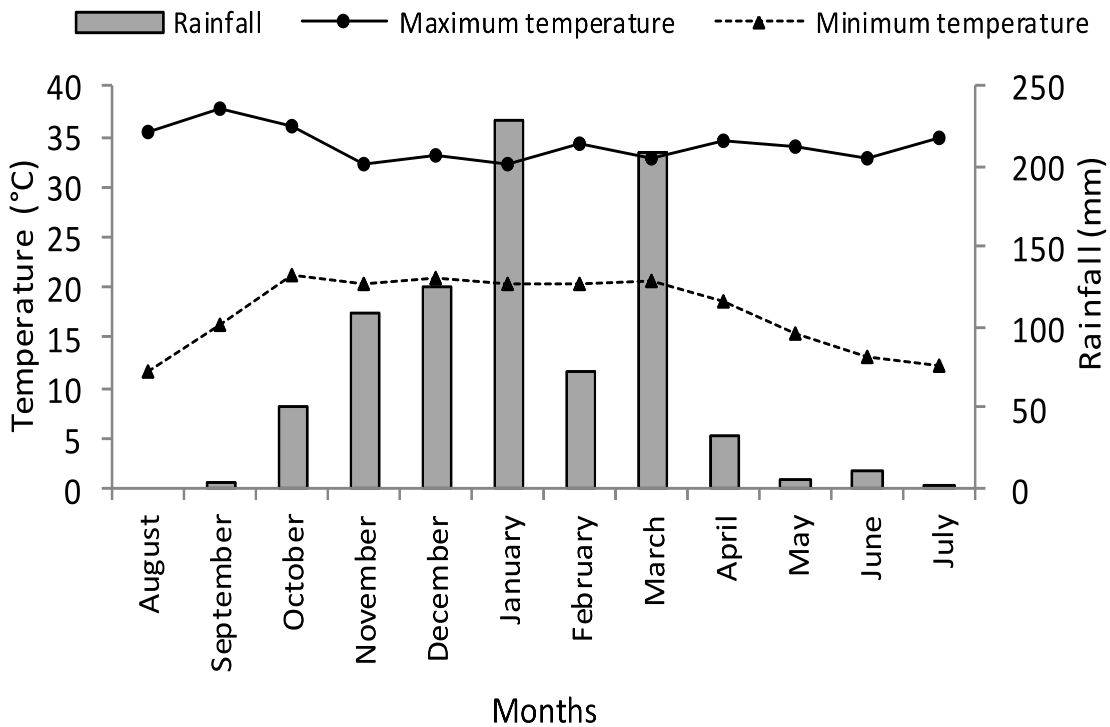

Figure 1. Maximum and minimum air temperature (ºC); and monthly rainfall (mm) during the experimental period. Ceres City, GO, Brazil, 2010/2011.

Table 1. Number of invasive plants, % soil cover and biomass production depending on cover crops under the weather and soil conditions in Ceres, GO.

Cover crops	Number of invasive plants m^{-2}	Soil cover (%)	Fresh weight (kg ha^{-1})	Dry weight (kg ha^{-1})
Crotalaria spectabilis	42.72[a]*	83.37[a]	39,023.75[a]	5,362.50[a]
Pennisetum glaucum	65.72[a]	65.15[a]	35,681.25[a]	5,781.25[a]
Mucuna aterrima	16.48[b]	74.70[a]	26,300.00[a]	5,010.00[a]
Spontaneous vegetation	73.72[a]	27.45[b]	32,322.50[a]	5,100.00[a]
Average	49.66	62.67	33,331.87	5,313.43
CV (%)	23.64	24.58	18.73	19.14

*Means followed by the same letter in the column do not differ from each other by the Scott-Knott'test at 5% probability level.

RESULTS AND DISCUSSION

Data on soil cover (%), number of invasive plants and cover crop biomass are presented in Table 1. There was no significant difference among treatments in dry and fresh biomass; however, there was a significant difference between the spontaneous vegetation and the other treatments in soil coverage. According to Duarte Júnior and Coelho (2008), such high speed coverage feature, in the initial period, gives *C. spectabilis* good erosion control and soil protection potential in a short period of time.

Mucuna was statistically different from the others when it came to invasive plant suppression; it presented 16.48 invasive plants per m² on average. However, it did not differ from the other straws (Table 1). Favero et al. (2001) found that black mucuna presented greater potential for invasive plant suppression. They also observed that the use of leguminous plants for green manuring leads to changes in the spontaneous species' suppression dynamics. Silva et al. (2010a) also found such effect in straw formed by mucuna plants.

The fresh and dry biomasses from the cover crops were not influenced by the studied species and they reached more than 26 and 5 t ha^{-1}, respectively (Table 1). The general dry biomass productivity mean was about 5.313 kg ha^{-1}. Darolt (1998) recommended 6 t ha^{-1} of dry mass in order to get obtain adequate soil coverage,

Table 2. Agronomic features of bean plants cultivated under the cover crop straw at Ceres, GO.

Treatments	Plant height	Number of pods plant^{-1}	Number of grains pod^{-1}	Weight of 100 grains (g)	Productivity (kg ha^{-1})
Crotalaria spectabilis	137.70^{b}*	9.00^{b}	4.55^{a}	22.42^{a}	2,299.75^{b}
Pennisetum glaucum	136.75^{b}	9.15^{b}	4.75^{a}	21.20^{a}	2,465.25^{b}
Mucuna aterrima	149.40^{a}	11.40^{a}	4.80^{a}	21.80^{a}	2,957.25^{a}
Spontaneous vegetation	147.30^{a}	9.40^{b}	5.05^{a}	21.21^{a}	2,398.00^{b}
Average	142.78	9.73	4.78	21.65	2,530.06
CV (%)	4.78	8.53	5.13	4.86	10.33

* Means followed by the same letter in the column do not differ from each other by Scott-Knott's test at 5% probability level.

whereas Kluthcouski (1998) suggested that something between 5.0 and 6.0 t ha^{-1}. Lopes et al. (1987) considered 4 t ha^{-1} of residue to be enough to achieve up to 95% hydric erosion reduction. Therefore, the obtained dry mass production values indicate that the studied cover crops may be used for soil coverage and they may work as additional tool in conservationist practices.

The dry weight produced by *M. aterrima* L. at Ceres (GO) was lower than that obtained by Duarte Júnior and Coelho (2008), who have achieved 10.05 t ha^{-1} in Campos dos Goytacazes (RJ), but did not differ from other cover crops, including the natural vegetation (Table 1). However, it was higher than the productivity achieved by Oliveira et al. (2002), who just obtained 1.09 t ha^{-1} at Lavras (MG). Such divergence in cover crop biomass production shows the need for studying and defining promising species for each region, including density, sowing season and crop interest.

Common beans height, number of pods per plant and productivity were influenced by the studied cover crops (Table 2). The obtained values were higher than those found by Oliveira et al. (2002) and by Siqueira (1989). Common bean plants cultivated under mucuna and spontaneous vegetation presented better height performance (Table 2). Such difference in plants height in response to soil coverage may be explained by a higher nutrients accumulation in soil.

There was no significant difference among treatments for the number of grains per pod and the mean weight of 100 grains; however, mucuna straw led to higher number of bean pods per plant and better productivity (Table 2). Bean plant productivity in mucuna straw was 23% higher compared with the natural vegetation. The productivity obtained in all treatments was more than the double of national average in 2012 cropping season (1.046 t ha^{-1}), according to CONAB (2012) data. Therefore, at Ceres environmental conditions, mucuna was the most promising cover crop before bean plant cultivation with greater plant productivity.

Cover crops also influenced the OM and K levels in the soil during the cropping season (Figures 2 and 3). The observed variations are associated with the rate and pattern of cover crops decomposition.

Bayer et al. (2003) found that the inclusion of leguminous species for soil covering increased organic carbon stocks and also led to greater cation exchange capacity. Camargo and Piza (2007) found significant differences in dry biomass production in forage species; however, they did not find any difference in the level of soil OM.

The OM content in the soil covered with *C. spectabilis* and *P. glaucum* was reduced during the 150 days after plants' harvest. In the first case, there was a reduction in the first 40 days and thereafter the OM stabilized in the soil (Figure 2). Mucuna was the cover crop that has led to an increase in OM in the soil right after the biomass cut. However, there was a decrease 40 days after the harvest, increasing again 75 days after the plant cut (Figure 2). The results the release of N, P and K of indicated that, in climatic conditions favor the decomposition of cultural residues of cover plants, it is necessary to optimize the synchrony between the release of nutrients and the demand for commercial crops (Salmi et al., 2006). These variations may be associated with the C/N ratio in the biomass, with the lignin rate in tissues and with decomposition speed.

The most intense change in the OM and K levels are associated with cover crop decomposition and with climatic conditions approximately 40 days after biomass cut. Figure 1 shows that there was rainfall and temperature increase in February and March which favored OM decomposition and nutrients release. Bean plants' flowering started approximately 35 days after emergence, therefore, at this point, the decomposition and nutrient release peak may have favored bean plant production. On the other hand, part of the K released during the residue decomposition may have been leached before flowering, due to the high rainfall rate (Figure 3).

Salmi et al. (2006) found that approximately 50% of K found in *C. cajan* biomass was released at the 30th decomposition day. Crusciol et al. (2008) showed that at the 50th day after oatmeal management as cover crop, almost all K in the straw was released. Teixeira et al. (2012) found that there was 99% mineralization of K found in the dry mass of millet, sorghum and spontaneous

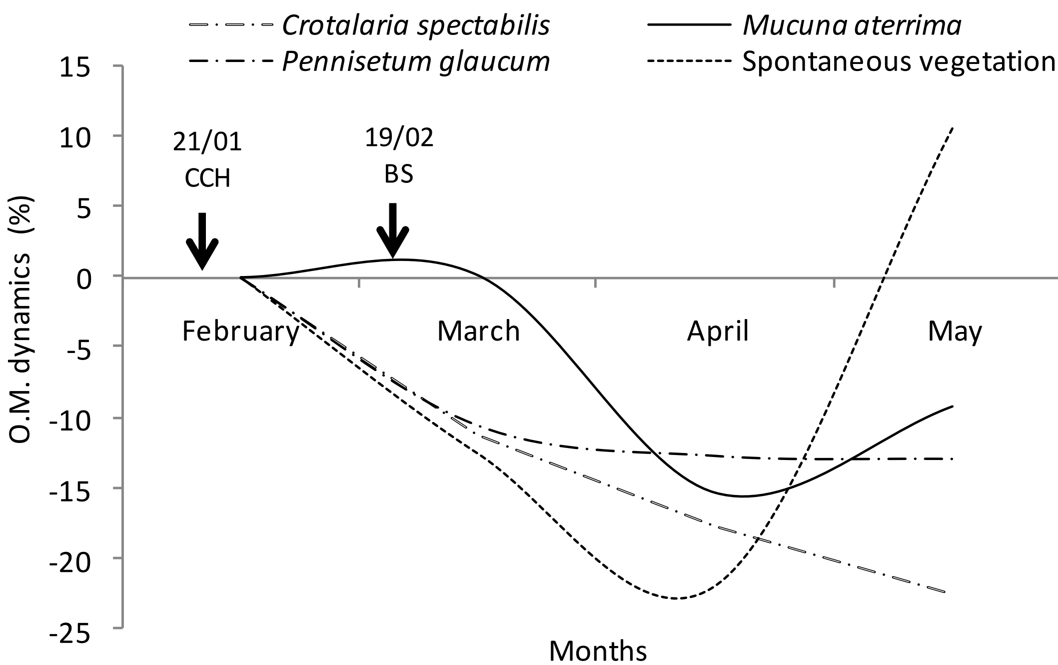

Figure 2. Organic matter (OM) dynamics in the soil during common bean plant cultivation under different cover crops. (CCH – cover crop harvest; BS – bean sowing).

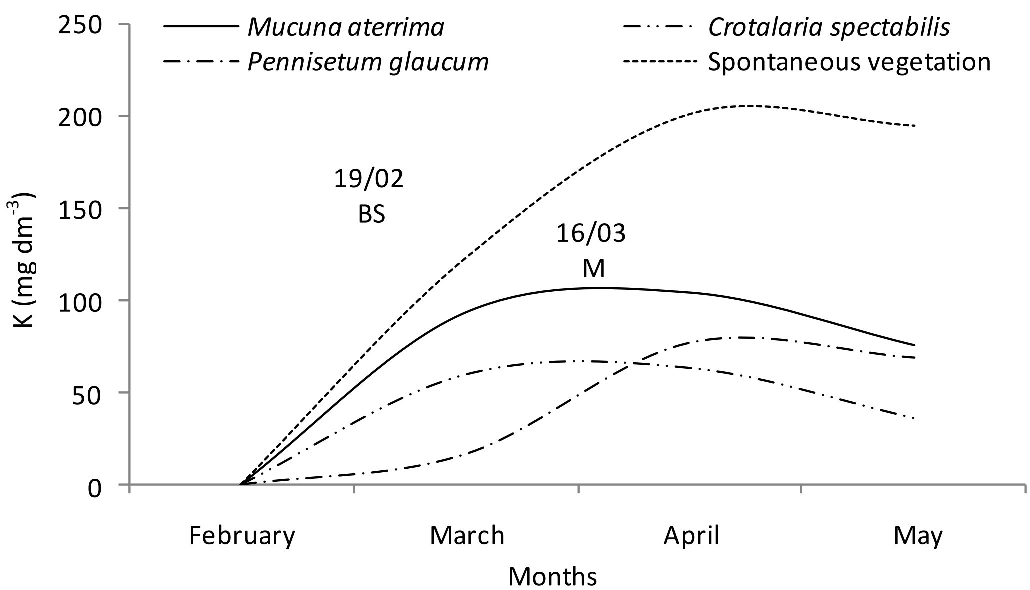

Figure 3. Potassium concentration in the soil during bean growth season under several cover crops (BS – bean sowing / M –manure).

vegetation 120 days after harvest. It shows that the release of nutrients in cover crops depend on plant species, as well as the climatic conditions of the region.

Cover crops influenced bean production as well as soil OM and K contents. Apparently, under the present climatic conditions, black mucuna was the best crover crop, either for common bean cv. Pérola productivity and to increase the OM and K contents in the soil. The increment in production beans can be associated with the availability of nutrients during the decomposition of the cover crops. Pittelkow et al. (2012) reported that K accumulation in *Crotalaria* and millet cover crops were

150.6 and 108.9 kg ha^{-1}, respectively, being released in soil and available plants during decomposition.

Conflict of Interests

The authors have not declared any conflict of interests.

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