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BIOAGENTS AND MIX OF COVER PLANTS AFFECTING SOYBEAN

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Abstract

The search for cultivation practices that provide productive, social and environmental benefits to the agroecosystem is of great importance for the sustainable intensification of agriculture. The objective of this study was to determine the effect of multifunctional microorganisms (MM) and mix of cover crops on gas exchange, production components and grain yield of soybean. In the field experiment, conducted by two growing seasons, the experimental design of randomized blocks in factorial scheme 8x2 was used, with four replications. The treatments were composed by the combination of eight vegetal cover and the use or not of MM. The vegetal cover were composed of: 1. Fallow, 2. Corn, 3. Mix 1 (white lupine, buckwheat, white oats, black oats, *Crotalaria ochroleuca*, *C. juncea*, turnip, coracana grass, white lupine), 4. Mix 2 (millet, *C. ochroleuca*, black oats, white oats, buckwheat, coracana grass), 5. Mix 3 (Millet, *C. ochroleuca*, black oats, white oats, buckwheat, coracana grass), 6. Mix 4 (*C. spectabilis*, buckwheat, millet and *C. breviflora*), 7. Mix 5 (oats, buckwheat, millet, piatã grass and *C. Ocholeuca*); and 8. Mix 6. (black oats, turnip forage, white lupine, coracana grass, buckwheat). The MM consortium used was *Serratia marcenses* (BRM 32114) + *Bacillus* sp. (BRM 63573). Soybean plants coinoculated with (BRM 32114) + (BRM 63573) showed an increase in photosynthetic rate (16.65%), stomatal conductance (37.50%), internal CO_2 concentration (10%), number of pods per plant (15%), mass of 100 grains (4.04%) and grain yield (14.83%). However, no differences were observed in soybean plants grown in succession to the mix of cover crops, except for the number of grains per pod. Therefore, in this study, the highlight was the consortium of multifunctional microorganisms, technology considered strategic for the sustainable intensification of agriculture.

Keywords: *Glycine max*; rhizobacteria; productivity; cover crops.

BIOAGENTES E MIX DE PLANTAS DE COBERTURA AFETANDO A SOJA

Resumo

A busca por práticas de cultivo que proporcionem benefícios produtivos, sociais e ambientais ao agroecossistema é de grande importância para a intensificação sustentável da agricultura. O objetivo deste estudo foi determinar o efeito de microrganismos multifuncionais (MM) e mix de plantas de cobertura sobre as trocas gasosas, componentes de produção e produtividade de grãos da soja. No experimento de campo, conduzido por duas safras agrícolas, utilizou-se o delineamento experimental de blocos casualizados em esquema fatorial 8x2, com quatro repetições. Os tratamentos foram compostos pela combinação de oito coberturas vegetais e do uso ou não MM. As coberturas vegetais foram compostas de: 1. Pousio; 2. Milho; 3. Mix 1 (Tremoço Branco, Trigo Mourisco, Aveia Branca, Aveia Preta, *Crotalaria ochroleuca*, *C. Juncea*, Nabo Forrageiro, Capim coracana) 4. Mix 2 (trigo Mourisco, *C. spectabiliis*, nabo forrageiro, aveia preta); 5. Mix 3 (Milheto, *C. ochroleuca*, aveia preta, aveia branca, trigo mourisco, Capim coracana); 6. Mix 4 (*C. spectabilis*, trigo mourisco, milheto e *C. breviflora*); 7. Mix 5 (Aveia, Trigo Mourisco, Milheto, Piatã e *C. ocholeuca*); e 8. Mix 6. (Aveia preta, Nabo Forrageiro, Tremoço Branco, Capim coracana, Trigo Mourisco). O consórcio de MM utilizado foi *Serratia marcenses* (BRM 32114) + *Bacillus* sp. (BRM 63573). Plantas de soja coinoculadas com (BRM 32114) + (BRM 63573) apresentaram aumento na taxa fotossintética (16,65%), condutância estomática (37,50%), concentração interna de CO_2 (10%), número de vagens por planta (15%), massa de 100 grãos (4,04%) e produtividade de grãos (14,83%). Contudo, não foram observadas diferenças nas plantas de soja cultivadas em sucessão aos mix de plantas de cobertura, com exceção do número de grãos por vagem. Portanto, nesse estudo, o destaque foi para o consórcio de microrganismos multifuncionais, tecnologia considerada estratégica para a intensificação sustentável da agricultura.

Palavras - chave: *Glycine max;* rizobactérias; produtividade; coberturas vegetais.

Introduction

Soybean (*Glycine max* (L.) Merr.) is a commodity, and it is the main oleaginous produced in the world and important protein and lipid component for various foods including animal feed and products for human consumption (VOGEL *et al.*, 2021). Brazil is the largest producer and exporter of soybeans in the world, with a planted area of 2,717 mil hectares and production of 3,069 million tons, resulting in a grain yield of 1,129 kg ha^{-1} in the 2022/23 growing season (CONAB, 2023).

The Brazilian agriculture has advanced safely towards sustainability over the last decades; however great challenges are still found, especially in a climate change scenario. Thus, investing in research, development and innovation in agriculture are essential for achieving the reduction of the use of pesticides and fertilizers, the conversion of non-farm land and agricultural practices that negatively impact the environment (SILVA *et al.*, 2020).

In this context, a promising approach in intensive and sustainable agricultural production, currently in use, is the exploitation of multifunctional and beneficial microorganisms to plants, which perform healthy services in agriculture, such as improving plant nutrition and health, strengthening natural defense systems and increasing soil quality (LUGTENBERG, 2015; CHATTERJEE *et al.*, 2019). The multifunctional microorganisms are associated with plants in the rhizosphere, by the composition of rhizoposits and root exudates, and may cause several modifications directed to the processes of cycling and distribution of nutrients to the soil, release of solubilizing substances of phosphates and iron chelators, biological fixation of nitrogen, production of enzymes such as lipases and ACC deaminase (1-aminocycloprane-1-carboxylate) and synthesis of phytohormones; and act in biological control (SPERANDIO *et al.*, 2017; MORENO *et al.*, 2021). Such mechanisms are able to promote plant growth and intensify tolerance to biotic and abiotic stresses (MORENO *et al.*, 2021).

Studies have shown the beneficial effects of microorganisms on nitrogen accumulation in the shoots of corn plants (MORENO *et al.*, 2021), higher nutrient uptake by upland rice plants (NASCENTE *et al.*, 2017) and increased soybean productivity (MUNDIM *et al.*, 2018). Additionally, the use of coinoculation, a technology characterized by adding two or more microorganisms in the target plant, has been growing, aiming to maximize the various beneficial effects of its interactions (CHIBEBA *et al.*, 2014).

Another extremely important practice is the use of cover crops, in mixed or single cultivation, in off-season periods (January to May) in the Cerrado region, to increase soil physical, chemical and biological quality; reducing the thermal amplitude in the soil, favoring macro and microorganisms; promoting the recycling of nutrients in the soil profile; increasing the content of organic matter in the soil, CTC and the sum of bases, reducing competition of weeds, due to suppression effects and allelopathy. In addition, they promote the control of phytonematodes and the reduction of pest and disease pressure due to the introduction of new plant species in agricultural systems (AMBROSANO *et al.*, 2005; ACHARYA *et al.*, 2017).

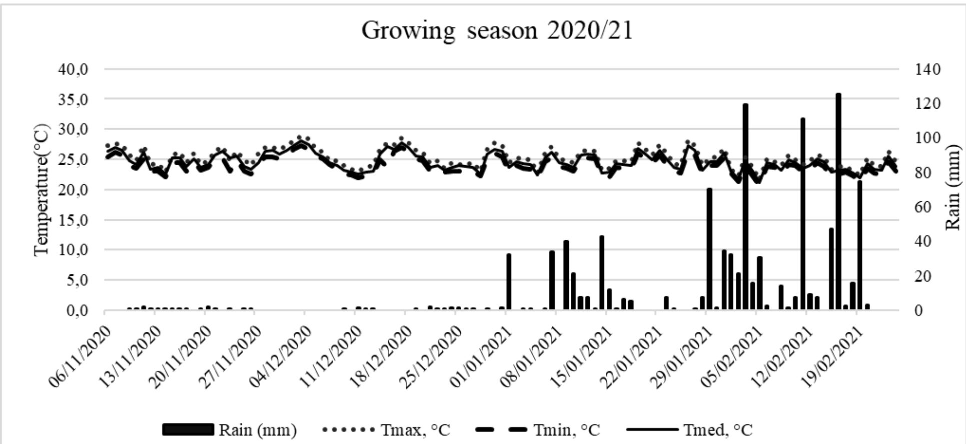
Studies with cover crops showed greater use of nitrogen and productive gains in rice (SILVA *et al.*, 2016), increased phytomass and, consequently, corn productivity (CARVALHO *et al.*, 2015), reduction of weed infestation in soybean and millet (ADAMI *et al.*, 2020) and nitrogen accumulation (N) and increased agronomic performance of common bean (OLIVEIRA *et al.*, 2017). Thus, the use of cover crops in agricultural systems has been incorporated as a sustainable strategy, enabling the reduction of the use of agrochemicals and, consequently, production costs, growth and increase in productivity (REZENDE *et al.*, 2021). However, few studies show the joint action of multifunctional microorganisms and cover crops in agricultural systems. Therefore, the objective of this study was to determine the effect of multifunctional microorganisms (MM) and mix of cover crops on gas exchange, grain yield and production components of soybean plants.

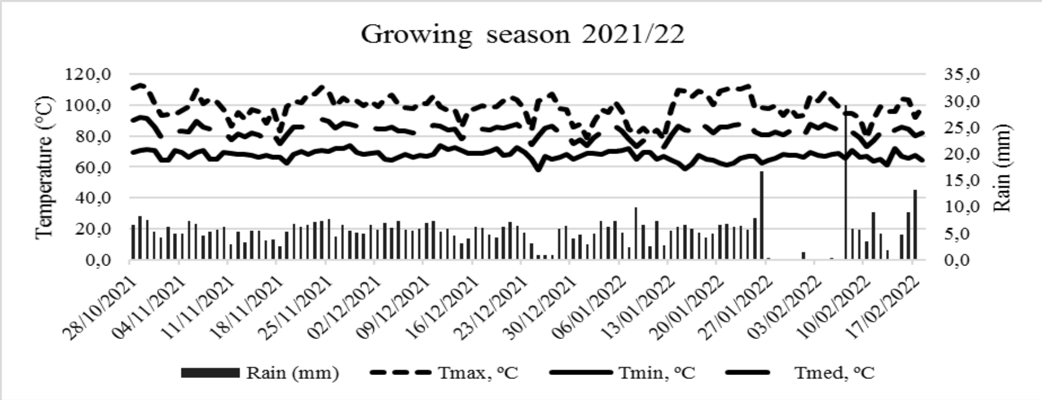
Material and Methods

The experiment was conducted in the growing seasons of 2020/21 and 2021/22 at the Embrapa Rice and Beans Experimental Station, located in Santo Antônio de Goiás, GO, Brazil, 16º28'00" S and 49º17'00" W coordinated, and at 823 m altitude. The climate is tropical savanna Aw (tropical with wet summer and dry winter) according to the Köppen classification (KÖPPEN, 1918). The average annual rainfall is between 1500 and 1700 mm, and the average annual temperature is 22.7 ºC, ranging annually from 14.2 ºC to 34.8 ºC. During the trial, temperature and rainfall data were recorded (Figure 1).

Before the beginning of the experiments, the analysis of soil fertility (Oxisol of medium texture), layer (0-0.20 m), was performed, with the following results: pH (H_2O) = 6.3; Ca^{2+} = 18.8 $mmol_c$ dm^{-3}; Mg^{2+}= 7.2 $mmol_c$ dm^{-3}; H + Al = 11 $mmol_c$; P = 3.1 mg dm^{-3}; K^+ = 142 mg dm^{-3}; Cu^{2+} = 0.6 mg dm^{-3}; Zn^{2+} = 1.5 mg dm^{-3}; Fe^{3+} = 6.7 mg dm^{-3}; Mn^{2+} = 13.8 mg dm^{-3} and organic matter = 31.2 g kg^{-1}. These values were determined following the methods proposed by Teixeira *et al.* (2017).

Figure 1. Temperature and rainfall during soybean cultivation in the growing seasons 2020/2021 and 2021/22. Santo Antônio de Goiás, Goiás, Brazil.





The experimental design was in randomized blocks in a factorial scheme 8x2, consisting of a mix of vegetal cover and the use or not of MM consortium. The vegetal cover were composed of: 1. Fallow, 2. Corn, 3. Mix 1 (white lupine, buckwheat, white oats, black oats, *C. ochroleuca, C. juncea,* turnip, coracana grass, white lupine), 4. Mix 2 (millet, *C. ochroleuca,* black oats, white oats, buckwheat, coracana grass), 5. Mix 3 (Millet, *C. ochroleuca*, black oats, white oats, buckwheat, coracana grass), 6. Mix 4 (*C. spectabilis,* buckwheat, millet and *C. breviflora*), 7. Mix 5 (oats, buckwheat, millet, piatã grass and *C. ocholeuca*); and 8. Mix 6. (black oats, turnip forage, white lupine, coracana grass, buckwheat). The MM consortium used was *Serratia marcenses* (BRM 32114) + *Bacillus* sp. (BRM 63573) soybean plants not treated with the consortium of microorganisms, with four replications.

The plots had dimensions of 5m x 10m and the useful area was composed by the three central rows, disregarding 0.50 m on each side. The microorganisms *Bradyrhizobium* (inoculant) and growth promoting bacteria *S. marcenses* (BRM 32114) + *Bacillus* sp. (BRM63573) (treatments) were applied via planting furrow with the equipment Micron. The microorganisms *S.marcenses* (BRM 32114) + *Bacillus* sp. (BRM63573) belong to the Embrapa Rice and Beans Microorganisms Collection. *Bradyrhizobium* belongs to the Grap Nodl formulation.

Bacterial suspensions of *S. marcenses* (BRM 32114) + *Bacillus* sp. (BRM63573) were prepared separately with nutrient broth, grown for a period of 24 hours in solid medium 523 (KADO; HESKETT, 1970), at 28 ºC, and the concentration fixed in spectrophotometer A540 = 0.5 (108 CFU). The broth was stored in a cold chamber and the mixture of microorganisms was performed in the Micron chamber on the day of planting, using 300 ml ha^{-1} of each suspension of rhizobacteria. The dosage used for the inoculant *Bradyrhizobium* was 600 ml ha^{-1}, following the manufacturer's recommendation.

The seeding of cover crops occurred on March 12th, 2020 and March 9th, 2021, at a density of 30 kg ha^{-1}, except for fallow (control), in which spontaneous plants grew in the area. It was not used any type of fertilization and irrigation during the period of development of the vegetal covers, remaining growing in the soil for 75 days in the first growing season and 70 days in the second growing season in the area. The cover crops were dried with glyphosate application (1.8 kg ha $^{-1}$ acid equivalent), 30 days before sowing the common bean. Soybean sowing occurred on November 6th, 2020 and October 28th, 2021, using 15 seeds per m², and seedling emergence was on the fourth day after sowing. The soybean cultivar NS 6909 IPRO was used, characterized as of excellent quality, medium cycle, indeterminate growth and high productivity (NIDERA, 2018). The basic fertilization, applied in the seeding furrows, was calculated according to the chemical characteristics of the soil, according to the recommendations of Sousa; Lobato (2003). The cultural practices to maintain the area free of weeds, diseases and insects followed the technical recommendations for the soybean crop (SEIXAS *et al.*, 2020).

Evaluations

Gas exchange

The analyses of gas exchange of soybean plants were performed only in the growing season 2020/2021, 59 days after emergence (DAE), a period that corresponds to the full flowering of the crop. Measurements of photosynthetic (A, μmol CO2 m^{-2} s^{-1}) and transpiratory (E, mmol H_2O m^{-2} s^{-1}), stomatal conductance (Gs, mol H_2O m^{-2}s^{-1}) and internal concentration of CO_2 (Ci, μ mol-^{1}) were performed in the upper third of the leaves (fully expanded and with good sun exposure). The evaluations were performed with the portable infrared gas analyzer (LCpro +, ADC BioScientific), from 8:00 am to 10:00 am. The equipment was configured to use concentrations of 370-400 mol^{-1} CO_2 in the air and the flux density of photosynthetically active photons (PPFD) was equal to 1200 μmol [quanta] m^{-2} s^{-1}. The minimum equilibrium time set for reading performance was 2 minutes.

Productivity and its components

The grain yield of the crop was determined mechanically after grain maturation (108 and 92 days after planting, growing seasons 2020/2021 and 2021/2022, respectively), in the useful area of each plot. To determine the number of pods per plant (NPP), number of grains per pod (NGP) and mass of 100 grains (M100, g) were manually collected 10 plants, within the useful area of each plot. The productivity was determined in the harvest of the useful area of each plot, with the drying of the grains (moisture correction to 13%) and expressed in kg ha^{-1}.

Statistical analysis

The data were submitted to analysis of variance, and when significance was detected by the F test, the means were compared by the LSD test ($p \leq 0.05$). The blocks and all block interactions were considered as random effects. The statistical package SISVAR 5.6 was used.

Results and Discussion

There was no interaction between the factors studied (multifunctional microorganisms and vegetal cover), thus, the isolated factors were analyzed (Tables 1 and 2). Microbial coinoculation, *S. marcenses* (BRM 32114) + *Bacillus* sp. (BRM63573) stimulated gas exchange in soybean plants, with the exception of transpiration rate (Table 1). The increase in photosynthetic rate, stomatal conductance and internal CO_2 concentration was 16.65, 37.50, and 11.00%, respectively. Lopes *et al.* (2021) reported that multifunctional microorganisms have the ability to modify plant metabolism by promoting increased leaf and root area, chlorophyll content, nitrogen fixation, nutrient availability, photosynthetic rate and biomass production. While, Silva *et al.* (2020) showed that soybean plants treated with *Bacillus* spp. and *Pseudomonas* spp. showed an increase of 75% in its photosynthetic rate compared to control plants (without microorganism).

Bacillus belong to the family Bacilliaceae, currently includes more than 60 species, are gram-positive, endospore-forming, chemooheterrophic, mobile, surrounded by flagella, resistant to physical and adverse chemical factors such as high temperatures (55 - 77 ºC) and radiation, and are commonly isolated from soils and plants, in anaerobic or aerobic systems. Among its main biochemical characteristics, it is cited production of hydrolytic enzymes that act in the degradation of polysaccharides; phytohormones such as IAA (indolacetic acid) and lipopeptide antibiotics, the surfactin family, bacitracin and polymyxin, nitrogen fixation, solubilization of nutrients; besides being considered biological control agent (BERGEY *et al.*, 2000; ANDERSON, 2003; RAGAZZO-SÁNCHEZ *et al.*, 2011; CHAGAS *et al.*, 2017). Study conducted with common bean plants inoculated with *Bacillus* sp. showed that the synthesis of auxin, cytokinin and gibberellin by the bacteria stimulated high germination rate of seeds and seedling emergence, with an increase of 33% in the dry mass of aerial part of seedlings (MANJULA; PODILE, 2005). In addition, Araújo (2008) showed that cotton, corn and soybean seeds inoculated with *Bacillus* sp. had increased seedling emergence rate. These results, according to Lanna Filho *et al.* (2010), promote shorter period of crop living in the field and, ultimately, less contact with soil pathogens in the early stages of plant development.

Serratia marcenses belong to the family Enterobacteriaceae, are gram-negative, mobile, found in several habitats, such as fresh or salt water, polluted or not, in soil and plants (GRIMONT; GRIMONT, 1992). Its main biochemical characteristics include solubilization of non-labile phosphorus, production of phytohormones such as IAA, siderophores, biofilm and bacteriocins. Barreti *et al.* (2009) showed that *S. marcescens*, among endophytic isolates selected in tomato, was able to control diseases and promote plant growth.

In relation to the predecessor vegetal covers, only stomatal conductance (Gs) was significantly different between soybean plants grown under straw of the different mix of cover crops and the control treatment (fallow) (Table 1). Results that corroborate with Wolschick *et al.* (2018), who reported that cover crops are associated with increased soil productive capacity and nutrient cycling efficiency, especially nitrogen, yielding benefits to the soil and in the productive contents of the successor crop, not establishing direct gains to the gas exchange of the plants.

Additionally, the total precipitation (989.9 mm) and (963.0 mm) with good distribution throughout the cycle of soybean plants, during the growing seasons 2020/2021 and 2021/22, environmental conditions for the development of plants in succession to different mix of cover plants (Figure 1). Thus, soybean plants benefited from environmental factors such as temperature and availability of sufficient water and nutrients for their development (SILVA *et al.*, 2019).

Table 1. Gas exchange: photosynthetic (A) and transpiratory (E) rates, stomatal conductance (Gs) and internal CO_2 concentration (Ci) of soybean plants treated with *S. marcenses* (BRM 32114) + *Bacillus* sp. (BRM 63573) crop 2020/2021. Santo Antônio de Goiás, Goiás.

Treatments	**A**	**E**	**gs**	**Ci**
Microbial (M)	**µmol CO_2 m $^{-2}$ s $^{-1}$**	**mmol H_2O m^{-2} s $^{-1}$**	**mol H_2O m^{-2} s^{-1}**	**µmol mol^{-1}**
BRM 32114 + *BRM63573*	12,70 a*	3,04	0,20 a	245a
No microorganisms	10,76 b	3,20	0,16 b	220b
Vegetal Cover				
Fallow	10,43	3,21	0,16 b	210
Corn	12,23	3,14	0,20 a	229
Mix 1	13,01	2,96	0,19 a	229
Mix 2	11,27	2,94	0,18 ab	248
Mix 3	11,31	3,24	0,19 a	230
Mix 4	11,92	3,14	0,18 a	242
Mix 5	11,87	3,16	0,18 a	240
Mix 6	11,81	2,98	0,19 a	233
Growing season (GS)				
2020/2021	11,73	3,10	0,18	233
Factors		ANOVA – F probability		
Microrganisms (M)	0,000	0,086	0,000	0,012
Vegetal Cover (VC)	0,090	0,866	0,036	0,678
M * VC	0,776	0,954	0,336	0,424
CV (%)	13,25	15,96	19,35	16,44

*Means followed by the same letter, in column, do not differ by the LSD test (P<0.05).

The use of the microbial consortium, *S. marcenses* (BRM 32114) + *Bacillus* sp. (BRM63573), promoted a significant increase in grain yield (14.83%), mass of 100 grains (4.04%) and number of pods per plant 15.00%); while the number of grains per pod (NGP) were similar to the control treatment, fallow (Table 2). The productivity, mass of 100 grains and number of pods per plant increased 13.82, 12.09 and 15.9% respectively, in co-inoculated soybean plants.

Braga Junior *et al.* (2018) reported the beneficial effect of the application of *Bacillus* sp. in soybeans, cultivated in different regions, where there were significant increases in root dry biomass and yield. Gagné-Bourque *et al.* (2015) observed that soybean plants co-inoculated with *Brachypodium distachyon* + *Bacillus thuringiensis* showed increased growth rate and production of growth promoting substances by microorganisms. Our results corroborate those obtained by Pacentchuck *et al.* (2020), who used the coinoculation of the rhizobacteria *Bradyrizobium* sp., *Bacillus* sp., *Pseudomonas* sp., *Burkoderia* sp. and *Azospirillum* sp. in the soybean planting furrow, and observed increases in productivity, number of grains per plant, thousand grain mass and nodule mass. According to these authors, the increase in productivity is the result, in part, of the early formation of nodules that, in turn, increases the efficiency of biological nitrogen fixation and robustness of the root system. Unlike the study conducted by Braga Junior *et al.* (2018), Pacentchuck *et al.* (2020) observed a great variability in the results obtained in the different places of experimentation, and suggests that the beneficial effects of microorganisms are dependent on various factors, as environmental conditions, soil atmosphere, water, pH, microbial metabolism and transformations of carbon, nitrogen (N), sulfur (S) and phosphorus (P).

Among the environmental conditions, the amount and distribution of rainfall are one of the main factors that influence grain yield in agricultural crops (NASCENTE *et al.*, 2020). In this study, the total precipitation was 989.9 and 963.0 mm; while in the period between flowering and grain filling of soybean plants was 264.8 and 227.2 mm, in the 2020/2021 and 2021/2022 growing seasons, respectively (Figure 1). However, higher productivity of soybean plants was obtained in the 2020/21 growing season, which may be related to excess rainfall in the harvest period in the 2021/22 growing season.

Table 2. Productivity (kg ha-1) and production components: number of pods per plant (NPP), number of grains per pod (NGP) and mass of 100 grains (M100, g) of soybean plants treated with *S. marcenses* (BRM 32114) + *Bacillus* sp. (BRM 63573) and cultivated after using mix of cover plants, crops 2020/2021 and 2021/2022. Santo Antônio de Goiás, Goiás.

Trataments	**NPP**	**NGP**	**M100**	**Productivity**
Microbial	**unit**	**unit**	**g**	**kg ha^{-1}**
BRM 32114 + BRM 63573	51 a	2	17,24 a	5655 a
No microorganisms	44 b	2	15,38 b	4968 b
Vegetal Cover				
Fallow	48 ab	2	15,86	5247
Corn	46 b	2	16,48	5328
Mix 1	49 ab	2	16,37	5380
Mix 2	48 ab	2	16,22	5351
Mix 3	46 b	2	16,34	5189
Mix 4	52 a	2	16,27	5426
Mix 5	48 ab	2	16,57	5226
Mix 6	46 b	2	16,35	5345
Growing season (GS)				
2020/2021	50 a	2	14,70 b	5744 a
2021/2022	46 b	2	17, 92 a	4880 b
Factors		ANOVA - F probability		
Microrganisms (M)	0,000	0,250	0,000	0,001
Vegetal Cover (VC)	0,160	0,876	0,927	0,519
Growing season (GS)	0,001	0,061	0,000	0,000
M * VC	0,183	0,294	0,257	0,458
M*GS	0,058	0,787	0,000	0,000
VC*GS	0,264	0,950	0,123	0,297
M * VC * GS	0,054	0,727	0,302	0,650
CV (%)	12,13	16,86	8,34	6,55

* The means followed by the same letter do not differ by the LSD test ($p<0.05$).

No differences were observed in the evaluated parameters of soybean plants grown in succession to the mix of cover plants, except for the number of grains per pod (Table 2). However, it is observed that mix 4 (*C. spectabilis*, buckwheat, millet and *C. breviflora*) showed a tendency to figure as the best. Millet is a grass adapts to adverse conditions, provides high production of dry biomass of shoots and roots, fast growing and has good adaptability to low fertility soils. Crotalaria is an annual legume that presents high accumulation of phytomass and incorporates nitrogen to the system through biological fixation. While, buckwheat is a short cycle plant, rustic, herbaceous and dicotyledonia that provides good soil coverage due to tolerance to acidity and the ability to use potassium and phosphorus salts (TOMAZI *et al.*, 2021).

Thus the consortium between legumes and grasses can cause effects on soil physical quality and promote joint action to improve soil properties and performance of the crop successor to use (BERTOLINO *et al.*, 2021). Carvalho *et al.* (2013) demonstrated that the consortium between legumes and grasses provide benefits due to the distinct root systems. Thus, this consortium favors the physical structure of the soil and the production of dry matter with intermediate C/N ratio, thus allowing a lower rate of decomposition of crop residues and promoting a long-term soil cover.

Wolschick *et al.* (2018) showed that there was no significant difference in the productivity of soybean plants in succession to cover plants in single cultivation of vetch, oats, turnip, as well as in succession to the mix of the three species. While, corn productivity increased by 95% when grown under straw mix of the three species. The authors emphasized the importance of the correct choice of the species that precede the main crop, to achieve the objectives of reducing chemical fertilization and production costs and, on the other hand, to enhance crop productivity. Forte *et al.* (2018) reported that the use of mix of cover crops provided an increase of 15%, 20% and 25% in productivity of different soybean crops, in relation to fallow. The authors suggested that these differences were due to the greater release of N in the initial phase of the development of the soybean plant provided by the cover crops, adoption of the no-tillage system and the type of soil. The use of cover crops mix in no-tillage system provides soil protection against excessive rainfall and provides greater amount of nutrient such as nitrogen, particularly for legumes. For Maneghette *et al.* (2019), the interactions between cover crops and climatic factors such as rainfall and temperature determine dry matter production, accumulation and release of micronutrients, soil microbiological activity and therefore, quantity and quality of plant waste.

There was interaction between the growing season of experimentation and the use of the consortium of microorganisms, *S. marcenses* (BRM 32114) + *Bacillus* sp. (BRM 63573) for productivity and mass of 100 grains. Inoculated plants presented higher productivity (6,545 kg ha^{-1}) and mass of 100 grains (16.73 g) in relation to control plants, in the 2020/2021 growing season (Table 3).

Table 3. Interaction between agricultural year and the consortium of microorganisms, *S. marcenses* (BRM 32114) + *Bacillus* sp. (BRM 63573) for productivity of 100 grains (M100) of soybean plants.

Crop 2020/21		
	M100	**Produtivicty**
Microbial Treatment	**(g)**	**(kg ha^{-1})**
BRM 32114 + BRM63573	16,73 a	6545 a
Control	12,67 b	4942 b
Crop 2021/22		
BRM 32114 + BRM63573	17,75	4766
Control	18,09	4994

* The means followed by the same letter, in column, do not differ by the LSD test (p<0.05).

The use of multifunctional microorganisms can bring benefits to the cultivation systems, by causing several chemical modifications directed to the processes of cycling and availability of nutrients in the soil, determining increments in the promotion of growth and productivity. Thus, the use of this technology enables lower production costs and helps in the use of sustainable techniques for the environment (LAVAKUSH *et al.*, 2014).

Conclusion

Soybean plants coinoculated with *Serratia marcenses* (BRM 32114) + *Bacillus* sp. (BRM63573) improved physiological (gas exchange) and agronomics (productivity and mass of 100 grains) performance.

The use of cover crops before soybean cultivation, in this study, did not promote increase of soybean plants development.

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