AGRONOMY (AGRONOMIA)

Revista Brasileira de Ciências Agrárias
ISSN (on line) 1981-0997
v.17, n.1, e8916, 2022
Recife, PE, UFRPE. www.agraria.pro.br
DOI: 10.5039/agraria.v17i1a8916 - Protocol 8916
Subm. 18/08/2020 • App. 08/02/2022 • Pub. 24/03/2022

Cover crops at soybean agronomic performance in the western region of Paraná state, Brazil

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ABSTRACT: Soybean crop is one of the main activities of Brazilian agribusiness, grown in practically all regions of the country. Even though it is of fundamental importance, the no-till system is fully adopted in a few situations. The objective of the present study was to evaluate the agronomic performance of soybean under no-till, with cultivation in succession of cover crops in two growing seasons. The experiment was conducted in Palotina, Paraná state, Brazil. This was a randomized block experimental design, with four replicates. The treatments consisted of seven cover crops: forage turnip, linseed, triticale, rye, canola, crambe, oats and fallow area. In succession, the soybean was planted. The variables, plant height, first pod height, number of pods per plant, 100 grain weight, and grain yield were not influenced by cover crops. Although cover crops did not have a marked influence on agronomic performance, crop assessments are required to investigate other effects from cover crops. It is very important to design systems to achieve sustainability in soybean crop. Cover crops can play a key role in this regard, where we have several species that can be used in the recovery of degraded soils and with the potential for their economic exploitation.

Key words: cover crops; crop residues; *Glycine max*; no-till system

Culturas de cobertura no desempenho agronômico da soja no oeste do estado do Paraná, Brasil

RESUMO: O cultivo da soja é uma das principais atividades do agronegócio brasileiro, cultivada em praticamente todas as regiões do país. Mesmo sendo de fundamental importância, o sistema plantio direto é adotado, em sua plenitude, em poucas situações. O objetivo do presente trabalho foi avaliar o desempenho agronômico da soja no sistema plantio direto, com cultivo em sucessão de culturas de cobertura em duas safras. O trabalho foi conduzido em Palotina, estado do Paraná, Brasil. O delineamento experimental utilizado foi o de blocos ao acaso, com quatro repetições. Os tratamentos foram constituidos por sete culturas de cobertura: nabo forrageiro, linhaça, triticale, centeio, canola, crambe, aveia e área de pousio, na sucessão foi semeada a soja. As variáveis, altura de planta, altura de inserção da primeira vagem, número de vagens por planta, massa de 100 grãos e produtividade de grãos, não foram influenciadas pelas culturas de coberturas. Embora, as culturas de cobertura, não tenham influenciado de forma marcante o desempenho agronômico, avaliações por safras, são necessárias para delimitar outros efeitos das culturas de cobertura. É muito importante projetar sistemas para alcançar a sustentabilidade na cultura da soja. As plantas de cobertura podem desempenhar um papel fundamental nesse sentido, onde temos diversas espécies que podem ser utilizadas na recuperação de solos degradados e com potencial para sua exploração econômica.

Palavras-chave: culturas de cobertura; restos culturais; *Glycine max*; sistema plantio direto

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Associate Editor: Adônis Moreira

Introduction

The cultivation of soybeans is among the main economic activities that grew the most in the national and international scenario. With an emphasis on Brazilian agribusiness, the development of new technologies is expanding. The soybean market has expanded due to the modernization of agriculture, the use of cooking oil and the animal feed production, and the widespread use of soybean derivatives, providing the export of grain to various regions of the world (Freitas, 2011).

For a long time, agricultural exploitation was limited only to natural resources, with constant crop cycles, extracting nutrients from the soil without replenishing them, changing its properties, affecting the growth and yield of the crops, negatively impacting agricultural production. The no-till system (NTS) arose from the need to overcome the problems caused by conventional cultivation, enabling sowing at the right time, saving inputs, simplifying and reducing operating expenses and contributing to soil recovery (Machado & Silva, 2001; Muraishi et al., 2005). Crop rotation is based on NTS, several crop rotations or successions favor the implementation of no-till, providing sustainable crop production (Brandt et al., 2006; Acharya et al., 2020).

In the NTS, the use of soil cover plants provides the diversity and stability of the system, improving the use of available natural resources: water, nutrients, and light, increasing soil fertility with nutrient recycling, increasing the organic content of the soil, improving physical, chemical and biological properties, reducing soil erosion and compaction, with an important role in the control of nematodes and weeds (Correia & Durigan, 2008; Piccoli et al., 2020; Pittman et al., 2020).

Cover crops must meet certain requirements for their adoption in the agricultural management system, for example, ease of establishment, rapid growth, high dry weight, yield capacity, resistance to diseases, not acting as a host of pests and diseases compatible with the successive crop and providing the possibility of economic exploitation. Several plant species can be used as cover crops, the species must be chosen according to the purpose of its use, and depending on the species, it can be used in the restoration of degraded soils, greater efficiency in nutrient recycling, rapid soil cover and alternative aid in weed control (Reeves, 1994; Fageria et al., 2005).

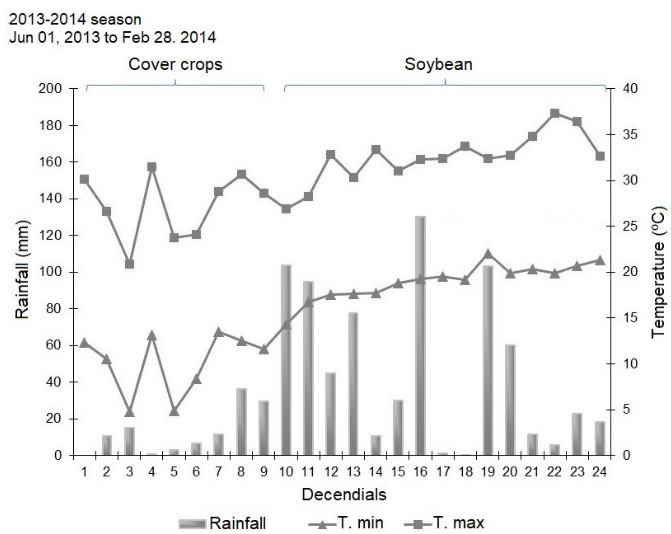
Despite the importance for agricultural sustainability, the NTS is not fully adopted in a few situations. It is believed that cover crops used in the NTS can affect the agronomic performance of soybean. Therefore, there is a need to evaluate the use of cover crops before soybean cultivation. In view of the above, the objective of the present study was to evaluate the agronomic performance of soybean under no-till, planted after cover crops in two growing seasons.

Materials and Methods

Experimental design and field conditions

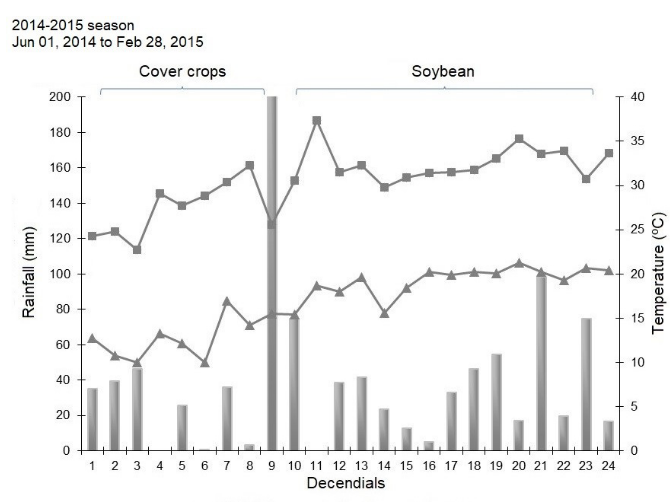
The experiment was conducted in the agricultural years of 2013-2014 and 2014-2015, in soil classified as Eutroferric Red Latosol with a very clayey texture (Santos et al., 2018), in Palotina, Paraná state (PR), Brazil (24°20'51" S 53°45'14" W, 356 m altitude). According to the Köppen climate classification, the predominant climate in the region is the Cfa - subtropical humid mesothermal.

Before the onset of the experiment, a soil sample (0-0.20 m) was taken from the experimental area, which had the following characteristics: pH (H_2O) = 5.3; P (Mehlich) = 5.2 mg dm^{-3}; O.M. = 3.9 g dm^{-3}; K = 0.2 cmol$_c$ dm^{-3}; Ca = 3.3 cmol$_c$ dm^{-3}; Mg = 0.6 cmol$_c$ dm^{-3}; base saturation = 50.6%. With clay, sand, and silt contents: 660, 210 and 130 g kg^{-1}, respectively. Data of rainfall, maximum and minimum temperatures in the two harvests (Figures 1 and 2). The sowing dates and other crop treatments are listed in Table 1.



Source: SIMEPAR (2015).

Figure 1. Rainfall and average temperatures (minimum and maximum), for the period referring to the cover crops and soybeans. Palotina, PR, Brazil, 2013-2014.



Source: SIMEPAR (2015).

Figure 2. Rainfall and average temperatures (minimum and maximum), for the period referring to the cover crops and soybeans. Palotina, PR, Brazil, 2014-2015.

Table 1. Sowing and burndown dates of cover crops, and sowing and harvest of soybeans. Palotina, PR, Brazil.

Growing seasons	Cover crops		Soybean	
	Sowing	Burndown	Sowing	Harvest
2013-2014	June 03, 2013	September 09, 2013	October 12, 2013	February 23, 2014
2014-2015	June 04, 2014	October 03, 2013	October 16, 2014	February 26, 2015

The randomized block experimental design, with four replications, whose treatments consisted of seven cover crops: forage turnip (*Raphanus sativus* L.), linseed (*Linum usitatissimum* L.), triticale (*Triticum turgidocereale* Kiss), rye (*Secale cereale* L.), canola (*Brassica* ssp.), crambe (*Crambe abyssinica* Hochst), oats (*Avena sativa* L.), in addition to fallow. The plots were 4.2 × 4.0 m, with a useful area disregarding 0.6 m from each end of the plot and 0.5 m from each side. The arrangement of treatments in the plots was the same in both harvests.

For sowing cover crops, a seeder with a spacing of 0.45 m was used to furrow the soil, moving it twice over the place, intersecting the furrows, obtaining rows with spacing of 0.23 m, where the cover crop seeds were deposited manually. For burndown, glyphosate herbicide (1,440 g acid equivalent ha^{-1}) was used, when, all cover crops were in full flowering.

In the succession of cover crops, the soybean cultivar NA 5909 RR (indeterminate growth habit) was used, with, 0.08 to 0.12 m first pod height, 0.65 to 0.84 m plant height, 88 to 104 days physiological maturity, 94 to 112 days harvest. Soybean was sown under NTS, with spacing between rows of 0.45 m, and 355,000 seeds ha^{-1}. Soybean seeds were treated with fludioxonil fungicide (200 mL 100 kg^{-1} seeds) and fipronil insecticide (100 mL 100 kg^{-1} seeds). Sowing fertilization was performed with 280 kg ha^{-1} of the formula 08-28-16 (N, P_2O_5, and K_2O). During the soybean cycle, the integrated management of weeds, diseases and pests, necessary for crop development, was adopted.

Evaluations and data collection

The evaluations carried out in the soybean crop were: plant height at V_4-V_5, R_1, R_2 and R_3 (Fehr et al., 1971), final plant height, first pod height, number of pods per plant, 100 grain weight and grain yield. The final heights of plant and first pod were determined at harvest time by randomly measuring ten plants per plot. Plant height was obtained by measuring the distance from the ground to the apex of the stem, and the first pod height was determined by the distance between the ground and the insertion of the first pod in the stem. The number of pods per plant was determined at harvest by randomly counting the number of pods in ten plants per plot.

For 100 grain weight, eight samples of 100 grains were counted per plot, the samples were weighed on a scale accurate to two decimal places. The value was determined by the average of the eight samples, with moisture corrected to 13%. Yield was measured after screening and cleaning the grains of the plants harvested within the useful area of each plot, represented by four rows of soybean plants with three meters in length. Grains were weighed on a scale accurate to two decimal places, the values were expressed in kg ha^{-1}, with moisture corrected to 13%.

Statistical analysis

Data were tested by analysis of variance (ANOVA), using the F-test ($p \leq 0.05$), according to Pimentel-Gomes & Garcia (2002). The means were compared by Tukey's (1949) test at 5% probability, using the Sisvar 5.3 software (Ferreira, 2011).

Results and Discussion

No difference was detected for soybean plant height in the 2013-2014 crop season, in the four evaluations. For the 2014-2015 crop season, a difference was found in the first evaluation, in which soybean showed greater height in the treatments composed of forage turnip and oats, superior to the treatment with canola. In the second evaluation, no significant difference was observed between treatments, in the third, the highest height was observed in the oat cover. In the last evaluation, the treatment with oats had the best performance while the treatment with forage turnip resulted in the lowest height (Table 2).

Some species of cover crops can have an allelochemical effect on soybean, which can be observed at the beginning of its growth and development and in yield. Silva et al. (2011) concluded that canola has an allelopathic effect on the soybean, which may have greater relevance in years with reduced rainfall, compromising yield. Other studies have also observed a possible allelopathic effect of canola on soybean, with reduced root mass, shoot growth, even chlorophyll index (Syed & Shinwari, 2016). However, it is noteworthy that the effect of canola on soybean in this study was minimal, with no effect on yield components (pods, grain weight and yield), in both harvests. Even though canola can be considered a cover crop, since Dadkhah (2015) observed that canola crop residues reduced weed infestation, and even increased soybean yield compared to control without crop residues.

There was no difference for the variables plant height, first pod height, number of pods per plant, 100 grain weight and yield in both harvests (Table 3), similar to what was observed by Carvalho et al. (2004), Brandt et al. (2006) and Mancin et al. (2009). In both harvests, soybean yield was not influenced by the cover crops used. Carvalho et al. (2004) in a soybean in succession of cover crops: black velvet bean (*Mucuna aterrima* [Piper and Tracy] Merr.), pigeonpea (*Cajanus cajan* [L.] Millsp.), crotalaria (*Crotalaria juncea* L.) and millet (*Pennisetum americanum* L.), observed that yield was not influenced by cover crops, both in the mulch no-till system, and in the conventional system in which the cover crop was incorporated into the soil. Also, Sanchez et al. (2014), in an

Table 2. Height of soybean plants, in four surveys. Palotina, PR, Brazil, 2013-2014 and 2014-2015 growing seasons.

Cover crop	V_4-V_5		R_1		R_2		R_3	
	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015
	(cm)							
R. sativus	24.5	19.9 a	37.8	41.5	54.9	52.0 b	62.7	60.2 b
L. usitatissimum	24.9	17.9 ab	38.8	45.6	56.5	54.6 ab	63.8	69.9 ab
A. sativa	24.0	19.4 a	38.9	43.7	56.2	63.7 a	64.0	76.8 a
S. cereale	25.3	18.0 ab	38.5	40.0	55.4	51.2 b	62.3	65.1 ab
Brassica ssp.	25.4	14.7 b	38.1	38.1	54.6	48.2 b	61.6	62.4 ab
T. turgidocereale	24.3	17.5 ab	39.3	40.7	56.5	51.6 b	63.8	66.4 ab
C. abyssinica	24.6	15.7 ab	37.5	37.9	55.1	45.7 b	62.6	65.1 ab
Fallow	24.4	16.2 ab	40.3	40.3	54.6	50.8 b	64.6	63.7 ab
CV (%)	4.2	10.2	7.6	10.1	5.8	7.5	6.4	9.7
LSD	2.5	4.2	7.0	9.7	7.6	9.2	9.6	15.2
F	ns	*	ns	ns	ns	*	ns	*

* Means followed by the same letter, in the column, do not differ by Tukey (1949) test at 5% probability.
ns: non-significant, means do not differ by the F-test (P≥0.05).

Table 3. Final height (H) of plants, height of insertion of the first pod (HFP), pods per plant, 100-grain weight (GW), and yield. Palotina, PR, Brazil, 2013-2014 and 2014-2015 growing seasons.

Cover crop	H		HFP		Pods		GW		Yield	
	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015
	(cm)						(g)		(kg ha^{-1})	
R. sativus	84.1	76.8	17.2	14.1	33.6	56.3	14.7	10.7	3,049	3,568
L. usitatissimum	91.1	80.1	17.9	17.0	37.0	54.3	13.9	11.1	3,255	3,477
A. sativa	87.4	83.5	18.3	15.3	33.6	51.0	14.0	10.8	2,834	3,787
S. cereale	82.9	74.4	17.8	15.6	33.1	56.4	13.8	10.8	2,934	3,716
Brassica ssp.	84.6	75.7	16.3	15.8	34.6	50.0	13.8	10.9	2,967	2,919
T. turgidocereale	84.0	79.7	17.7	15.8	31.0	41.9	13.7	11.0	2,592	3,145
C. abyssinica	89.1	80.0	16.3	15.7	39.3	50.4	14.7	10.4	3,493	3,156
Fallow	86.3	77.1	16.8	14.9	35.8	51.1	14.9	10.5	3,512	3,226
CV (%)	6.1	5.8	6.6	11.7	17.1	13.1	4.7	4.7	17.94	21.27
LSD	12.4	10.8	2.7	4.3	14.1	15.9	1.6	1.2	1,311	1,703
F	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns: non-significant, means do not differ by the F-test (P≥0.05).

analysis of four cover crops: common vetch (*Vicia sativa* L.), forage turnip (*Raphanus sativus* L.), ryegrass (*Lolium multiflorum* Lam.) and black oat (*Avena strigosa* Schreb) found no difference in soybean yield in succession.

Results of yield, verified in the 2013-2014 crop season, were between 2,592 and 3,512 kg ha^{-1}, in the 2014-2015 crop season between 2,919 and 3,787 kg ha^{-1}. Although no significant difference was detected between the treatments for soybean yield, the cover crops had satisfactory performance, which showed yield within the average of the Paraná state.

Although cover crops, in two growing cycles, had no great impact on the agronomic performance of soybean observed in this study, it is noteworthy that no allelopathic effects were observed on soybean, which is reported in some situations. Just because of this aspect, the use of the species used is already justified, other studies report the positive effects of different cover crops.

For example, improvements in the physical properties of the soil through the use of oats and wheat (Alhameid et al., 2020; Mtyobile et al., 2020), increases in fertility through the use of canola and/or oats (Hunter et al., 2019; Moreira et al., 2019), suppression of weeds by the use of rye and other cereals (Singh et al., 2020; Pittman et al., 2020), or sorghum for the allelopathic effect (Biesdorf et al., 2018). For these and other reasons, sometimes with gains in yield (Adeli et al., 2019; Nouri et al., 2019; Almoussawi et al., 2020), which is corroborated by Volsi et al. (2020), including economic analysis, with greater gains for producers who adopted higher diversity in crop rotation.

It is very important to design systems to achieve sustainability in soybean crop. Cover crops can play a key role in this regard, where we have several species that can be used in the recovery of degraded soils and with the potential for their economic exploitation.

Conclusion

Plant height, first pod height, number of pods per plant, 100 grain weight and grain yield of soybean, were not influenced by cover crops in the 2013-2014 and 2014-2015 crop seasons. Although the cover crops used in succession in the evaluated system did not expressively influence the agronomic performance of soybean, evaluations for more growing seasons and involving soil quality, are necessary to reveal other effects from cover crops.

Acknowledgements

The authors would like to thank the Colégio Agrícola Estadual Adroaldo Augusto Colombo, the Universidade Estadual Maringá, the Universidade Federal do Paraná, Supra Pesquisa team, the Cooperativa Central de Pesquisa Agrícola (COODETEC) and Instituto Agronômico do Paranrá (IAPAR), for being directly and indirectly involved in this research.

Compliance with Ethical Standards

Author contributions: Conceptualization: AOG, LPA, AJPA; Data curation: AJPA, LPA; Formal analysis: AOG; Investigation: AOG, FHK, DMR, VJS, AFMS, TTM; Supervision: AJPA, LPA; Writing–original draft: AFMS, AOG; Writing–review & editing: AOG, LPA, AJPA, AFMSilva, FHK, DMR, VJSCesco, TTM.

Conflict of interest: There is no conflict of interest.

Financing source: Not applicable.

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