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CROP SUCCESSION AND ITS REFLECTIONS ON SOYBEAN PERFORMANCE

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Abstract
The fluctuations in yield and consequently in production occurred due to climatic adversities in the main producing states of Brazil. Farming has changed over time, and past scenarios have shown high exploitation of natural resources focusing on soil tillage and conventional seeding methods. This study aimed to determine the yield performance of soybean grown under 10 consolidated crop succession systems. The experiment was conducted during the 2018/2019 crop season, before the research project entitled "Sustainable production systems with better use of biological and natural resources, with treatments arranged in a randomized block design and four replications". The treatments consisted of the following predecessor crops: *Avena sativa*, *Avena strigosa*, *Triticum aestivum*, *Secale cereale*, *Brassica napus*, *Raphanus sativus*, *Avena strigosa* + *Raphanus sativus* + *Vicia sativa*, Fallow, *Avena strigosa* + *Lolium multiflorum*, and *Triticum aestivum* – Fodder. Soybean was subsequently sown across winter crops. The succession that showed superior yield was *Avena strigosa* + *Lolium multiflorum*. This attribute was established by associating taller plants with the maximization of the number of grains per pod, hundred-grain mass, grain mass, and plant dry mass; in contrast, there was a lower emphasis on plant residue. The determining attributes for soybean yield were plant stand, plant height, the number of pods per plant, and total grain mass, with contrasts among groups composed of the succession of *Avena sativa*, *Avena strigosa*, *Triticum aestivum*, *Secale cereale*, and *Brassica napus*, distanced from *Raphanus sativus*, *Avena strigosa* + *Raphanus sativus* + *Vicia sativa*, Fallow, *Avena strigosa* + *Lolium multiflorum*, and *Triticum aestivum* - Fodder.

Keywords: Crop Production, Rotation, and Succession Systems. Integrated Systems.

1. Introduction

Soybean is one of the main commodities grown and traded in the world. The main soybean-producing countries are the United States of America, Brazil, and Argentina, corresponding to more than 70% of the world production of this oilseed. It is extensively used in human and animal food through the production of oil, bran, animal feed, and biodiesel. Thus, the demand for this grain is increasing, which requires efficient management practices such as predecessor crops that maximize crop yield.

The soybean crop in 2018/2019 was based on a cultivated area of more than 35 million hectares, with production exceeding 115 million tons of grains and a 3.6% reduction relative to previous harvests (CONAB 2019). These fluctuations in yield and consequently in production occurred due to climatic adversities in the main producing states of Brazil. Farming has changed over time, and past scenarios have shown the exploitation of natural resources focusing on soil tillage and conventional seeding methods. However, with the advent of no-tillage, the plant residue of the predecessor species was preserved, causing a higher nutrient accumulation and cycling in the agricultural layer of the soil, increasing organic matter, and improving the physical, chemical, and biological properties of the soil.

In the dynamics of crop succession from one production cycle to another, there is a period of absence of crops in the production area. Unoccupied areas are favorable environments for the growth and development of invasive plants, inoculum of diseases, surface and wind erosion, and reduced nutrient cycling. Based on this agricultural scenario commonly observed in the producing regions of Brazil, it is interesting to use cover plants, which are intermediate species to crops of agronomic interest that will allow cycling, recycling, and surface protection (Schnitzler 2017).

Currently, many areas in the southern region of Brazil express the dynamics of crop succession unrelated to the principles of crop rotation, which is sufficient to strategically position service crops, promoting agronomic and environmental benefits in the production system in which soybean is consolidated nationally. Using this rationale dynamic will promote increases in the magnitude of plant waste and organic matter in this soil, nutrient release, thermal insulation, higher accumulation of available water, deep biopores, and the minimization of favorable conditions to the seed bank of invasive plants working as physical impediments, thus reducing the effects of pathogens and nematodes intrinsic to soil conditions.

Based on the lack of technical-scientific studies addressing this topic and gathering information applicable to the crop level, this study aimed to determine the yield performance of soybean grown under 10 consolidated crop succession systems.

2. Material and Methods

The experiment was conducted during the 2018/2019 crop season at the Regional Institute for Rural Development - IRDeR, in Augusto Pestana, RS, Brazil, located at latitude coordinates of 28º 26 ’00.99” and longitude of 54º 00 ’30.96”. The soil is classified as a typical dystrophic Red Latosol (Oxisol) (Santos et al. 2006) and the climate is characterized by Köeppen as humid subtropical. The LG 60150 RR2 IPRO™ cultivar was used with a relative maturity group of 5.0 and an indeterminate growth habit. The experiment was conducted before the research project entitled “Sustainable production systems with better use of biological and natural resources, with treatments arranged in a randomized block design and four replications”. The experimental units consisted of 150 m² and a useful area of 146 m². The treatments consisted of the following predecessor crops: *Avena sativa*, *Avena strigosa*, *Triticum aestivum*, *Secale cereale*, *Brassica napus*, *Raphanus sativus*, *Avena strigosa* + *Raphanus sativus* + *Vicia sativa*, Fallow, *Avena strigosa* + *Lolium multiflorum*, and *Triticum aestivum* – Fodder. Soybean was subsequently sown across winter crops.

For the cultivation of winter species, the recommendation was followed, as the biomass produced by different winter crops was evaluated with a square meter of the area collected when the species started their flowering period. Later, the samples were directed to the forced-air circulation oven for 72 hours at 70ºC. Soybeans were sown on October 31, 2018, with 45-cm spacings, fertilization based on the soil analysis recommendation, and control of invasive plants, pest insects, and diseases according to crop requirements. The variables analyzed include plant stand (plants per hectare), the number of pods per plant (units), the number of grains per pod (units), hundred-grain mass (grams), grain yield (kg ha^{-1}), and harvest index (dimensionless).

The data obtained were submitted to the model of assumptions, normality, and homogeneity of the residual variances and additivity of the statistical model. Subsequently, an analysis of variance at a 5% probability was used to identify variations attributed to the effects of crop succession. Based on the characters that differed statistically, the multiple means comparison test by Duncan at a 5% probability was used. After the need for identifying the trend of association among the characters, a linear correlation was used for all variables with significance based on the t-test at a 5% probability. Likewise, grain yield was listed as the main character, and multiple linear regression was applied with the stepwise method to select the independent variables and determine the selection target in each succession management. Considering the various characters involved in this study, multivariate tools such as canonical correlations were applied to define the interrelationships between group I, corresponding to the primary components of productivity (grain yield, hundred-grain mass, and harvest index); and group II, corresponding to the secondary components of productivity (the number of grains per plant pod, the number of pods per plant, and mass of vegetable waste from the succession). The average Euclidean algorithm was applied to obtain the distance matrix, serving as the basis for the UPGMA cluster responsible for showing the dendrogram and the main components.

3. Results

The climatic data during the experiment (Figure 1) reveal that the rainfall volume accumulated 920 mm, and the minimum and maximum temperatures varied between 7.6ºC and 35.8ºC.

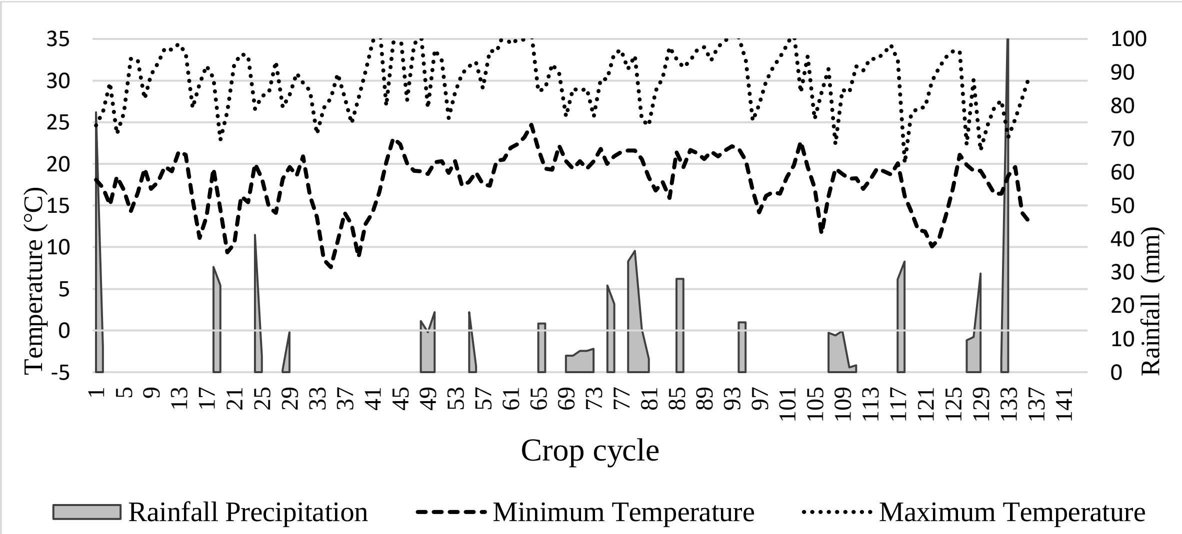

Figure 1. Experimental climate approach - Regional Institute for Rural Development.

The analysis of variance (Table 1) revealed that using different crop successions significantly affects all the variables studied at a 5% probability, which indicates a different behavior of soybean compared to other predecessor crops from the succession management (Table 2).

The linear correlations (Figure 2) indicate that taller plants tend to reduce the magnitude of pods with two grains and the harvest index, which is confirmed by the field conditions whose minimum temperatures compromised these attributes. The number of grains per pod was inversely proportional to pods with only one or two grains formed. However, for pods containing three and four grains, the hundred-grain mass and biological dry mass determined this character.

Plants with a higher magnitude of pods are determined by the positive manifestation of pods with two, three, and four grains, as well as the increase in plant dry and biological masses. The reduction in the final plant population per unit area explicitly affected the proportion of pods with only one and two grains. Soybean shows high compensatory capacity due to the smaller plant population and problems from the initial establishment, among others. In contrast, this plasticity is due to the increased number of reproductive nodes, flowers, pods, and grains per plant. The increase in plant population is directly related to the grain and dry mass of the plant, which is why cultivars are specific in this regard. In this scenario, the grain yield of soybeans was related to taller plants, the number of grains per pod, hundred-grain mass, grain mass, and plant dry mass, but there was a lower emphasis on vegetable residue.

Table 1. Mean square for plant stand (STD, plants/ha^{-1}), plant height (PH), the number of pods of 1, 2, 3, and 4 grains (NP1, NP2, NP3, NP4), the number of pods per plant (NPP), the number of grains per pod per plant (NGPP), total grain mass (TGM), hundred-grain mass (HGM), plant dry mass (PDM), biological dry mass (BDM), harvest index (HI), and grain yield (YI) of soybean grown under different crop successions - UNIJUÍ, 2019.

		MEAN SQUARE														
SV	DF	STD	PH	NP1	NP2	NP3	NP4	NPP	NGPP	TGM	HGM	PDM	BDM	HI	YI	MVI
TREATMENT	9	10,681.34*	1,276.41*	7.06*	82.5*	816.98*	2.1*	1,365.71*	0.11*	322.39*	20.89*	633.93*	87.52*	0.012*	1,110,583.13*	13,680*
BLOCK	3	11,213.82	485.01	10.51	18.86	30.67	2.99	55.49	0.20	94.22	8.93	244.39	15.78	0.001	2,418,667.7	1,250
CV (%)	-	16.94	7.39	119.8	37.72	33.00	150.65	27.17	7.9	29.31	11.82	30.4	33.33	7.70	11.75	17.97
Mean	-	295.2857	72.79	1.54	15.05	52.69	0.57	70.49	2.37	23.74	14.76	41.84	17.79	0.56	5368.198	7.07

Table 2. Mean comparisons for the variables of plant stand (STD, plants/ha^{-1}), plant height (PH), the number of pods of 1, 2, 3, and 4 grains (NP1, NP2, NP3, NP4), the number of pods per plant (NPP), the number of grains per pod per plant (NGPP), total grain mass (TGM), hundred-grain mass (HGM), plant dry mass (PDM), biological dry mass (BDM), harvest index (HI), and grain yield (YI) of soybean grown under different crop successions - UNIJUÍ, 2019.

TREATMENT	STD	PH	NP1	NP2	NP3	NP4	NPP	NGPP	TGM	HGM	PDM	BDM	HI	YI	MVI
Avena sativa	272,222 c	67.15 d	1.85 ab	14.94 abc	48.15 b	0.60 abcd	67.35 b	2.29 c	20.73 d	13.36 e	37.07 cde	16,340 b	0.55 bc	4,607.51 d	6,900 bcd
Avena strigosa	271,111 c	74.05 c	2.90 a	17.55 ab	53.45 ab	0.15 d	74.05 ab	2.27 c	22.16 cd	13.75 de	41.53 bcde	19,375 ab	0.53 c	5,205.63 abcd	8,500 ab
Triticum aestivum	323,988 a	78.55 b	1.60 b	13.10 c	45.25 b	0.40 bcd	61.30 b	2.30 c	18.86 d	13.45 e	34.60 e	15,740 b	0.54 c	4,990.55 bcd	9,500 ab
Secale cereale	328,899 a	73.60 c	1.05 b	13.10 c	46.73 b	0.35 bcd	60.89 b	2.31 bc	18.63 d	14.15 cde	36,185de	16,190b	0.55 bc	4,760.37 cd	11,100 a
Brassica napus	310,000 ab	61.60 e	1.00 b	13.55 bc	52.50 ab	0.30 cd	67.35 b	2.35 abc	23.10 bcd	15.63 ab	38,810 cde	15,710b	0.59 a	4,986.95 bcd	7,400 bc
Raphanus sativus	286,677 bc	65.00 de	1.55 b	16.05 abc	53.85 ab	0.80 abc	72.40 ab	2.36 abc	27.26 ab	15.89 ab	44.89 abcd	17,630b	0.60 a	5,623.72 abcd	4,800 cde
Avena strigosa + Raphanus sativus + Vicia sativa	275,566 bc	63.21 e	1.95 ab	18.60 a	62.30 a	0.90 abc	83.75 a	2.44 ab	30.51 a	16.04 a	50.42 a	19,905ab	0.59 a	5,840.13 ab	8,700 ab
Fallow	283,333bc	79.15 b	1.00 b	15.95 abc	54.65 ab	0.30 cd	74.55 ab	2.44 ab	26.60 abc	15.30 abc	45.93 abc	17,411 b	0.57 ba	5,735.17 abc	2,600 e
Avena strigosa + Lolium multiflorum	280,000 bc	81.35 ab	1.05 b	15.05 abc	63.50 a	1.10 a	81.65 a	2.46 a	27.59 a	14.78 bcd	49.73 ab	22,145 a	0.55 bc	6,188.43 a	4,000 de
Triticum aestivum – Fodder	323,988 a	84.36 a	1.42 b	12.36 c	43.94 b	0.94 ab	60.68 b	2.47 a	20.54 d	15.36ab	39.09 cde	17,468b	0.55 bc	5,743.49 abc	7,200 bc

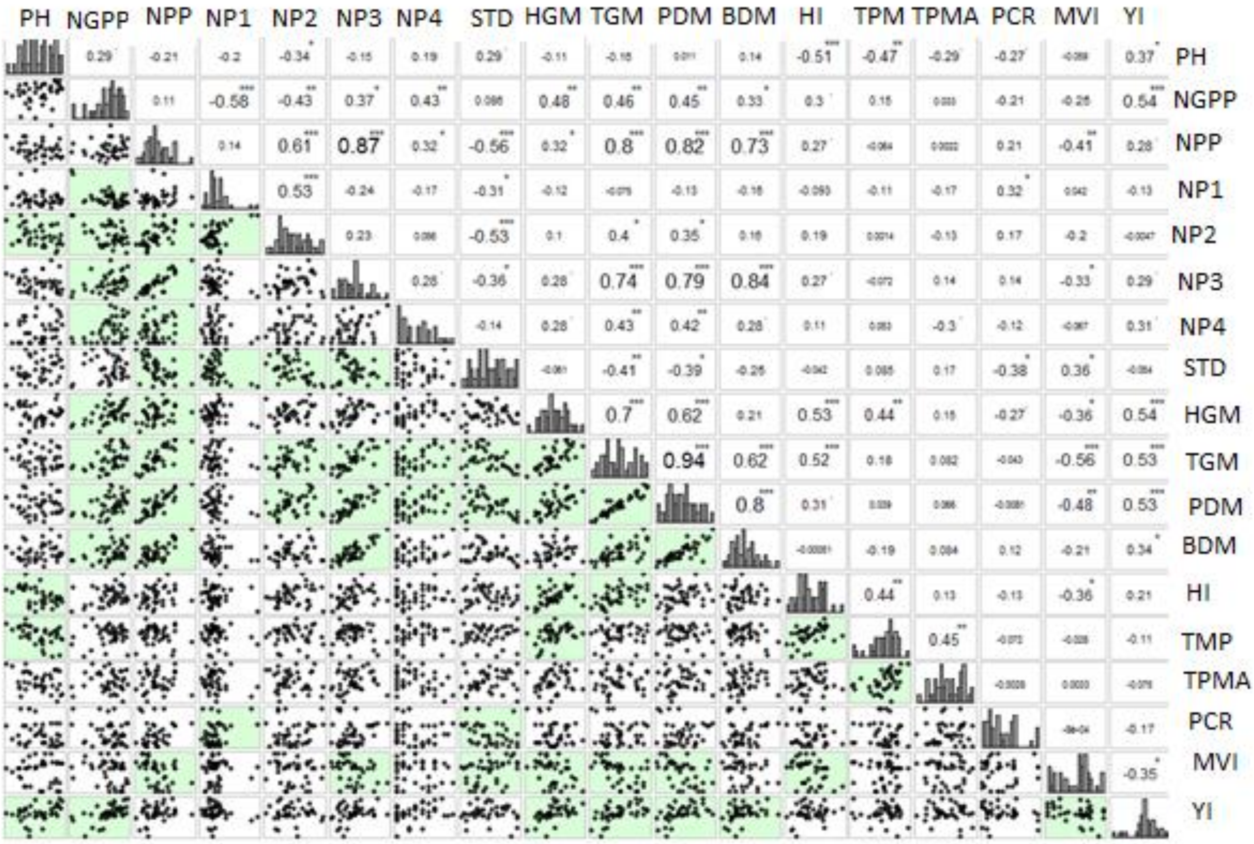

Figure 2. Linear correlations for the attributes measured in soybeans.
* significant associations at a 5% probability by the t-test.
** significant associations at a 1% probability by the t-test.

Canonical correlations were extracted for two groups of productivity components, with group 1 representing the primary components and group 2 the secondary components. The maximum likelihood indicated interclass significance for the groups, which proved the close relationship between the groups (r = 0.75) of characters (Table 3).

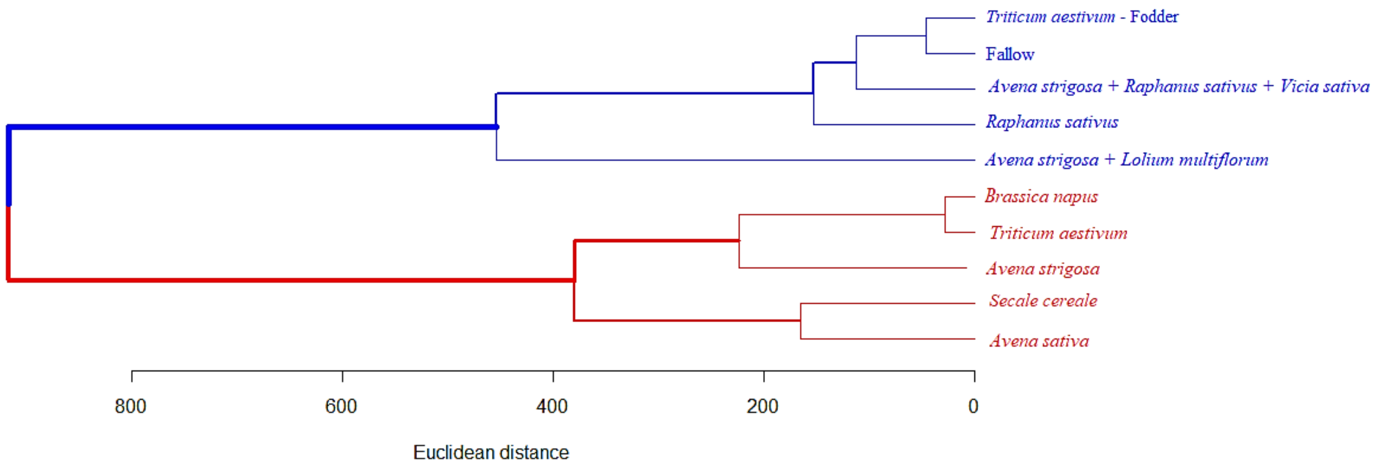

Figure 3. Dendrogram obtained with the matrix of multivariate distances.

The dendrogram (Figure 3) shows the treatments that have affinities regardless of the variables. Two major groups stand out: the grouped treatments in red and blue colors.

Table 3. Predictive models to determine yield specifically by the succession crop.

Predictive model										
Predecessor crop	Explanatory variables of the model									
Y	Intercept	STD	PH	NP1	NP2	NP4	NPP	NGPP	TGM	PDM
Avena sativa	5,194.16	-	-	-1,713.81	-	-	-	-	-	-
Avena strigosa	5,606.94	-	-	-	-16.84	-	-	-	-	-
Triticum aestivum	-4,807.49	9.57	88.24	-	-	-	-	-	-	-
Secale cereale	-10,418	-	-	-	-	-	174.66	-	218.83	-
Brassica napus	6,195.57	-	27.23	-	-291.76	-	-	-	-	-
Raphanus sativus	2,701.42	-	-	-	-	-	-	-	-	69.87
Avena strigosa + Raphanus sativus + Vicia sativa	6,657.49	-	-	-408.68	-	-	-	-	-	-
Fallow	8,553.42	-	-	-	-	-	-	-2,367.75	116.36	-
Avena strigosa + Lolium multiflorum	-542.05	-	-	-	-	465.10	428.51	-	-	-
Triticum aestivum - Fodder	5,724.19	-	-	-	92.37	-996.71	-	-	-	-

Table 4. Canonical correlations for the primary (Group 1) and secondary (Groups 2) components of soybean.

Components	Canonical pair
Group 1	
YI	0.45
HI	0.58
HGM	0.72
Group 2	
NGPP	0.61
NPP	0.16
MVI	-0.38
*R	0.75733
**P	<0.0193

* inter-class correlation; ** significance due to the maximum odds ratio.

The biplot analysis of the main components represents the variable/treatment ratio (Figure 4).

4. Discussion

For the adequate development of the soybean crop, the volume of rainfall distributed throughout its cycle becomes crucial, as well as adequate temperatures. Studies by Zanon et al. (2016) highlight that soybean needs approximately 800 mm to express their productive potential. During the development cycle, the minimum temperature was a limiting factor for crop development because 40 days after sowing, the soybean was affected by temperatures of 7.6ºC concomitantly with the phenological stages V2 to V3, whose recommended optimal temperatures are close to 31ºC (Zanon et al. 2018).

Studies by Wolschick et al. (2016) define that predecessor crops such as black oats, vetch, and forage turnip consortium provide a high production of dry mass and vegetable waste, regulate soil temperature and humidity, and minimize the incidence of invasive plants. For Santos et al. (2014), strategically positioned predecessor crops enhance grain yield, the number of pods per plant, the number of grains per pod, and soybean plant height.

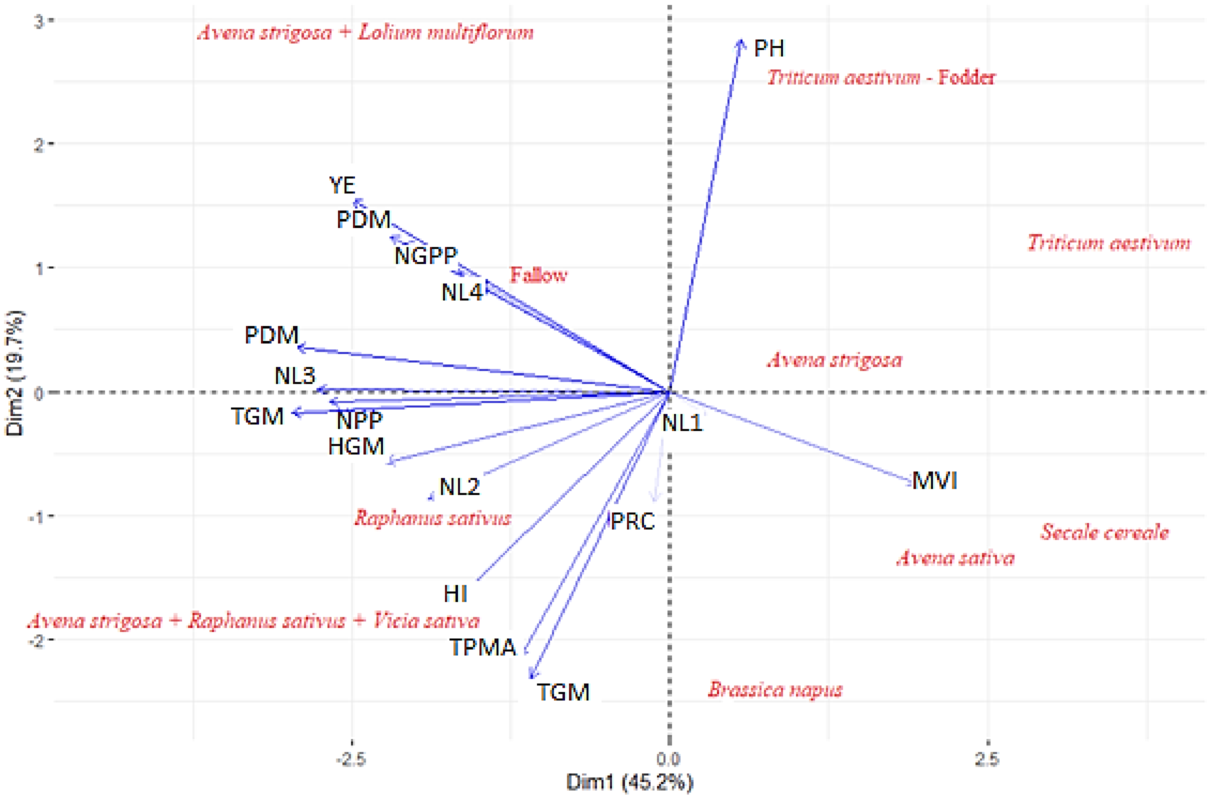

Figure 4. Main components obtained to define multivariate associations among the effects of crop succession of the variables measured in soybean.

Figure 5. Technical presentation of the performance of soybeans grown in different crop successions.

Hence, the secondary characters were determinants for the primary soybean yield, with high yield and harvest indexes obtained when the number of grains per pod and pods per plant of the secondary components increased and there was a lower emphasis on the residue of succession. This behavior is due to the dynamics for establishing the network of productivity components. In this dynamic, increasing production units in the plant and grains per production unit causes an expected higher yield and harvest rate. High production of plant residue in the predecessor crop may be somewhat beneficial because when obtaining a high concentration of vegetable waste from only one species, this material will extract a high amount of nutrients that soybean may need if the base and top dressing fertilizations are ineffective.

The soybean yield is determined by several aspects that can be directly or indirectly affected, as shown in Table 3, by the explanatory variables of the model, which can contribute positively or negatively to the soybean yield in different treatments. For the predecessor crops of *Avena sativa* and *Avena strigosa* + *Raphanus sativus* + *Vicia sativa*, the determining variable for grain yield was NP1, which presented a negative relationship, providing a lower number of these pods, and other components were maximized, perhaps with an increase in NP2, NP3, and NP4 grains. In the treatments with *Avena strigosa* and *Triticum aestivum* - Fodder, the NP2 variable affected yield negatively because the reduction in this component allows other components to define grain yield. The opposite occurred for the second crop, as the determinant variable for grain yield was the increase in NP2. For *Triticum aestivum*, the variables with the highest positive contribution to grain yield were the highest STD and PH, which indirectly influence the total number of pods per plant.

The predecessor crop of *Secale cereale* and the NPP and TGM variables showed higher participation in soybean yield, with an increased number of pods per plant and total grain mass, which corresponds directly to a higher yield. For the treatment with *Brassica napus*, the yield was positively influenced by an increase in PH and a reduction in NP2. Plant height affects yield because the crop emits more reproductive nodes, resulting in a larger production area. Considering the reduction of NP2, a higher number of pods is maximized with one, three, and four grains, resulting in a higher number of total pods, which directly compose soybean yield. For the *Raphanus sativus* crop, the PDM variable positively affected grain yield, meaning that heavier plants tend to be more productive. As this is an indirect yield characteristic, it is mainly influenced by grain weight.

For the predecessor Fallow treatment, the variables that stood out the most for yield were NGPP, which is negatively influenced, and TGM, positively influenced, that is, with the reduction of NGPP, the plant can move its photoassimilates to optimize grain weight, thus increasing TGM and promoting higher yield. For *Avena strigosa* + *Lolium multiflorum*, the NP2 variables, which are positively influenced, were discarded, and NP4 negatively influenced yield, that is, this treatment showed an increase in the first variable, which was decisive for yield, and a reduction in the other variable. This characteristic is little expressed due to abiotic factors.

In the group of treatments in red, stratification occurred between similar treatments. The first one was *Brassica napus* and *Triticum aestivum* due to the similarity among the variables. *Brassica napus* contributes to nutrient recycling and root development, as it manages and develops well in compacted soils, contributing to developing the successor crop, which in this case was soybean. The treatment with *Triticum aestivum* contributes to the system due to the soil cover, which regulates soil temperature and humidity because of the low decomposition. These characteristics occurred particularly for a certain similarity between the variables, especially grain yield. Another similar treatment was *Avena sativa* and *Secale cereale*. Using grasses in crop succession or rotation systems contributes to reducing surface erosion, as well as the benefits aforementioned for *Triticum aestivum*.

In the group of treatments in blue, Fallow and *Triticum aestivum* – Fodder were similar. An aspect that stands out is the low presence of soil cover in the area, considering that the animals grazed in the dual-purpose wheat, resulting in less coverage. Hence, taller plants were developed, which provided a higher number of pods and grain mass and caused a similar yield.

When analyzing the two large groups, they were grouped as follows: the red ones for treatments with *Avena sativa*, *Avena strigosa*, *Triticum aestivum*, *Secale cereale*, and *Brassica napus*; and the blue ones with *Raphanus sativus*, *Avena strigosa* + *Raphanus sativus* + *Vicia sativa*, Fallow, *Avena strigosa* + *Lolium* *multiflorum*, and *Triticum aestivum* - Fodder. In the first group, the grouped treatments belonged to grass families, and another group had intercropped cultures with a high capacity for nutrient recycling and the presence of animals, which also helps this process.

The treatments with *Avena strigosa*, *Triticum aestivum*, and *Triticum aestivum* - Fodder presented a closer relationship with the PH variable, highlighting the last treatment. Table 2 shows that the dual-purpose wheat cover presented the highest mean of 84.36 cm due to the low cover production in the area where the animals remained with the referred treatment, with a winter matter production of 7,200 kg/ha^{-1}. The dry matter production values for the respective treatments refer to the final residue after the last animal grazing. This may have favored the rapid seedling emergence, growth, and establishment. Seedling establishment is one of the essential parameters for plant survival (Taiz 2017), from which plants start photosynthesis, not depending on the nutritional reserves of cotyledons. This favors the accumulation of primary biomass that contributes to an initial rapid growth (Floss 2011). Therefore, the faster the emergence, growth, and establishment of a plant, the sooner it starts photosynthesis, increasing growth, development, and the number of reproductive nodes, which promotes a higher number of pods and grain mass, and consequently higher yield. Figure 3 shows the soybean height in the referred successions.

The treatments with *Avena strigosa* + *Lolium multiflorum* and Fallow showed a closer relationship with the variables of YI, BDM, NGPP, NP4, PDM, and NP3. Highlighting the YI variable, the highest mean was found in the treatment with Oats + Ryegrass with 6,188.43 kg/ha^{-1}. This treatment also presented higher TGM, HGM, and NPP, and the latter is the most important component to promote increases in grain yield. This is due to a potential high variation, which guarantees the phenotypic plasticity of soybeans. The number of pods produced depends on the number of flowers and pods attached (Mundstock and Thomas 2005). It should be noted that the Oats + Ryegrass treatment showed the highest number of pods with four grains compared to the other treatments.

The presence of animals positively affects the area (Assman 2013). In this sense, Silva et al. (2012) highlights that yield increases when analyzed in isolated points of cattle manure, with productions of up to 4.00 Mg/ha^{-1} compared to areas without manure, which produced 3.33 Mg/ha^{-1}. The same authors conclude that the presence of animals increases nutrient availability, such as P and K, favoring the highest number of pods per plant and grain yield.

The rainfall graph (Figure 2) shows a good rainfall distribution in the reproductive period of the crop, causing high grain production regardless of crop succession. It should also be noted that plant yield relates to photosynthesis, photorespiration, and respiration. Therefore, yield increases require higher photosynthetic and lower respiratory rates. In regions of milder temperatures at night, plants tend to have a lower respiratory rate, thus accumulating more biomass due to the net photosynthesis balance, producing a higher yield potential (Floss 2011).

When observing the maximum and minimum temperatures during the crop cycle, on the 61st day of development, the temperatures varied between 17ºC and 35ºC, and the crop was approximately at the R1 to R2 stages. Another period with lower temperatures occurred on the 85th day when temperatures varied between 14ºC and 30ºC, and the crop was in the R4 development stage. Thus, the maximum temperatures did not restrict the rate of liquid photosynthesis, with no significant increase in the photorespiration rate.

As the experiment has already been performed for four years in this crop succession system, changes in soil structure may occur, increasing the infiltration rate and water availability for the crop, and maintaining soil moisture due to the coverage of previous crops, which also reduces the evapotranspiration rate. The milder temperatures previously mentioned also contribute to this lower rate. Stone et al. (2006), when studying the evapotranspiration rate in common bean crops, reported that it varies according to the amount of dry matter provided by cover crops. Moreover, the difference in evapotranspiration is associated with crop development, in which the growing of beans at stages V2 to V4 on *Brachiaria* straw provides a 28% reduction in evapotranspiration and a 34% reduction in the R4 stage due to the crop covering the soil.

The treatments with *Raphanus sativus* and *Avena strigosa* + *Raphanus sativus* + *Vicia sativa* showed a closer relationship with the variables of NPP, TGM, HGM NP2, and HI. In the first variable, the treatment that stood out the most was *Avena strigosa* + *Raphanus sativus* + *Vicia sativa*, with 83.75 pods (Table 2). This probably occurred because this treatment had the lowest stand compared to the others, with 275 thousand plants/ha. The soybean crop has a high ability to compensate for lower plant densities, mainly forming a higher number of pods per individual, but it occurs up to a limit (Procopio et al. 2013).

For the TGM and HGM variables, as previously mentioned, the development of soybeans on *Raphanus sativus* and *Avena strigosa* + *Raphanus sativus* + *Vicia sativa* presented problems with the development of plant stand and height, thus reducing the number of reproductive nodes and pods but compensating for the higher grain filling rate. This can be explained by the better source/drain ratio that causes a higher grain weight, as heavier grains also result in higher plant weight.

The harvest index (HI) measures plant efficiency, showing the proportion of photoassimilates directed to the grains. The higher the value, the higher the use and targeting of these photoassimilates to the grain. The treatments showed similarities for this variable because it has a smaller height, resulting in a distribution of photoassimilates more directed to the grains and not to the total dry mass of the plant. Studies have shown that the HI of a crop is highly influenced by seeding density, water and nutrient availability, and temperature (Duarte et al. 2013). The MVI variable regarded the treatments with *Avena sativa*, *Secale cereale*, and *Brassica napus*. Grasses are more prominent for this variable due to the amount of dry matter produced, favoring the production system such as soil cover for a longer time and maintaining humidity and soil temperature.

5. Conclusions

The succession that showed superior yield was *Avena strigosa* + *Lolium multiflorum*. This attribute was established by associating taller plants with the maximization of the number of grains per pod, hundred-grain mass, grain mass, and plant dry mass; in contrast, there was a lower emphasis on plant residue.

The determining attributes for soybean yield were plant stand, plant height, the number of pods per plant, and total grain mass. There were contrasts between groups composed of the succession of *Avena sativa*, *Avena strigosa*, *Triticum aestivum*, *Secale cereale*, and *Brassica napus*, distanced from *Raphanus sativus*, *Avena strigosa* + *Raphanus sativus* + *Vicia sativa*, Fallow, *Avena strigosa* + *Lolium multiflorum*, and *Triticum aestivum* - Fodder.

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