Acta Agronómica
ISSN: 0120-2812
ISSN: 2323-0118
Universidad Nacional de Colombia

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Acta Agronómica, vol. 71, no. 2, 2022, April-June, pp. 162-170
Universidad Nacional de Colombia

DOI: https://doi.org/10.15446/acag.v71n2.102894

Available in: https://www.redalyc.org/articulo.oa?id=169977434007

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Acta Agronómica

UNIVERSIDAD NACIONAL DE COLOMBIA

Sequential plantations of rice, edamame soybeans, and peanuts as a product of alternative and mineral fertilization in the Roraima Cerrado in Brazil

Plantaciones secuenciales de arroz, soja edamame y maní como producto de fertilización alternativa y mineral en el Cerrado Roraima en Brasil

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https://doi.org/10.15446/acag.v71n2.102894

2022 | 71-2 p 162-170 | ISSN 0120-2812 | e-ISSN 2323-0118 | Rec.: 2022-05-27 Acep.: 2023-01-31

Abstract

The objective of this study was to determine the production of sequential rice, soybean, and peanut plantations as a function of mineral and alternative fertilization. To meet the objectives of the work, three independent experiments were carried out in the Experimental Field of Embrapa in Brazil. The first experiment was with rice BRS Sertaneja, conducted in the period from May to September in two agricultural years (2009 and 2010), with the purpose of evaluating the yield, germination, and vigour of BRS Sertaneja rice seeds as a function of mineral and alternative fertilization. The second experiment was performed with soybeans BRS 258 and the strain BR9452273, which were evaluated in the period from October to January in two years (2009/2010 and 2010/2011), to determine the agronomic attributes of green grain production (R_6 stage). In the third experiment, BRS 151 L-7 (red) and 184 AM L-7 (cream) peanut crops were cultivated from February to April in two years (2010 and 2011), to determine the yield of pods and grains, weight of 100 pods, weight of 100 seeds, weight of husks, weight in seeds of 100 pods, relative grain yield in relation to pods (RR, %), and grain yield. Intermediate fertilization is indicated to increase the yield of peanut pods and grains BRS 151 L-7 and 184 AM L-7 in the highlands of the Roraima Cerrado in Brazil.

Keywords: *Arachis hipogaea*, *Glycine max*, *Oryza sativa*, yield, grains.

Resumen

El objetivo de este trabajo fue determinar la producción de plantaciones secuenciales de arroz, soja y maní en función de la fertilización mineral y alternativa. Para cumplir con los objetivos del trabajo, se realizaron tres experimentos independientes en el Campo Experimental de Embrapa en Brasil. El primer experimento fue con arroz BRS Sertaneja, realizado de mayo a septiembre en dos años agrícolas (2009 y 2010), con el objetivo de evaluar la productividad, germinación y vigor de las semillas de arroz BRS Sertaneja en función de la fertilización mineral y alternativa. El segundo experimento se realizó con la soja BRS 258 y el linaje BR9452273, los cuales fueron evaluados en el período de octubre a enero en dos años (2009/2010 y 2010/2011), para determinar los atributos agronómicos de producción de grano verde (etapa R_6). En el tercer experimento, con maní BRS 151 L-7 (rojo) y 184 AM L-7 (crema), el cultivo se sembró de febrero a abril en dos años (2010 y 2011), determinándose el rendimiento de vainas y granos, peso de 100 vainas, peso de 100 semillas, peso de cascarilla, peso de semilla de 100 vainas, rendimiento relativo de granos con relación a las vainas (RR, %) y rendimiento del grano. La fertilización intermedia está indicada para aumentar la productividad de las vainas y granos de maní BRS 151 L-7 y 184 AM L-7 en las tierras altas del Cerrado Roraima en Brasil.

Palabras claves: *Arachis hipogaea*, *Glycine max*, *Oryza sativa*, rendimiento, granos.

Introduction

Considered one of the most important oilseeds worldwide, peanuts (*Arachis hipogaea* L.) participate with 10 % of edible oil production while its grain production represents 23.5 million tons per year. In Brazil, the average production is 466 000 t per year, being the second largest peanut producer and exporter in Latin America. The state of São Paulo concentrates more than 90 % of the national peanut production. In contrast, in northern Brazil, especially in the state of Roraima, research on peanut production is still scarce (Smiderle *et al.*, 2020).

The activities related to agricultural systems on a small scale in Roraima use technologies of low level in crop exploitation (Smiderle, 2019). This restriction on the use of techniques more appropriate to crops, such as fertilization, soil conservation practices, irrigation, among others, is confronted, on the other hand, with the intense use of chemicals, especially to control pests and invasive plants.

The soils of the Roraima Cerrado present low natural fertility. Under these conditions, the adoption of agronomic practices, soil and crop management are important factors, aiming at increasing the quality, yield, and sustainability of agricultural activities (Smiderle *et al.*, 2019).

The studies focused on the development of sustainable agricultural systems are based on some assumptions, and those that favour the adoption of agronomic management systems that maintain soil protection through the continuous contribution of organic waste are of recognized importance (Krenchinsk *et al.*, 2018).

Among the research about this topic, Smiderle *et al.* (2016) conducted studies with reduced use of chemical fertilizers in the obtention of high-quality *Glycine max* seeds. In addition to this, Cordeiro *et al.* (2010) highlighted that rice agribusiness (*Oryza sativa* L.) in Roraima is one of the few production chains effectively stabilized in the State and also that the main rice cultivation systems are continuous flood irrigation with broadcast seeds or lines, and wet floodplains, used only in rainy seasons.

It is also worth mentioning that there are no studies with peanut cultivars and/or strains adapted to the conditions in Roraima, and this is thus an important basis regarding decision-making for producers in the region. In light of the above, the objective of this work was to determine the production of sequential plantings of rice, soybean, and peanut stemming from mineral and alternative fertilization in the highlands of the Roraima Cerrado.

Materials and methods

The experiments were carried out in the Experimental Field belonging to Embrapa Roraima, in the municipality of Boa Vista (Roraima), whose geographic coordinates are 02º 39' 00' latitude, 60º 49' 40'' longitude and 90 m altitude.

The climate of the region is described by Smiderle *et al.* (2016). The soil was classified as Yellow Red Acrisol of medium texture. Before the present work, soil samples were collected in the 0-20 cm layer and the chemical and physical characteristics (Table 1) were determined according to the methodology described by Embrapa (1999).

For the establishment of the procedures, the entire experimental area was limed. In order to increase the calcium and magnesium contents in the soil, 1.000 kg ha^{-1} of dolomitic limestone were applied and corrected for total relative neutralizing power (PRNT) of 100 %; 50 kg ha^{-1} of FTE BR-12 were also applied. Both products were incorporated with a rotary hoe.

The corrective phosphate fertilization performed in 2009 consisted of the incorporation of 760 kg ha^{-1} of magnesium thermophosphate in the different fertilization alternatives performed, which were as follows: conventional fertilization (ADC): base fertilization with 100 kg ha^{-1} of P_2O_5 (simple

Table 1. Physicochemical characteristics obtained from the soil of the area of rice, soybeans and peanut cultivation in the Roraima Cerrado

Depth (cm)	pH	P	K^+	Na^+	H^++Al^{+3}	Al^{+3}	Ca^{+2}	Mg^{+2}	SB	CEC	V	m	O.M.
	H_2O (1:2.5)	mg/dm^3			cmolc/dm^3						%		g/kg
0-20	5.4	19.20	31.28		2.81	0.00	1.15	0.25	1.48	0.0	40.0	0.0	13.72
			Rice, soybean and peanut: second crop cycle										
0 - 20	5.9	52.20	28.28		1.93	0.03	1.66	0.48	1.48	1.87	49.0	2.0	14.72

Granulometry (g kg)			
Depth (cm)	Sand	Silt	Clay	Textural Class
0 - 20	740	70	190	Franca sand

H^++Al^{+3}: Potential acidity; SB: Sum of bases; CEC: Cation exchange capacity; V: Base saturation; m: Aluminum saturation; O.M.: Organic matter.

superphosphate) and 90 kg ha^{-1} of K_2O (potassium chloride); intermediate fertilization (ADI): application of 1000 kg ha^{-1} of natural phosphate + application of 50 % of conventional fertilization; alternative fertilization (ADA): application of 1000 kg ha^{-1} of natural phosphate in soybean planting; Manipueira: application of alternative fertilization, plus 12.5 m^3 ha^{-1} of manipueira applied in cover in the soybean line at 30 days (dilution in water 1:1); carbonized rice hull fertilization (ADCAC): application of alternative fertilization, plus 10 t ha^{-1} of charred rice hull, applied to the soil surface 30 days after plant emergence. To meet the objectives of the work, three independent experiments were carried out in the Monte Cristo Experimental Field, belonging to Embrapa Roraima.

The first experiment was with BRS Sertaneja cv. conducted in two crops in the period May-September in 2009 and 2010, in order to evaluate the grain yield, germination, and vigor of the rice seeds as a function of mineral and alternative fertilization in soils with low productive capacity. The second experiment was with soybean BRS 258 and the strain BR9452273, which were evaluated in two crops in the period October-January 2009/2010 and 2010/2011, for the agronomic attributes of green grain production (R_6 stage) as a function of mineral and alternative fertilization in soils of low productive capacity.

In the third experiment, peanut BRS 151 L-7 (red) and 184 AM L-7 (cream) was cultivated in two crops in the period February-April 2010 and 2011, determining the yield of peanut pods and grains, weight of 100 pods (W100P in g), weight of 100 seeds (W100S in g), husk weight (W husk, in g), weight in seeds of 100 pods (WS100P, in g), relative grain yield in relation to pods (RP, %) and the grain yield (YIELD, in g) as a function of mineral and alternative fertilization.

It is noteworthy that the experiments were carried out in two sequential cycles of cultivation for the three crops (rice, soybean, and peanut), with the first plantation of rice taking place in 2009 (May-September), followed by the cultivation of soybean (October-January), and then peanut (February-April), repeating in a second cycle. Soil samples were collected and examined in 2009 (Table 1) and after the second peanut plantation (Table 1).

Experiment I: Production of BRS Sertaneja rice in the Cerrado of Roraima

The BRS Sertaneja rice was manually seeded in May with a spacing of 0.40 m between rows, with 50 viable seeds per linear meter at 3 to 5 cm depth. The experimental design was completely randomized, in a 5 x 2 factorial scheme (five fertilizations x two crops). The variables evaluated were grain yield (GY), determined after harvest, and trail and weighing of the useful area of the treatments of each repetition, with the aid of a conventional scale. The values were then converted to kg ha^{-1}, correcting the degree of humidity up to 13 %. In germination (G), four replicates of 100 seeds of each treatment were used and the seeds were sown on germitest paper moistened with distilled water (the amount of water was 2.5 times the weight of the dry paper), then, the seeds were kept in a germinator at 25 °C. The counts were performed at seven days after the beginning of the test and at the 14th day. The results were expressed in percentage (BRAZIL, 2009). To obtain the seed vigor, the values of the first count of the germination test (BRAZIL, 2009) of the rice seeds cv. Sertaneja, obtained in both plantations, were used, as a function of mineral and alternative fertilization.

Experiment II: Soybean production in R_6 stage (Edamame) in the Cerrado of Roraima

In the established sequence, after rice cultivation (May-September), the second experiment was installed with soybeans sown in October (beginning of the dry season) and harvested in January (harvest of R_6- grains) of two different soybean genotypes, one BR9452273 and the other cv. BRS 258. The experimental design was completely randomized, in a 5 x 2 x 2 factorial scheme (five fertilizations x two genotypes x two plantations). The plot presented dimensions of 4 m x 2 m (8 m^2), containing five lines, and of these, three central lines, discarding 0.5 m at each end, which constituted the useful area (2.4 m^2). The spacing was 0.40 m between rows, with an average population of 12 plants per linear meter. The irrigation was executed by sprinklers, in order to keep the soil moist, when necessary. The treatments related to the control of pests, diseases, and spontaneous plants for soybean crops in the Roraima Cerrado were performed according to the recommendations of Smiderle *et al.* (2020).

The harvest and processing of the grains were performed manually at the R_6 stage (green grains), thus obtaining the edamame grains for laboratory evaluations.

Characters evaluated at stage R_6

The morphological characterization of immature soybeans or edamame grains in stage R_6 was performed in the first half of January 2010 and January 2011. The harvest was carried out in the morning, with a lower temperature, to facilitate the rapid commercialization and consumption as fresh food. The variables evaluated here were yield of green pods (YIELD, kg ha^{-1}), total number of pods in 500 g (TN), ratio grains x total pods (RG/TP), and grains x pods (RG/P), green grains humidity (H, %), and mass of 100 green grains (M100GV).

Experiment III: Peanut production in the Cerrado of Roraima

In the established sequence, after the cultivation of soybean (October-January), the third experiment (February-April) was initiated, consisting of peanuts of two genotypes, one of red grains (BRS 151 L-7) and one of cream grains (184 AM L-7). The experimental design was completely randomized, in a 5 x 2 x 2 factorial scheme (five fertilizations x two genotypes x two plantations) with four replications. The variables evaluated first were pod yield (YIELD pg, in kg ha^{-1}) and grain yield (YIELD g, in kg ha^{-1}) of the BRS 151 L-7 and 184 AM L-7 peanuts, while in the second, pod yield (YIELD pg, in kg ha^{-1}), weight of 100 pods (W100 P, in g), weight of 100 seeds (W100S, in g), husk weight (W husk, in g), weight in seeds of 100 pods (WS100 P, in g), relative grain yield in relation to pods (RP, %), and grain yield (YIELD G, in g) of peanuts BRS 151 L-7 and 184 AM L-7 were evaluated.

Data analysis

The data were submitted to a variance analysis (ANOVA). In cases of significant interactions by the F-test ($p \leq 0.05$), the qualitative means were compared by the Tukey test at the level of 5 % probability using the Software SISVAR 5.4 (Ferreira *et al.*, 2018).

Results

Experiment I. Agronomic attributes of BRS Sertaneja rice in the Cerrado of Roraima

The variance analysis performed with the data revealed interaction between the factors plantings and alternative fertilization for yield and vigor. However, the variables yield, vigor and germination showed significant differences for the fertilization factor, which were detailed in Table 2.

In cv. BRS Sertaneja rice cultivation there was a significant interaction between the plantations as a function of conventional fertilization. The first planting stands out when compared to the second one (Table 2), the latter showing a maximum yield value of 4.815 kg ha^{-1} with an increase of 20.70 % in yield when compared to the first planting. In addition, intermediate fertilization in the second planting also obtained a gain of 20.17 % when compared to the first one. It should be noted that, in the second planting, alternative fertilization and rice husk were superior when compared to the first planting (Table 2).

It is also worth mentioning that there was no significant difference for the germination variable between the two cycles. However, for the fertilization factor in the first planting, the rice husk method presented the highest value (92 %), not differing from the conventional (90 %), intermediate (90 %), and alternative (91 %) fertilizations. In addition, the average values observed for germination in the second planting in conventional and rice husk fertilization presented approximately 11 % less germinated seeds when compared to manipueira fertilization (Table 2).

Experiment II. Production of soybean in Stage R_6 (Edamame)

Yield of immature soybean grains or edamame in stage R_6

The variance analysis did not reveal any interaction between the factors genotype x fertilization x plantations for all yield variables of soybeans in stage R_6. However, these same variables isolated showed significant differences for the genotype factor and alternative fertilization. In addition, the variables green pod yield, total number of pods in 500 g, grain/total pod ratio, grain/pod ratio, green grain humidity and mass of 100 green soybean grains in stage R_6 showed significant differences for cultivar factor and alternative fertilization (Table 3).

The analyses performed on the different variables evaluated in the two genotypes (BR 9452273 and BRS 258) of soybean in conventional (chemical), intermediate (half of the chemical + alternative), and

Table 2. Yield and vigor of BRS Sertaneja rice seeds produced with five fertilizations in the highlands of the Roraima Cerrado, divided in two crops

Fertilizations	Yield (kg ha^{-1})		Vigor (%)		Germination (%)	
	First	Second	First	Second	First	Second
Conventional	3818 aB	4815 aA	85 aA	77 bB	90 aA	89 aA
Intermediate	3774 bB	4728 aA	83 aA	78 bB	90 aA	86 bA
Alternative	3768 bB	4220 bA	85 aA	79 bB	91 aA	84 bA
Manipueira	3454 cA	3463 cA	77 bA	76 bA	84 bA	80 cA
Rice husks	3509 bcB	4446 bA	84 aA	85 aA	92 aA	90 aA
Averages	3665	4334	83	79	89	86
CV%	7.2	9.3	6.1	7.7	5.2	5.0

*The averages followed by different lowercase letters in columns and uppercase letters in rows indicate significant differences ($p < 0.05$) through the Tukey Test. CV%: Variation coefficient.

alternative crops showed differences in their mean values (Table 3). It was verified that the variation coefficients were low (< 9.9 %), indicating accurate results.

In the first planting (Table 3), there were significant differences between soybean genotypes regarding the mean values of yield of green pods and mass of 100 green grains, with special emphasis on the genotype BR9452273. This fact was also evidenced for the second planting for the same genotype (Table 5). In addition to this, in the first planting, the genotype BR9452273 showed gains regarding the total number of pods 13.6 % more when compared to BRS 258. On the other hand, in the value resulting from the division of the grains and the total pods, that is, the RGTP, a similarity between the genotypes for the first crop was verified.

However, for the mean values of green pod yield in R_6 stage (Edamame) in the second planting, the highest values were observed for the BR9452273 strain when compared to cv. BRS 258 (Table 3). This fact was also evidenced for the mass of 100 green grains with a gain of 18 % in their weight when compared to cv. BRS 258 (Table 4). On the contrary, the total number of pods in 500 g showed that the cv. BRS 258 strain was superior to the BR9452273 one. However, the variables grain/total pod ratio, grain/pod ratio, green grain humidity and mass of 100 green soybean grains in stage R_6 were similar between the two strains.

For the average values of green pod yield in the R_6 stage (Edamame) in the second planting, the highest values were noticed for the BR9452273 strain, with an increase of 10.62 % in yield when compared to cv.

Table 3. Average yield values of green pods (YIELD, t ha^{-1}), total number of pods in 500 g (TP), grain ratio X total number of pods (GR/TP), and grains x pods (RG/P), humidity of green grains (HU, %), and mass of 100 green grains (M100GG) of two soybean genotypes produced in an area of the Roraima Cerrado as a function of fertilization applied to the soil in the first planting

	YIELD		TP		GR/TP		RG/P		HU		M100	
						Genotypes						
BR9452273	10.66	a	364.2	b	58.4	a	57.8	a	51.3	b	47.4	a
BRS 258	9.11	b	421.7	a	59.8	a	59.4	a	59.0	a	38.1	b
						Fertilization						
Conventional	10.17	a	351.1	b	64.5	a	56.5	a	62.2	a	44.9	a
Intermediate	9.98	a	403.0	a	58.4	b	55.6	a	63.1	a	41.5	b
Alternative	10.02	a	408.6	a	58.5	b	56.4	a	62.9	a	36.6	c
Manipueira	10.15	a	341.6	b	50.9	c	57.7	a	63.5	a	34.9	c
Rice husks	11.10	a	342.7	b	50.6	c	56.1	a	63.5	a	35.8	c
Averages	10.0		369.4		56.8		56.6		63.0		38.7	
C.V.(a%)	9.5		8.1		8.7		7.3		1.21		7.7	
C.V.(b%)	9.2		2.1		3.9		9.9		2.6		8.8	

*In columns, averages followed by the same letter did not present significant differences according to the Tukey Test at 5 % of probability.

Table 4. Average yield values of green pods (YIELD, t ha^{-1}), total number of pods in 500 g (TP), percentage ratio grains x total pods (RG/TP, %), grains x pods (RG/P, %), humidity of green grains (HU, %), and mass of 100 green grains (M100GG) of two soybean genotypes produced in an area of the Roraima Cerrado in two different fertilizations

Genotype	YIELD		TP		RG/TP		RG/P		HU		M100	
BR9452273	12.6	a	304.2	b	51.4	a	57.8	a	66.3	a	51.4	a
BRS 258	11.3	b	381.7	a	53.4	a	59.4	a	65.0	a	42.1	b
						Fertilization						
Conventional	12.27	a	334.7	a	52.5	a	60.5	a	66.2	a	46.9	a
Intermediate	11.70	ab	343.0	a	52.4	a	55.0	a	65.1	a	47.5	a
Alternative	11.92	ab	344.6	a	53.5	a	56.6	a	64.9	a	46.6	a
Manipueira	11.15	b	349.6	a	51.9	a	60.7	a	66.5	a	44.9	a
Rice husk	12.90	a	342.7	a	51.6	a	60.2	a	65.5	a	47.8	a
Average	11.9		342.9		52.4		58.6		65.7		46.8	
C.V.(a%)	9.5		3.3		2.7		10.1		1.76		6.5	
C.V.(b%)	10.7		3.6		4.0		10.6		3.4		9.6	

*In the column, averages followed by the same letter did not present significant differences according to the Tukey Test at 5 % of probability.

BRS 258 (Table 4). This fact was also evidenced for the mass of 100 green grains, with a gain of 18 % in their weight when compared to cv. BRS 258 (Table 5).

Experiment III. BRS 151 L-7 and 184 AM L-7 peanut production:

Production of BRS 151 L-7 and 184 AM L-7 peanuts in the Cerrado Roraima in the first crop

The variance analysis revealed no interaction between the factors genotype x fertilization x plantations for the yield variables of pods and peanut grains. Additionally, when examined separately, these same variables showed significant differences for cultivar factor and alternative fertilization.

Thus, in the established sequence, after the cultivation of soybean, the two genotypes of peanuts (February-April) were sown; one genotype consisted of red grains and the other of cream-colored grains. The peanut BRS 151 L-7 (red) showed on average 4.25 t of grains per hectare in the first planting (Table 5) with intermediate fertilization, while for genotype 184 AM L-7 (cream), the maximum grain yield was 4.12 t of grains per hectare (Table 5), with alternative fertilization.

In general, intermediate fertilization composed of half of the chemical + alternative fertilizers presented better responses for both genotypes, followed by alternative fertilization in the first planting. In turn, when evaluating conventional fertilization in this

Table 5. Average values of pod (YIELD, pg), and grain (YIELD, G) yield of peanuts BRS 151 L-7 and 184 AM L-7 produced in the Roraima Cerrado, considering different fertilizations

Fertilization	YIELD, pg		YIELD, G	
	BRS 151 L7	184 AM L7	BRS 151 L7	184 AM L7
Conventional	4446 c	4478 c	3676 b	3627 b
Intermediate	5031 a	5043 a	4257 a	4125 a
Alternative	4870 b	4815 b	4077 ab	3656 b
Manipueira	4474 c	4321 c	3768 b	3565 b
Rice husk	4444 c	4454 c	3709 b	3716 b
Averages	4653	4642	3897	3798
C.V %	9.3	9.7	8.9	9.8

*In the column, averages followed by the same letter did not present significant differences according to the Tukey Test at 5 % of probability.

Table 6. Average values of pod yield (YIELD, in kg ha^{-1}), weight of 100 pods (W100P, in g), weight of 100 seeds (W100S, in g), husk weight (W husk, in g), weight in seeds of 100 pods (WS100V, in g), relative grain yield in relation to pods (RP, %), and grain yield (YIELD, in g) of peanut BRS 151 L-7 and 184 AM L-7 produced in the Roraima Cerrado in the second crop

Fertilization	BRS 151 L-7						
	YIELD,kg ha^{-1}	W100P	W100S	W HUSK	WS100V	RP	YIELD, in g
Conventional	5342 ab	151.1 a	61.7 a	34.2 a	116.8 a	77.4 a	4135 a
Intermediate	5498 ab	156.4 a	64.6 a	39.7 a	116.8 a	74.8 a	4112 a
Alternative	5537 ab	154.7 a	62.9 a	36.6 a	118.0 a	76.3 a	4225 a
Manipueira	4833 b	148.2 a	59.8 a	37.5 a	110.8 a	74.8 a	3613 a
Rice husk	5990 a	157.8 a	64.4 a	41.2 a	116.6 a	73.9 a	4421 a
Averages	5440.4	153.6	62.7	37.9	115.8	75.4	4101.8
CV (%)	9.2	7.3	6.7	13.5	6.5	2.7	9.7
	184AM L-7						
Conventional	7018 a	157.6 a	61.2 a	43.1 a	114.5 a	72.6 a	5097 a
Intermediate	6129 ab	150.9 a	60.6 a	41.1 a	109.8 a	72.9 a	4457 ab
Alternative	5731 b	160.8 a	62.4 a	44.3 a	116.4 a	72.4 a	4153 b
Manipueira	5444 b	139.6 a	54.6 a	35.7 a	103.9 a	74.4 a	4048 b
Rice husk	6194 ab	155.3 a	66.3 a	41.9 a	113.5 a	73.1 a	4531 b
Averages	6103.7	152.8	61.0	41.2	111.6	73.1	4531 ab
CV (%)	7.8	8.2	9.9	11.7	7.6	2.2	7.2

*Average values followed by the same letters, in columns, did not differ from each other, according to the Tukey Test at 5 % of probability.

study, fertilization with manipueira and with charred rice husk showed a decrease of approximately 11.4 % in pod yield when compared with intermediate fertilization in the BRS 151 L-7 genotype, while conventional, manipueira and carbonized rice husk fertilization exhibited approximately 12.4 % of genome research for the model 184 AM L-7 in the first crop.

It is worth highlighting the superiority of 11.7 % in the yield of peanut grains of the BRS 151 L-7 genotype within the alternative fertilization compared to the other ones in the first crop (Table 5). Similar values were also obtained with the genotype BRS 151 L-7 for peanut grain yield between intermediate fertilization and alternative, conventional, and manipueira fertilizations.

Production of peanut BRS 151 L-7 and 184 AM L-7 in the Cerrado Roraima in the second crop

For the second crop, no significant interaction was observed for the genotypes and fertilization factors in relation to the variables weight of 100 pods (W100P, in g), weight of 100 seeds (W100S, in g), husk weight (W husk, in g), weight in seeds of 100 pods (WS100P, in g), relative grain yield in relation to pods (RP, %) and grain yield (YIELD, in kg ha^{-1}), except for the last variable in genotype 184AM L-7 (Table 6).

The yield of BRS 151 L-7 peanut pods in the second crop was affected by the fertilizations, showing that the use of charred rice husk fertilizers produced more than 800 kg of grains (Table 7) compared to the fertilization composed of manipueira. In addition to this, in the genotype 184AM L-7 there was also a significant difference in the yield of pods due to fertilization, especially in conventional fertilization, which presented greater results compared to the fertilization with charred rice husk or manipueira.

Table 7. Estimated average values in grain yield (t ha^{-1} and %) for the three crops evaluated in two crop cycles in an area of the Roraima Cerrado

	First		Second		Average	
	Yield					
Rice	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%
BRS Sertaneja	4.33	31.0	3.67	25.8	4.00	28.4
Soybean						
BRS 258	5.45	38.9	6.03	42.5	5.74	40.7
BR9452278	6.23	44.5	6.48	45.6	6.36	45.1
Peanut						
BRS 151 L-7	3.90	27.8	4.10	28.9	4.00	28.4
184 AM L-7	3.80	27.1	4.53	31.9	4.16	29.5
Total Yield	13.6 a 14.5 t ha^{-1}		13.8 a 14.7 t ha^{-1}			
General average	14.0	100	14.2	100	14.1	100

However, for the 184AM L-7 strain, the average pod yield for the different fertilizations was between 5.444 and 7.018 kg ha^{-1} of shelled peanuts, resulting in 4.048 to 5.097 kg ha^{-1} of grains, considering that on average 73.14 % of the pods were grains (RR). The mean of the experiment was 4.457 kg ha^{-1} of peanut grains, indicating a high performance of the crop considering the conditions in Roraima (Table 6).

The mean values of shelled peanut (genotype 184AM L-7) yield obtained in the second crop, with the addition of intermediate fertilization, showed an increase of 17.71 % in relation to the first crop (Tables 5 and 6). Regarding the first planting, with the addition of conventional fertilization, the genotype 184AM L-7 showed possible limitations in pod yield (Table 5) with a decrease of 36.1 % in relation to the second planting (Table 6).

Analysing the two cycles of cultivation of the three crops (Table 7), in short, high yield values were noticed for the system as a whole when considering only the grain.

In the two crops of the three grains studied (Table 7), the yield of soybean BR9452278 showed higher values in relation to rice BRS Sertaneja and peanuts in the same year of cultivation, representing on average 31.6 % of the grains produced in the cycle. In addition, for peanuts and soybeans, there was an increase in yield from the first to the second planting, with the opposite occurring with the rice crop (Table 7). In the second planting, BRS Sertaneja showed a decrease of 16.77 % in relation to the first crop (Table 7), with average grain yield (between the two crops) of 4 t ha^{-1}. On the other hand, the soybean yield of cv. BRS 258 in the second planting showed a gain of 8.47 % in relation to the first planting (Table 7). Sequential plantings used in two consecutive cycles resulted in approximately 14 t ha^{-1} of grains in the area of the Roraima Cerrado; the proportions were: rice 28.4 %, peanut 29 %, and soybean 42.6 %.

In this sense, the soybean genotype BR9452278 showed similar average yields in the two crops, with an average of 6.36 t ha^{-1}. In general, the BR9452278 strain exhibited the highest general average yield of soybean grains with approximately 10 % gain in relation to cv. BRS 258, under the conditions of the Roraima Cerrado (Table 7).

Discussion

Experiment I: BRS Sertaneja rice

As well as the results gathered in this paper, other studies have also confirmed that alternative and mineral fertilization induce superiority in the agronomic attributes of several oilseeds and annual crops in successive plantations (Smiderle *et al.*, 2020). This type of fertilization is described as effective in

the field because it induces efficiency in physiological processes that promote rapid initial growth of plants (Krenchinsk *et al.*, 2018). The superiority in yield of the rice crop BRS Sertaneja verified in the Roraima Cerrado with the use of conventional fertilization in the first planting (Table 2) may be related to two factors acting concomitantly.

In addition to this, the increases in rice grain yield in relation to the fertilizers obtained in the present study showed a positive effect on both the vigor and germination of BRS Sertaneja rice seeds. This allows to elucidate that conventional fertilization was the most appropriate for the conditions of the Cerrado in the first planting due to the higher yield obtained, while conventional, intermediate, alternative, and charred rice husk fertilization promoted improvement in the seed vigor of BRS Sertaneja.

As for the second planting, the BRS Sertaneja cultivated in the Roraima Cerrado was directly influenced by fertilization, as a result of the chemical improvement of the soil in the second agricultural year as shown in Table 2. Suhre *et al.* (2008) and Smiderle *et al.* (2010), working with different cultivation systems in the State of Roraima, verified that the cultivar BRS IRGA 409 was very promising because it exhibited better physiological quality and yield in different cultivation systems. This classifies both the cv. BRS Sertaneja of the present study, as well as the BRS IRGA 409 studied by the authors mentioned above, as alternatives for cultivation in the conditions of the Roraima Cerrado.

Experiment II. Production of soybean in stage R_6 (Edamame)

When evaluating the yield of BRS 258 green soybean grains submitted to different fertilizations in the Roraima Cerrado, Smiderle *et al.* (2009) determined an average yield of 9.852 kg ha^{-1} of green pods (Edamame) in 2007/2008, while in the agricultural year 2008/2009, the same authors verified the average mass of 100 green grains (Edamame) ranging from 42.1 to 48.8 g for BR9452273 and 37.4 to 40.3 g for BRS 258; these values are lower than the ones presented in this research for both cultivars in the second crop cycle (Table 5). In addition, Lima and Smiderle (2013), when evaluating the physiological potential of the soybean seeds cultivar BRS 258 and the BR 9452273 strain produced in the second crop, after harvest and at 12 months of storage, found that BR9452273 soybean seeds (stage R_8) produced using carbonized rice husk fertilization showed better physiological quality after harvest, and substantial reduction in vigor at 12 months of storage.

According to Smiderle *et al.* (2009), cultivars and/or soybean lineages should preferably have pods with two or more grains per unit. Therefore, strains that have less amount of pods with one grain, and greater amount of pods with two and three grains, should be selected. In the present study, this was demonstrated both for the cultivar BRS 258 and for the BR9452273 strain, which are pods with three to four grains per unit. Charlo *et al.* (2011), after evaluating ten soybean lineages, concluded that the JLM010 strain revealed high yield and large grains.

As the mass of 100 green grains of the BR9452273 strain presented an increase greater than 18 % when compared to cv. BRS 258, this strain is highly recommended for the state of Roraima. According to Smiderle *et al.* (2009), large green grains (R_6) are of fundamental importance at the time of commercialization because consumers of this type of vegetable are very demanding regards the quality of the product, and pods with a greater number of large grains and without any damage are more attractive.

Experiment III. BRS 151 L-7 and 184 AM L-7 peanut production

Bernardi *et al.* (2009), when evaluating the efficiency of potassium fertilization in relation to doses, modes, and times of application of sequential plantings on cultivated soybean-cotton-millet crops, found that millet showed a more efficient use of potassium (60 kg ha^{-1}) than soybean, while for the cotton crop, the highest yield was obtained with a dose of 146 kg ha^{-1} of K_2O.

This fact is evidenced in the sequential crops of rice, soybean, and peanut, since the peanut presented preference for mineral fertilization in the first crop (Table 5), while in the second one (Table 6), some improvements on the soil solution were noticed, such as V% that was within the appropriate range (40 %) proposed by Malavolta *et al.* (1997), who classified the values between 40.1 and 60 % in a layer of 0.20 m as adequate (Table 1). An increase in phosphorus content in the 0.20 m soil layer was also observed in the second crop.

This level is considered to be "very good" for annual crops and vegetables according to Alvarez *et al.* (2005), that is, phosphorus levels above 45.0 mg dm^{-3}. The technical and scientific recommendations for peanut cultivation adapted to the edaphoclimatic conditions present in the Roraima Cerrado resulted in the indication of promising genotypes with application of mineral and alternative fertilization (Table 6), due to the excellent and productive results (Table 7) of the three crops (rice, soybean and peanut) and fertilization. It should be noted that the use of sequential crops can be a business option with high added value for small farmers.

Conclusions

The use of rice, soybean and peanut crops as sequential plantations in different fertilizations is indicated for the Roraima Cerrado.

Conventional fertilization is indicated for rice and soybean cultivation as sequential plantations in the first crop.

The soybean genotype BR9452273 presented high yield for both crops.

Intermediate fertilization is indicated because it increases the yield of BRS 151 L-7 and 184 AM L-7 peanut pods and grains.

Sequential crops of rice, soybean, and peanuts in two cycles altered crop yield due to different fertilizations.

Fertilization with charred rice husk was indicated for a higher BRS 151 L-7 peanut yield in the second cycle, in the highlands of the Roraima Cerrado.

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