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Economic Feasibility of Management of Fertilization in the Soybean-Corn System Cultivated in Succession

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Abstract

Fertilization management is one of the agricultural practices that demand high investment. Thus, the objective was to evaluate the economic viability of using combinations of fertilizers applied to soybean and corn cultivated in succession in Goiás Savanna soil. The experiment was carried out in the field, in randomized blocks. The fertilization management consisted of the combination of monoammonium phosphate fertilizers; urea; 08:40:00 +9.3%S and 3.2% Ca; simple superphosphate; potassium chloride; elemental sulfur; polyhalite (37% K_2O + 9.2% S, 5.8% Ca and 1.7% Mg) and polyhalite S (14% K_2O + 19.2% S, 12% Ca and 3.6% Mg) which were applied in soybean sowing and evaluated the residual effect on corn. The economic assessment took into account crop productivity and fertilizer prices in the 2018/2019 agricultural year. For each treatment, the operating cost (COi) and profitability indicators were calculated: gross revenue (GRi); net revenue (NRi); profitability index (PITi); equilibrium production (Yei) and equilibrium price (Pei). Crop productivity was not influenced by fertilizer management, showing that economic indicators can help producers choose the management with the best return and that adjusts to the financial situation of the rural company. Thus, it is concluded that the management of MAP + KCl fertilization was economically outstanding in soybean cultivation and the MAP/S + KCl applied to soybeans, associated with nitrogen fertilization in corn coverage was the most viable for off-season corn. The economic indicators showed that the MAP+KCl fertilization performed on soybean, associated with urea in corn coverage, is the most viable management system for the soybean-corn production system cultivated in succession.

Keywords: net revenue, profitability, equilibrium price, equilibrium production

1. Introduction

Agribusiness is one of the sectors that, in recent years, has leveraged the Brazilian economy. The Confederation of Agriculture and Livestock of Brazil (CNA) indicated that, in 2020, the sector was responsible for 26.6% of the Gross Domestic Product (GDP), resulting, according to the General Register of Employed and Unemployed (CAGED) in 61,637 thousand job vacancies from January to December (Cna, 2021). In addition, revenues in the first quarter of 2022 in the Brazilian agro sector totaled US$79 billion, 26% higher than that recorded in the same period in the previous year (Cepea, 2022).

The main products in the Brazilian agricultural production chain are soybeans, corn, rice, wheat, beans, cotton and sorghum (CONAB, 2021). Soybeans and corn are prominent crops in agribusiness, as they have high socioeconomic value due to the versatility of the products produced from them and are important sources for export (Colussi, Weiss, Souza & Oliveira, 2016; Silveira, Bonetti, Tragnago & Neto, 2015).

The 2020/21 agricultural year saw the State of Goiás occupying the 4th and 2nd places in the ranking of the States that produced the most soybeans and second-crop corn in Brazil, behind the States of Mato Grosso (MT), Rio Grande do Sul and Paraná for soybeans and only MT for second-crop corn. Soybean production reached 13,723.2 million tons, in an area of 3,694.0 million hectares, reaching an average grain yield of 3,715 kg ha^{-1}. Corn obtained 1,656.6 million hectares planted, production of 6,957.7 million tons and average productivity of 4,200 kg ha^{-1} of grain (CONAB, 2021).

Soybean and corn production in Goiás is carried out by adopting the crop succession system in direct seeding, representing the most adopted succession system in Brazil (Alves & Garcia, 2017). This system is characterized by providing insufficient amounts of plant residues to the soil, because associated with the climatic conditions of the State, the straw decomposes quickly. These factors do not favor the system to the point of bringing the desired physical-chemical benefits to the system that would be under the responsibility of the accumulation of organic matter in the soil (Leal, Lazarini, Tarsitano, Sá, & Gomes Júnior, 2005).

Organic matter plays a fundamental role in the functionality and longevity of production systems in Brazilian soils, especially those under the Brazilian savanna vegetation. Most of these have limiting chemical properties to cultivated plants, since pedogenesis has made them acidic and of low fertility (Bezerra, Loss, Pereira, & Perin, 2013). Thus, the high yields achieved in Goiás are largely due to fertilization management (Bezerra, Loss, Pereira, & Perin, 2013; Artuzo, Foguesatto, Souza, & Silva, 2018). In this sense, Sentelhas et al. (2015) shows that factors related to the soil, such as the availability of nutrients, can affect crop productivity by up to 23% and factors related to the management of the system, such as fertilization, interfere in up to 14% in crop production potential.

Reflections on the soybean-corn production system in succession show that the management of factors linked to production favors the sustainability of the rural enterprise (Artuzo, Foguesatto, Souza, & Silva, 2018). To this end, knowing the panorama of investments and returns related to production over the years is essential (Richetti & Ceccon, 2014). The determination of production costs should be adopted as a factor for decision-making and capitalization of the rural environment and not only as an analyzer of the producer's profitability (Neves & Andia, 2003).

Producers who have up-to-date production costs are able to plan future actions. In this way, production costs make it possible to allocate resources in order to increase the net income and profitability of the production area linked to increases in crop productivity, keeping the rural business economically viable (Richetti & Ceccon, 2014).

As seen, evaluating the economic scenario of the soybean-corn production system is a relevant topic for the agricultural sector, especially in the State of Goiás. Thus, the objective was to evaluate the economic viability of using combinations of mineral fertilizers applied to soybean and corn grown in succession in in Goiás Savanna soil.

2. Method

The experiment was carried out in a field situation in Rio Verde city, Goiás under a Red Oxisol. A randomized block design with four replications was adopted, with treatments consisting of a combination of different mineral fertilizers that will be described below (Table 1). The experimental plots had six seeding lines measuring 6 m in length and spaced 0.5 m, representing 18 m^2 of total area.

Soybean (crop) and corn (off-season) were cultivated in the crop succession system in the 2018/19 crop year. Soybean (M7110 IPRO cultivar) and corn (conventional P3898 hybrid) sowing were carried out respecting the technical positions and phytosanitary management indicated by the companies holding the rights to the genetic materials. It is noteworthy that during the period of cultivation of the crops there were no climatic events limiting the crops.

Fertilization management consisted of a combination of fertilizers MAP (monoammonium phosphate; 11:52:00 % $N:P_2O_5:K_2O$); Urea (46% N); MS (08:40:00 + 9.3%S and 3.2% Ca); SS (single superphosphate; 21% P_2O_5 + 10% S and 18% Ca); KCl (potassium chloride; 60% K_2O); PH (polyhalite; 37% K_2O + 9.2% S, 5.8% Ca and 1.7% Mg); S (elemental sulfur; 90% S) and PHS (polyhalite; 14% K_2O + 19.2% S, 12% Ca and 3.6% Mg). Fertilization was carried out at soybean sowing, verifying the residual effect of treatments on corn. However, cover fertilization was carried out at a dose of 120 kg ha^{-1} of N with urea, when the corn plants had eight well-developed leaves (Sousa & Lobato, 2004).

Table 1. Treatments composed of the combination of fertilizers and their respective doses applied in the furrow and in the s broadcast at soybean sowing (2018/19 harvest)

Treat	Furrow							Broadcast		N	P_2O_5	K_2O			S	Ca	Mg
	MAP	Urea	MS	SS	KCl	PH	S	KCl	PHS			Furrow	Broadcast	Total			
	kg ha^{-1}																
1	154									17	80	0	0	0	0	0	0
2	154							134		17	80	0	80	80	0	0	0
3	74	20		200				134		17	80	0	80	80	20	36	0
4	154						22	134		17	80	0	80	80	20	0	0
5	154								217	17	80	0	80	80	20	13	4
6	154					106		108		17	80	15	65	80	20	13	4
7	154				25			108		17	80	15	65	80	0	0	0
8			200					134		16	80	0	80	80	19	6	0

Note. 1: MAP; 2: MAP + KCl; 3: MAP/UREA/SS + KCl; 4: MAP/S + KCl; 5: MAP + PHS; 6: MAP/PH + KCl; 7: MAP/KCl + KCl; 8: MS + KCl

At the end of the cycle of each culture, the productivity was quantified as a function of the treatments applied. For this purpose, 2 m of the four central rows of each plot were harvested for the two cultures (usable area of 4 m^2). For the economic evaluation of the treatments, the prices of the fertilizers used in the plots for the production of soybeans and corn, in the agricultural year 2018/2019, were first raised. The values were obtained in the Rio Verde-GO market and then dollarized according to the time of the experiment (Table 2).

Table 2. Prices for the purchase of fertilizers and a bag of soybeans and corn at the time of sale. Rio Verde-GO, 2018/2019 harvest

Product	P_i collection period	Price*	
		US\$ sc^{-1}	US\$ kg^{-1}
Soybean grain	02/25 to 03/01/19	16.518	0.2753
Corn grain	08/12 to 08/16/19	6.522	0.1087
MAP	08/18		0.4568
KCl	08/18		0.3561
Urea	08/18		0.3586
SS	08/18		0.2284
PH	04/21		0.2643
PHS	04/21		0.4172
MS	08/19		0.4057
S	08/18		0.3193

Source: Rio Verde-GO Market. * Dollar quotation at the time of commercialization.

The fertilization managements for the cultivation of soybean and corn, individually, were analyzed economically. Then, the economic analysis was performed considering the soybean and corn production system together. Thus, the operational cost of each treatment (CO_i), in US\$ ha^{-1}, was defined as the product between the dose used of the fertilizer used in plot i (Df_i), in kg ha^{-1}, multiplied by its respective price (Pf_i), in US\$ kg^{-1}. As the treatments all received the same management, the final cost of the plots differed solely and exclusively by the expense related to the use of fertilizers. Thus, the cost of each installment was calculated as:

$$CO_i = \sum_{i=1}^{n} Df_i \times Pf_i \quad (1)$$

Then, the indicators of analysis of profitability results were calculated for the treatments used in the work, following the methodologies described by Francischini, Silva, and Tessmann (2018) and Martin, Serra, Antunes, Oliveira, and Okawa (1998). The calculated indicators were:

(a) Gross revenue from treatment (GR_i), in US$ ha^{-1}: revenue obtained from the sale of production. It is the value of the product between the crop yield in the treatment (Yc_i), in kg ha^{-1} and the price actually received in the market for the sale of the production (Pc_i), in US$ kg^{-1}, given by the following expression:

$$GR_i = Yc_i \times Pc_i \tag{2}$$

(b) Treatment Net Revenue (NRi), in US$ ha^{-1}: it is the operating profit and is the result of the difference between the GRi and the total operating cost in each treatment (COi). This indicator represents the amount left over to invest or allocate to other essential steps in the production process. The indicator is obtained by the following expression:

$$NR_i = GR_i - CO_i \tag{3}$$

(c) Treatment Profitability Index (PIT_i), in %: obtained from the relationship between the NR and the GR is the result that expresses the part of the revenue that will be available for future investments after the payment of operating costs (CO), obtained by the following expression:

$$PIT_i = \frac{NR_i - CO_i}{GRB_i} \times 100 \tag{4}$$

(d) Equilibrium Production (Ye_i), in kg ha^{-1}: value that determines how many bags of the product are needed to be produced per area units to pay for CO_i. It is the relationship between the CO_i and the price of the product in the market at commercialization (Pc_i). Determined by the following expression:

$$Ye_i = \frac{CO_i}{Pc_i} \tag{5}$$

(e) Equilibrium Price (Pe_i), in US$ kg-1: minimum price to be obtained to cover the total operational cost, taking into account the average productivity of the activity in each treatment (Yc_i), per unit of area, obtained by the expression:

$$Pe_i = \frac{COT_i}{Yc_i} \tag{6}$$

Soybean and corn yield data were submitted to ANOVA in the Sisvar 5.6 program (Ferreira, 2019) and when significance was detected, the Sckott-Knott mean test ($p \leq 0.05$) was adopted. For the economic analysis, statistical tests were not used. Therefore, once the profitability indicators are calculated, the treatment(s) that present the highest NR and PIT and the lowest Ye and Pe will be considered interesting from an economic point of view.

3. Results and Discussion

The yields obtained by soybean and corn cultivated in the succession system and the total yield of grains produced using different combinations of fertilizers are shown in Figure 1. It is observed that the yield of soybeans varied from 3,139.12 to 4,111.06 kg ha^{-1}. These values represent around 52 to 68 bags of soybeans per hectare.

However, despite the coefficient of variation (CV) of 15.77%, considered low for experiments in field conditions, statistical analysis indicated that there was no significant difference between the fertilization managements used. Even so, the productivity obtained by most treatments was higher than the average recorded for Goiás in the 2018/19 crop of 3,290 kg ha^{-1} of soybeans (CONAB, 2019).

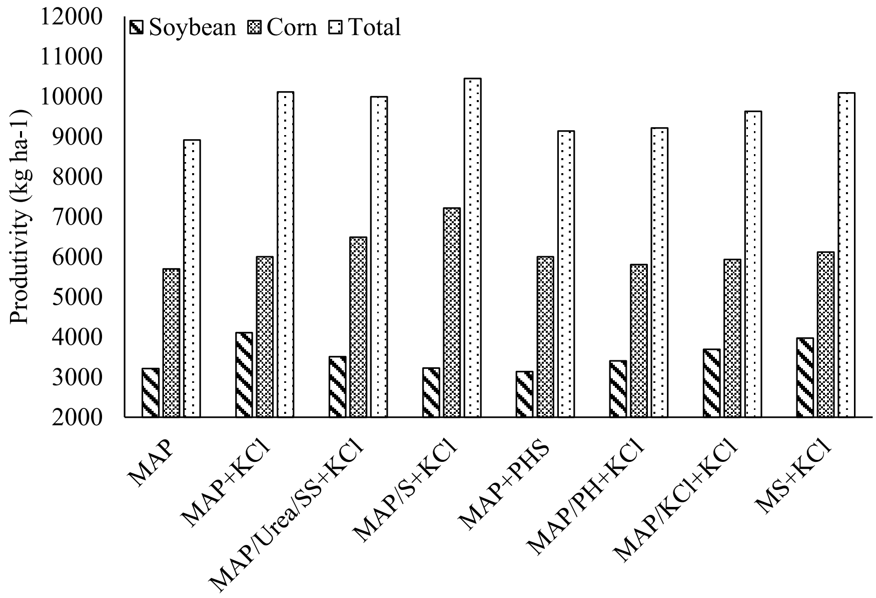

Figure 1. Yields of soybean and corn grown in succession, as a function of the combination of fertilizers applied in soybean sowing in Rio Verde-GO. The absence of letters indicates that the treatments do not differ by the Sckott-Knott test ($p \leq 0.05$)

The residual effect of the fertilizers in conjunction with the topdressing nitrogen fertilization provided corn yields that ranged from 5,699.18 kg (95 bags) to 7,217.61 kg (120 bags) for each cultivated hectare (Figure 2). The statistical test of means shows that the treatments did not differ, even obtaining CV of 12.04% in the corn crop. The corn grain yield obtained in the MAP/S + KCl treatment was higher than the average yield of the State of Goiás, which was 6,720 kg ha^{-1} (CONAB, 2019) and the others approached this indicator.

The total grain production obtained in the 2018/2019 agricultural year ranged from 8,831.30 kg (147 bags) to 11,328.67 kg (168 bags), representing 147 bags and 168 bags of soybeans and corn produced in succession. The average productivity of Brazilian production of soybeans and off-season corn in that year was 9,063.50 kg ha^{-1} (CONAB, 2019). Thus, the average grain production obtained as a result of fertilization management (10,080 kg ha^{-1}) exceeded the national average.

The literature shows studies using commercial fertilizers and their implications for crop yields. In these, long-term crops confronting fertilized and non-fertilized areas are contemplated (Stewart & Roberts, 2012). Steward, Dibb, Johnston and, Smyth (2005) collected data from 362 agricultural crops where they proved that 40 to 60% of production can be attributed to the use of fertilizers.

Fertilization managements adopting different sources of nutrients demonstrating effects on the productivity of soybean and corn cultivated between 1998 and 2005 were evaluated by Pauletti, Serrat, Motta, Favaretto and Anjos (2010). The authors showed that there was no increase in soybean yield in the first seven harvests as a result of phosphorus and potassium application. Corn obtained higher yield with the application of phosphorus, potassium and nitrogen.

The evaluation of phosphate and potassium fertilization at the recommended rate and its double in a soybean-corn rotation system in the North American States of Minnesota, Iowa, Michigan, Arkansas and Louisiana showed that soybean yields were similar regardless of the time of fertilizer application (in the crop production year or before the previous corn crop). The results show that the practice of biennial application of phosphate and potassium fertilizers at recommended doses before the production of corn in the first year of the corn-soybean rotation does not prove to be a limiting factor for yield in production systems aiming at high yields (Broring et al., 2018).

It is noteworthy that the absence of statistical differences in yields can also be explained by the fact that the area where soybean and corn were cultivated had a history of grain production and, therefore, received fertilization prior to conducting the experiment. In addition, as already mentioned, there was no water restriction for the crops, thus favoring the reactions that determine the availability of nutrients in the soil (Cavalli & Lange, 2018; Battisti et al., 2020).

Considering that the statistical analysis did not allow defining which of the tested fertilization managements was efficient to increase soybean and corn productivity, the analysis of economic viability can help producers in decision-making related to the acquisition and use of fertilizers. In addition, it is an important tool that allows the planning and targeting of resources in the rural enterprise (Francischini, Silva, & Tessmann, 2018).

The conditions under which the soybean cultivar M7110 IPRO was grown in the 2018/19 harvest allow some observations to be made about the economic viability of the fertilization managements used. It is observed that the use of MAP alone resulted in lower operating costs when compared to other fertilization managements.

At first, one can have the idea that this management would be the most viable for the cultivation of the crop. However, this management showed a low soybean grain yield (YCs) (3,218 kg ha^{-1}) resulting in a gross income (GR) of only US$ 885.84 per hectare (Table 3). It is noteworthy that the MAP treatment alone is not recommended, since there was no addition of potassium (K) in this fertilization management.

Table 3. Average values for the operational cost (CO), gross revenue (GE) and yield in the soybean crop (Ycs) with the use of fertilizers in the soybean crop. Rio Verde-GO (2018/19 harvest)

Treatments	CO	Yc_s	GR
	US$ ha^{-1}	kg ha^{-1}	US$ ha^{-1}
MAP	70.35	3,218	885.84
MAP + KCl	118.06	4,111	1,131.78
MAP/Urea/SS + KCl	134.37	3,508	965.88
MAP/S + KCl	125.09	3,228	888.57
MAP + PHS	160.88	3,139	864.20
MAP/PH + KCl	136.82	3,404	937.07
MAP/KCl + KCl	117.71	3,695	1,017.23
MS + KCl	128.86	3,974	1,093.96

Source: Survey data. Calculated by the author.

The management with the use of MAP + KCl (Table 3) was one of the treatments with the lowest operational cost and presented the highest Ycs (4,111 kg ha^{-1}) resulting in the highest gross revenue (GR) among the evaluated fertilization managements (1,131.78 US$ ha^{-1}). Although MAP + KCl management increased CO by 47.71 US$ ha^{-1}, when compared to MAP alone (lowest CO found), it provided an increase in Ycs of 893 kg ha^{-1}, causing GR to contribute 245.94 dollars more for each hectare produced. Thus, it is evident that the reduced YCs is possibly due to the lower concentration of K in the soil solution, characterizing the effect of the law of minimum in this treatment. It is noteworthy that, with the exception of the MAP management, the others received equal amounts of nutrients, which are the appropriate managements to be used and, as a result, the treatments will be evaluated in terms of economic return.

The net revenue (NR), profitability index (PIT), equilibrium production (Ye) and the equilibrium price (Pe) of soybean cultivation (2018/19 harvest) under different fertilization managements are presented in Table 4. MAP + KCl management was the most economically viable, since it provided savings (net income) of US$ 1,013.71 for each hectare planted with the cultivar M7110 IPRO.

The adoption of this management provided the producer with PIT of 89.6%, indicating that the savings achieved allow allocating this resource in other activities linked to the production system. In addition, the MAP + KCl management presented the lowest Ye and Pe, consolidating this combination of fertilizers as the most economically viable.

Also noteworthy is the MS + KCl management. Although it demanded slightly higher CO (128.86 US$ ha^{-1}), it obtained productivity of 3,974 kg ha^{-1}. This made the management the second most profitable, as it resulted in NR of 965.10 US$ ha^{-1}, Ye of 468 kg ha^{-1} and Pe of 0.032 US$ kg^{-1} of soybean produced (Table 4).

The literature shows that investing in inputs and technology increases production costs. However, despite higher expenses, incomes also increased, resulting in better returns for the farm. Investments in inputs that make it possible to increase productivity are important since economic profitability is directly associated with the increase in crop yields (Francischini, Silva, & Tessmann, 2018).

Table 4. Mean values for net revenue (NR), profitability index (PIT), equilibrium production (Ye) and equilibrium price (Pe) for the use of fertilizers in the soybean crop. Rio Verde-GO (2018/19 harvest)

Tratamentos	NR	PIT	Ye	Pe
	US$ ha^{-1}	%	kg ha^{-1}	US$ kg^{-1}
MAP	815.49	92.1	256	0.022
MAP + KCl	1,013.71	89.6	429	0.029
MAP/Urea/SS + KCl	831.51	86.1	488	0.038
MAP/S + KCl	763.48	85.9	454	0.039
MAP + PHS	703.32	81.4	584	0.051
MAP/PH + KCl	800.25	85.4	497	0.040
MAP/KCl + KCl	899.52	88.4	428	0.032
MS + KCl	965.10	88.2	468	0.032

Source: Survey data. Calculated by the author.

The economic analysis regarding the residual effect of the fertilization management carried out on soybean associated with the application of urea in topdressing in the corn crop are discussed below. Thus, as already mentioned in soybean cultivation, there was no statistical difference between treatments, with regard to productivity and climatic conditions during the 2019 off-season were not restrictive for the cultivation of the conventional P3898 corn hybrid.

It is verified that all the fertilization managements presented the same CO (Table 5), because here, the topdressing fertilization performed with urea in the corn crop was taken into account. It is clearly observed that the MAP management did not perform well, as the yield achieved by corn (Ycm) and GB were the lowest among the treatments (5,600 kg ha^{-1} and 619.50 US$ ha^{-1}). This reinforces the discussion that the isolated use of MAP would not be the most indicated due to the lack of K in the fertilization.

On the other hand, the MAP/S + KCl management provided the highest Ycm of 7,218 kg ha^{-1} and GR of 784.55 US$ ha^{-1}, followed by the MAP/Urea/SS + KCl management with Ycm and GR of 6,488 kg ha^{-1} and 705.29 US$ ha^{-1} respectively (Table 5). Possibly, the presence of sulfur (S) in soluble forms in these two managements can explain this result. The element S, sulfur, is essential for increasing the production of proteins and aminoacids, among other factors, which may have increased production in this treatment.

As CO is used to obtain Ye, all treatments presented a value of 1,003 kg ha^{-1} (Table 6). Table 6 allows consolidating the statement that the MAP/S + KCl and MAP/Urea/SS + KCl managements proved to be the most viable for the cultivation of off-season corn (2019) taking advantage of the fertilization carried out on soybeans, complementing with nitrogen topdressing.

Table 5. Average values for the operational cost (CO), gross revenue (GR) and yield in the maize crop (Ycm) with the use of fertilizers in the maize crop. Rio Verde-GO (2018/19 harvest)

Tratamentos	CO	Yc_m	GR
	US$ ha^{-1}	kg ha^{-1}	US$ ha^{-1}
MAP	109.01	5,699	619.50
MAP + KCl	109.01	6,002	652.41
MAP/Urea/SS + KCl	109.01	6,488	705.29
MAP/S + KCl	109.01	7,218	784.55
MAP + PHS	109.01	6,002	652.44
MAP/PH + KCl	109.01	5,810	631.50
MAP/KCl + KCl	109.01	5,935	645.09
MS + KCl	109.01	6,118	664.98

Source: Survey data. Calculated by the author.

The MAP/S + KCl management presented the best economic indicators, as it obtained RL of 675.54 US$ ha^{-1}, PIT of 86.1% and Pe of 0.015 US$ kg^{-1}. The adoption of a fertilizer composed of MAP/Urea/SS + KCl allowed the following economic parameters: NR of 596.28 US$ ha^{-1}, IL of 84.5% and Pe of 0.017 US$ kg^{-1}.

In the literature, there are studies that evaluated the economic indicators of corn cultivation. Evaluating the economic viability of crop rotation and green manures prior to corn cultivation in a no-tillage system in the Brazilian Savanna soil, Leal, Lazarini, Tarsitano, Sá, and Gomes Júnior (2005) concluded that corn cultivation that occurred in succession to *Crotalaria juncea* presented the best economic performance. In addition, they also mention that in the no-tillage system, sowing cover crops in the spring, preceding the corn grown in the summer, is an economically viable practice to the detriment of fallow.

Table 6. Average values for net revenue (NR), profitability index (PIT), gross margin (GM), equilibrium production (Ye) and equilibrium price (Pe) for the use of fertilizers in corn. Rio Verde-GO (2018/19 harvest)

Tratamentos	NR	PIT	Ye	Pe
	US$ ha^{-1}	%	kg ha^{-1}	US$ kg^{-1}
MAP	510.49	82.4	1,003	0.019
MAP + KCl	543.40	83.3	1,003	0.018
MAP/Urea/SS + KCl	596.28	84.5	1,003	0.017
MAP/S + KCl	675.54	86.1	1,003	0.015
MAP + PHS	543.43	83.3	1,003	0.018
MAP/PH + KCl	522.49	82.7	1,003	0.019
MAP/KCl + KCl	536.08	83.1	1,003	0.018
MS + KCl	555.97	83.6	1,003	0.018

Source: Survey data. Calculated by the author.

The economic viability of sources and doses of nitrogen in the cultivation of corn second crop in no-tillage system, studied by Souza, Salatier, and Moreira (2015), showed that topdressing nitrogen fertilization using ammonium sulfate at the rate of 100 kg ha^{-1} of N or 150 kg ha^{-1} of N in the form of urea were the most profitable fertilization managements. It is also highlighted that corn intercropped with forage sorghum is an economically viable crop system (Rezende et al., 2020).

The need to provide more basis for producers to make more assertive decisions regarding the investments to be made in the areas, the evaluation of the soybean-corn production system cultivated in succession was also carried out jointly. In this way, the inferences regarding the economic viability of the fertilization managements are supported by the data presented in Table 7.

It can be seen in Table 7 that the use of MAP in the soybean-corn system provided the lowest CO, which was expected, because in the evaluation of soybeans, this was the management where there was less financial investment. However, the values of GR and NR found (1,505.34 and 1,325.98 US$ ha^{-1}) make clear the economic unfeasibility of this fertilization.

As observed in the economic evaluation of soybean cultivation alone, the management MAP + KCl, followed by MS + KCl were the most economically viable for the soybean-corn cropping system in crop succession. This statement is clearly evident due to the managements presenting GR and NR of 1,784.18 and 1,557.11 US$ ha^{-1} and PIT of 87.3% (MAP + KCl) and 1,758.94 and 1,521.07 US$ ha^{-1} and 86.5% PIT (MS + KCl).

Table 7. Economic viability indicators for the soybean-corn system using fertilizers. Rio Verde-GO (2018/19 harvest)

Tratamentos	CO	RB	RL	IL
	--------------------------------	US$ ha^{-1}	--------------------------------	%
MAP	179.36	1,505.34	1,325.98	88.1
MAP + KCl	227.07	1,784.18	1,557.11	87.3
MAP/Urea/SS + KCl	243.38	1,671.17	1,427.79	85.4
MAP/S + KCl	234.10	1,673.12	1,439.02	86.0
MAP + PHS	269.89	1,516.64	1,246.75	82.2
MAP/PH + KCl	245.83	1,568.57	1,322.74	84.3
MAP/KCl + KCl	226.72	1,662.32	1,435.60	86.4
MS + KCl	237.87	1,758.94	1,521.07	86.5

Source: Survey data. Calculated by the author.

The economics of the soybean-corn production system cultivated in succession has aroused the interest of the scientific community. The rotation of corn with the soybean crop is an economically viable practice, as it provides increases in the grain yield of the corn crop in relation to monoculture (Leal, Lazarini, Tarsitano, Sá, & Gomes Júnior, 2005). In land leasing systems, the cultivation of soybeans in the harvest, with Bt corn as an off-season, was a viable system due to the lower expenditure on pesticides in soybeans grown in the region of Mato Grosso do Sul, and care should be taken to verify the fluctuations in the agricultural market (Alves & Garcia, 2017). It is correct that increases in crop productivity have increased economic gains on properties and provided economic growth in many countries (Ball, Bureau, Nehring & Somwaru, 1997; Mullen, 2007; Chavas, 2008).

With the accomplishment of this study, it was possible to observe that even without the possibility of defining fertilization managements through the increase of crop productivity, this definition becomes possible with the aid of economic analysis, involving the prices of fertilizers today. Thus, it is shown how much it is necessary for rural producers and the technical assistance team of the farms to have an understanding of the economic indicators to assist in decision making regarding the actions to be carried out in the rural company.

4. Conclusions

The management of MAP + KCl fertilization was the one that presented greater economic viability in soybean cultivation. The residual effect of the fertilization managements carried out on soybean, associated with nitrogen fertilization in corn cover, showed that the most viable management for the production of off-season corn was MAP/S + KCl. The economic indicators showed that the fertilization performed on soybean with MAP + KCl plus the fertilization with urea in corn coverage is the most viable management system for the soybean-corn production system cultivated in succession.

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