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Diagnosis of the soybean production sector in Porto Nacional, Tocantins, Brazil

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ABSTRACT

Soybean is the most important oil crop for Brazil since almost all production is destined for export, which contributes significantly to the gross domestic product (GDP) of the country. However, soybean production fields have not responded to high levels of grain yield. Therefore, as we are facing a scarcity of natural resources, especially regard to new areas for agricultural expansion, to increase production it will be necessary to produce more grains in the same area since there is no guarantee of exploration of new areas. Thus, the aim of this research was to identify the main difficulties of the soybean production sector in the region of Porto Nacional, state of Tocantins, Brazil. A questionnaire was applied to 24 farmers of the region to obtain the information. The results indicate that the highest soybean grain yield for the Porto Nacional (TO) region occurs in areas where the farmers use the application at variable rate fertilizer, liming frequently and perform the management of the fertility at deeper soil layers.

KEYWORDS: agriculture; agribusiness; soil management; soybean yield.

1 INTRODUCTION

The soybean [Glycine max (L.) Merril.] is one of the main crops of the economic importance of the country, leaving Brazil to a prominent place in the agribusiness world. This is because soybean has high representativeness among commodities and it has high productive potential to meet consumer market demand. All of this can be justified by the increase in consumption of beef, swine and poultry meat, which are the main consumers of soybean (CARVALHO et al., 2012). Brazil stands out because its soils has high agricultural potential, extensive agricultural areas (flat areas or slightly wavy areas), climatic conditions that allow, in many regions, more than one harvest a year.

In the agricultural harvest of 2018/2019, the 113.82 million tons of grain yield were cultivated in 35.78 million hectares. In the North region, the state of Tocantins was the largest producer of soybeans with a production of 3.03 million tons (CONAB, 2019). The municipality of Porto Nacional has about 180,000 hectares planted with soybeans, which represents 21% of the total soybean area in the state of Tocantins (CONAB, 2019). However, it has been noticed that harvest after harvest the productivity that could be achieved, most of the time has not been reached due to some details that persist in the soybean production systems.

Moreover, the grain transport logistics, a problem that is much discussed and represents one of the main problems of the agricultural sector (ZAMBOM, 2013), there are still other problems that are often considered by farmers as a detail in the production process, are not taken so seriously. However, these details are highly representative when accounting productivity losses.

Among the main problems of the soybean production sector, the physiological and sanitary quality of the seeds (seeds acquired by non-certified companies) has been considered as one of the main factors that restrict productivity. The quality of soybean seed is of great importance for the success of stand establishment, with rapid emergence and uniformity of seedlings, being one of the factors that can confer high productivity gains, since it is the seed that carries the genetic and technological potential which will spread to future generations (MARCOS-FILHO, 2013). Therefore, the establishment of soybean fields with high-quality seeds is of fundamental importance (FRANÇA-NETO et al., 2016).

The sowing time is also a factor of importance, especially in the Tocantins region, where the long dry period without rainfall can impair the establishment and development of the crop, which reflects in lower productivity levels. Therefore, knowing the climatic zoning of the region to carry out sowing is of fundamental importance for soybean farmers. According to Guimarães et al. (2008) and Motta et al. (2000), the sowing time, the use of cultivars with high seed quality, the harvest at the appropriate time, storage conditions are the main factors that can potentiate productivity losses.

Regarding soil characteristics, clayey soils have a higher production potential when compared to sandy soils, with an increase of productivity of about 7 to 10%. However, when high technological levels are used, sandy soils also have high productive potential (SEDIYAMA, 2016). In addition, the adequate management of fertilization with macronutrients and micronutrients also acts directly on soybean grain yield. However, for these yield increases to be reached, it is necessary to establish the equilibrium point of the nutrients in the soil and the plant, as well as to understand the interactions of these nutrients with the other factors of soybean production (SEDIYAMA, 2016).

However, the application of fertilizer and limestone according to soil analysis is still a poor agricultural practice performed by soybean farmers, and producers who perform fertilization and liming often forget the physical properties of the soil. It is known that the soil surface layer of 0-20 cm is not exclusive to the crop management and that the roots can develop in greater depth, and this represents gains in productivity. In this context, promoting root growth in deeper layers (RAIJ, 2010), and knowing the soil profile is the differential for soybean cropping.

The understanding of all these characteristics can represent significant gains in crop yield. The farmer who does the proper planning of his farm, with respect to planted area, machinery, supplies, storage and appropriate management of the chemical and physical properties of the soil, certainly can have a differential in the yield of his crops. Therefore, the proposal of this research was to evaluate the main difficulties of the soybean production sector in the region of Porto Nacional, state of Tocantins, Brazil, and from this information propose alternatives and state public policies that minimize the effect of these problems on soybean yield.

2 MATERIAL AND METHODS

The study was carried out in the municipality of Porto Nacional, located in the central region of the State of Tocantins, Brazil (10°42'28 "S, 48°25'01" W, and altitude of 232 m). The regional climate, according to the Köppen classification, is Aw, characterized as tropical savanna, with a tendency towards high rainfall levels in the summer, and dry winters. The mean annual temperature is 26.1 °C, with a mean annual rainfall of 1,600 mm.

The municipality of Porto Nacional belongs to the hydrographic basin of the Tocantins river and has a flat relief with typical Cerrado vegetation. The predominant soils in the region are the Ferralsols (Latossolos), Acrisols (Argissolos), Plinthosols (Plintossolos) and Arenosols (Neossolos Quartzarênicos), and these classes of soil have no restrictions for use and management.

Twenty-four rural farms that have as main income the cultivation of soybean was visited. The selection of the rural properties was carried out by the Agronomist of the Department of Agriculture of the municipality of Porto Nacional, who also assisted in the initial contact with the farmers. According to the last agricultural Census of 2006, Porto Nacional had 14 rural properties. Therefore, this number was considered the minimum sample value to perform the data collection. With the assistance of the Municipal Department of Agriculture for the visits, it was possible to access 24 rural properties.

A questionnaire was applied to the responsible manager of the farm, with the objective of identifying the profile of the soybean farmer of the municipality and verify the management practices adopted in soybean crops in the region. Thus, it was possible to identify the most limiting factors that affect the soybean yield of farms.

The questionnaire was developed according to the Survey methodology proposed by Bethlehem (2009). In this methodology, the interviewee speaks freely about the question posed, with minimum interference on the part of the interviewer to avoid the induction of certain answers. The questionnaire was elaborated in three parts, the first consisted of characterizing the rural property. In the second part, a series of questions related to the cultivation and management of the soil and soybean crop were placed, where the interviewee could give scores ranging from 0 to 10. Scores 0 indicates that the farmer does not know the subject, 1 to 4 does not give importance to the subject, 5 to 7 the subject has average importance, and notes from 8 to 10 the interviewee gives much importance to the subject. The third part was elaborated to describe the technical management used before and during the cultivation of soybean.

The information obtained was tabulated in a spreadsheet and, then, it was found that the scores of many answers obtained from the interviewees were homogeneous, resulting in very low or null variance. As a result, the contribution of these answers (descriptors) to the objectives of the analysis to be applied, i.e., to segregate and group the interviewees (observations) through the application of the multivariate analysis, would be minimal. As a function of this, the responses of the matrix to be analyzed were excluded.

After this procedure, the answers were grouped into two subsets, having as criterion the nature of the questions asked to the interviewee. Thus, it was established that "opinion questions" in which a note was assigned to a question to verify the interviewee's knowledge about a certain aspect of the production system, or even of the importance given by the interviewee to a specific management procedure, should be analyzed separately from the second group. This second grouping was then composed of quantitative questions that sought to recognize the management practices that the farmer adopts in soybean production systems. Thus, two basic matrices were constructed, the first called "Matrix A" and the second "Matrix B".

In total, 24 soybean farmers (n observations) were interviewed, who answered nine questions (p descriptors) in matrix A, and four questions in matrix B. A similarity matrix ($n \times n$) was generated by calculating the Gower coefficient (LEGENDRE; LEGENDRE, 1998). This similarity matrix was submitted to the Principal Coordinate Analysis (PCoA) (GOWER, 2016), aiming to reduce the dimensionality of the matrix data. The reduction of dimensionality of the matrix was accompanied by the observation of the explanatory percentages of each axis obtained through the eigenvalues (λn) of each eigenvector (LEGENDRE; LEGENDRE, 1998).

The resulting axes in linear regression models were used (QUINN; KEOUGH, 2002), where the axes extracted from the analysis were used as predictors and the grain yield reported by the farmer was used as response variable. The use of eigenvector scores has the advantage that they are orthogonal to one another (LEGENDRE; LEGENDRE, 1998), eliminating, therefore, the problems derived from the collinearity between the predictors (QUINN; KEOUGH, 2002). However, before selecting the predictors, the first three eigenvectors were arbitrarily chosen, using as a criterion that the sum of the three eigenvectors resulted in more than 60% of the original data information. Then, the predictors of the model were selected by the corrected Akaike information criterion (AICC) to increase the parsimony of the model (HOOTEN; HOBBS, 2015 and QUINN; KEOUGH, 2002).

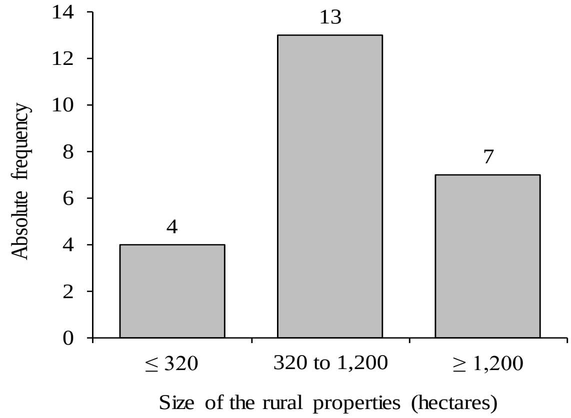
The residuals of the final models were checked for deviations from the normality assumptions, using the Shapiro-Wilk test, and homogeneity of the variances (homoscedasticity) (QUINN; KEOUGH, 2002).

3 RESULTS AND DISCUSSION

3.1 General characteristics of rural properties

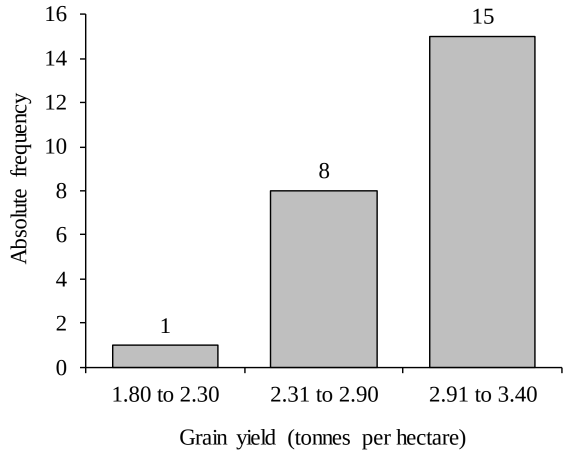
The fiscal module in the region is equivalent to the rural module, which corresponds to 80 hectares (SILVA; ALMEIDA, 2007). According to the legislation, a rural property is considered small when it has 1 to 4 fiscal modules, while a medium-sized rural property has 4 to 15 fiscal modules, and properties with more than 15 fiscal modules are considered large. In the state of Tocantins, rural properties with areas of up to 320, up to 1,200 or greater than 1,200 hectares are considered small, medium and large properties, respectively. Therefore, it is verified that in the municipality of Porto Nacional there is predominance of medium soybean farmers, since of the 24 properties sampled in this study, 13 were classified as medium-sized property, four are small and seven are large rural properties (Figure 1).

Figure 1. Absolute frequency distribution of the size of the 24 rural properties studied in Porto Nacional, Tocantins, Brazil.



The average grain yield in the last soybean harvested was 3.18; 2.96; 3.01 t ha-1, for the average of Brazil, Tocantins, and Porto Nacional, respectively (CONAB, 2019). The data obtained in the 24 rural properties of the municipality of Porto Nacional indicated that the average soybean yield was higher than 3.0 t ha-1 in most of the farms (Figure 2), which is higher than the average grain yield of the state.

Figure 2. Absolute frequency distribution of the grain yield reported by the 24 soybean farmers interviewed in Porto Nacional, Tocantins, Brazil.



In relation to the predominant type of soil in the farm areas, only one farmer was not able to answer which was the predominant type of soil in the property. Most farmers responded that the predominant soil on their rural property was of the clayey type. It is known that the variability of the soil classes is very large, which makes difficult the technical management of the agricultural areas. In this region, there is the occurrence of stony soils (Plinthic Inceptisols) and sandy soils (Quartzipsamments) of low agricultural potential, in association to soils of greater agricultural potential, which are clay soils (Oxisols). However, since most of the farmers' responses always associate the clayey texture as the predominant occurrence in the farm area, we can consider that the farmers of Porto Nacional cultivate their soybean fields in the best soils that occur on the farm.

When farmers were questioned about the amount of crops grown annually in the area, many answered that they only harvest one crop per crop year during the spring-summer period, except two farmers who mentioned that they also grow sorghum/maize or soybeans for seed production with irrigation during the summer-fall period.

Regarding the use of implements for soil preparation, limestone incorporation and soil decompaction, such as harrow, disc plough, chisel plow and subsoiler, 38% of the interviewees answered that they do not use any type of soil preparation implement, and that they adopt the no-till system (NTS), whereas 50% of the interviewees said that they use agricultural implements only when they need to incorporate limestone or to remove compaction layers, and 12% reported using the conventional planting system, with annual soil preparation.

Soil preparation in the conventional system consists of the revolving of superficial layers in order to increase the porosity, to incorporate correctives and fertilizers, to increase the permeability facilitating the root growth of the plants (BRAUNACK; DEXTER, 1989). However, this practice of soil preparation is responsible for potentializing soil degradation and erosion processes, reducing the production potential of the agricultural areas. The no-till system has been very effective in controlling soil erosion, especially when large amounts of plant residues are kept on the soil surface. No-till system also improves water and nutrient availability and soil physical properties, reflecting positive aspects of soil chemical characteristics (BALBINO et al., 1996). Therefore, it is noticed that most of the farmers of Porto Nacional (i.e., 88%) adopt the no-till system, but of these, 57% in any year will use agricultural implements to incorporate limestone.

3.2 Analysis of the responses as a function of grain yield

The application of the principal coordinate analysis (PCoA) to the similarity matrix generated from the matrix A data was able to explain little more than 60% of the original information in only three eigenvectors. In addition, there was a relatively equivalent proportion of this information distributed between eigenvectors 1 and 2 (Table 1). Matrix A refers to the questions in which the interviewee gave a note according to the level of importance of the question topic.

For the matrix B data, the analysis resulted in a much more concentrated expression of information on the first axis of PCoA, where the first three eigenvectors explained almost 82% of the original variance of the similarity matrix generated by the data of this matrix. The matrix B refers to the direct questions, which were made with the intention of understanding the management that the farmer carried out in the areas under soybean cropping.

Table 1. Eigenvalues (λn) and percentage of total variance explained by the Principal Coordinate Analysis (PCoA) on the similarity matrices for the observations contained in matrix A or B

Principal component	Matrix A			Matrix B		
	Eigenvalue (λ_n)	Variance (%)	Cumulative (%)	Eigenvalue (λ_n)	Variance (%)	Cumulative (%)
1	0.79	29.3	29.3	1.06	43.6	43.6
2	0.61	22.6	51.9	0.72	29.5	73.1
3	0.26	9.6	61.6	0.21	8.7	81.8

The choice of the eigenvectors that were used as predictors of the grain yield reported by the interviewees through the Akaike information criterion (AICC) resulted in the selection of the first eigenvector generated from matrix A (AICC = 25.213), as well as eigenvectors 1 and 3 (AICc = 15.547), among those that were generated from matrix B.

The results of the first regression model between grain yield reported by the interviewees here considered as response variable, and the only predictive variable, in this case, the first axis of the PCoA applied to the matrix A data are shown in Table 2. The results indicate that it is not possible to establish a significant linear relationship between the data of both variables.

Table 2. Summary of the information obtained from the regression model of the eigenvector 1 scores (Matrix A) against grain yield reported by the interviewee (response variable)

n = 24	r = –0.24	R^2 adj. = 0.02	$F_{(1,22)}$ = 1.35	*p* = 0.26
Predictive variable	*β*	SE of *β*	*T*	*p*
$PCoA_{(1)}$	–0.24	0.21	–0.43	0.26

n = number of observations; r = correlation coefficient; R^2 adj. = adjusted determination coefficient; F = calculated F value; *p* = probability; β = standardized regression coefficient; SE of β = standard error of β.

On the other hand, Table 3 shows that the second model, having as predictive variables the first and third axis of PCoA applied to the matrix B data, obtained a significant adjustment (F = 8.32; p = 0.002). Negative regression coefficients indicate an inversely proportional relationship between the response variable and the predictors.

Table 3. Summary of the information obtained from the regression model of the eigenvector 1 and 3 scores (Matrix B) against grain yield reported by the interviewee (response variable)

n = 24	r = 0.66	R^2 adj. = 0.39	$F_{(2,21)}$ = 8.32	*p* < 0.002
Predictive variable	*β*	SE of *β*	*T*	*p*
$PCoA_{(1)}$	–0.59	0.16	–3.62	1.6×10^{-3} **
$PCoA_{(3)}$	–0.31	0.16	–1.89	7.3×10^{-2} ns

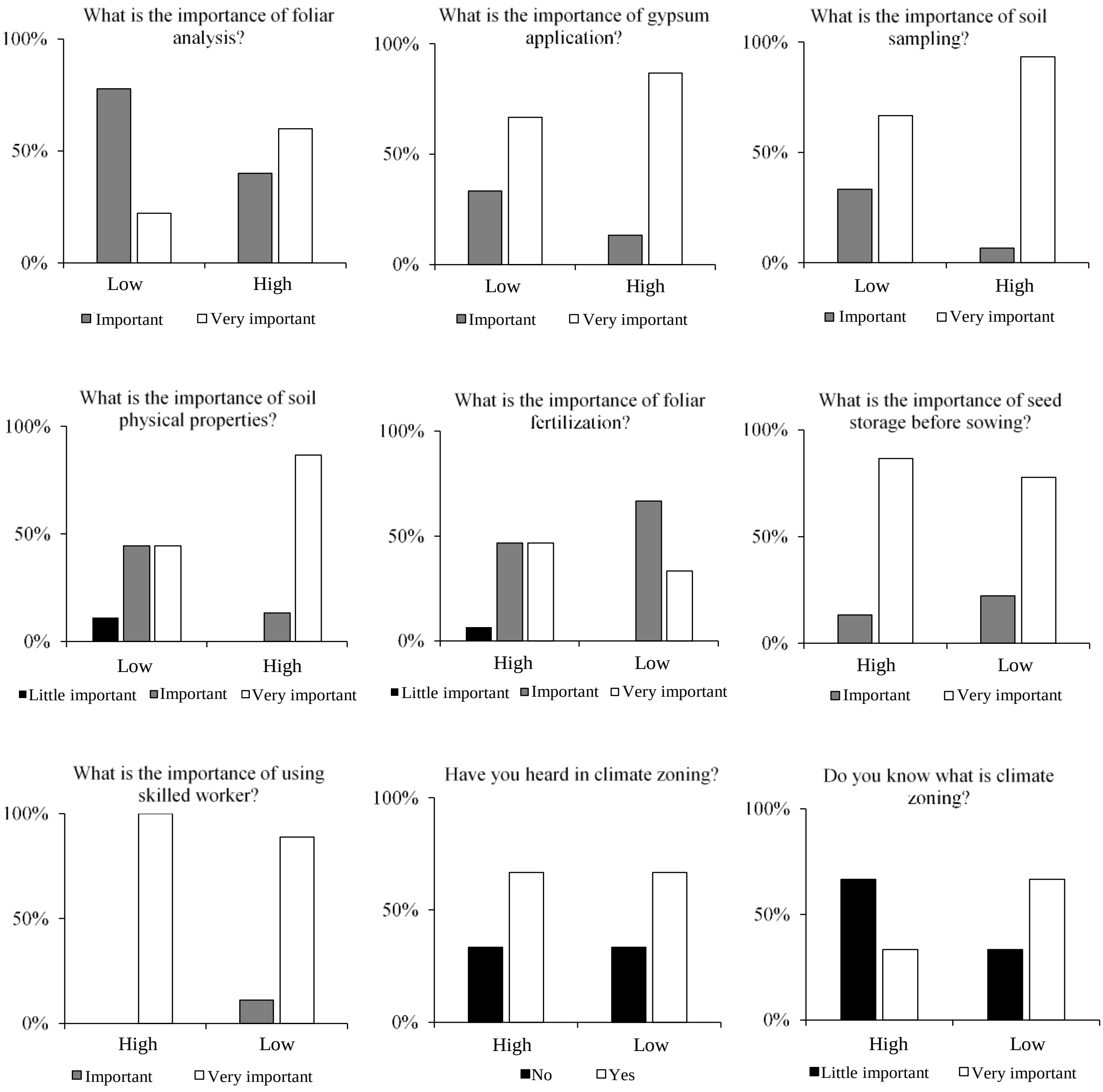
n = number of observations; r = correlation coefficient; R2 adj. = adjusted determination coefficient; F = calculated F value; p = probability; β = standardized regression coefficient; SE of β = standard error of β. ** = significant at 1%; ns = not significant.

The model residues had a normal distribution attested (Shapiro-Wilk test = 0.97; p = 0.58) and their graphical analysis did not show any perceptible deviations from the homoscedasticity assumption.

The matrix A accumulated little variance in relation to matrix B, i.e., the questions that were assigned notes, did not help to understand the behavior of farmers in the region. This demonstrates that farmers who have declared high and low grain yields theoretically give importance to the same agricultural practices adopted for the production of soybeans. The questions that had some variability were submitted to the statistical test, and it is possible to verify these differences in Figure 3.

For other questions related to liming; soil fertility; seed treatment; seed quality and germination; use of new cultivars; resistance of weeds, pests and diseases, all farmers interviewed responded that they are very important, therefore, these practices are less likely to be responsible for differences in soybean grain yield.

Figure 3. Relative frequency distribution of the responses of 24 soybean farmers interviewed regarding the questions that comprised the questionnaire of Matrix A.



On the other hand, of all the questions asked in matrix B, only four presented some variance in the response pattern, while the others did not reflect on the response variable, indicating that the interviewees adopted the same posture and, therefore, these questions could not be either explanation for the occurrence of low grain yields.

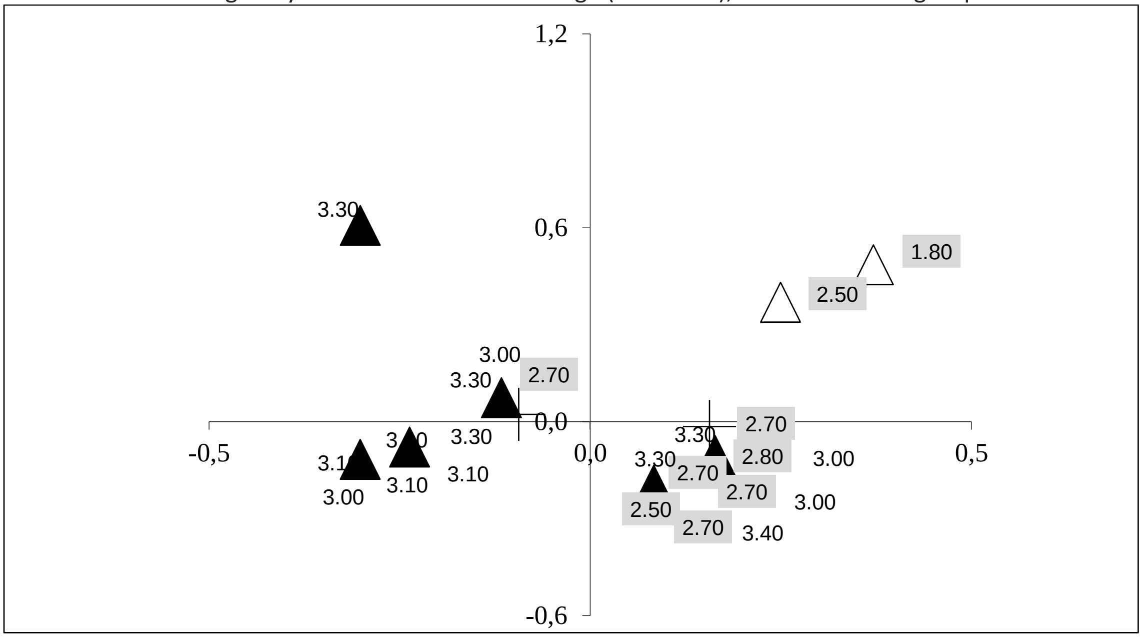
All farmers responded that they consult an agronomist to assist in technical decision making. All the farmers interviewed responded that they had already lost soybean production due to the lack of rainfall. Such evidence indicated that the planning of the sowing season is still a determining factor in soybean cropping in the Porto Nacional region. What we realize is that farmers do not have adequate administration over the quantity and availability of agricultural machinery needed to prepare the soil and to perform sowing due to the size of the areas and, above all, the lack of knowledge and/or the lack of use of the information of the climatic zoning of the State of Tocantins.

The questions regarding the frequency of use of agricultural machinery, amount of crops per year and type of soil were analyzed in the item general property characteristics, together with grain yield and area size.

The summary of information from regression model 2 is shown in Figure 4. It is observed that the ordering of the data caused by the positioning of the observations of the two-dimensional space, formed by the scores of the two eigenvectors in question [PCoA(1) and PCoA(3)], point to a tendency of segregation in two groups. The first group includes the properties that had lower than average grain yield reported by all the interviewees, that is, less than 2.9 t ha-1. This grouping is concentrated on the right in the cartesian plane of Figure 4. On the left side of this same ordering, the plan is a good part of the observations whose grain yield was higher than 2.9 t ha-1. This fact explains the inverse relationships between the PCoA(1) scores (more negative for the group of lower grain yield, more positive for the group with the highest grain yield) verified in model 2.

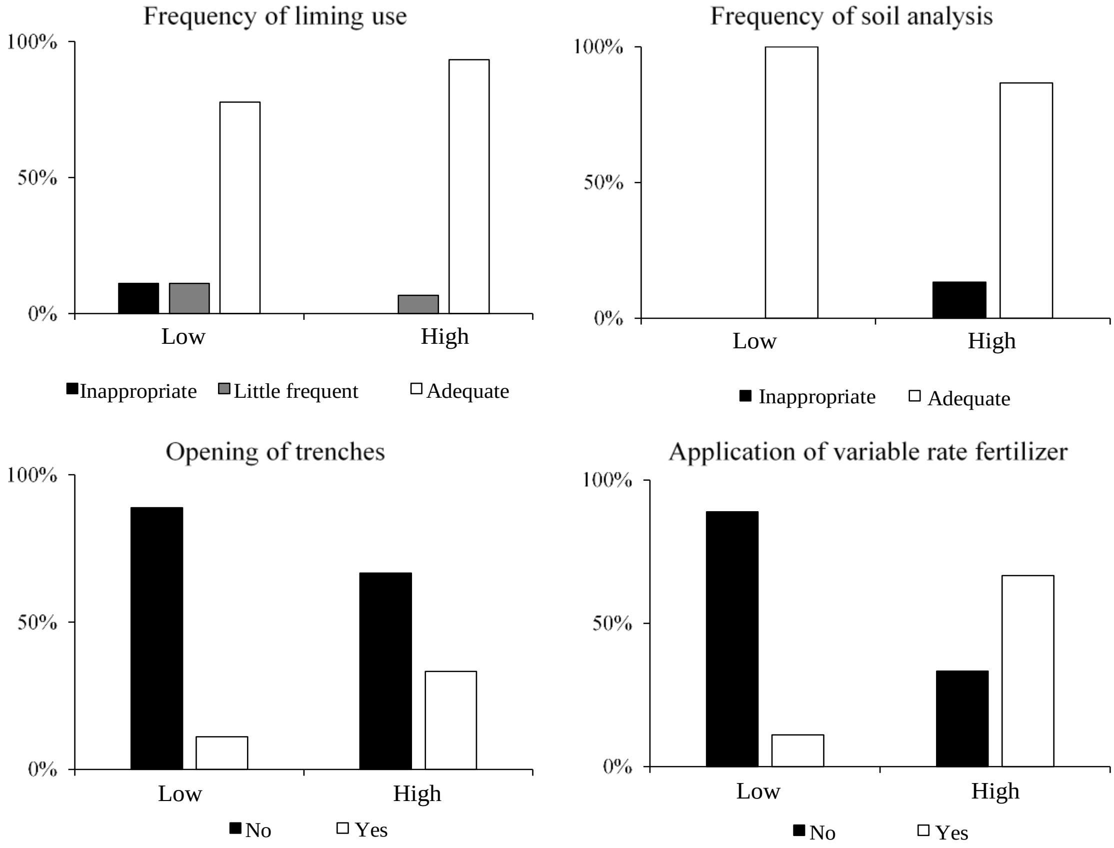
Figure 5 aids in the interpretation of the ordering results, considering that it points to differences in the response pattern of the groups previously described and shown in Figure 4. It can be seen that those farmers who reported higher grain yields on their farms tend to make liming more frequently, use more advanced technologies for fertilization, such as the application of variable rate fertilizer, and are concerned with soil analysis in larger depths, considering that they have opened profiles to understand the nutrient dynamics below the 0-20 cm surface layer. Regarding the frequency of soil analysis, there is a tendency of the group of lower grain yield to perform more soil analysis when compared to the group with the highest grain yield. This is because the latter group has not noticed a decrease in soybean yield because they are soybean cropping in soils with higher fertility.

Figure 4. Two-dimensional diagram showing the spatial distribution of the observations according to the PCoA(1) and PCoA(3) axis scores. The titles of the observations represent the grain yield reported by the interviewed farmers and were used as predictor variables in model 1. Δ = Group a – grain yield below the total average (2.9 t ha-1); ▲ = Group b – grain yield above the total average (2.9 t ha-1); + = centroids of groups a and b.



The use of liming was extremely widespread, especially in the Cerrado region, considering that the soils of this region are characterized by being acidic and of low natural fertility. However, many farmers still fail to apply limestone in their areas, and those who responded that do not perform liming are within the group that adopts the no-till system. It is known that the efficiency of limestone application in no-tillage areas is restricted to the first centimeters of the soil (CAIRES et al., 2000), so this is probably the main reason for farmers not to perform liming. The efficiency of the surface application of limestone in no-tillage soil is very controversial. Some results indicated small or no limestone movement below the site of its application (RITCHEY et al., 1980 and PAVAN et al., 1984). Caires et al. (2000) reported that limestone action applied to the no-tillage system was restricted to 10 cm depth.

Figure 5. Relative frequency distribution of the responses of 24 soybean farmers interviewed regarding the questions that comprised the questionnaire of Matrix B.



Precision agriculture recommends the application of fertilizers at a varied and localized rate, respecting the spatial variability of the soil fertility of the area (MOLIN, 2000). This practice optimizes the use of natural resources, avoids unnecessary use of inputs, promotes proper soil management, provides sufficient amounts of nutrients to plants, and consequently reduces the environmental impact of agricultural activities. Although it is a very complex and expensive technology, many farmers are beginning to use this management practice to increase the grain yield of their soybean fields.

In relation to the soil analysis at higher depths, CESB (2016a) describes that the levels of organic matter, phosphorus, potassium, calcium, magnesium, base saturation and cation exchange capacity (CEC) at various soil depths up to 100 cm, has significant differences and a positive influence on the soybean grain yield. This is a topic that has gained publicity in recent years, however, is being very discussed by the soybean farmers in Brazil. The soil depth known as 0-20 cm "arable layer" is very limiting for plant development, and the CESB (Brazil Soybean Strategic Committee) trials have shown that it is of fundamental importance to provide a chemically and physically better environment for the development of roots at greater depths.

The fertility of the soil profile in the 40-100cm deep layer is important so that soybeans can express their production potential (CESB, 2016b). This is because areas with grain yield potential greater than 90 sc ha-1, have a base saturation greater than 30%, calcium saturation in the CEC greater than 20%, Ca levels greater than 8 mmolc dm-3, pH between 5 to 5.5 and soil penetration resistance less than 1.5 MPa for the depth of 40 to 100 cm. Thus, adequate soil management with characteristics to improve root development and soil volume exploration in greater depth is an alternative that can be considered to increase grain yield of soybean crop in Brazil (CESB, 2016c).

4 FINAL CONSIDERATIONS

Management practices that resulted in higher grain yields by soybean farmers in the Porta Nacional (TO) region are the use of limestone, application of variable rate fertilizer and management of soil fertility at greater depths.

Farmers who have lower soybean yields consider many important agricultural practices, however, most of them do not use these management practices.

Public policies should be implemented with the continuation of this survey for the entire state of Tocantins.

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Diagnóstico da cadeia produtiva de soja na região de Porto Nacional – TO

RESUMO

A cultura da soja é de grande importância nacional, visto que quase toda produção é destinada para exportação, o que contribui significativamente com o produto interno bruto (PIB) do país. Contudo, as lavouras de soja não têm respondido a altos níveis de produtividades. Tendo em vista que estamos enfrentando uma escassez dos recursos naturais, principalmente no que se refere a novas áreas para expansão agrícola, é sabido que para aumentar a produção será preciso produzir mais numa mesma área, pois não há mais garantias de abertura de novas áreas. Desta forma, o objetivo desta pesquisa foi identificar os principais gargalos da cultura da soja da porteira para dentro, na região de Porto Nacional, estado do Tocantins. Foram aplicados um questionário para 24 produtores da região para a obtenção das informações. Os resultados indicam que o maior rendimento de grãos de soja para a região de Porto Nacional (TO) ocorre nas áreas agrícolas onde os agricultores utilizam a aplicação de fertilizante com taxa variada, utilizam a prática de calagem com maior frequência e realizam o manejo da fertilidade em maiores profundidades do solo.

PALAVRAS-CHAVE: agricultura; agronegócio; manejo do solo; produtividade de soja.

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