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PRINCIPAL COMPONENTS ANALYSIS IN BEAN SOWING OPERATION IN RELATION TO THE TILLAGE SYSTEM

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ABSTRACT: The quality of tillage can influence the performance of the fertilizer-seeders, creating the necessity of evaluate the sowing operation in different soil conditions. The aim of this study was to evaluate the characteristics of bean sowing operation in three tillage systems using the multivariate analysis of principal components. The tillage systems studied were: conventional, reduced and no-till. The variables considered were: fuel consumption, operational capacity, power required in the draw bar during sowing, the slip of the driving wheels of the tractor, soil covering after sowing and the number of bean plants emerged. It was possible to observe by the principal components analysis that the statistic method used differentiated the variables according to the behavior of each one in relations to the tillage applied. The reduced tillage is correlated with high fuel consumption and slip of the driving wheels; the conventional tillage showed correlation with a smaller power in the drawbar; and the no-till system presented correlation with high soil covering, emergence of bean plant and higher operational capacity of sowing.

KEYWORDS: agricultural mechanization, sowing, multivariate techniques, *Phaseolus* vulgaris L.

ANÁLISE DE COMPONENTES PRINCIPAIS NA OPERAÇÃO DA SEMEADURA DE FEIJÃO EM FUNÇÃO DO PREPARO DO SOLO

RESUMO: A qualidade do preparo do solo pode influenciar o desempenho das semeadoras-adubadoras, tornando-se necessário avaliar a operação de semeadura em diferentes condições de solo. O objetivo desse estudo foi avaliar as características da operação da semeadura do feijão em três preparos do solo, utilizando-se da técnica multivariada de análise de componentes principais. Foram estudados os preparos: convencional, reduzido e sistema plantio direto. As variáveis consideradas foram: consumo de combustível, capacidade operacional e potência exigida na barra de tração na semeadura, patinagem das rodas motrizes do trator, cobertura do solo após semeadura e número de plantas emergidas de feijão. Pôde-se observar por meio da análise de componentes principais que o método estatístico utilizado diferenciou as variáveis conforme o comportamento de cada uma, em relação aos preparos utilizados, sendo que o preparo reduzido se correlacionou com o alto consumo de combustível e patinagem das rodas motrizes, o preparo convencional mostrou-se correlacionado com uma menor potência na barra de tração e o sistema de plantio direto apresentou correlação com alta cobertura do solo, emergência de plantas de feijão e maior capacidade operacional da semeadura.

PALAVRAS-CHAVE: mecanização agrícola, semeadura, técnicas multivariadas, *Phaseolus vulgaris L.*

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1 INTRODUCTION

Brasil is a great producer bean (Phaseolus vulagaris L.), with expectation of achieving, in the 2011/2012 crop, the production of 3.14 million tons, with average yield of 855 kg ha^{-1}. Given its importance, it is considerable the development of studies aiming the improvement of field condition to the bean crop. (COMPANHIA NACIONAL DE ABASTECIMENTO - CONAB, 2012).

The tillage purpose is to provide favorable conditions to seed germination, emergence of seedlings and development of the crops, but, the quality of the systems can help or harm the performance of the fertilizer-seeders. These machines have furrow opening mechanisms, such as, furrowers, covering discs, and firming, that, by its types, can present different performances. Thereby, it is important evaluate how these machines work in different soil conditions.

According to the EP 291.1 standard (AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS - ASAE, 1997), there is several tillage systems separated in categories defined as: conventional, which is the combination of two or more operations; reduced, which consists in only one operation; and no-till that is the sowing in soil without any preparation.

The techniques of water and soil conservation are essential to keep the chemical, physical and biological characteristics of the soil. For this reason, the study of these conservation techniques with tillage systems that reduce the environmental problems, like soil loss, has gotten a lot of acceptance among the producers, the no-till system is one of these techniques (Camilo et al., 2004). Nevertheless, the conventional system, which uses one plowing and two harrowing, is still the most used in Brazilian agriculture, thus, it is given the importance of the optimization of this system.

There is still another tillage system, an intermediate one, the reduced tillage, which aims the decrease of tillage operations, by scarifications (Boller, 2003).

Furlani (2000) confirms that, for both soil covering after sowing and number of bean plants emerged, higher values in the no-tillage system are obtained than in the conventional and reduced systems.

Something important for sowing is the soil heterogeneity, Mahl et al. (2004) confirm that this factor is relevant in the efficiency valuation of mechanized sets, and they conclude that the condition of soil surface affects the field operational capacity of the set.

Another important factor is the vegetation management, that has the purpose of providing appropriate conditions for the utilization of tillage machines, mainly, seeders. According to Mahl (2006) the stubble in the soil surface hinders the grip of wheelsets of the tractor to the ground, increasing their slippage, what, consequently, increases the traction force demand and power in the drawbar.

About fuel consumption in sowing operation, Nagaoka and Nomura (2003), related that in no-tillage the value founded was 4.61 L h^{-1}, showing the advantage of this method in relation to the others (conventiona l (12.71 L h^{-1}) and reduced (10.45 L h^{-1}).

According to Furlani et al. (2004) the requirement of traction force in the fertilizer seeder was bigger in scarified soil than in no-tillage. The energy consumption and fuel consumption per hour were greater in scarified soil in comparison with no-till, but with the effective field capacity the opposite happened. These results presuppose that the tillage system can interfere in the traction force, potency, fuel consumption, slippage of the tractor wheels and operational capacity.

The multivariate analysis came up as an important obtaining tool of a large number of data, what would hardly be generated with a univariate method (Beebe et al., 1998). In the multivariate statistic, the phenomenon depends on many variables, so it is not enough knowing the variables isolated, but knowing them in their totality, because one depends on the other, and the information are provided by the group and not individually (Grobe, 2005).

Fikdalski et al. (2007) say that the studies that quantify the soil quality, in general, present many variables, which are described by univariate statistical analysis, possibly compromising the interpretations and the conclusions of the study, by not being explored the existence, or the non-existence, of dependency between the variables analyzed.

The analysis of the principal components is a technique of complementary multivariate statistic that has great acceptance in the data analysis. It can be used to judge the importance of to chose original variables, which means, the original variables with bigger importance in the linear combination of the first principal components are the most important from the statistic viewpoint.

The aim of this study was to evaluate the characteristics of bean (Phaseolus vulgaris L.) sowing operation, in three tillage systems (conventional, reduced and no-tillage), using the multivariate statistical technique of principal components analysis.

2 MATERIAL AND METHODS

The experiment was performed at the Experimental Farm Lageado, property of the Faculty of Agricultural Sciences – UNESP – Botucatu Campus, São Paulo state, located under geographic coordinates 22o 49’ South Latitude and 48o 25’ West Longitude, average altitude of 770 meters and average slope of 3%. The soil of the experiment was classified as typichapludo (, 2006), very loamy and with good drainage.

The three tillage systems consisted of: conventional tillage, one plowing with disc plow and two harrowing leveling (CO); reduced tillage, one scarification conjugated with coulter disc and roller (RE); and no-tillage system (NT).

In the conventional tillage it was used a reversible plow, Jan brand, model AR-430, assembled, with four discs of 760mm (30'') diameter; and a leveling harrow light, brand Tatu , model GNL32, pull type, with 32 discs (16 smooth and 16 notched) of 508 mm (20'') diameter. In scarification, it was used chisel plow brand Jan, model Jumbo Matic JMHD-7, pull type, with seven parabolic shanks spaced of 334 mm, tip of 50 mm width, equipped with coulter discs of stubble and leveling roller. Both tillage systems were regulated to work with depth of 30 cm. The fertilizer seeder used was of pull type, Tatu brand, model PST2, with six lines spaced 550 mm, furrowers like chisel, seed and fertilizer reservoir, with capacity for 40 kg by line and 725 kg respectively.

In sowing, it was applied 60 kg ha^{-1} of bean, cv. IAC – Carioca, with germination power of 87% and purity of 99%.

For the tillage operations (plowing, harrowing and scarification), and the sowing of bean crop, it was used a tractor, Valmet brand, model 128-4 with engine power of 90.5 kW (123.1 cv).

The variables considered were: fuel consumption, field operational capacity and power required in the drawbar during sowing, slippage of the driving wheels of the tractor, soil covering after sowing and number of beans plants emerged.

The fuel consumption was determined through an equipment built and described by Gamero et al. (1986). The operational capacity of the fertilizer seeder was calculated by eq. (1):

$$Fc = Wa\ S\ 0.36 \qquad (1)$$

where,

Fc – field capacity of the fertilizer seeder, ha h^{-1},
Wa – width worked area by the equipment, m;
S – displacement speed of the set tractor-seeder, m s^{-1}, and 0.36 unit conversion factor, to express the result in Ha h^{-1}.

The power required in the drawbar of the tractor in sowing operation was obtained with the result of the traction force (obtained through load cell) and displacement speed.

The determination of slippage of the tractor rear driving wheels was obtained by pulse sensors connected to the wheels. The percentage of soil covering of vegetal residues was determined according to the methodology of Laflen et al. (1981). To determinate the number of emerged bean plants, it was counted the number of plants in 2 meters with two samples per parcel. These values were later transformed in number of emerged plants per hectare.

The data were tabbed and submitted to Principal Components Analysis (PCA) and multivariate statistic, using the STATISTICA computer program, version 7.0 (STATSOFT, 2004). In an original matrix data each site has a value for each environmental variable.

In PCA, each site has value for each component. These components can be seen as "supervariables" constructed by the correlation combination between the variables and are extracted decreasingly, according to the importance of its contribution to the total variation of data. Eigenvector is the value that represents the weight of each variable in each component (axes) and works as correlation coefficients that vary from -1 to +1. The variables with high eigenvector in the first axis tend to have an inferior eigenvector in the second axis. Eigenvector is the value that represents the relative contribution of each component to explain the total variation of data.

There is an eigenvalue for each component. Mathematically, the process of extract more axes can go until the number of axes, or components, be the same to the number of variables, but, the posterior axis will contribute each time fewer to explain the data (Kent E Coker, 1992). In most studies, as in the present case, only the first two axes are used, because they are considered sufficient to explain the data and for the easiness of interpretation of a graph in two dimensions.

3 RESULTS AND DISCUSSION

The principal components analysis allowed only one access distribution (principal component 1 (PC1) x principal component 2 (PC2)). Both principal components enabled a two-dimensional ordination of the access and of the variables, what allowed the construction of a biplot graph (Figure 1). The total information quantity of original variables retained by both principal components was 75.07 % [53.30% (first principal component) + 21.77% (second principal component)] (Figure 1).

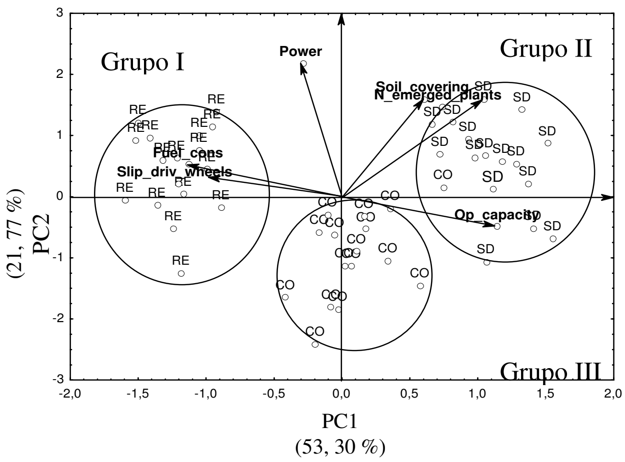

Figure 1: *Dispersion (biplot graph) of bean sowing operation in different tillage systems.*

Fuel_cons: fuel consumption; Slip_driv_wheels: slippage of the driving wheels; Power: power required in the drawbar; Soil_covering: soil covering after sowing; N_emerged_plants: Number of bean seedling emerged; Op_Capacity: operational capacity.

Table 1 presents the correlation values, the closer to 1 or -1; greater is the discriminatory power of the variable in the respective principal component.

Table 1: *Correlation between each principal component and tillage system in bean crop.*

Variable	PC1	PC2
Fuel Consumption	- 0.801742	0.146978
Operational Capacity	0.584335	-0.132854
Power in Drawbar	- 0.072303	0.701279
Slippage of the driving wheels	- 0.7814350	0.061786
Soil covering	0.650982	0.441935
Number of emerged plants	0.683150	0.406949

PC1: Principal component 1. PC2: Principal component 2.

The graphical representation and the variables correlation in the PC1 and PC2 (Figure 1 and chart 1) allowed characterizing the variables that discriminated more in the formation of the groups I, II, and III (Figure 1).

In Figure 1 are represented the principal components 1 and 2. The horizontal axis corresponds to PC1, and the vertical to PC2. The more distant of the center is the variable, the greater is the discriminatory power of the variable inside the PC. Still in Figure 1, the biplot graph for PC1 and PC2 represents, graphically, each sample point, its distribution in a two-dimensional plan, and the distribution of variables according to the principal components 1 and 2, where it is clearly observed the formation of the three groups of tillage.

The variables fuel consumption (-0.80) and slippage of the driving wheels (-0.78) are responsible for the discrimination of group I, located on the left of PC1 (negative correlations), while the variables soil covering (0.65), number of emerged plants (0.68) and operational capacity (0.58) are responsible for the discrimination of group II, located on the right (positive correlations), showing correlations not as high as the variables of group I, however, sufficient for the formation group II as shown in figure 1.

In the second principal component, only the variable power in the drawbar, with positive correlation of 0.70, discriminated the access located in the superior part of the biplot graph (Figure 1), indicating that these access require greater power in the drawbar, than those located in the inferior part (group III), which would require within the three groups, the lowest power drawbar of the tractor-seeder set.

This way, group I (reduced tillage – RE) is characterized by greater fuel consumption with greater slippage of the driving wheels. It happened because this treatment presented greater superficial roughness, once that being the soil looser it was required more of the tractor wheelsets, this fact was also confirmed by Furlani et al. (2004).

Group II (no-till system – NT) is characterized by having greater soil covering after sowing, with greater operational capacity and number of bean plants emerged. About the soil covering, how in this system there is no soil disturbance, the vegetal covering remains on the surface, so the smaller soil desegregation degree caused greater operational capacity of the mechanized set. Now for the number of emerged plants per hectare, the result may have occurred because of the great quantity of straw on the soil, what may have enabled greater water storage, or also the slippage of the wheels of the seeder. While group III (conventional tillage system – CO) is characterized as presenting smaller power requirement in the drawbar.

4 CONCLUSIONS

The statistic technique used showed that the different tillage systems influenced the characteristics studied in bean sowing.

The principal component analysis indicated that the reduced tillage was correlated with high fuel consumption and slippage of the driving wheels. The conventional tillage showed correlation with low power in the drawbar. And the no-till system correlated with a high soil covering, emergency of bean seedling and greater operational capacity.

The multivariate classification by principal components analysis demonstrated to be a useful tool to represent the behavior of the evaluated variables in the bean sowing operation, and it can contribute to improve the planning and the sowing bean control, as well as the activities of soil management.

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