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Application of Plant Densities in Management Units in the Soybean Cultivation

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Abstract

The application of management units (MU's) aims to make economically viable to precision agriculture, making the technique accessible to a greater number of producers. Using MU's, the experimental area is divided into plots with different productive potentials. In this context, the objective of the experiment was to verify the effectiveness of the area division in MU's and to define the soybean plant density that provides higher productive efficiency in each MU. For the formation of MU's it was used the altitude variation and the soil penetration resistance 0-0.1 m in the experimental area, being that the area was divided into 2 MU's, called MU1 and MU2, and each MU was composed of 8 plots. At planting, 2 plant densities were applied, 214 000 and 257 000 plants ha^{-1}, and each density was applied in 4 plots per MU, using row spacing of 0.70 m. In relation to productivity, there was a significant difference, applying the t-Student test, between MU's, and the MU2, unit with higher productive potential, located in the highest part in the area, achieved higher productivity; and there was an effect, using the Tukey test, on the application of the 2 different plant densities in the MU's, being that the densities of 214 000 and 257 000 plants ha^{-1} reached, respectively, higher productivity in MU2 and MU1.

Keywords: altitude variation, precision agriculture, productivity, soil penetration resistance

1. Introduction

Precision agriculture (PA) is still a technique that finds barriers to its application due to its operational and deployment cost of this technique. Thus, new ways of apply PA with lower sampling costs, reducing the amount of inputs and the definition of management units (MU's) (Roudier, Tisseyre, Poilve, & Roger, 2008; Suszek, Souza, Uribe-Opazo, & Nobrega, 2012) comes to make the PA a technique more practical and economic.

The MU's are plots within the field that have similar characteristics and productive potential, being that each MU is susceptible to receive the same agronomic practice in all its extension (Schepers et al., 2004). For the determination of MU's different methods can be used with the use of soil attributes or crop parameters (Blackmore, 2000; Fraisse, Sudduth, & Kitchen, 2001), in addition to attributes attached to the relief (Zhu & Lin, 2011).

The relief, most of the time, assumes an important role in the determining of MU's, because the impact of the topography in the field is important to explain the yield variability of the crops (Kumhalova & Moudry, 2014). In several studies authors received positive results applying MU's in the productive area (Fleming, Westfall, Wiens, & Brodahl, 2000; Anuar, Goh, Tee, & Ahmed, 2008; Diacono et al., 2012).

The identification of MU's in the area allows the site-specific management of important cultural practices in the formation of the final productivity of crop, such as the adjustment in the plant density in sowing. Being that, Ribeiro et al. (2017) reports that plant density in soybean cultivation is an important component to increase grain yield, thereby reducing production costs.

In the experiment the objective was to verify the effectiveness of the area division in MU's and to define between 2 selected soybean plant densities, the density that provides the highest productive efficiency in each MU and in the experimental area.

2. Materials and Methods

2.1 Characteristics of Area, Climate and Soil

The experiment was conducted in experimental area located in the Céu Azul city, Paraná State, Brazil. The area has approximately 15.5 ha and your central geographical location has approximate geographical coordinates of 25°06′32″ S and 53°49′55″ W. The average annual temperature in the municipality is 18.5 °C and the average annual rainfall is 1890 mm. The climate is warm and temperate and classified as Cfa in the classification of Köppen. The soil of the experimental area has a clayey texture and is classified as Dystroferric Red Latosol (EMBRAPA, 2006).

2.2 Soil Analysis

The delimitation of the experimental area was performed with GPS and for composition sample grid were used 40 sampling points. The sampling points were determined attributes related to altitude, slope, chemical and physical attributes (soil penetration resistance, total porosity). Altitude was obtained by electronic total station and after the slope was calculated.

In the determination of the soil chemical attributes were collected by soil samplings with a auger at a depth of 0.2 m for each sampling point within of 3 m of radius (Wollenhaupt, Wolkonski, & Clayton, 1994). The collected soil was placed in plastic bags and transferred to the laboratory for analysis.

Non-deformed soil samples were collected with a volumetric ring at the depth of 0.2 m in the determination of total soil porosity, soil samples were removed from the volumetric ring, covered with permeable wipes and tied with string. These samples were maintained for 24 h in a tray with water at a height of 2/3 of the volumetric ring, after 24 h the samples were drained in a drainage table (EMBRAPA, 1997).

The soil penetration resistance was determined using an Falker PenetroLOG electronic penetrometer with which were performed 4 measurements around each sampling point in a maximum distance of 3 m. The mean of the measurements for the point plot was calculated at depths 0-0.1, 0.1-0.2 and 0.2-0.3 m.

2.3 Area Divisions

In the process that involved the definition of MU's in the experimental area the software was used to define management units (SDUM). Schenatto et al. (2016) performed the definition of MU's in the area and this definition occurred in the following steps: insertion of data in SDUM; evaluation of spatial correlation and selection of attributes related to productivity; interpolation of data; and, data grouping and MU generation.

The experimental area was divided into 2 MU's and each MU was divided into 8 plots, these divisions and location coordinates of the area are represented in the Figure 1, being that the plots are numbered.

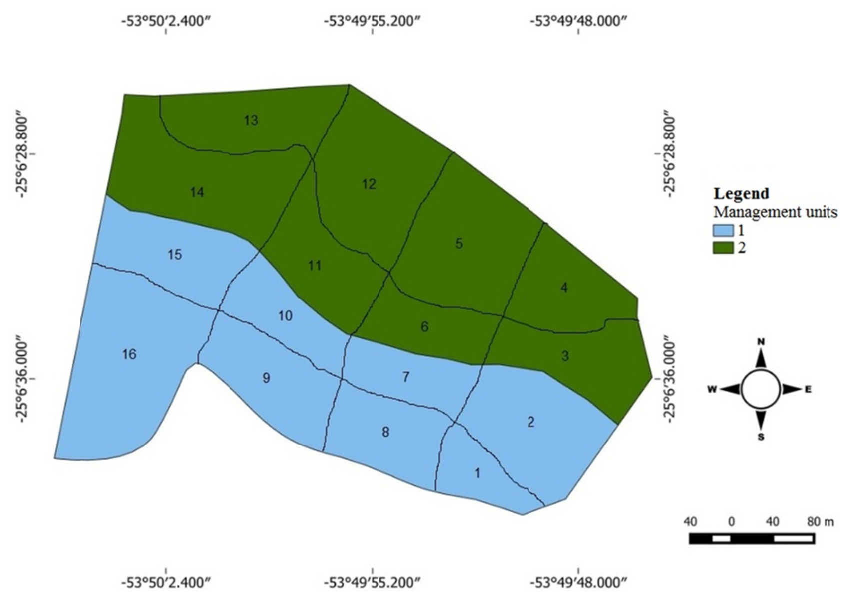

Figure 1. Representation of the experimental area, location coordinates and the divisions in MU's and plots

The altitude variation in the area and the soil penetration resistance at depth 0-0.1 m were used as the basis for the configuration of the MU’s, because showed higher spatial correlation with productivity in the experimental area in the analysis performed in the agricultural years 2011/2012 and 2012/2013 (Schenatto et al., 2016), the most recent period was also the soybean planting. Being that, the MU2 has the highest productive potential and was established in the highest region, while the MU1 is located in the lower part of the area.

It was used Moran’s bivariate spatial autocorrelation statistic (Czaplewski & Reich, 1993) to evaluate the spatial correlation between the analyzed attributes and to establish the spatial correlation matrix, which makes it possible to analyze which attributes influence positively or negatively the productivity. In selecting the attributes used to generate the MU’s: spatially correlated the attributes (chemical and physical soil attributes and area relief), eliminated the attributes less spatial correlation between themselves and between soybean yield (Bazzi, Souza, Uribe-Opazo, Nóbrega, & Rocha, 2013).

2.4 Plant Densities

In the agricultural year 2015/2016, 2 different plant densities were used in the area, being that the lowest density was suggested by the farmer and applied also in the agricultural years 2011/2012 and 2012/2013 in the total area. The highest density was defined in this work and is 20% higher than the lowest density. At planting each density was applied in 4 plots per MU.

Seeding rates (seeds ha^{-1}) used in plots in the MU’s were 10% higher than plant densities (plants ha^{-1}) because the seed germination rate for Syngenta 1359 had 90% germination effectiveness. The seeding parameters are shown in Table 1.

Table 1. Seeding parameters performed

Plant spacing in the planting line (m)	Seeds m^{-1}	Plants m^{-1}	Seeds ha^{-1}	Plants ha^{-1}
0.06	17	15	243 000	214 000
0.05	20	18	286 000	257 000

2.5 Statistical Analysis

The statistical analysis were performed using Randomized block design (RBD), being that the treatments was represented by the plant densities and each MU was considered a block. The Tukey test was used to compare the productivity reached by the plant densities within of the MU’s. For MU’s, it was compared the yield reached by the MU’s using t-Student test.

2.6 Planting, Harvesting and Productivity Estimate

The soybean seeds were planted on October 17, 2015 and the mechanized harvest was performed on February 25, 2016.

The estimate of the average productivity of the 2 MU’s that would be reached using the most efficient plant density by each MU, among the 2 tested in the experiment, in the agricultural year of 2015/2016 was performed with the objective of determining the highest yield of the area. This average productivity was compared with the average achieved without the use of MU’s in the agricultural years 2011/2012 and 2012/2013.

3. Results and Discussion

3.1 Analysis of Soil Attributes and Fertilizing

The analysis of soil attributes was carried out in the years of 2013 and 2015 (Table 2), there was no analysis of soil attributes in 2014, because the soil did not present adequate conditions for the drought presented in the period.

Table 2. The results of the soil characteristics of each the MU

Chemical characteristics										
Year	UM	Ca	Mg	K	Al	H+Al	CTC	P	V	pH
		---------------------------- cmolc/dm³ ------------------------------						mg/dm³	%	-
2013	1	6.104	2.061	0.686	0.048	5.546	14.397	24.267	61.286	5.076
	2	5.712	1.733	0.576	0.212	6.458	14.478	25.853	55.363	4.821
2015	1	6.623	2.804	0.675	0.004	4.590	14.692	24.235	68.488	5.657
	2	7.068	2.658	0.621	0.006	4.757	15.104	17.404	68.207	5.568

The results of pH, CTC, V, Al and the macronutrients Ca, Mg, N, P, K in the MU's are considered adequate for soybean cultivation. However, it is recommend a fertilization of 50 to 60 kg of P2O5 to obtain an increase of P and, consequently, to increase the productivity in the MU's (Costa & Oliveira, 2001). Therefore, aiming to meet the recommendation, NPK mineral fertilizer 8-40-00 was applied throughout the area in a quantity of 125 kg ha^{-1} made directly to the soil along with the planting.

3.2 Management Units

In relation the MU's in the t-Student test, the results demonstrated that the productivity reached for the soybean is different between the MU's, and the MU2 reached productivity of 3.380 t ha^{-1}, while the MU1 reached 3.250 t ha^{-1}(Figure 2).

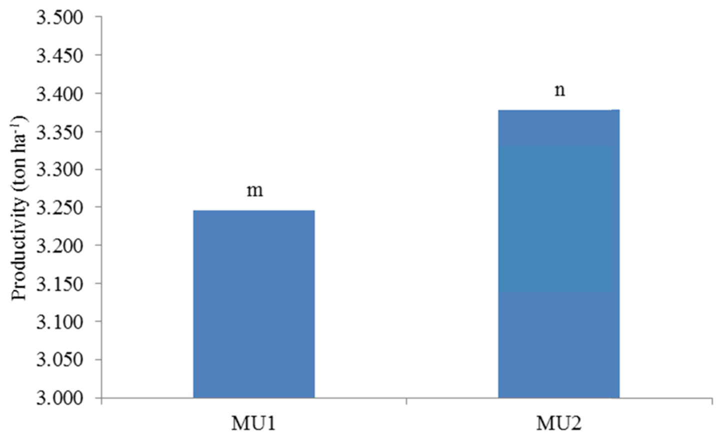

Figure 2. Productivity achieved in the management units by applying plant densities, being that the productivities reached for the management units followed by the same letter does not differ in the t-Student test on the basis 5% significance level; MU1: Management Unit 1; MU2: Management Unit 2

In accordance with the results found in the t-Student test in the comparison of productivity between MU's, other authors have found significant results that show the effectiveness of MU's application to manage productivity in the area (Ortega & Santibáñez, 2007; Delalibera, Weirich Neto, & Nagata, 2012; Hörbe, Amado, Ferreira, & Alba, 2013; Jacintho, Ferraz, Silva, & Santos, 2017).

3.3 Plant Densities

Accomplishing the Tukey test for the plant densities within the MU's, it was observed that in MU1 there was a significant difference in productivity and density with a higher number of plants, 257 000 plants ha^{-1} reached 3.300 t ha^{-1}, while the density 214 000 plants ha^{-1} reached 3.200 t ha^{-1} (Figure 3). In relation to MU2, it was also observed that there is a difference in productivity by applying the 2 different plant densities, the plant density 214 000 ha^{-1} plants reached 3.440 t ha^{-1}, while the density 257 000 plants ha^{-1} reached 3.320 t ha^{-1} (Figure 3).

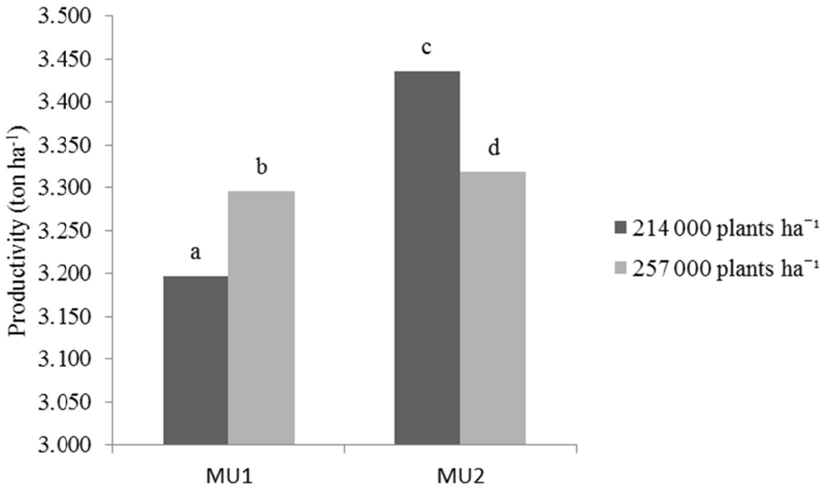

Figure 3. Productivity achieved by plant densities within the management units, being that productivities reached for the plant densities followed by the same letter does not differ in the Tukey test on the basis of 5% significance level; MU1: Management Unit 1; MU2: Management Unit 2

The results found for the plant densities are in agreement with the results found by other authors who obtained significant effect on productivity applying variable plant density (Rahman & Hossain, 2011; Pricinotto & Zucareli, 2014; Zhang et al., 2014; Cruz, Junior, Santos, Lunezzo, & Machado, 2016; Petter et al., 2016).

Rahman and Houssain (2011) and Cruz et al. (2016) reached higher productivity by applying higher plant density, results that are similar to those achieved in MU1. However, in contrast to these results Pricinotto and Zucareli (2014) and Petter et al. (2016) achieved higher grain yield in their experiments applying lower plant density, in line with the results observed in MU2. In the literature there are also studies that obtained low soybean response to plant density variations (De Luca & Hungria, 2014; Souza, Teixeira, Reis, & Silva, 2016; Ribeiro et al., 2017).

3.4 Area Productivity

It was estimated the average productivity that could be reached in the area, in the agricultural year 2015/2016, with the application of plant densities 257 000 and 214 000 plants ha^{-1}, respectively, in MU1 and MU2 that would be 3.370 t ha^{-1}. In relation the productivity, the average of 3.370 t ha^{-1} is higher than the obtained in the same area in the agricultural year 2011/2012 of 2.440 t ha^{-1}, but is lower than the average reached in 2012/2013 of 3.930 t ha^{-1}.

However, analyzing data from SIMEPAR (2016) (Figures 4A and 4B) in the São Miguel do Iguaçu city, city close to the experimental area, it should be considered in relation to productivity in the agricultural years 2012/2013 and 2015/2016, that in 2012/2013 there was a better distribution of rainfall than 2015/2016, with higher rainfall in the period with higher water requirement for the soybean plant—full seed stage.

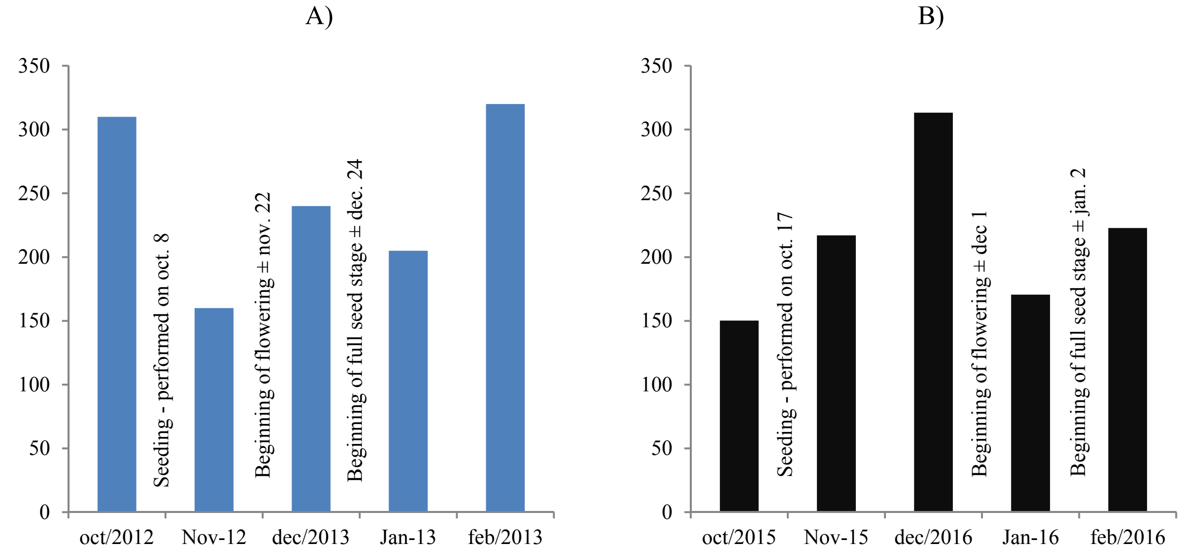

Figure 4. Precipitation in São Miguel do Iguaçu City (A) Precipitation in harvest of the 2012/2013 (mm); (B) Precipitation in harvest of the 2015/2016 (mm). Source: SIMEPAR (2016)

The full seed stage corresponds from R5 to R7 stage, and the water requirement for the plants reaches the value of 9 mm d^{-1} (Steduto, Hsiao, Fereres, & Raes, 2012). In the agriculture year 2015/2016, there were a lot of days without rainfall in full seed stage, with 10 days without rainfall, this factor may have affected the soybean yield.

4. Conclusion

The division of the productive area in MU's considering the altitude variation and soil penetration resistance obtains success in the increase of productivity in the soybean cultivation.

The use of 2 plant densities provided inverse results according to the MU. In MU2, unit with higher productive potential, the higher plant density resulted in lower productivity, while in MU1, unit with lower productive potential, the effect was the opposite, resulting in higher productivity.

It was confirmed that the division of the area into 2 MU's, with the application of appropriate plant density to the productive potential of each MU, provides greater productivity in the cultivated area.

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