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Adjustment of corn population and nitrogen fertilization based on management zones

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Abstract. *The main objective of this study was to adjust the corn population and nitrogen fertilization according to management zones, based on past grain yield maps (seven of soybean and three of corn) and soil electrical conductivity. The study was carried out in Não-Me-Toque, Rio Grande do Sul, Brazil, and it was conducted in a factorial strip blocks with 3 repetitions in each management zone, being the treatments: corn populations (56000, 64000, 72000, 80000 and 88000 plants ha^{-1}), nitrogen rates (0, 60, 120, 180 and 240 kg ha^{-1}) and management zones (high, medium and low potential). There was a significant interaction between management zones and corn population and also between management zones and nitrogen rates, for grain yield. Optimization of the corn plant population and nitrogen rate within the field increased grain yield compared to the reference plant population (72000 plants ha^{-1}) used by the farmer, and nitrogen flat rate. In the low potential zone, the highest yield was reached with the lowest tested population (56000 plants ha^{-1}) and 164 kg ha^{-1} of nitrogen, while in the high potential zone the corn population, which provided the best profitability, was 88000 plants ha^{-1}, with 195 kg ha^{-1} of nitrogen, so that, this zone was the most responsive to nitrogen and corn population. In the medium potential zone, the reference corn population was the most profitable, with 175 kg ha^{-1} of nitrogen.*

Keywords. *Precision agriculture, site-specific management, grain yield*

Introduction

One of the basic premises of precision agriculture is the management of the factors that cause yield variability in an attempt to maximize the economic return and reduce the environmental impact in agriculture. Variable rate applications of fertilizers are a common practice aiming at becoming the agricultural areas more homogeneous, however many soil attributes are not easy to change, such as clay content, organic matter content and topographical features, which define different management zones with distinct yield potential within agricultural areas.

In these case, site-specific interventions that respect the yield limiting factors are appropriate, and since the variable rate seeding technology has become a common accessory in seeders, the adjustment of plant population, arrangement of different genotypes (hybrids or varieties) in the same field, and consequently, the adjustment of fertilization for each population, hybrid or variety, has become a more usual practices among farmers. Thus, the main objective of this study was to adjust the corn population and nitrogen fertilization according to management zones.

Material and methods

One cropland located in Não-Me-Toque city, at the coordinates 28°29' S and 52°51' W, was selected to this study. This area makes part of the Aquarius project (www.ufsm.br/projetoaquarius) and it has been managed under precision agriculture since the year 2000. The soil is classified as a Typic Hapludox according to U.S. Soil Taxonomy, and the climate, according to Köeppen classification, is Cfa-humid subtropical. The warmest month is January, having an average temperature of 24.6°C, and the coldest is June with an average of 12.9°C. Rainfall is evenly distributed during the year with an annual rainfall ranging from 1500 to 1750 mm.

Management zones were delimited using previous yield maps (seven of soybean and three of corn), elevation, slope and soil apparent electric conductivity. All spatial data were interpolated using ordinary kriging in the R statistical environment (R Core Team 2015), with "rgdal" package. Management zones were delineated following the protocol described by Córdoba et al. (2016). This protocol involves cleaning and re-scaling of spatial data, as well as multivariate and geostatistical analyses in a logical sequence, analysis like spatial principal components (sPCA) and the logic fuzzy c-means were used during the process.

The experimental design was a factorial strip blocks with 3 repetitions in each management zone, and the treatments were corn plant populations (56000, 64000, 72000, 80000 and 88000 plants ha^{-1}) and N rates (0,60,120,180 and 240 kg ha^{-1}) applied in V4 growth stage. The plots dimensions were 60 m of width and 24 m of length. The corn hybrid used in this study was the Pioneer brand 1630 Herculex hybrid. This hybrid is one of the most commonly planted by farmers in this area and it was seeded in the beginning of September. Further, at least 15 m were left as buffer between the start and the end of each experimental unit, in order to improve fertilizer applications and yield monitor performance. Every experimental unit received 70 kg ha^{-1} of P_2O_5, and 70 kg ha^{-1} of K_2O during the seeding.

Grain yield was evaluated using an optical yield sensor equipped in the combine. The head dimensions of the combine were smaller than the plot dimensions, so that, only one passed in the center of the plot was used to compute the grain yield.

In order to compare treatments in the management zones, including the interaction N rates x plant populations x MZ one mixed linear model (MLM) of ANOVA was adjust to grain yield:

$$Y_{ijkl} = \mu + N_i + P_j + MZ_k + B(MZ)_{l(k)} + N \times MZ_{(jk)} + N \times P_{(ij)} + N \times P \times MZ_{(ijk)} + ER_{(il)k} + EC_{(ij)k} + \varepsilon_{ijkl} \quad (1)$$

where Y_{ijkl} represents the observed grain yield, with the N fertilizer rate i, plant population j, in MZ k, block l; μ represents the overall mean; T_i is the fixed effect of N fertilizer rate with i = 1,..,t; Pj is the fixed effect of plant population with j = 1,..,f; MZ_k is the fixed effect of the MZ with k =1, .. .,z; $B(MZ)_{l(k)}$ is the random effect of blocks within the management zone with l =1, ...,b; $NxMZ_{(ik)}$ is the effect of interaction between N rate and MZ; $PxMZ_{(jk)}$ is the effect of interaction between plant population and MZ; $NxP_{(ij)}$ is the effect of interaction between N rates and plant population; $NxPxMZ_{(ijk)}$ is the effect of interaction between N rates, plant population and MZ; $(RP)_{il(k)}$ is the row plot error; $(CP)_{jl(k)}$ is the column plot error; and ε_{ijkl} is the random error which is potentially correlated under two covariance models: a random block (RB) model, and then a random block model plus spatial correlation of plot errors (RB + SP). For the RB + SP models, exponential, gaussian and spherical correlation functions without nugget effect were evaluated using a ‘‘nlme’’ (Pinheiro et al. 2015) package of the R statistical software. These models (RB, RB + SP(Exp), RB + SP(Gau), RB + SP(Sph)) were adjusted with homogenous and heterogeneous variances for the different MZ. Model selection for the correlation structure was done following the Akaike information criteria (AIC). When comparing homoscedastic and heteroscedastic models, Likelihood Ratio Test (LRT) was used. A regression analysis was performed when quantitative effects were statically significant ($p<0.05$).

Results and discusssion

After the delineation of MZ, they were classified based on accumulated yield grain, so the zone with a higher yield was denominated high potential yield zone (HYZ), the zone with a medium yield was denominated medium yield potential zone (MYZ) and the zone with smaller yield was denominated low yield potential zone (LYZ).

ANOVA showed that interaction for MZ x nitrogen rates, MZ x plant population was significant ($p<0.05$). Similar results have already been reported in the literature, justifying the increments in grain yield and economic return based on corn plant population variation (Hörbe et al. 2013; Shanahan et al. 2004) and nitrogen rate based on MZ (Inman et al. 2008; Khosla et al. 2002; Peralta et al. 2015).

On the other hand, the interactions for plant population x nitrogen rate and plant population x nitrogen rate x MZ were not significant. Naturally, an interaction between plant population and nitrogen rate is expected, mainly because in most cases increases in plant density results in a grain yield increment, as observed by Boomsma and Vyn (2002), however absences of interaction for plant population and nitrogen rates were also reported by Nafziger and Clark (2009), and Thomison et al. (1994). Moreover, Shapiro and Wortmann (2006) demonstrated that nitrogen uptake was influenced by plant population but it was not necessary a true for nitrogen fertilization demand, and it can be explained by the fact of the nitrogen use efficiency can potentially be improved by the plant population adjustment (Horbe, 2012). Further, Lana et al. (2014) still demonstrated that the relationship between plant population and nitrogen rate for corn was different in conditions where the competition between plants was higher and smaller (narrow and wide spacing).

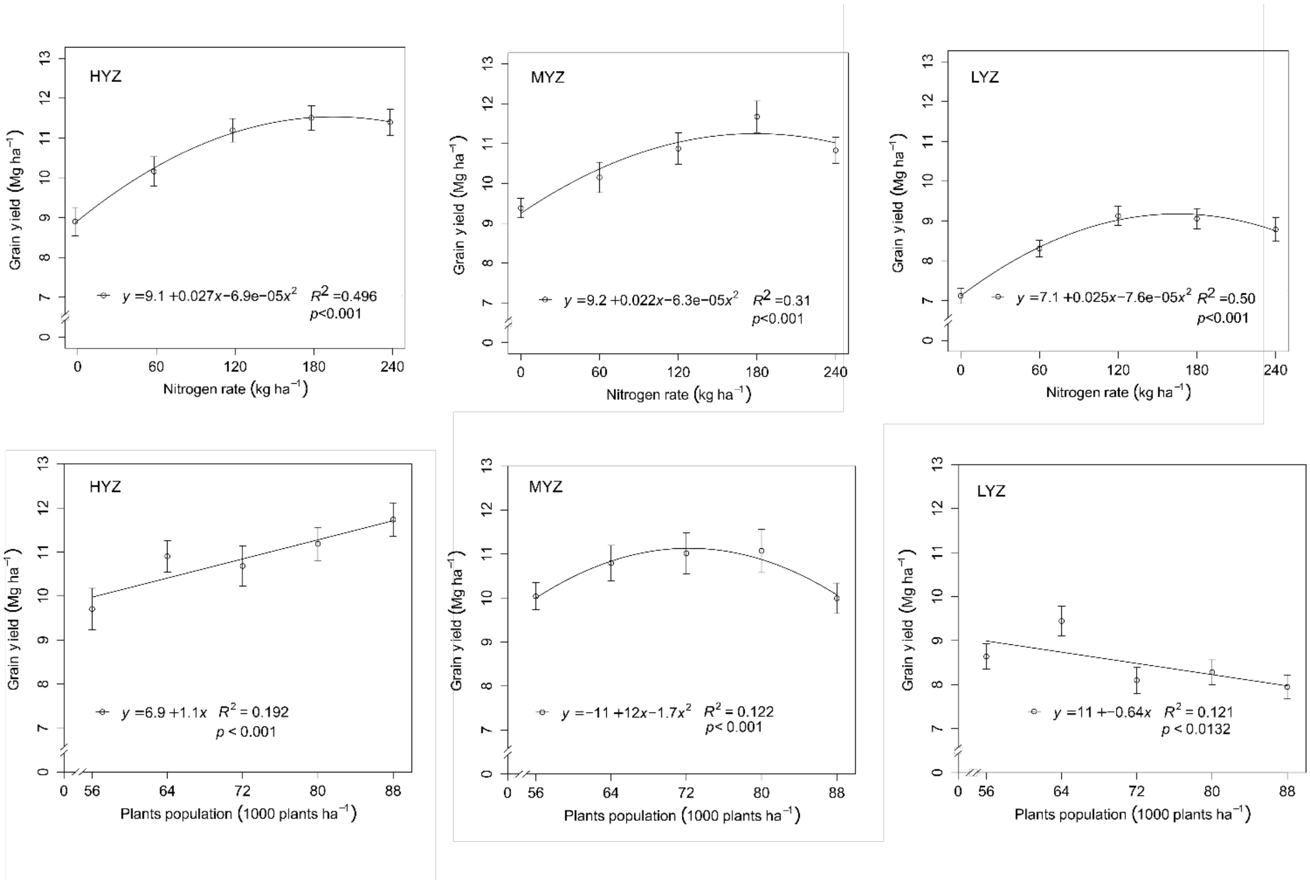

Fig. 1 Nitrogen and plant population yield response according managemnt zones. HYZ = high yield zone, MYZ = medium yield zone and LYZ = low yield zone.

Optimization of the corn plant population and nitrogen rate within the field increased grain yield compared to the reference plant population (72000 plants ha^{-1}) used by the farmer, and nitrogen flat rate. In the low yield potential zone, the highest yield was reached with the lowest tested population (56000 plants ha^{-1}) and 165 kg ha^{-1} of nitrogen, while in the high potential zone the corn population which provided the best profitability, was 88000 plants ha^{-1}, with 195 kg ha^{-1} of nitrogen, so that, this zone was the most responsive to nitrogen and corn population. In the medium potential zone, the reference corn population was the most profitable, with 174 kg ha^{-1} of nitrogen. This results for corn plant population were similar to the ones found by Hörbe et al. (2013).

The adjustment of plant population and nitrogen rate in the low potential yield zone was not sufficient to overcome the effect of this zone, because it always showed lower values to grain yield in relation to the other zones, independent of the plant population or nitrogen rate tested.

The crop demand for nitrogen agrees with the grain yield because the zone with the highest grain yield presents responses to nitrogen until more elevate rates, and the zone with the low grain yield have the most limited response to mineral nitrogen fertilization.

Conclusion

The use of past grain yield maps, soil apparent electric conductivity and topographical features were adequate to delineated management zones with differences to optimum corn plant population and nitrogen rates. The results indicated that the optimizing of corn population and nitrogen rate according to management zones is a promising tool for precision agriculture in Southern Brazil. Besides the absence of interaction between plant population and nitrogen rates more studies are needed to generate more security and conclusive results because this relationship still is not elucidated.

Hence, plant population and nitrogen rates adjustment was not sufficient to overcome the management zones effect in the low yield potential zone.

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