Identification of Nutritional Patterns in Maize By the Images Analysis

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INTRODUCTION

Image analysis is a technique capable of providing information extracted from the leaves, which may contribute to the early identification of nutrient deficiency, which may allow for corrections in the same crop cycle avoiding yield losses. The objectives were to identify nutritional patterns of nitrogen (N) and potassium (K) in maize plants submitted to interaction of both fertilizers using image analysis, evaluate their effects on the N and K content, and yield.

MATERIAL AND METHODS

The study was conducted in no-tillage system area at the Eldorado Agro Industrial Group in Tapuirama-Minas Gerais/Brazil. Soil fertility was: pH in $CaCl_2$ = 5.2, P resin = 10 and S = 22 in mg dm^{-3}, K = 1.6, Ca = 32, Mg = 15, H + Al = 63, Sum of bases = 49 e CEC = 112 in $mmol_c$ dm^{-3}, organic matter = 23 g kg^{-1}, base saturation (V%) = 43%. The hybrid P30F53 EH® was grown during November 2014 - April 2015 (corn harvest 2014-2015).

The experimental design was a randomized block in a factorial design with 6 N doses (0, 60, 120, 180, 240 and 300 kg ha^{-1}) combined with 4 doses of K (0, 30, 60 and 90 kg ha^{-1}) with 3 replicates (72 experimental plots), which were established at the V4 stage (topdressing of corn). The area of each experimental plots was 60 m^2 (Figure 1). Fertilizer (NPK + Boro) was applied pre-planting in the respective levels (50, 130, 276.5 and 1.2 kg ha^{-1}). Samples of maize leaves were taken at the V6 and R1 stage (6 leaves of each plots) for N and K analysis according to methodology of Bataglia et al. (1983). At the end of the cycle the yield was assessed.

To study images analysis, the leaves in V6 stage were scanned in 1200 dpi (scanner model Scanjet HP 3800) and after were processed in the Matlab software. In this step were extracted in the images blocks of 20*20 pixel (100 blocks for each treatment) of each block was extracted characteristics of 4 spectral indices (excess green-Eg, normalized red-Nr, normalized green-Ng, green-red ratio-Rgv and the combinations of them), and separated into classes that correspond to N and K combinations (Figure 2). The global percentage of right (GPR) was based on a statistical classifier described by Gonzalez and Woods (1992) and the correctness confidence (Kappa index) according to Adami (2004).

The results for the nutrient content in leaves and yield were statistically analyzed (SAS 9.3) by analysis of variance and in case of significance were made studies of polynomial regressions Based on the relative production was determined critical level (LC) of nitrogen.

Figure 1. Experimental plots. Maize plants at V4 stage (a and b), V6 (c and d) and R1 (g and h).

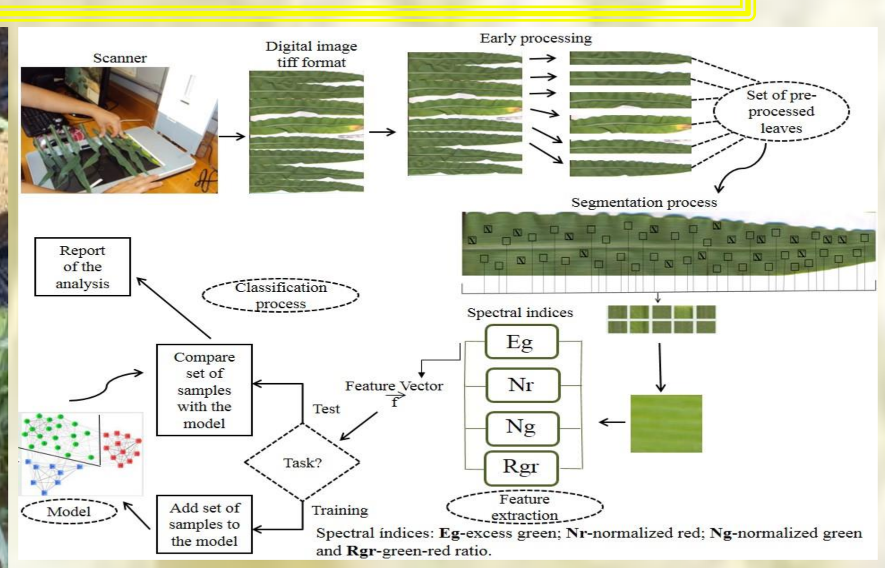

Figure 2. Procedure used in image analysis for the study (adapted of Romualdo et al., 2014).

RESULTS

Visual symptoms of N deficiency were observed in older leaves at R1 stage, with chlorosis from the tip to base of the leaves, with gradual loss of green color for pale green tonality, being distributed uniformly on the leaf surface (Figura 3). Symptoms evolved to the tip drying of old leaves that advanced along of the central nervure, and finally necrosis.

Figure 3. Deficiency symptoms of N in the older leaves of maize plants at R1 stage grown with corresponding to the levels of N/K_2O: 0/0 kg ha^{-1} (C1) and 120/90 kg ha^{-1} (B21). Maize plants at R1 stage, subjected to 300/0 kg/ha^{-1} (B6). Comparison of plants subjected to 240/90 kg ha^{-1} (C5) with plants which were fertilized with 300/90 kg ha^{-1} (C24).

There has not been significant effect of K doses and interaction $N \times K_2O$ for the evaluated parameters. The N content in the leaves at V6 stage replied with quadratic effect for levels of the N supplied, so that the greatest N concentration (35.75 g kg^{-1}), with the N dose of 185 kg ha^{-1} (Figure 4a); at R1 was observed linear effect for N content (Figure 4b).

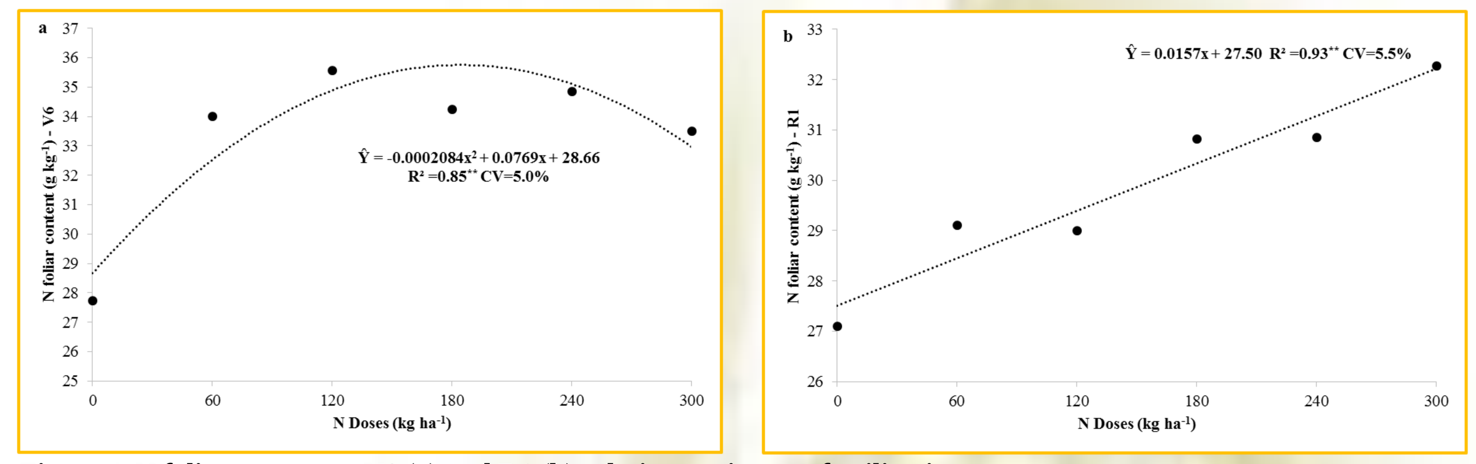

Figure 4. N foliar content at V6 (a) and R1 (b) relative to nitrogen fertilization.

As shown in figure 5a, The nitrogen dose of 234 kg ha^{-1} provided the highest yield (8.8 t ha^{-1}) of corn. The critical level of N was 137.6 kg ha^{-1} set out at 90% of relative production (Figure 5b).

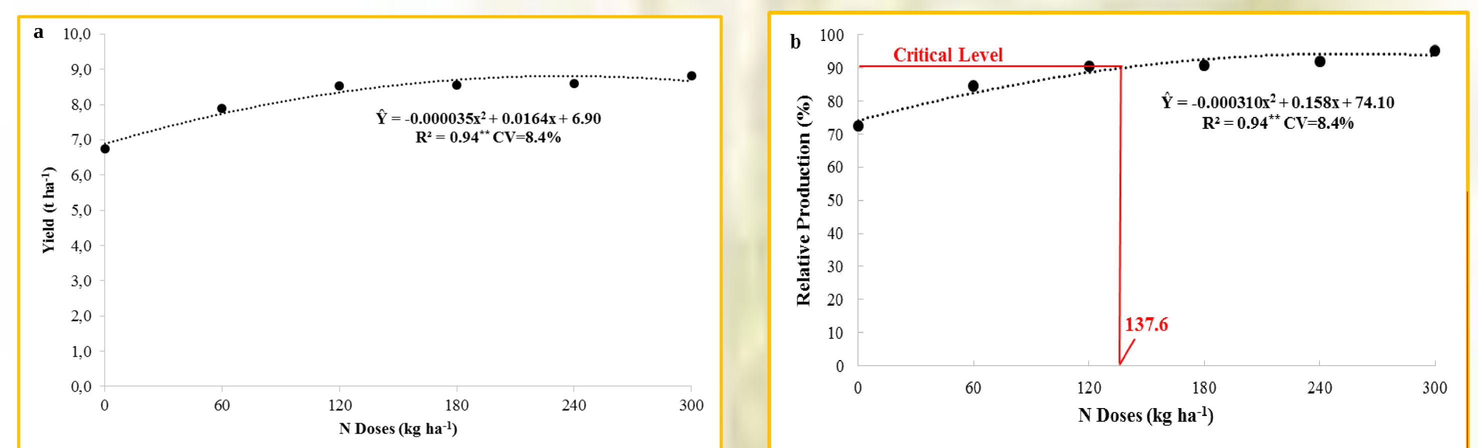

Figure 5. Corn yield relative to nitrogen fertilization (a), relative production and N critical level (b).

The image analysis was able to identify the following combinations $N \times K_2O$ (kg ha^{-1}): 0/0, 120/0, 130/30, 180/30, 240/30, 0/60, 240/60, 300/60, 0/90 and 240/90, with GPR of 85% and excellent Kappa index (0.8) when combined with three or more spectral indices (Table 3 and 4).

Spectral indices	GPR	kappa
Eg	23	0,21
Nr	18	0,16
Ng	24	0,21
Rgr	14	0,11
Eg and Nr	33	0,30
Eg and Ng	36	0,33
Eg and Rgr	32	0,29
Nr and Ng	34	0,31
Nr and Rgr	27	0,24
Ng and Rgr	32	0,29
Eg, Nr and Ng	40	0,37
Eg, Ng and Rgr	42	0,40
Nr, Ng e Rgr	39	0,36
Eg, Nr, Ng and Rgr	45	0,43

Table 1: Analysis of 24 combinations $N \times K_2O$

Spectral indices	GPR	kappa
Eg	51	0,46
Nr	55	0,50
Ng	43	0,37
Rgr	41	0,34
Eg and Nr	68	0,62
Eg and Ng	66	0,62
Eg and Rgr	68	0,64
Nr and Ng	69	0,66
Nr and Rgr	65	0,61
Ng and Rgr	70	0,67
Eg, Nr and Ng	73	0,70
Eg, Ng and Rgr	82	0,80
Eg, Ng and Rgr	86	0,84
Nr, Ng e Rgr	85	0,83
Eg, Nr, Ng and Rgr	85	0,83

Table 3: Analysis of 10 combinations $N \times K_2O$

Table 2. Confusion matrix of the best results classification (combination of the Eg-excess green; Nr-normalized red; Ng-normalized green and Rgr-green-red).

Percentage of image classified into each dose combination.

$N \times K_2O$	0/0	60/0	120/0	180/0	240/0	300/0	0/30	60/30	120/30	180/30	240/30	300/30	0/60	60/60	120/60	180/60	240/60	300/60	0/90	60/90	120/90	180/90	240/90	300/90
0/0	50	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	10	0	0	0	0	30	0
60/0	0	20	0	0	0	0	0	0	30	0	0	0	0	20	10	10	0	0	0	0	0	10	0	0
120/0	0	0	80	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	10	0	0	0
180/0	0	0	0	40	0	20	0	0	0	0	0	0	0	0	0	0	0	10	0	20	0	0	0	10
240/0	0	0	0	0	30	0	40	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0
300/0	0	10	0	30	0	10	0	0	0	0	0	0	0	20	0	0	0	0	0	10	0	0	0	20
0/30	0	0	0	0	50	0	40	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
60/30	0	0	0	10	0	0	0	40	0	0	0	0	10	0	0	20	0	0	0	10	0	0	0	10
120/30	0	0	0	0	0	0	0	0	60	0	0	0	0	10	0	0	0	0	0	0	30	0	0	0
180/30	10	0	30	0	0	0	0	0	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
240/30	0	0	0	0	10	0	10	0	0	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0
300/30	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	10	0	10	30	0	10
0/60	0	0	0	0	0	0	0	10	0	0	0	10	60	0	0	0	0	0	10	0	0	10	0	0
60/60	0	10	0	0	0	10	0	10	0	0	0	0	0	10	0	40	0	0	10	10	0	0	0	0
120/60	0	10	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	50	0	0	0
180/60	0	0	0	20	0	10	0	20	0	0	0	0	0	30	0	0	0	0	0	10	0	0	0	10
240/60	0	10	0	0	0	0	0	0	0	0	0	10	0	0	0	0	70	0	0	0	0	10	0	0
300/60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	0	10	0	0	0	0
0/90	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	70	0	10	0	0	10
60/90	0	0	0	20	0	20	0	0	0	0	0	0	0	0	0	20	0	0	0	30	0	0	0	10
120/90	0	10	0	0	0	0	0	0	0	0	0	10	0	0	30	0	0	0	10	0	40	0	0	0
180/90	0	0	0	0	0	10	0	0	0	0	0	40	0	0	0	0	10	0	0	0	0	40	0	0
240/90	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	0
300/90	0	10	0	0	0	0	0	40	0	0	0	0	0	10	0	10	10	0	0	0	0	10	0	10

Tables 2 and 4 show the confusion matrix of best performance of classification, whereas in their diagonal the amount of images that were correctly classified. In the lines, it can be seen the amount of images that the system assigned to another class (wrong of interpretation).

Table 4. Confusion matrix of the best results classification (combination of the Eg-excess green; Nr-normalized red and Rgr-green-red).

Percentage of image classified into each dose combination.

$N \times K_2O$	0/0	120/0	120/30	180/30	240/30	0/60	240/60	300/60	0/90	240/90
0/0	70	0	0	10	0	0	0	10	10	0
120/0	0	90	0	10	0	0	0	0	0	0
120/30	0	0	100	0	0	0	0	0	0	0
180/30	10	20	0	50	0	0	0	20	0	0
240/30	0	0	0	0	100	0	0	0	0	0
0/60	0	0	0	0	0	100	0	0	0	0
240/60	0	0	0	0	0	1	90	0	0	0
300/60	0	0	0	30	0	0	0	70	0	0
0/90	0	0	0	0	0	1	0	0	90	0
240/90	0	0	0	0	0	0	0	0	0	100

CONCLUSION

Nitrogen fertilization promoted increases in leaf N concentration, implying quadratic effects in grain yield. Spectral indices enabled the identification of nutritional patterns of N and K at V6 stage of maize.

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