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Cientific Paper

Anticipation of nitrogen fertilization and their implications on nutrient concentrations and maize yield

Flávia M. Nascimento[1]
Sílvio J. Bicudo[2]
Dirceu M. Fernandes[2]
José G. L. Rodrigues[3]
Jairo C. Fernandes[4]

Abstract

The objective of this study is to evaluate the response of maize crop in succession to winter crops, with the anticipation of nitrogen applications on the black oat crop, in increasing doses, in no–tillage system. The experiment was conducted at the FCA/UNESP, Botucatu *campus*. The experimental design used was randomized blocks with four replications, in a scheme of subdivided plots. The parcels of 0, 20, 40 e 60 kg ha^{-1} of nitrogen doses were applied on the black oat crop and the doses applied to the maize crop were considered subparcels, varying in the following doses: 60, 80, 100 and 120 kg ha^{-1}, applied in two parcel in the maize crop. The foliar diagnosis was carried, by occasion, at the flourish and after harvest the productivity was calculated. The results indicate that the effect of the anticipated application of N in maize is dependent on the former crop, and that the doses and time of those applications had influenced in the concentrations of the nutrients, reflecting in the productivity of the maize crop.

Keywords: fertilizer; management of fertilizer; mineral nutrition.

Antecipação da adubação nitrogenada e suas implicações na concentração de nutrientes e produtividade do milho

Resumo

O objetivo da pesquisa foi avaliar a resposta da cultura do milho em sucessão à culturas de inverno, havendo a antecipação da aplicação do nitrogênio na cultura da aveia, em doses crescentes, no SPD. O experimento foi conduzido na FCA/UNESP, Campus de Botucatu-SP. O delineamento experimental foi de blocos ao acaso com quatro repetições, em parcelas subdivididas, sendo consideradas parcelas as doses de nitrogênio aplicadas na cultura da aveia: 0, 20, 40 e 60 kg ha^{-1} e as doses de nitrogênio aplicadas em cobertura na cultura do milho, foram consideradas subparcelas, variando nas seguintes doses: 60, 80, 100 e 120 kg ha^{-1}, aplicados de forma parcelada em dois estádios da cultura do milho. A diagnose foliar foi feita por ocasião do florescimento e após a colheita foi calculada a produtividade. Os resultados indicam que a aplicação antecipada de N na cultura do milho é dependente da cultura antecessora e que as doses e épocas destas aplicações influíram nas concentrações dos nutrientes, refletindo na produtividade do milho.

Palavras chave: fertilizantes; manejo de adubação; nutrição mineral.

Anticipación del aporte del abono nitrogenado y sus implicaciones en concentración de nutrientes y productividad del maíz

Resumen

El objetivo de la investigación fue evaluar la respuesta del maíz en la sucesión de los cultivos de invierno, con la anticipación de la aplicación de nitrógeno en el cultivo de avena, en dosis crecientes, en sistema de siembra directa - SPD. El experimento se realizó en la FCA/UNESP, campus de Botucatu-SP. El diseño experimental fue de bloques al azar con cuatro repeticiones, en parcelas divididas, las parcelas se consistieran del nitrógeno aportado en la avena: 0, 20, 40 y 60 kg ha^{-1} de nitrógeno y

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1 Professor of the Universidade Estadual do Sudoeste da Bahia-UESB Estrada do Bem Querer, Km 04, CEP: 45031-900, Vitória da Conquista, BA, Brazil. E-mail:flavia10meinicke@gmail.com Author for correspondence
2 Professors of the Universidade Estadual Paulista – UNESP- Botucatu/SP
3 Professor of the Educational Association of the Jurumim Vale – EDUVALE-Avaré/SP
4 Professor of the Instituto Federal Baiano – IFBA- Itapetinga/BA

las dosis aportadas en cobertura en cultivo del maíz, consistieron en las parcelas secundarias, con las siguientes dosis: 60, 80, 100 y 120 kg ha^{-1}, aportado de forma dividida en cuotas en dos etapas de desarrollo del maíz. El análisis de las hojas fue tomada durante la floración y después de la cosecha se calculó el rendimiento total. Los resultados indican que el aporte anticipado de N en el maíz depende del cultivo anterior y que las tasas y las épocas de estas aplicaciones influyeron en las concentraciones de nutrientes, lo que influencia en la productividad del maíz.

Palabras clave: fertilizantes; el manejo del abono; nutrición mineral.

Introduction

The maize crop is found among those with greatest potential of production of phytomass per unit of area. However, for getting this high biological yield, the maize needs to have its nutritional demands fully attended, since elevated productivities imply great extraction of nutrients (SANGOI and ALMEIDA, 1994).

The knowledge of these quantities allows estimating the rates which are going to be exported through the grains harvest and the ones which can be restituted to the soil through the crop residues (BÜLL, 1993).

According to MAR et al. (2003), to obtain maximum efficiency of the nitrogen fertilizer is important to determine the seasons in which this nutrient is more demanded by the plants, thus allowing, to correct the deficiencies which may occur in the crop development. The efficiency of the nitrogen fertilizer is dependent of the weather conditions, such as of soil type, acidity, clay content, cultivars, preceding crop, distribution of rains, levels of nitrogen fertilization and its interaction with other nutrients (SIMS et al., 1998).

The type of vegetal residue in decomposition on the soil surface, in the no-tillage system, can affect the efficiency of the use of nitrogen fertilization on the crop in succession. In the case of black oats, due to the high carbon/nitrogen relation (C/N) of its residues, occur losses with relation to the balance of N on the soil, when is cultivated maize in succession, due to the immobilization of N, lowering its availability to the maize in the early stages of development (WOLSCHICK et al., 2003).

Besides the characteristic symptoms of one or another disorder, which manifest only in severe cases, the identification of the nutritional status of the plant only is possible through chemical analysis of the same. The use of the leaf analysis as diagnosis criteria is based on the premise that exist a well defined relation between the growth and the production of the crops and the nutrients content in its tissues. The leaf diagnosis has been used in the following situations (MARTINEZ et al., 1999): a) in the evaluation of the nutritional status of the probability of response to the fertilizations; b) in the verification of the nutritional balance; c) in the observation of the occurrence of deficiencies or toxicity of nutrients; d) in the accompaniment, evaluation and assistance in the adjustment of the fertilization program; e) in the occurrence o high salinity in irrigated areas or hydroponic crops.

The correct use of the leaf diagnosis, as method of evaluation of the plant nutritional status depends of the knowledge of the limitations of the technique. It is necessary to question the reliability of the data, the use of the relation and balance of the nutrients, the effect of cultivars and of variable concentrations of nutrients changing the physiological processes (JONES et al., 1991).

As stated by ARNON (1975), the stage of development more used for the leaf diagnosis of maize is the flowering, which corresponds to eleven weekends after the planting, for constituting a stage of great demand of nutrients for most of the varieties. HIROCE et al. (1979) showed that exist genetic differences in the absorption of nutrients and in the efficiency of conversion of the assimilated elements in production of maize grains.

Considering the hypothesis that the effect of anticipation of the application of N in the maize crop is dependent of the preceding crop, the present study had as aim to assess the influence of the doses and seasons of application of N and its interferences in the concentrations of the nutrients, done through the leaf diagnosis and its relations with the productivity of the maize in no-tillage system.

Material and Methods

The experiment was conducted at the FCA/UNESP - Botucatu-SP, latitude of 22º 51' S, longitude 48º 26' W and 740 meters of altitude, in soil classified as Nitossolo Vermelho Distroférrico[1] (EMBRAPA,

1 Brazilian soil classification.

2006), clayey texture. The region's weather, according to the Köppen classification, is of the type Cfa, being defined as temperate (mesothermal), region constantly humid, having four or more months with average temperature superior to 10 °C, where the temperature of the hottest month is equal or superior to 22 °C.

The Figures 1 and 2 present the data of the rainfall (mm month^{-1}) and the maximum and minimum temperatures and monthly averages (°C) from the months of April 2006 to April 2007.

The experiment was installed in a planting area of first year, where the straw in this area was derived from maize crop. Before the installment of the experiment, it was collected a sample composed of soil, whose chemical analysis results are found in Table 1.

The experimental design used was

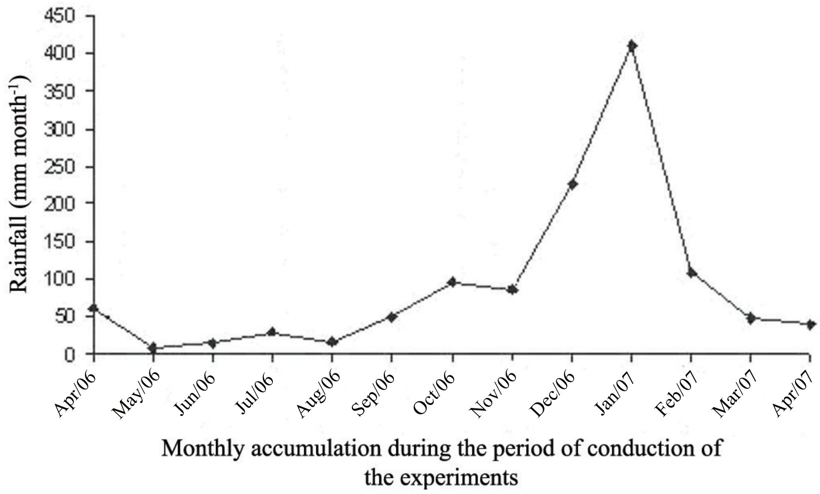


Figure 1. Monthly accumulation of the rainfall (mm month^{-1}) registered during the conduction of the experiment, Botucatu/ SP.

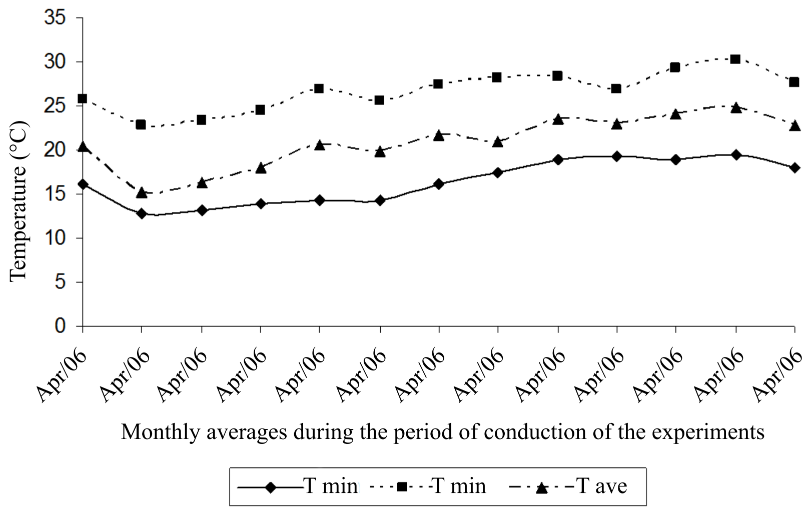


Figure 2. Maximum and minimum temperatures and monthly averages, registered during the conduction of the experiment, Botucatu/ SP.

Table 1. Chemical characterization of the soil of the area where was installed the experiment.

pH	M.O.	P resin	H+Al	K	Ca	Mg	SB	CTC	V
$CaCl_2$	g dm^{-3}	mg dm^{-3}			$mmol_c$ dm^{-3}				%
5.3	24	34	41	2.2	47	20	63	109	63

randomized blocks with four replications, in a scheme of subdivided plots. The plots were constituted of a black oats crop with four treatments, being the cause of variation the doses of nitrogen: 0, 20, 40 and 60 kg ha^{-1}. The nitrogen was applied on the line, manually, on the surface of the soil without incorporation, 15 days before the cutting of the oats and then was done irrigation after the application. The source used was the urea. The plots had the dimensions of 4x20 m with spacing of 0.17 m between lines and 80 seeds m^{-1}.

The subplots constituted of maize crop with four sub treatments, being cause of the variations the doses of nitrogen: 60, 80, 100 e 120 kg ha^{-1} of N. The source of N was the urea. The top dressing in the maize crop was plotted in the following way: 1st application in the stage of 3 to 4 leaves, when 50% of the doses were applied; and the 2nd application in the stage of 6 to 7 leaves fully distended, occasion in which were applied the remaining 50%. The nitrogen was applied on the line, manually, on the soil surface without incorporation and was also done, after the applications, irrigations. The subplots had the dimensions of 4x5 m, with lines of sowing having spacing of 0.45 m with a population of 50000 plants ha^{-1}. It was applied supplemental water through sprinklers in the oat crop, totalizing 425.5 mm of water, during the whole cycle of the crop, according with the water requirement of the plants. Soil samples were collected at a depth of 0 to 0.20 m, for chemical characterization of the area (Table 1), before the installment of the experiment.

The oat was sowed at July 13th of 2006, with spacing of 0.17 m between lines and 80 seeds m^{-1}, using seeder to thin grains. It was used 4 L ha^{-1} of the desiccant Gliz 480 SL (gliphosate), before the sowing of the oat. The cutting of the oats was done by occasion of the flowering, with a brushcutter at the 123 days after sowing (DAS). It was not used seeds treatments, neither applied chemical products to control plagues and diseases during the cycle.

The maize was sowed manually at November 23rd of 2006, with 5 lines having 0.45 m of spacing, using the simple hybrid 2A525, of early cycle, midsize to tall, orange coloration, semi-hard texture, of the Dow AgroScience Company. It was not used seeds treatments. It was used 2.5 kg ha^{-1} of Round-up (gliphosate) to desiccation of the area. The lateral two lines were considered surrounds and the three central harnessed, for the assessments.

The fertilization of the maize sowing was based in the soil analysis and in the Recommendation Table for the state of São Paulo (RAIJ et al., 1997). The mineral fertilization in the sowing was 107 kg ha^{-1} of the formula 08-28-16, equivalent to 8.5 kg of N, 30 kg ha^{-1} of P_2O_5 and 17 kg ha^{-1} of K_2O.

It were made applications of 0.4 L ha^{-1} of the herbicides of post emergence, Sanson 40SC (nicosulfuron); 3.0 L ha^{-1} of Atrazina Nortox 500 SC (atrazine) and 50 mL ha^{-1} of the insecticide Tracer (spinosad) to control the Spodoptera (*Spodoptera frugiperda* L.). The maize harvest was done manually at April 12nd of 2007, 140 days after the emergence.

The collection of leaves to leaf diagnosis was done at the season of flowering, being retrieved the leaf of the corn ear base at the middle third of the plant, in four plants per subplot, when 50% of the plants had already emitted the tassel, according to the method described by CANTARELLA et al. (1997). For the determination of the productivity, were collected all corn ears in the three central lines of each subplot, which presented 5 m of length. The result is expressed in kg ha^{-1}, being the content of water adjusted to 13%.

The data were submitted to the variance analysis and compared through the F test. The regression equations and the coefficients of determination (R^2) had its significance tested at the level of 5% of probability and considered significant when R^2 was superior to 60%. The models were adjusted by the T test at 5% of probability, and only when the results were meaningful were presented such models, independent of the F test was significant or not.

Results and Discussion

For the nitrogen in the plant at the time of the leaf diagnosis was obtained linear adjustment for the doses of N applied in the oat (Equation 1), being that the higher value presented for the content of this element was achieved through the application of 60 kg ha^{-1} of N in the oat and 100 kg ha^{-1} of N in the maize (Figure 3).

$y = 0.045x + 22.4$; ($R^2 = 0.66$) (Eq. 1)
CV (%) = 16.26

Now at analyzing the effect of the nitrogen doses applied in the maize (Equation 2 and 3), it can be observed that was obtained increasing linear adjustment, when there is absence of N application and also when was done application of 40 kg ha^{-1} of N in the oat, associated to the highest dose applied in the maize, 120 kg ha^{-1} of N, was the combination of doses which provided greater content of N in the maize plants. The values found for the contents of nitrogen are below the adequate range for the crop, which is of 27.0 to 35.0 g kg^{-1} of N. This fact must have occurred due to the immobilization of nitrogen in function of this experiment has been installed on maize straw (Figure 4).

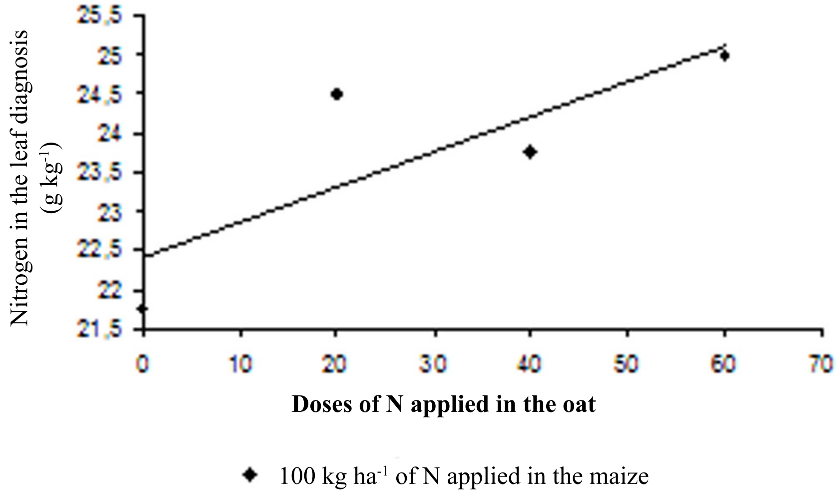


Figure 3. Nitrogen in the leaf diagnosis (g kg^{-1}) in function of the doses of N applied in the oat, when applied 100 kg ha^{-1} of N in the maize.

$y = 0.045x + 17.075$; ($R^2 = 0.93$) (Eq. 2)
CV (%) = 8.26

$y = 0.0675x + 16.55$; ($R^2 = 0.95$) (Eq. 3)
CV (%) = 8.26

For the phosphorus was obtained decreasing linear adjustment in function of the doses of N applied in the oat (Equation 4), through the application of the highest dose in the oat, 60 kg ha^{-1} of N, associated to the dose of 60 kg ha^{-1} of N in the maize, was obtained the smallest value for the content of this nutrient (Figure 5).

$y = -0.007x + 2.88$; ($R^2 = 0.70$) (Eq. 4)
CV (%) = 32.93

For the doses of nitrogen applied in the maize crop was obtained quadratic adjustment (Equation 5), being that the higher value for the content of phosphorus was found with combination of the doses of 95.5 kg ha^{-1} of N in the maize and 60 kg ha^{-1} of N in the oat (Figure 6).

$y = -0.0004x^2 + 0.0764x – 0.8012$; ($R^2 = 0.99$) (Eq. 5)
CV (%) = 9.92

For the potassium in the plant was obtained increasing linear adjustment for the doses of N applied in the oat (Equation 6), being that the greater response for the content of this element was found when it was applied 60 kg ha^{-1} of N in the oat and 80 kg ha^{-1} of N in the maize (Figure 7).

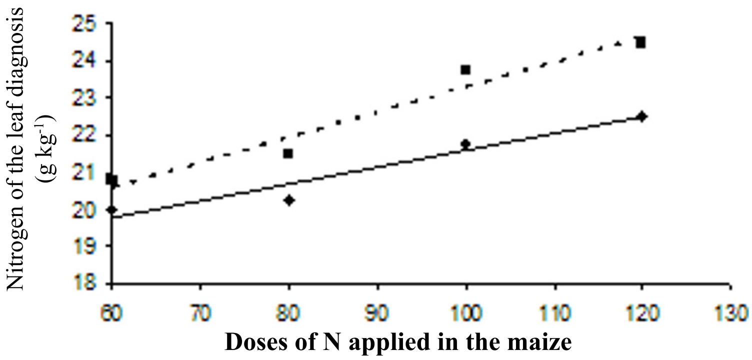


Figure 4. Nitrogen in the leaf diagnosis (g kg^{-1}) in function of the doses of N used in the maize, when applied 0 kg ha^{-1} and 40 kg ha^{-1} of N in the oat.

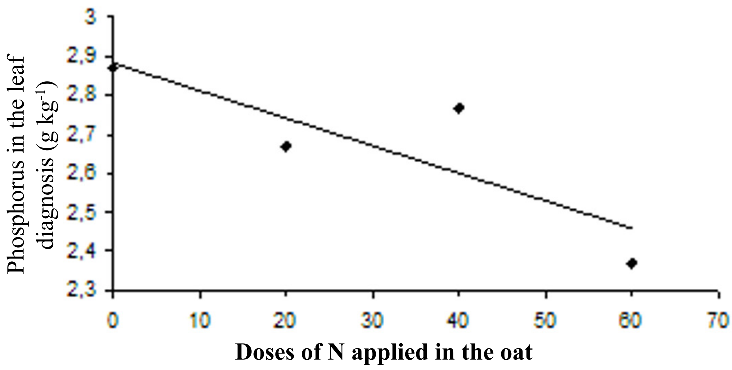


Figure 5. Phosphorus on the leaf diagnosis (g kg^{-1}) in function of the doses of N used in the oat, when it was applied 60 kg ha^{-1} of N in the maize.

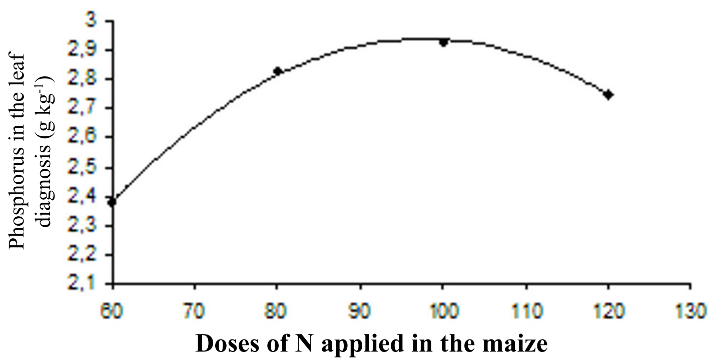


Figure 6. Phosphorus on the leaf diagnosis (g kg^{-1}) in function of the doses of N applied in the maize, when it was applied 60 kg ha^{-1} of N in the oat.

$y = 0.0338x + 23.675$; ($R^2 = 0.66$) (Eq. 7)
CV (%) = 6.5

For the nitrogen doses applied in the maize crop was obtained increasing linear adjustment (Equation 7), being that the maximum values for the potassium were found when was 120 kg ha^{-1} of N in the maize and 20 kg ha^{-1} of N in the oat (Figure 8). Equation 7: $y = 0.0463x + 19.9$; ($R^2 = 0.99$); CV (%) = 5.37

However it can be also observed that was obtained quadratic adjustment for the doses of N applied in the maize (Equation 8), being the maximum value for the content of potassium obtained with the combination of 94.7 kg ha^{-1} of N in the maize and 60 kg ha^{-1} of N in the oat. Therefore, it can be considered that for the conditions in which the experiment was carried out, the maximum values for the content of potassium in the maize leaves were found at the range of 20 to 60 kg ha^{-1} of N in the oat and 95 kg ha^{-1} of N in the maize, when applying doses of N in the maize (Figure 8).

$y = -0.0019x^2 + 0.36x + 8.6$; ($R^2 = 0.80$) (Eq. 8)
CV (%) = 5.37

For the calcium was obtained increasing linear adjustment for the doses of nitrogen applied in the oat (Equation 9), being that the maximum value for the content of this nutrient was obtained through the combination of the maximum dose in the oat, 60 kg ha^{-1} of N, and 100 kg ha^{-1} of N in the maize (Figure 9).

$y = 0.01x + 2.825$; ($R^2 = 0.64$) (Eq. 9)
CV (%) = 24.77

For the magnesium was obtained quadratic adjustment for the doses of N applied in the maize (Equation 10), presenting maximum value for the content of this element when was applied 86.5 kg ha^{-1} of N in the maize and 60 kg ha^{-1} of N in the oat (Figure 10).

$y = -0.0003x^2 + 0.0519x – 0.3$; ($R^2 = 0.81$) (Eq. 10)
CV (%) = 8.85

For the sulfur was obtained increasing linear adjustment in function of the doses of N applied in the oat crop (Equation 11), being that the maximum value for the content of this element was obtained when was applied 60 kg ha^{-1} of N in the oat and 100 kg ha^{-1} of N in the maize (Figure 11).

$y = 0.007x + 1.79$; ($R^2 = 0.90$) (Eq. 11)
CV (%) = 14.99

For the doses of the nitrogen fertilizer applied in the maize was also obtained increasing linear adjustment (Equations 12 and 13), being that the highest values for the contents of sulfur in the maize plants were obtained when was applied 20 kg ha^{-1} and 60 kg ha^{-1} of N, in the oat when combined with

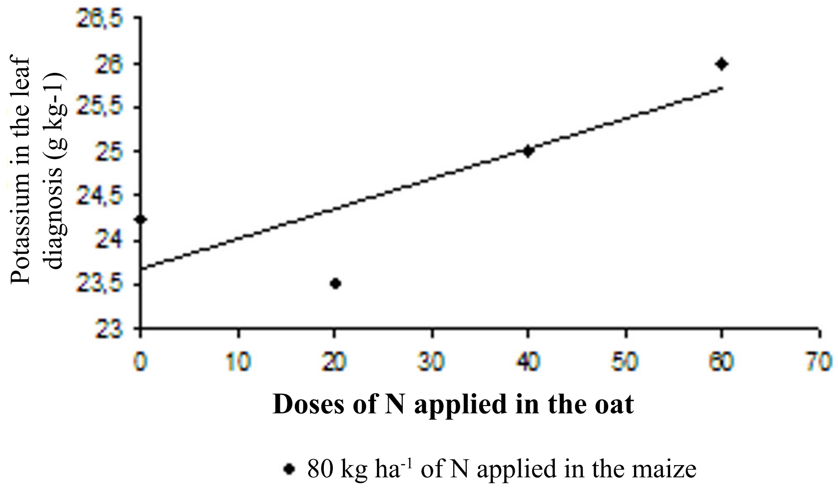
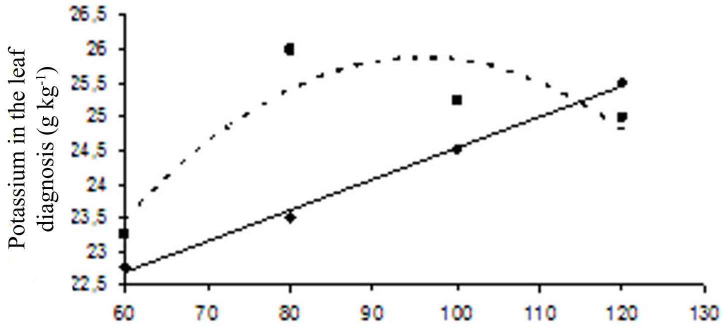


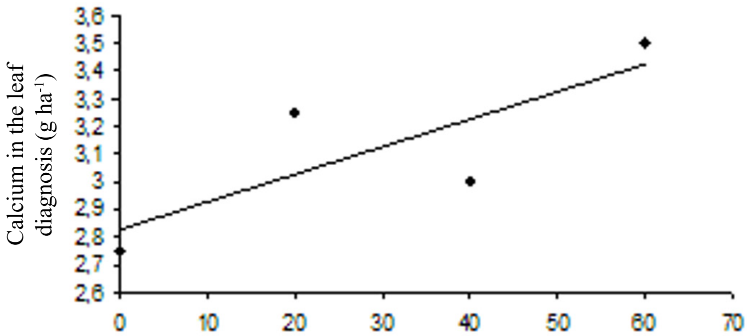
Figure 7. Potassium in the leaf diagnosis (g kg^{-1}) in function of the doses of N applied in the oat, when it was applied 80 kg ha^{-1} of N in the maize.



Doses of N applied in the oat

◆ 20 kg ha^{-1} of N applied in the oat
■ 60 kg ha^{-1} of N applied in the oat

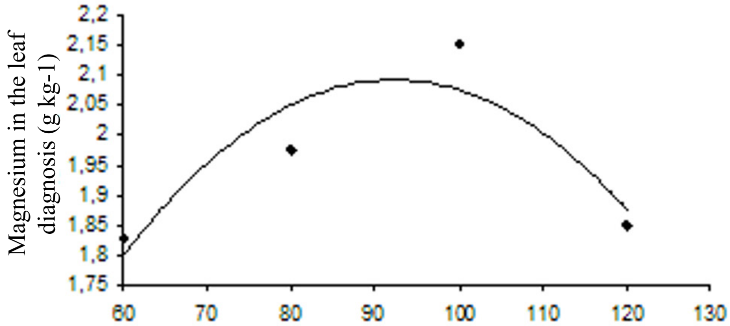
Figure 8. Potassium in the leaf diagnosis (g kg^{-1}) in function of the doses of N applied in the maize, through the application of 20 kg ha^{-1} and 60 kg ha^{-1} of N in the oat.



Doses of N applied in the oat

◆ 100 kg ha^{-1} of N applied in the maize

Figure 9. Calcium in the leaf diagnosis (g kg^{-1}) in function of the doses of N applied in the oat, when applied 100 kg ha^{-1} of N in the maize.



Doses of N applied in the maize

◆ 60 kg ha^{-1} of N applied in the oat

Figure 10. Magnesium in the leaf diagnosis (g kg^{-1}) in function of the doses of N applied in the maize, when applied 60 kg ha^{-1} of N in the oat.

the application of the maximum dose in the maize, 120 kg ha^{-1} of N (Figure 12).

$y = 0.0066x + 1.1725$; ($R^2 = 0.85$) (Eq. 12)
CV (%) = 9.36

$y = 0.0073x^2 + 1.302$; ($R^2 = 0.79$) (Eq. 13)
CV (%) = 9.36

However was also obtained quadratic adjustment for the doses of N applied in the maize (Equation 14), being that the highest value for the content of this nutrient was obtained with the combination 83.2 kg ha^{-1} of N in the maize and 40 kg ha^{-1} of N in the oat (Figure 12).

$y = -0.0003x^2 + 0.0499x - 0.1912$; ($R^2 = 0.99$) (Eq. 14)
CV (%) = 9.36

In this way, it can be considered that for the conditions in which the experiment was carried out, the highest values for the content of sulfur were found

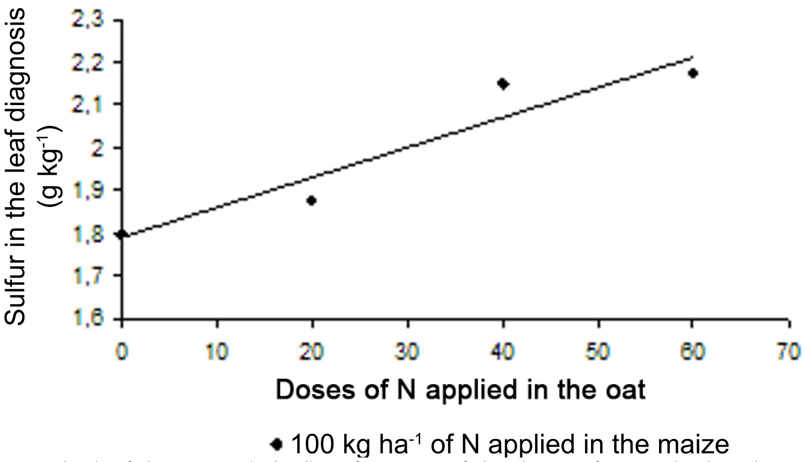


Figure 11. Sulfur in the leaf diagnosis (g kg^{-1}) in function of the doses of N applied in the oat, when applied 100 kg ha^{-1} of N in the maize.

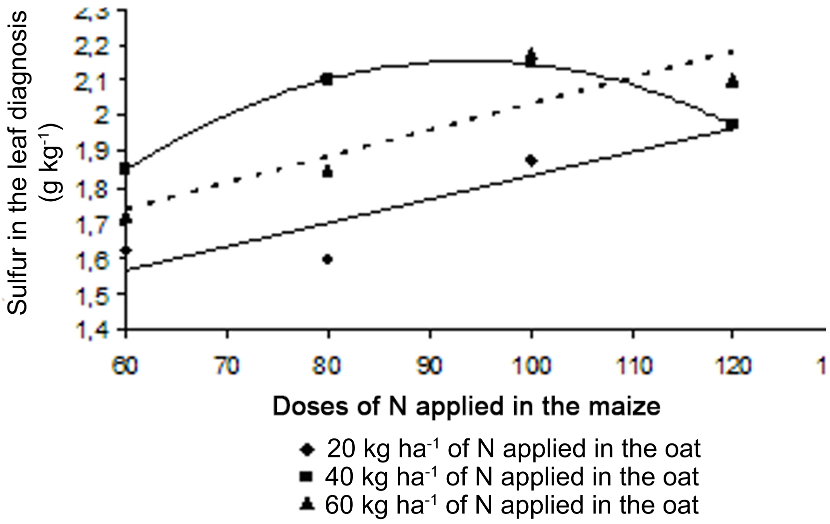


Figure 12. Sulfur in the leaf diagnosis (g kg^{-1}) in function of the doses of N applied in the maize, when applied 20; 40 and 60 kg ha^{-1} of N in the oat.

at the range of 20 kg ha^{-1} to 60 kg ha^{-1} of N in the oat and of 85 kg ha^{-1} to 120 kg ha^{-1} of N in the maize, when were applied the doses of the nitrogen fertilizer in the maize crop.

The boron did not present a significant effect and therefore was not possible to establish a model.

For the copper were obtained increasing linear adjustments in function of the doses of nitrogen applied in the maize (Equations 15 and 16), being that the maximum values for the contents of copper were found when was applied 40 kg ha^{-1} of N and 60 kg ha^{-1} of N in the oat associated to the maximum dose applied in the maize, 120 kg ha^{-1} of N (Figure 13).

$y = 0.0238x + 6.55$; ($R^2 = 0.96$) (Eq. 15)
CV (%) = 11.29

$y = 0.045x + 4.575$; ($R^2 = 0.84$) (Eq. 16)
CV (%) = 11.29

For the iron was obtained increasing linear adjustment in function of the doses of the nitrogen fertilizer applied in the maize crop (Equation 17), being that the maximum value for the content of this nutrient was obtained when was applied 60 kg ha^{-1} of N in the oat and 120 kg ha^{-1} in the maize (Figure 14).

$y = 0.6325x + 42.95$; ($R^2 = 0.88$) (Eq. 17)
CV (%) = 20.95

For the manganese was obtained increasing linear adjustment in functions of the doses of N applied in the maize (Equation 18), being that the maximum value for the content of this nutrient was obtained when was applied 20 kg ha^{-1} of N in the oat and 120 kg ha^{-1} of N in the maize (Figure 15).

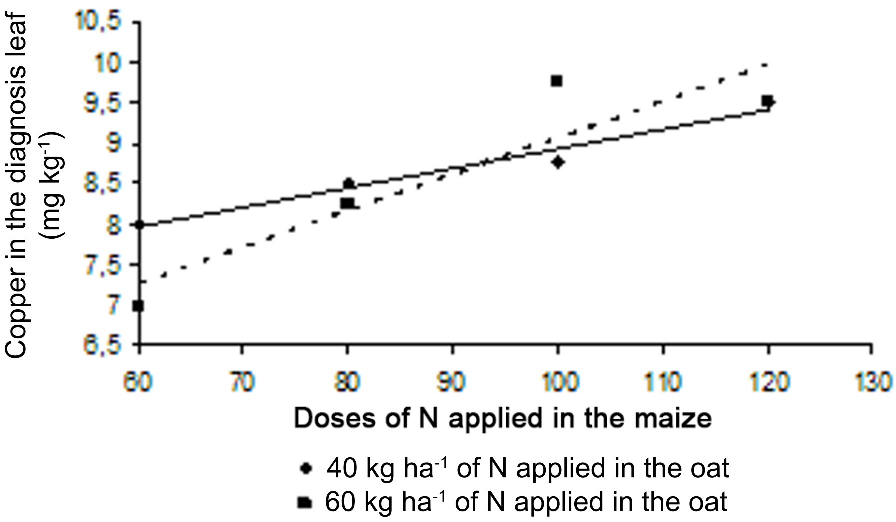


Figura 13. Copper in the leaf diagnosis (g kg^{-1}) in function of the doses of N applied in the maize, when applied 40 and 60 kg ha^{-1} of N in the oat.

$y = 0.2475x + 17.6$; ($R^2 = 0.67$) (Eq. 18)
CV (%) = 14.55

For the zinc was obtained quadratic adjustment in function of the doses of N applied in the maize (Equation 19), being that the maximum value for the content of this nutrient was obtained when was applied 60 kg ha^{-1} of N in the oat and 95.6 kg ha^{-1} of N in the maize (Figure 16).

$y = -0.0036x^2 + 0.6881x - 3.7125$; ($R^2 = 0.79$) (Eq. 19)
CV (%) = 9.52

For yield was obtained quadratic adjustment in functions of the doses of N applied in the oat (Equation 20), being that the association of 100 kg

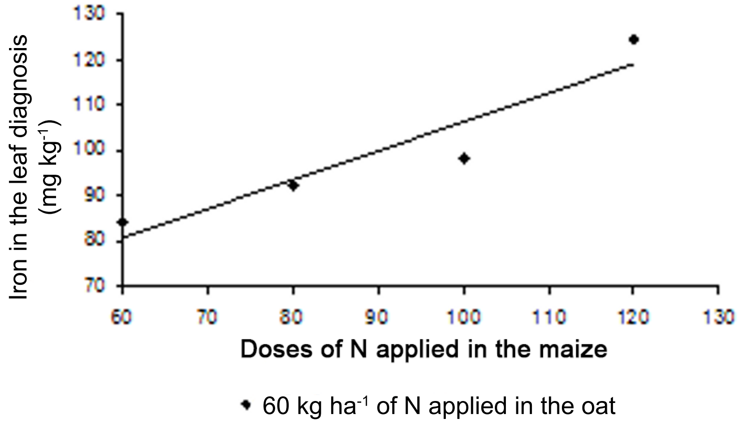


Figure 14. Iron in the leaf diagnosis (mg kg^{-1}) in function of the doses of N applied in the maize, when applied 60 kg ha^{-1} of N in the oat.

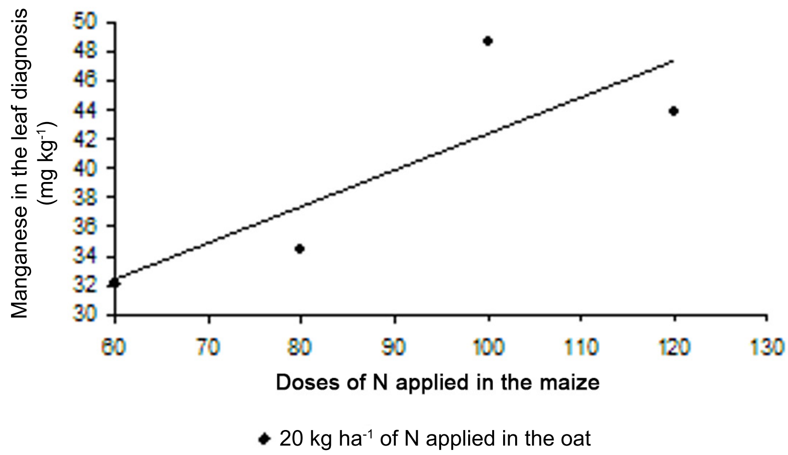


Figura 15. Manganês na folha diagnose (mg kg^{-1}) em função das doses de N aplicadas no milho, quando aplicados 20 kg ha^{-1}de N na aveia.

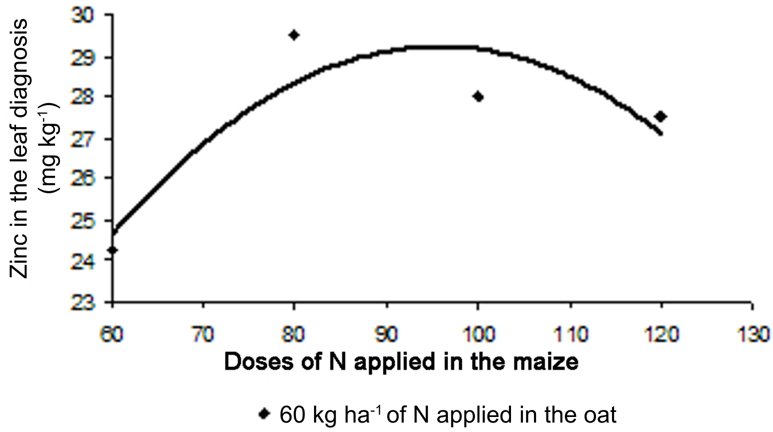


Figura 16. Zinco na folha diagnose (mg kg^{-1}) em função das doses de N aplicadas no milho, quando aplicados 60 kg ha^{-1}de N na aveia.

ha^{-1} of N in the maize and 30.8 kg ha^{-1} of N in the oat, was the combination of doses which allowed to the maize express its greater yield potential (Figure 17).

$y = -1.68x^2 + 103.73x + 5432.8$; ($R^2 = 0.78$) (Eq. 20)
CV (%) = 39.34

For the effect of the doses of nitrogen applied in the maize (Equation 21), it is noted that was obtained increasing linear adjustment, with high value of R^2, 99% being that the maximum value for this characteristic occurred when there was absence of the application of the nitrogen fertilizer in the oat, associated to the application of the maximum dose in the maize, 120 kg ha^{-1} of N (Figure 18).

$y = 26.261x + 2925.8$; ($R^2 = 0.99$) (Eq. 21)
CV (%) = 17.06

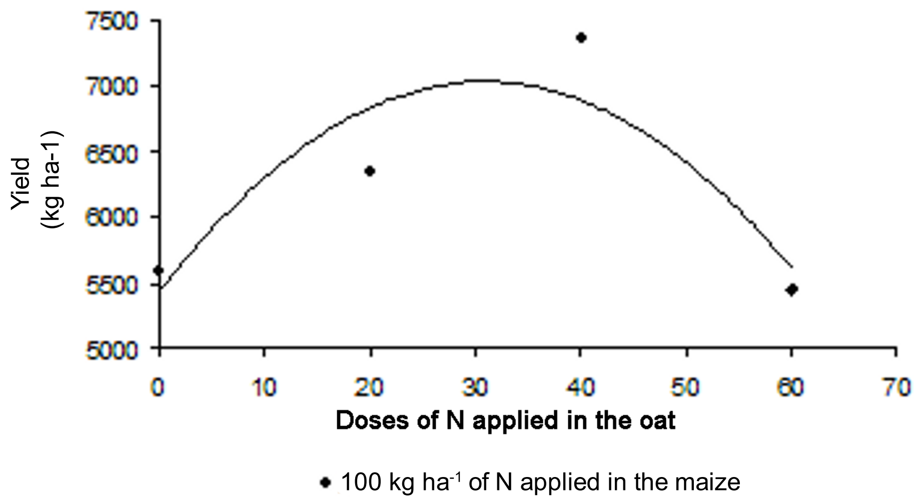


Figura 17. Produtividade do milho (kg ha^{-1}) em função das doses de N aplicadas na aveia, quando aplicados 100 kg ha^{-1}de N no milho.

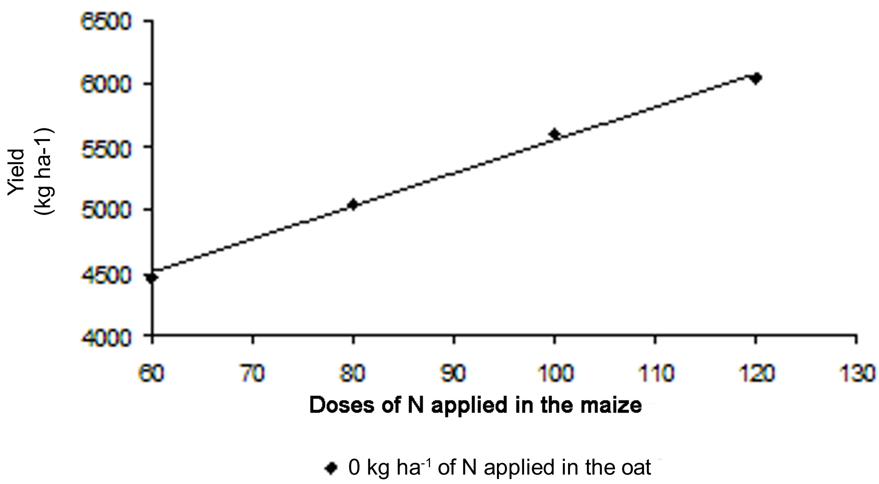


Figure 18. Yield of the maize (kg ha^{-1}) in function of the doses of N applied in the maize, when was applied 0 kg ha^{-1} of N in the oat.

Conclusions

The development and yield of the maize in no-tillage system is dependent of the nutritional status of the plants and that the response of the maize crop to early application of N is function of the doses and seasons of these applications.

The preceding crop is determinant in the content of nutrients of the plants, reflecting in the productivity of the maize crop.

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