FINANCIAL ANALYSIS OF NITROGEN FERTILIZATION IN DRIP-IRRIGATED MAIZE

F. L. F. de Jesus[1], F. H. Campos[2], M. V. Talamini. Junior[3], A. C. Sanches[4], R. G. Maffei[5], F. C. Mendonça[6]

ABSTRACT: The objective of this work was to determine the most adequate nitrogen dose in order to maximize fertilization profitability in six maize hybrids (*Zea mays* L.) under subsurface drip-irrigation. Six different hybrids were studied (H_1, H_2, H_3, H_4, H_5 and H_6) and four different nitrogen doses were applied (0; 60; 120; 180 kg ha^{-1}). This experiment took place during the crop season from November 2016 to March 2017 on an experimental field area at ESALQ-USP, in Piracicaba – SP. The experiment was set in a randomized block design in a factorial scheme (6 x 4) with four replicates. The financial analysis was based on marginal costs and revenues of fertilization compared to control treatment. The analysis was carried considering inputs needs for fertilization and average costs for machinery and workforce of nitrogen application. The nitrogen fertilization had a significant influence ($p<0.05$) on marginal profit per hectare; the highest profitability was obtained at dosage of 180 kg ha^{-1} for hybrids 2, 3, 4 and 6, and at dosage of 120 kg ha^{-1} for hybrids 1 and 5. Profit increase was also significant ($p<0.05$) and had the best results were found for H_6 and H_2 with an increase of 2649.15 and 2633.79 R$ ha^{-1}, respectively, compared to H_5 and H_1 444.03 and 498.91 R$ ha^{-1}, respectively.

KEY WORDS: Profit, fertilizers in maize, maximum financial efficiency.

ANÁLISE FINANCEIRA DA FERTILIZAÇÃO NITROGENADA EM MILHO IRRIGADO POR GOTEJAMENTO

RESUMO: O objetivo deste trabalho foi determinar a dose de nitrogênio mais adequada para maximizar a rentabilidade da fertilização em seis híbridos de milho (Zea mays L.) sob irrigação por gotejamento subterrâneo. Foram estudados seis híbridos diferentes (H_1, H_2, H_3, H_4, H_5 e H_6) e quatro doses de nitrogênio diferentes (0; 60; 120; 180 kg ha^{-1}). Este experimento ocorreu durante

[1]Agricultural and Environmental Engineering, Doctor student in Agricultural Systems Engineering, ESALQ/USP, fernandalamede@usp.br
[2] Master student in Agricultural Systems Engineering, ESALQ/USP, flavio.campos@usp.br
[3] Master student in Agricultural Systems Engineering, ESALQ/USP marcus.talamini@usp.br
[4] Doctor student in Agricultural Systems Engineering, ESALQ/USP, arthur_carniato@hotmail.com
[5] Graduate student in Agronomist, ESALQ/USP, ESALQ/USP, rodolfo.maffei@usp.br;
[6] Doctor professor, Department of Biosystems Engineering - ESALQ/USP, fernandomendonca@usp.br

a safra de novembro de 2016 a março de 2017 em uma área de campo experimental na ESALQ-USP, em Piracicaba-SP. O experimento foi definido em um delineamento de blocos ao acaso em esquema fatorial (6 x 4) com quatro repetições. A análise financeira baseou-se nos custos marginais e nas receitas de fertilização em relação ao tratamento de controle. A análise foi realizada considerando as necessidades de insumos para fertilização e os custos médios de máquinas e mão-de-obra da aplicação de nitrogênio. A adubação nitrogenada teve influência significativa (p <0,05) no lucro marginal por hectare, obteve-se a maior rentabilidade na dosagem de 180 kg ha^{-1} para os híbridos 2, 3, 4 e 6 e na dosagem de 120 kg ha^{-1} Para os híbridos 1 e 5. O aumento do lucro também foi significativo (p<0,05) e os melhores resultados foram encontrados para H_6 e H_2 com um aumento de 2649,15 e 2633,79 R$ ha^{-1}, respectivamente, em comparação com H5 e H1 444,03 e 498,91 R $ ha^{-1}, respectivamente.

PALAVRAS-CHAVE: Lucro, adubação do milho, máxima eficiência financeira.

INTRODUCTION

Corn (Zea mays L.) plays a key role in Brazilian agriculture both in the economy, due to the extensive production chain and because it is a commodity on the rise in the international market, and from the agronomic point of view, composing the crop rotation system (Bono Et al., 2008). The maize crop has high productive potential and stands out because it is very responsive to management systems such as fertilization and irrigation. It is increasingly striking the search for greater productivity at a lower cost and in this way; increasing water productivity has been one of the most important challenges in agriculture.

In recent years, Brazilian culture has undergone important changes in management and cultural practices, which has resulted in significant increases in grain yield (Biscaro et al., 2011). These changes refer to the adoption of seeds of cultivars with higher production potential, changes in spacing and sowing density and improvement in soil quality, irrigation and fertilization (Von Pinho et al., 2009). As in irrigated areas, the risks of crop failure are minimized, producers tend to use fertilizers in higher amounts and even higher than recommended, in the expectation of increased productivity (Pavinato et al., 2008).

Fertilization is an important factor in maintaining maize productivity and has a significant impact on the composition of production costs. It is estimated that nitrogen fertilizers represent 75% of fertilizer costs and approximately 40% of the total cost of crop production, and are sources of environmental pollution of agricultural systems (Machado et al., 1998).

Nitrogen fertilizers when applied to the soil, either manually or mechanically, undergo a series of chemical and microbiological changes, which can result in nutrient loss. In this context, considering the cost of nitrogenous fertilizers, it is fundamental to develop adequate nitrogen fertilization management that aim at the best use of N by the crop (FRANCO; TRIVELIN, 2010).

In recent years, maize cultivation under irrigation has been significantly increased, promoting some changes in crop management practices, through the more intensive use of areas to compensate for high investment, with greater number of crops and crops involved and the possibility of Use of higher fertilizer doses (Pavinato et al., 2008). In this sense, crops under irrigation should be planned for greater economic returns of production and less impact on the environment, since the environmental damages caused by the excessive use of fertilizers, especially nitrogen fertilizers, are large (LINK et al., 2006).

In view of the above, the objective of this work was to determine the most adequate nitrogen dose for grain yield and the best economic return from fertilization with maize under drip irrigation.

MATERIAL AND METHODS

The work was conducted in the agricultural year 2016/17 in the experimental area of ESALQ / USP (Latitude 22º 42 'south and Longitude 47º 38' West, with altitude 546 m) from November 2016 to March 2017. The climate of the region according to Köppen classification is of the Cwa - Subtropical Altitude type, with hot summers, infrequent frost and rainfall concentration in the summer months (KOTTEK et al., 2006). The soil of the region is classified as Latosol eutrophic red nitosol (SANTOS et al., 2010).

The seeds were sown manually, with fertilization of planting of formulation 0-14-14 (N, P2O5, K2O) applying 400 kg ha^{-1}. The cover fertilization was carried out with the nitrogen doses for each treatment on December 10th, 2016. The emergence of the plants occurred in 07 days after sowing. Weed control was performed by manual weeding. The corn hybrids DOW 2B587 (H1), DEKALB 175 Pro (H2), PIONEER 30F53VYHR (H3), DOW 2B587 PW (H4), DOW 2B633PW C4M CRUISER (H5) and St Helena SHS7930 PRO2 (H6) were used.

The plots were irrigated using drip tapes spaced 0.50 m per emitter, with an average flow rate of 1 L h^{-1}, with three lines per plot between rows of plants. Irrigation management was carried out by means of 6 tensiometers installed at 0.20 m depth. The average water tension readings were collected every 4 days with subsequent irrigation when it reached 10 kPa (ANDRADE; STONE, 2011). An irrigation of 20 mm of establishment was carried out for corn germination.

In this way, the irrigation depth to be applied was determined by the difference between the volumetric moisture in the field capacity (θ_{cc}) and the current volumetric moisture (θi), multiplied by the effective root depth (Z), equal to 400 mm. The moisture at the field capacity (θ_{cc}) was considered as the moisture corresponding to the value of $\Psi m = 0.06$ bar (ANDRADE; STONE, 2011). The values of θi were estimated by means of the soil water retention curve, obtained with the aid of a Richard's extractor in the Laboratory of Soils and Water Quality of the ESALQ / USP and adjusted by the equation according to methodology recommended by Van Genuchten (1980).

The accumulated irrigation depth in the experimental period was 34.76 mm distributed in three irrigation events. During the experimental period, there was accumulated rainfall of 700.6 mm, with 407.8 mm in the vegetative stage and 292.6 mm in the reproductive stage.

To evaluate grain yield, the spikes were collected in 1 m linear of plants, with 0.7 m spacing, totaling 0.7 m^2 of area for evaluation of each treatment.

The experiment was conducted in a randomized complete block design in a factorial scheme, being the factor 1 the maize hybrids (in a total of six) and factor 2 nitrogen doses (0, 60, 120 and 180 kg ha^{-1}), with 4 replicates. The experiment consisted of 96 experimental plots with 3.2 by 3.85 m equal to 12.32 m^2 each, totaling 1182.72 m^2. The results were submitted to analysis of variance. The averages for productivity were compared by the Tukey test ($p < 0.05$), while the effects of N doses were evaluated by regression analysis, adopting as criterion to choose the model the magnitude of the coefficients of determination of the significant model to 5% probability by the F test.

The economic analysis of productivity was performed considering the marginal increase in production costs and revenues promoted by nitrogen fertilization, which led to increases in productivity and costs. Fertilizer production and utilization increase data were collected experimentally, while data for products and inputs, mechanization costs and manure for fertilization were estimated considering average values found in the literature.

RESULTS AND DISCUSSION

The increase of productivity for each hybrid at different doses of nitrogen fertilization can be seen in the figure below (Figure 1). There was a high variation in the measured productivity; with an average elevation of 8607 kg $ha^{-}1$, as well as the productivity variation between hybrids was high, indicating varieties better adapted to the region.

It can be observed that in Figure 1, the hybrids H1 and H5 performed different behavior to the other hybrids studied at the doses of 120 and 180 kg ha^{-1} of N applied, where there was a slight decrease in grain yield, indicating the dose of 120 kg ha^{-1} as the maximum dose which provides higher productivity of these two hybrids.

In irrigated crops, fertilization levels can be increased, since the risks of loss of productivity due to water deficit are minimized (CERETTA & SILVEIRA, 2001). Pavinato et al. (2008) observed that the application of increasing doses of N resulted in increased grain yield, which corroborates the results found in the present work for hybrids H2, H3, H4 and H6. However, it is important to point out that the N doses to obtain the maximum efficiency of grain yield is observed in irrigated cultivation, which can decrease a lot in dry cultivation.

The incremental cost of fertilization per hectare was calculated for each dosage level considered and its average was R$ 621.47 per hectare. This cost considered the purchase of total urea required fertilizing the area in the respective dosage and the variation of total operational costs analyzed between production systems with and without nitrogen fertilization. All values found in literature were deflated to better represent the present value.

In this way, the return of the fertilization practice was analyzed by the coefficient between investment and financial return of the practice, in R $, presented in figure 2. It can be seen that the practice was highly profitable, presenting the minimum and maximum ratios of 2.3 and 5.9 (R$ revenue / R$ cost) respectively.

The incremental profit of nitrogen fertilization, in R$ ha^{-1} for the different hybrids studied is shown in Figure 3.

It is possible to observe that only hybrids 1 and 5 did not obtain maximum results in the dose of 180 kg ha^{-1}. This can be justified not only by the slight reduction in productivity (Figure 1) as well as by the increase in input costs at higher doses (Table 1).

Table 1 shows the financial results obtained for each nitrogen dosage studied for all hybrids. It can be seen that increasing the dosage in this experiment has increased profitability. It is also noted that the increase in dosage was not directly proportional to the increase in dosage due to the dilution of the contributions in fixed costs, increasing only the variable cost of the acquisition of this input.

The analysis of the productivity data and the relationship of nitrogen to the applied nitrogen dose (Table 1), determined the most economically feasible nitrogen dose (180 kg ha^{-1} of N), considering the price of Urea at R$ 91.16 per kg and the sack at 60 kg corn at R$ 26.60.

Bono et al. (2008) evaluated the effect of the application of nitrogen in the form of urea in cover and via foliar in the agronomic characteristics and productivity of corn irrigated by central pivot and concluded that the financial analysis indicated, however, that the dose of 90 kg ha^{-1} of

N, applied through cover or foliar route, as the one that provided greater financial profitability for the crop.

CONCLUSIONS

Productivity was affected by doses of N.

The maximum yield of corn grains under subsurface drip irrigation and maximum economic efficiency are obtained with the application of 180 kg ha-1 of N applied to nitrogen in hybrids H2, H3, H4 and H6.

The type of hybrid chosen directly influences the production and economic efficiency, in response to the proposed investment, be it fertilization or irrigation.

REFERENCES

MACHADO, A.T.; SODEK, L.; DOBEREINER, J.; REIS, V. M. Efeito da adubação nitrogenada e da inoculação com bactérias diazotróficas no comportamento bioquímico da cultivar de milho nitroflint. **Pesquisa Agropecuária Brasileira**, n.33, p.961-970, 1998.

BISCARO, G. A.; MOTOMIYA, A. V. A.; RANZI, R.; VAZ, M. A. B.; PRADO, E. A. F. do; SILVEIRA, B. L. R. Desempenho do milho safrinha irrigado submetido a diferentes doses de nitrogênio via solo e foliar. Revista Agrarian, v.4, n.11, p.10-19, 2011.

ANDRADE, R. D. S.; STONE, L. F. Estimativa da umidade na capacidade de campo em solos sob Cerrado. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 15, n. 2, p. 111–116, 2011.

FERNANDES, F.C.S.; BUZETTI, S.; ARF, O.; ANDRADE, J.A.C. Doses, eficiência e uso de nitrogênio por seis cultivares de milho. **Revista Brasileira de Milho e Sorgo**, v. 4, n. 2, p. 195-204, 2005.

FORNASIERI FILHO, D. **Manual da cultura do milho**. São Paulo: Funep, 2007. 574 p.

FRANCISCO, de A. S. e S.; CARLOS, A. V. de A. The Assistat Software Version 7.7 and its use in the analysis of experimental data. **African Journal of Agricultural Research**, v. 11, n. 39, p. 3733–3740, 29 set. 2016.

FREIRE, F. M.; VIANA, M.C.M.; MASCARENHAS, M.H.T.; PEDROSA, M.W.; COELHO, A.M.; ANDRADE, C.L.T. Produtividade econômica e componentes da produção de espigas verdes de milho em função da adubação nitrogenada. **Revista Brasileira de Milho e Sorgo**, v.9, n. 3, p. 213- 222, 2010.

KOTTEK, M.; GRIESER, J.; BECK, C.; RUDOLF, B.; RUBEL, F. World map of the Köppen-Geiger climate classification updated. **Meteorologische Zeitschrift**, v. 15, n. 3, p. 259–263, 2006.

OKUMURA, R. S.; MARIANO, D.C.; ZACCHEO, P. V. C. Uso de fertilizante nitrogenado na cultura do milho: uma revisão. **Revista Brasileira de Tecnologia Aplicada nas Ciências Agrárias**, v. 4, n. 2, p. 226–244, 2011.

PAVINATO, P. S.; CERETTA, C. A.; GIROTTO, E.; MOREIRA, I. C. L. Nitrogênio e potássio em milho irrigado: análise técnica e econômica da fertilização. **Ciência Rural**, Santa Maria, v.38, n. 2, p. 358-364, 2008.

SANTOS, R. D. dos; PEREIRA, L. G. R.; ARAÚJO, G. G. L. de; VOLTOLINI, T. V.; MORAES, S. A. de; NEVES, A. L. A.; COSTA, C. T. F. Consumo e Digestibilidade Aparente das Silagens de Seis Genótipos de Milho Precoce ou Super-Precoce. **Revista Científica de Produção Animal**, v. 12, n. 2, p. 188–191, 2010.

SILVA, S. F. da; GARCIA, G. de O.; REIS, E. F. dos; DALVI, L. P. Uso agrícola da vinhaça para produção de forragem de milho durante três anos de cultivo. **Irriga**, v. Edição Esp, p. 59–69, 2016.

SILVA, P. S. L.; SILVA, P. I. B. Parcelamento da adubação nitrogenada e rendimento de espigas verdes de milho. **Horticultura Brasileira**, v. 21, n. 2, p. 149-152, 2003.

SOUZA, E. J.; DA CUNHA, F. F.; MAGALHÃES, F. F.; DA SILVA, T. R.; DA SANTOS, O. F. Eficiência do uso da água pelo milho doce em diferentes lâminas de irrigação e adubação nitrogenada em cobertura. **Revista Brasileira de Agricultura Irrigada**, v. 10, nº 4, p. 750-757, 2016.

VAN GENUCHTEN, M. T. **A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils1Soil Science Society of America Journal**, 1980.

KOTTEK, M.; GRIESER, J.; BECK, C.; RUDOLF, B.; RUBEL, F. World map of the Köppen-Geiger climate classification updated. **Meteorologische Zeitschrift**, v. 15, n. 3, p. 259–263, 2006.

VON PINHO, R.G.; RIVERA, A.A.C.; BRITO, H.N.; LIMA, T.G. Avaliação agronômica do cultivo de milho em diferentes níveis de investimento. **Ciência e Agrotecnologia**, Lavras, v.33, n.1, p.39-46, 2009.

BONO, J.; RODRIGUES, A.; MAUAD, M.; ALBUQUERQUE, J.; YAMAMOTO, C.; CHERMOUTH, K.; FREITAS, M. Modo de aplicação de fertilizantes nitrogenados na qualidade fisiológica de sementes de milho. **Revista Agrarian**, v.1, n.2, p.91-102, 2008.

LINK, J.; GRAEFF, S.; BATCHELOR, W. D.; CLAUPEIN, W. Evaluating the economic and environmental impact of environmental compensation payment policy under uniform and variable-rate nitrogen management. **Agricultural Systems**, v.91, p.135-153, 2006.

PAVINATO, P. S.; CERETTA, C. A.; GIROTTO, E.; MOREIRA, I. C. L. Nitrogênio e potássio em milho irrigado: análise técnica e econômica da fertilização. **Ciência Rural**, Santa Maria, v.38, n. 2, p. 358-364, 2008.

ANDRADE, R. D. S.; STONE, L. F. Estimativa da umidade na capacidade de campo em solos sob Cerrado. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 15, n. 2, p. 111–116, 2011.

CERETTA, C.A.; SILVEIRA, M.J. Manejo da fertilidade do solo para altas produtividades. In: CARLESSO, R. et al. (Ed.). Irrigação por aspersão no Rio Grande do Sul. Santa Maria: UFSM, 2001. p.10-20.

FRANCO, H. C. J.; TRIVELIN, P. C. O. Adubação nitrogenada em cana-de-açúcar: reflexos do plantio à colheita. In: CRUSCIOL, C. A. C.; SILVA, M. A.; ROSSETTO, R.; SORATTO, R. P. Tópicos em ecofisiologia da cana-de-açúcar. Botucatu: FEPAF,

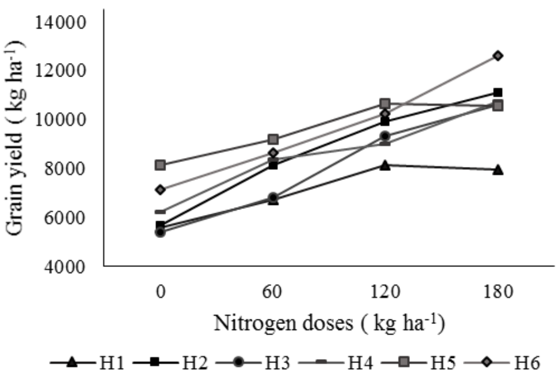

Figure 1. Productivity of maize hybrids at nitrogen doses

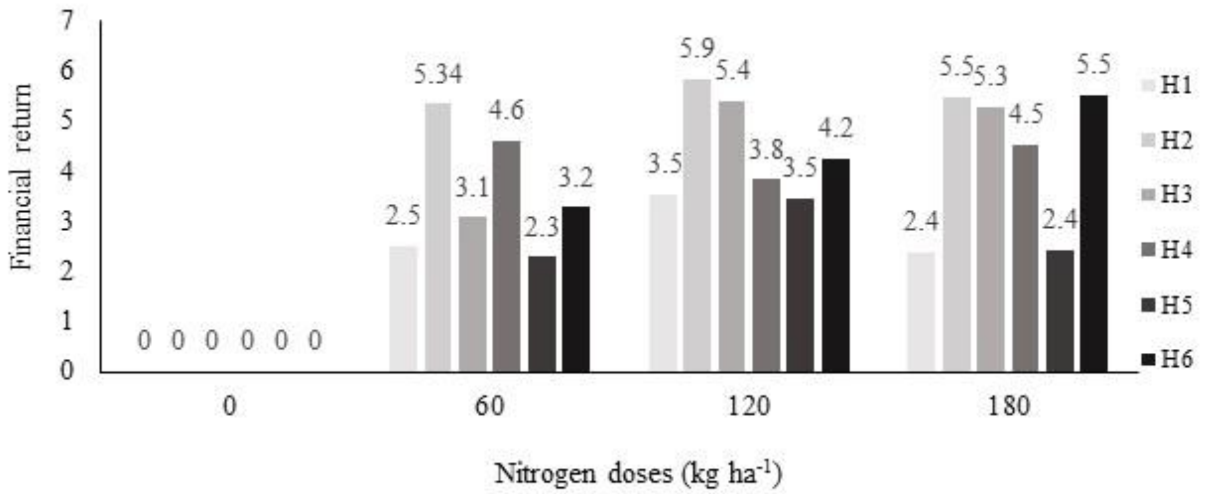

Figure 2. Profitability of nitrogen fertilizations in the different hybrids studied

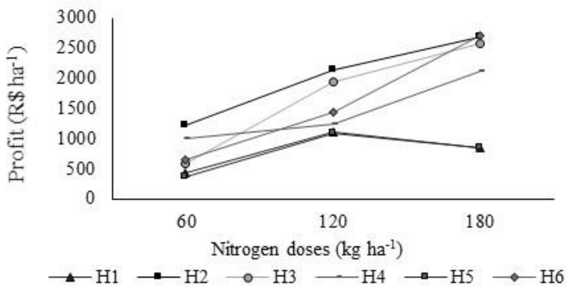

Figure 3. Marginal profit from nitrogen fertilization

Table 1. Revenue and marginal cost as a function of the nitrogen rates applied (R$ ha^{-1})

N- Doses (kg há)	Average Marginal Revenue per hectare	Average Marginal Cost per hectare	Sum of Marginal Profit
60	982.44	-377.26	14524.15
120	1928.28	-631.85	31114.45
180	2562.68	-855.29	40977.47
Grand total	**1824.47**	**-621.47**	**86616.08**