ECONOMIC VIABILITY OF CORN CROP AS FUNCTION OF DOSES, FORMS AND APPLICATION TIMES OF NITROGEN IN BRAZILIAN SAVANNAH†

[VIABILIDAD ECONÓMICA DEL CULTIVO DE MAÍZ COMO FUNCIÓN DE DOSIS, FORMAS Y TIEMPOS DE APLICACIÓN DE NITRÓGENO EN SABANA BRASILEÑA]

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SUMMARY

Alternatives to reduce losses of nitrogen (N) in the soil, increasing the use of the plant nutrient efficiency are important depending on N dynamics in the soil, to increase their use and achieve high yields economically profitable. In this context, economically-analyzed whether the effect of the mechanical application of N doses as urea, in different forms and times of application, in the grain yield of corn in Cerrado region with low altitude (Brazilian Savannah). The experiment was conducted in Selvíria – state of Mato Grosso do Sul, an Oxisol clayey, in 2013/14. The experimental design was a randomized complete block design with four replications, in a factorial 6 x 2 x 2, as follows: 6 N doses (0, 50, 100, 150, 200, 250 kg ha^{-1}), 2 application times (totally in sowing or topdressing) and 2 application forms (surface or incorporated) of N, analyzing total operacional cost (TOC), effective operacional cost (EOC), gross revenue (GR), operating profit (OP), profitability index (PI), equilibrium price (EP), and equilibrium yield (EY). The urea application at a dose of 150 kg ha^{-1}, fully applied at sowing and surface provides greater profitability in irrigated maize, ensuring profitability with production of grains in the Cerrado with low altitude.

Keywords: *Zea mays;* nitrogen fertilization; urea; total operational cost; profitability index.

RESUMEN

Las alternativas para reducir las pérdidas de nitrógeno (N) en suelo, aumentando la eficiencia de uso de nutrientes de las plantas son importantes dependiendo de la dinámica de N en suelo, para aumentar su uso y lograr altos rendimientos económicamente rentables. En este contexto, se analizó económicamente si el efecto de la aplicación mecánica de las dosis de N como urea, en diferentes formas y tiempos de aplicación, en el rendimiento de grano del maíz en la región del Cerrado con baja altitud. El experimento se realizó en Selvíria - MS, una arcilla de Ferralsol, en 2013/14. El diseño experimental fue un diseño de bloques completos con cuatro repeticiones, en un factorial 6 x 2 x 2, de la siguiente manera: 6 N (0, 50, 100, 150, 200, 250 kg ha^{-1}), 2 tiempos de aplicación (totalmente en siembra o topdressing) y 2 formas de aplicación (superficie o incorporados) de N, analizando el costo operacional total (TOC), costo operacional efectivo (COE), ingreso bruto (GR), utilidad operacional (OP), índice de rentabilidad (PI), precio de equilibrio (EP) y rendimiento de equilibrio (EY). La aplicación de urea a una dosis de 150 kg ha^{-1}, totalmente aplicada en la siembra y en la superficie proporciona mayor rentabilidad en maíz irrigado, garantizando la rentabilidad con la producción de granos en el Cerrado con baja altitud.

Palabras clave: *Zea mays*; fertilización nitrogenada; urea; costo total de operación; índice de rentabilidad.

INTRODUCTION

Corn is one of the oldest and most widespread crops in the world. Despite technological advances available, average Brazilian yield is still very low, around 5,401 kg ha^{-1}, taking into consideration the harvest and second crop (Conab, 2015). This demonstrates the need to seek management techniques to obtain increased productivity and consequently guarantee profits to the producer.

In order to obtain high grain yields of this cereal, it is necessary to apply high doses of nitrogen (N), since the soils in general do not supply the crop demand during its cycle (Galindo *et al.*, 2016). In non-legume crops, nitrogen fertilization represents one of the highest costs of the production process (Nunes *et al.*, 2015), with wheat, corn and rice crops consuming approximately 60% of the total nitrogen fertilizer produced in the world (Espindula *et al.*, 2014). Therefore, N fertilization management is carried out with the aim of guaranteeing good productivity and the dynamics of N in the soil, adding large amounts of N, which raises farmers production costs (Teixeira Filho *et al.*, 2014).

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Generally, annual crops receive only a fraction of the total N dose they require at sowing, and the remainder is applied between the lines at times of greatest demand. This is due to three factors: low initial demand, possibility of leach losses and high salt content of nitrogen fertilizers. At present, the application period of N is one of the most controversial aspects in the management of nitrogen fertilization of grasses under no-tillage system, with succession of grasses, since, in the first years of adoption of this system, the initial lack of N due to the immobilization caused by the microbial decomposition of the residues of the predecessor crop (Teixeira Filho *et al.*, 2010). Thus, in some cases, the anticipation of nitrogen fertilization, in relation to conventional recommendations or, even, in relation to crop sowing, may be more efficient in increasing the yield of annual grain crops (Kluthcouski *et al.*, 2006). However, there is a need for further studies, for corn crop in regions with dry winter and controlled irrigation.

The N application in a single time (in pre-sowing or sowing) can result in accumulation of $N\text{-}NO_{3^-}$ in soil, which is the main form of nitrogen loss by leaching, in the initial stages of corn development, since total demand of plant is small at this stage of development. While in the usual application period of N in top-dressing (4 to 8 leaves), the uptake of N by plants is more intense.

N can be applied to soil by different methods, being the most used the haul on the soil surface and incorporated in lines. When the N source is urea, most commonly used in agriculture, and rain does not occur in the first few days after application, soil incorporation may be important to minimize ammonia ($N\text{-}NH_3$) formation into the soil and release in atmosphere. Lara Cabezas *et al.* (2000), observed higher losses of urea-derived $N\text{-}NH_3$ when it was applied at the soil surface compared to its incorporation into the soil in corn. These authors estimated that there may be a reduction in corn grain yield due to the volatilization of $N\text{-}NH_3$ at the rate of 10 kg ha^{-1} of grains for each 1% of volatilized N.

In view of the above, there is a concern to seek viable alternatives to increase the efficiency of nitrogen fertilization, allowing its reduction in the production system, without causing a decrease in production and in the quality of agricultural products. However, in literature, there are few studies that show economically the effect of forms of application associated with times and N doses. To be feasible to the farmer, it is not enough that technological innovations increase yield, and there must be, in parallel, studies which report economic viability (Kaneko *et al.*, 2015).

In this way, the objective of this work was to analyze economically the effect of mechanized distribution of N doses in urea form, at different times (sowing or cover) and forms of application (surface or incorporated) in corn grain yield, in Brazilian Cerrado region of low altitude (Brazilian Savannah).

MATERIAL AND METHODS

The experiment was conducted during the crop years of 2013/14 in an experimental area belonging to the Faculty of Engineering at UNESP, located in Selvíria, MS, Brazil (335 m asl). The soil of the experimental area was classified as a Latossolo Vermelho distrófico (Oxisol) with clayey texture, according to Santos *et al.* (2013), and had been cultivated with annual crops for over 27 years, with the last 10 years under the no-till system, and the crops prior to corn were fallow. Precipitation, air relative humidity, and the maximum, mean, and minimum temperatures recorded during the experimental period are shown in Figure 1.

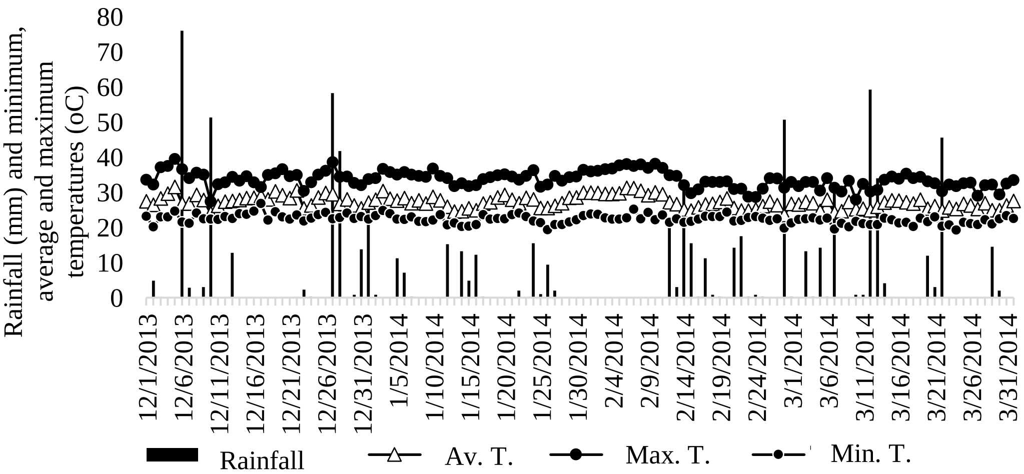

Figure 1. Rainfall, maximum, average and minimum temperatures obtained from the weather station located in the Education and Research Farm of FE / UNESP during the corn cultivation in the period December 2013 to April 2014.

The soil chemical attributes in the arable layer were determined before the implementation of the corn experiment in 2013, following the methodology proposed by Raij *et al.* (2001). The following results were obtained: 10 mg dm^{-3} P (resin); 5 mg dm^{-3} S-SO_4; 22 g dm^{-3} OM; pH 5.3 ($CaCl_2$); K, Ca, Mg, H+Al = 2.4, 21.0., 18.0, and 28.0 mmol$_c$ dm^{-3}, respectively; Cu, Fe, Mn, and Zn (DTPA) = 3.2, 22.0, 24.2, and 1.2 mg dm^{-3}, respectively; 0.16 mg dm^{-3} B (hot water); and 60% base saturation.

A randomized-block design with four replications was set up in a 6 × 2 × 2 factorial arrangement consisting of six N doses (0, 50, 100, 150, 200 and 200 kg ha^{-1}) two forms of application (incorporated or in surface); and 2 times of application (totally in sowing or top-dressing). The treatments were all mechanically applied, and the nitrogen source was urea (45% N) in granule. Experimental plots comprised seven 13-m long rows spaced 0.45 m apart, with the two central rows as the usable area of the plot and excluding 0.5 m of extremities.

The area used was fallow in the year 2012/2013, therefore, 15 days before sowing were used for desiccation the herbicides glyphosate - Roundup Ready® (1800 g ha^{-1} of the active ingredient [a.i.]) and 2,4-D - NORTOX® (670 g ha^{-1} of the a.i.).The triple-hybrid corn DKB 350 VT PRO (resistant to the fall armyworm [*Spodoptera frugiperda*]) was mechanically sown on 12/16/2013, at three seeds per meter, and seedling emergence occurred five days after seeding, on 12/21/2013. To control post-emergence weeds, the herbicides tembotrione - SOBERAN® (84 g ha^{-1} of a.i.) and atrazine – NORTOX® 500 sc (1,000 g ha^{-1} of the a.i.) were applied, and an adjuvant, vegetable oil - NORTOX® (720 g ha^{-1} of the a.i.), was added to the herbicide spray on 01/07/2014. Insect control was performed with methomyl - LANNATE® (215 g ha^{-1} of the a.i.) and triflumurom - CERTERO® (24 g ha^{-1} of the a.i.) on 01/21/2014. Whenever necessary, irrigation was applied via spraying, using a center pivot with an average water depth of 14 mm and an irrigation interval of approximately 72 h.

In the sowing fertilization, 112 and 64 kg ha^{-1} of P_2O_5 and K_2O, in the form of urea, triple and simple phosphate and potassium chloride respectively, were applied, based on the soil analysis and the expectation of corn yield, avoiding the application of N at sowing. Nitrogen fertilization was done according to the treatments mentioned above, and always between corn lines, that is, at the time of sowing on 12/17/2013, or in the V4 stage of corn (01/08/2014). When incorporated into the soil, urea was deposited at a depth of about 5 to 7 cm above ground level. The experimental area was sprinkled by means of a central pivot on the following day of the cover fertilization.

The corn harvest was performed on 04/18/2014, 118 days after emergence of the plants, when 90% of the ears had the grains with 20% moisture. The grain yield was determined by the collection of the ears contained in 10 m of each of the two central lines of the plot. The material was subjected to drying in full sun and after the mechanical track, the grains were quantified, and the data transformed in kg ha^{-1} at 13% (wet basis).

For the economic analysis, the metric total operating production costs (TOC) used by the Institute of Agricultural Economics (IEA) were adopted, according to Matsunaga *et al.* (1976). This measure consists of the sum of operating expenses: operations performed, inputs (fertilizers, seeds, pesticides, etc.), labor, machinery, and irrigation and was termed effective operating costs (EOC). Other operating expenses and interests, amounting to 5% of the EOC (Matsunaga *et al.*, 1976), were also included to yield the total operating cost (TOC), which was extrapolated to one hectare.

To determine the profitability of the involved treatments, profitability analyses were carried out following Martin *et al.* (1998). To this end, the following variables were determined: gross revenue (GR) (in R$), as the product of the amount produced (in number of 60-kg sacks) by the average sale price (in R$); operating profit (OP), as the difference between the gross revenue and total operating cost; profitability index (PI), understood as the ratio between operating profit (OP) and the net revenue (NR), as a percentage; equilibrium price, given a certain total operating production cost, as a the minimum price calculated to cover this cost, considering the average productivity of the producer; and equilibrium yield, given a certain total operating production cost, as the minimum productivity to cover this cost, considering the average price paid to the producer.

The average prices were quoted in the region of Selvíria – MS, Brazil, in 2014 average of the year (IEA, 2016). In this study, simulations were performed as if each experimental treatment represented commercial crops. To help expand on the data, especially concerning the machine-hour dose, the machine yield, the inputs utilized, and the price of the sack of corn, the grain producers of the region were interviewed concerning the prices paid for the inputs for the 2013/2014 crop. To facilitate the discussion, the values referring to the yields were transformed into 60-kg sacks, which was the basic unit of sale by local producers. The cost of the sack of corn for the municipality of Selvíria was R$24.00 per unit produced. As regards the N sources, the price paid by the farmer was R$1,780.00. The 2014 average exchange rate was: R$2,97 = U$1,00.

RESULTS AND DISCUSSION

Table 1 shows the structure of the total operating cost (TOC) in corn crop, in the municipality of Selvíria - MS. The treatment with N application in the incorporated form and in sowing at 0 kg ha^{-1} urea. This model of TOC structure was used in all treatments.

It can be seen from Table 1 that fertilizer costs, followed by mechanized operations, were the highest, corresponding to 34.7 and 25.6% of the TOC, respectively, corroborating with Kaneko *et al.* (2010), studying the viability of corn crop for northwest region of São Paulo, in 2007/2008 and 2008/2009 crops, under no-tillage and N application doses up to the 120 kg ha^{-1} dose, also showed higher yields with fertilizers and mechanized operations, corresponding to 32.7 and 30.9% of TOC, with yields varying between 85.9 and 146.1 sc ha^{-1}. It is noteworthy that with the increase of N doses and the incorporation of the source analyzed, there is a tendency to increase the percentage of expenses in relation to the TOC of the fertilizers.

Garcia *et al.* (2012), working with corn in Selvíria - MS region, due to different consortia with forages obtained higher costs related to corn seed inputs (46.5%), followed by fertilization costs (39.0% %), And higher operating costs with central pivot irrigation (45.3%), with yields varying between 105 and 137 sacks of 60 kg of corn, using as urea nitrogen fertilizer at a dose of 100 kg ha^{-1}. Although in the present study the cost of central pivot irrigation and seeds were not the highest costs, it is worth noting that the expense was high with the two items mentioned above, with 13.1 and 23.9% of the TOC, respectively.

The costs with nitrogen fertilization in top-dressing, due to the increasing N doses, ranged from 9.2 to 31.4% of TOC. Kaneko *et al.* (2015), working with doses (0, 45, 90, 135 and 180 kg ha^{-1} in top-dressing), obtained cost with sowing fertilization in the first and second harvests respectively of 31.8 and 24 , 2% of TOC, with yields ranging from 119 to 191 sacks of 60 kg of corn. For the costs with nitrogen fertilization in top-dressing, the values varied, in both crops between 12 and 14% with the urea source.

Regarding the TOC and productivity of the treatments evaluated (Table 2), the highest value for TOC refers to the treatment in the dose of 250 kg ha^{-1} of N, applied in an incorporated form and in top-dressing (R$ 3,387.05) . The lowest value for TOC corresponds to the treatments without nitrogen fertilization (0 kg ha^{-1}), applied on sowing surface (R$ 2,274.81). However, it is worth noting that N reserves of soil are depleting, as nutrient extraction occurs, if it is not restored to the soil, compromising crop productivity over time.

Table 1. Total operating costs structure model of corn for the treatment incorporated in sowing at the N dose of 0 kg ha^{-1}, per hectare. Selvíria – MS, Brazil, 2013/2014

Description	Specification[1]	Times	Amount	Unitary Value (R$)	Total value (R$)
A. OPERATIONS					
Dessication	HM	1.00	0.50	85.00	42.50
Hoeing (triton)	HM	1.00	0.50	85.00	42.50
Seedling	HM	1.00	1.20	110.00	132.00
Harvest	HM	1.00	0.60	118.00	70.80
Irrigation (pivô)	mm	1.00	120.00	2.50	300.00
Subtotal A					587.80
B – AGRICULTURAL INPUTS					
Fertilizer 08-28-16	t	1.00	0.40	1.998,00	799.20
Urea	t	1.00	0.00	1.750,00	0.00
Corn Seed DKB 350 YD	sc (20 kg)	1.00	1.22	450.00	549.00
Glyphosate	L	1.00	4.00	14.51	58.04
2,4-D	L	1.00	1.00	13.24	13.24
Tembotrione	L	1.00	0.20	403.21	80.64
Atrazine	L	1.00	2.00	14.48	28.96
Vegetable oil adjuvant	L	1.00	0.78	8.41	6.56
Subtotal B					1,535.64
Effective operating cost (EOC)					2,123.44
Other expenses					106.17
Interest cost					69.01
Total operating cost (TOC)					2,298.63

HM = Hour machine

sc = sack

2014 average exchange rate: R$2,97 = U$1,00.

Regarding productivity, the highest values were verified in the treatments with dose of 250 kg ha^{-1} in sowing and applied in an incorporated form, presenting average productivity of approximately 177 sacks of 60 kg ha^{-1}. On the other hand, in the absence of nitrogen fertilization, regardless of incorporation or not or fully application in sowing or cover, the corn grain yield was lower, with approximate values of 108 sacks of 60 kg ha^{-1}.

Regarding gross revenue per hectare (Table 2), obtained in the treatments combinations (nitrogen fertilization management) for corn, it is observed that, with corn sales price constant, gross treatments revenue follow the same yield trend (Table 2), that is, increases in revenue are due to increases in grain yield. This result is in agreement with Silva *et al.* (2007) and Duete *et al.* (2009), according to which yield is a prime factor to ensure good profitability for producer. According to Duete *et al.* (2009), even in regions where the producer obtains good prices for corn, if productivity is low, profitability is compromised. Thus, the investment in management practices, such as balanced nitrogen fertilization, increases the grain yield and the gross revenue of corn crop, regardless location.

For values related to operating profit (Table 3), the values obtained were positive for most of the treatments studied, regardless the N dose, form or time of application. Only in the treatments in the dose of 250 kg ha^{-1} of N, applied in an incorporated form in top-dressing the operating profit was negative (-R$ 287.98). Gomes *et al.* (2007), studying the economic viability of N doses in top-dressing (25, 50, 100 and 150 kg ha^{-1}) with the urea source, obtained a negative profitability regardless of the applied dose.

Even in the absence of nitrogen fertilization, which would lead to a reduction in costs, with the possibility of an increase in OP, if good yields were obtained, both with incorporated and surface application, completely in sowing or in cover, corn cultivation would be viable in function of the profits obtained, however, it is noteworthy that the profitability of the non-fertilized treatments was lower than all other doses applied, except for the application of 250 kg ha^{-1} incorporated in top-dressing, reinforcing the importance of the nitrogen fertilization management to obtain high yields, and consequently, financial return. Similar results were obtained by Aguiar *et al.* (2008), who verified a positive effect of corn marketed in April 2007, under no-tillage system under no-tillage, as well as Kaneko *et al.* (2015), which obtained an index of profitability in the absence of nitrogen fertilization of 42.36%.

Table 3 shows the values referring to the profitability index, following the same trend of the operating profit. The treatment that resulted in greater profitability was the 150 kg ha^{-1} dose applied on the surface and on sowing, providing PI of 29.9%, followed by treatment at a dose of 50 kg ha^{-1}, also applied on the surface and at sowing with PI of 29.6%.

Kaneko *et al.* (2010), studying nitrogen fertilization management (N applied completely in sowing, top-dressing or in installment), in a no-tillage system in the Cerrado region, until the dose of 120 kg ha^{-1} of N verified greater PI when urea was totally applied in sowing compared to the fully top-dressing application, with PI in 2007/2008 and 2008/2009 seasons for the treatments applied in sowing and top-dressing, respectively, of 3.26 and 7.24 and 2.82 and 2.40%, respectively.

Table 2. Total operating cost, grain yield and gross revenue of corn crop in function of doses, forms and time of N application, using urea. Selvíria - MS, Brazil, 2013/14

	Sowing			Top-dressing		
Doses	TOC R$	YIELD*	GR -----R$-----	TOC	YIELD*	GR ---R$---
Incorporated						
0	2,298.63	107.66	2,583.84	2,334.62	107.66	2,583.84
50	2,509.11	130.48	3,131.53	2,545.11	148.10	3,554.34
100	2,719.60	137.56	3,301.37	2,755.59	161.65	3,879.60
150	2,930.08	135.95	3,262.74	2,966.08	151.87	3,644.85
200	3,140.57	146.70	3,520.81	3,176.56	143.57	3,445.62
250	3,351.06	176.64	4,239.48	3,387.05	129.13	3,099.07
Surface						
0	2,274.81	107.66	2,583.84	2,320.82	107.66	2,583.84
50	2,485.30	147.18	3,532.40	2,531.30	147.39	3,537.26
100	2,695.78	150.79	3,618.93	2,741.78	153.75	3,689.91
150	2,906.27	172.74	4,145.66	2,952.28	156.52	3,756.60
200	3,116.76	138.26	3,318.27	3,162.75	167.91	4,029.87
250	3,327.24	141.18	3,388.36	3,373.25	148.30	3,559.18

*YIELD in sc 60 kg ha^{-1}

**Corn trading price R$ 24,00 per 60-kg sack according to IEA (2016).

Table 3. Operating profit (OP) and profitability index (PI) of corn crop in function of doses, forms and time of N application, using urea. Selvíria - MS, Brazil, 2013/14.

	Incorporated				Surface			
	Sowing		Top-dressing		Sowing		Top-dressing	
Doses	OP	PI	OP	PI	OP	PI	OP	PI
	R$	--(%)--	R$	--(%)--	R$	--(%)--	R$	--(%)--
0	285.21	11.04	249.22	9.65	309.03	11.96	263.02	10.18
50	622.42	19.88	1,009.23	28.39	1,047.10	29.64	1,005.96	28.44
100	581.77	17.62	1,124.01	28.97	923.15	25.51	948.13	25.70
150	332.66	10.20	678.77	18.62	1,239.39	29.90	804.32	21.41
200	380.24	10.80	269.06	7.81	201.51	6.07	867.12	21.52
250	888.42	20.96	-287.98	-9.29	61.12	1.80	185.93	5.22

2014 average exchange rate: R$2,97 = U$1,00.

Silva *et al.* (2005), testing N doses in cover crops (30, 60, 90, 120 and 180 kg ha^{-1}), applied completely in sowing, top-dressing or splitted, in no-tillage system in the Cerrado region obtained PI between 2.80 and 22.98%, while in the absence of nitrogen fertilization, the PI was -17.37%, again reinforcing the importance of the nitrogen fertilization management to obtain profitability with the corn crop. The authors also verified, in a similar manner to the present study, the economic feasibility of applying N totally to corn sowing, with positive PI ranging from 9.91 to 20.07% as a function of increasing doses. Differently, Kaneko *et al.* (2015), obtained PI ranging from 42.36 to 51.56 and 42.36 and 52.71% with urea source, as a function of the doses of 0, 45, 90, 135 and 180 kg ha^{-1}, higher than those verified in the present study.

In relation to equilibrium yield (minimum yield to cover costs), it was possible to verify that (Table 4), for the price of R $ 24.00 per sack of 60 kg of corn, when the applied dose was 250 kg ha^{-1} incorporated and in top-dressing, the equilibrium yield was higher, being 141.13 sc per hectare, while at the same applied dose of 250 kg ha^{-1}, in the absence of incorporation, the equilibrium price remained very close, with 140,55 sc per hectare. With the application of nitrogen fertilizer, applied on the surface and on sowing, the lowest equilibrium productivity was observed, being 94.78 sc per hectare to cover production costs.

Although the lower equilibrium productivity was obtained in the absence of nitrogen fertilization, it should be pointed out that the non-supply of N in cultivated soils may lead to a decrease in their levels over the years, thus compromising the success of Activity, over time, if there is no replacement of the exported nutrient, which in the long run would culminate in greater investment to build soil fertility lost through poor nutrient management.

There were very small variations between the treatments incorporated and applied on the surface and for the treatments applied completely in sowing or covering in relation to the equilibrium productivity, in the same doses applied, which is due to the low relative cost of incorporation and application in sowing, being this one of the main benefits of these types of forms and times of N application. To Kaneko *et al.* (2015), the equilibrium productivity varied from 68 to 89 sacks per hectare with urea application, as a function of the N rates of 0, 45, 90, 135 and 180 kg ha^{-1}, respectively. However, in the Chapadões region (Chapadão do Sul – MS, Brazil) (2009/2010 harvest), the equilibrium productivity, for the value of R$ 12.81 per sack of 60 kg of grains, was 158 sacks per hectare (Kaneko and Leal 2010), evidencing, a great oscillation between corn prices and yield producing regions, due to different agricultural crops.

Table 4. Equilibrium price and equilibrium yield of corn crop in function of doses, forms and time of N application, using urea. Selvíria- MS, Brazil, 2013/14.

	Incorporated				Surface			
	Sowing		Top-dressing		Sowing		Top-dressing	
Doses	EP	EY	EP	EY	EP	EY	EP	EY
	R$ sc^{-1}	sc 60 kg ha^{-1}	R$ sc^{-1}	sc 60 kg ha^{-1}	R$ sc^{-1}	sc 60 kg ha^{-1}	R$ sc^{-1}	sc 60 kg ha^{-1}
0	21.35	95.78	21.69	97.28	21.13	94.78	21.56	96.70
50	19.23	104.55	17.19	106.05	16.89	103.55	17.17	105.47
100	19.77	113.32	17.05	114.82	17.88	112.32	17.83	114.24
150	21.55	122.09	19.53	123.59	16.82	121.09	18.86	123.01
200	21.41	130.86	22.13	132.36	22.54	129.87	18.84	131.78
250	18.97	139.63	26.23	141.13	23.57	138.64	22.75	140.55

2014 average exchange rate: R$2,97 = U$1,00

Table 4 shows the values (in R$) of 60 kg corn sack, for the equilibrium price (minimum price to cover TOC). The grains produced with the surface application obtained a lower equilibrium price when compared to those produced with incorporation of N in the form of urea. In relation to nitrogen management, doses of 150 and 50 kg ha^{-1} provided a lower equilibrium price, when applied to the surface and totally in sowing, presenting values of R$ 16.82 and R$ 16.89, respectively. On the other hand, when the treatments were applied at a dose of 250 kg ha^{-1}, applied in a cover-up and sowing surface respectively, the equilibrium price presented the highest values, at R$ 26.23 and R$ 23, 57, respectively. For Kaneko *et al.* (2015), the equilibrium price of corn sacks varied from R$ 16.38 to R$ 18.30 for treatments using urea, according to the doses of 0, 45, 90, 135 and 180 kg ha^{-1} of N.

The magnitude of values related to profitability and economic return due to N doses is very high, not only due to different agricultural years, but also of the localities under study, highlighting the importance of new cost and profitability analysis studies, including nitrogen fertilization.

With regard to the application of N totally in sowing, this technology can be an economically viable alternative, combining low cost with increase in profitability of agricultural activity with corn crop, being a technique that should be more explored and used by the rural producers, since which with great discretion and based on the edaphoclimatic conditions of the region.

According to Civardi *et al.* (2011), to reduce losses due to volatilization of ammonia, it is recommended the incorporation of ammoniacal or amide nitrogen fertilizers, in alkaline or limestone soils, associated to the subsequent and immediate irrigation. In the case of urea, the losses of NH_3 can reach almost 80%, with the superficial application in no-tillage, and 30% in the conventional tillage, and the incorporation in approximately 5.0-7.0 cm of depth in soil reduces, drastically, the loss of ammonia (Tasca *et al.*, 2011). However, urea incorporation and eventual decrease in N losses due to volatilization did not reflect higher grain yields and higher economic returns, which may have occurred in function of area to be irrigated by central pivot, as reported by Knoblauch *et al.* (2012), which conclude that the application of urea to soil by irrigation water reduces losses by volatilization of ammonia to insignificant values, minimizing N losses and allied to conservation practices, such as the no-tillage system adopted in the area for more than 10 years, which potentially increased OM contribution and N availability. Therefore, it would be more interesting to apply N to surface due to the greater ease of application and lower operational cost.

CONCLUSIONS

N application completely in sowing is economically viable for corn crop, independently of the dose and form of application of N. The supply of N in urea form, incorporated into soil does not favor grain yields economically superior to urea applied on the surface, therefore, it is recommended to use surface applied urea due to the ease of application and greater economic return. The N dose of 150 kg ha^{-1}, applied completely in sowing and on the surface, provides greater economic viability in the cultivation of irrigated corn, guaranteeing profitability with the production of corn grains in the low altitude Cerrado.

REFERENCES

Aguiar, R.A., da Silveira, P.M., Moreira, J.A.A., Wander, A.E. 2008. Análise econômica de diferentes práticas culturais na cultura do milho (*Zea mays* L.). Pesquisa Agropecuária Tropical, 38:241-248.

Companhia Nacional de Abastecimento- CONAB 2015. Avaliação da safra agrícola 2015/2016: primeiro levantamento – outubro/2015. Brasília: CONAB, 2015. Disponível em: < http://www.conab.gov.br/OlalaCMS/uploads/arquivos/15_10_09_17_45_57_boletim_graos_outubro_2015_novo.pdf> Acesso em: 12 out. 2015.

Civardi, E.A., Silveira Neto, A.N.D., Ragagnin, V.A., Godoy, E.R. Brod, E. 2011. Ureia de liberação lenta aplicada superficialmente e ureia comum incorporada ao solo no rendimento do milho. Pesquisa Agropecuária Tropical, 41:52-59. http://www.scielo.br/pdf/pat/v41n1/a12v41n1.pdf

Duete, R.R.C., Muraoka, T., Silva, E., Trevelin, P., Ambrosano, E.J. 2009. Viabilidade econômica de doses e parcelamentos da adubação nitrogenada na cultura do milho em Latossolo vermelho Eutrófico. Acta Scientiarum Agronomy, 31:175-181. http://dx.doi.org/10.4025/actasciagron.v31i1.6646

Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA 2013. Centro Nacional de Pesquisa de Solos. Sistema brasileiro de classificação de solos. 3. ed. Brasília, DF: EMBRAPA, 353p.

Espindula, M.C., Rocha, V.S., Souza, M.A.D., Campanharo, M., Pimentel, A.J.B. 2014. Urease inhibitor (NBPT) and efficiency of single or Split application of urea in wheat crop. Revista Ceres, 61:276-279. http://dx.doi.org/10.1590/S0034-737X2014000200016

Galindo, F.S., Teixeira Filho, M.C.M., Buzetti, S., Santini, J.M.K., Alves, C.J., Nogueira, L.M., Ludkiewicz, M.G.Z., Andreotti, M., Bellote, J.L.M. 2016. Corn Yield and Foliar Diagnosis Affected by Nitrogen Fertilization and Inoculation with *Azospirillum brasilense*. Revista Brasileira de Ciência do Solo, 40:e015036. http://dx.doi.org/10.1590/18069657rbcs20150364

Garcia, C.M.P., Andreotti, M., Tarsitano, M.A.A., Teixeira Filho, M.C.M., Lima, A.E.S., Buzetti, S. 2012. Análise econômica da produtividade de grãos de milho consorciado com forrageiras dos gêneros *Brachiaria* e *Panicum* em sistema plantio direto. Revista Ceres, 59:157-163. http://dx.doi.org/10.1590/S0034-737X2012000200002.

Gomes, R.F., da Silva, A.G., de Assis, R.L., Pires, F.R. 2007. Efeito de doses e da época de aplicação de nitrogênio nos caracteres agronômicos da cultura do milho sob plantio direto. Revista Brasileira de Ciência do Solo, 31:931-938. http://dx.doi.org/10.1590/S0100-06832007000500010

Instituto de economia agrícola – IEA. Banco de dados. Disponível em: < http://www.iea.sp.gov.br/out/bancodedados.html> Acesso em: 01 jun. 2017.

Kaneko, F.H., Arf, O., Gitti, D.C., Tarsitano, M.A.A., Rapassi, R.M.A., Vilela, R.G. 2010. Custos e rentabilidade do milho em função do manejo do solo e da adubação nitrogenada. Pesquisa Agropecuária Tropical, 40:102-109. https://www.revistas.ufg.br/pat/article/view/6888

Kaneko, F.H. and Leal, A.J.F. 2010. Estimativa do custo de produção da cultura do milho na região dos Chapadões, safra 2009/10. Pesquisa - Tecnologia - Produtividade, 3:128-134.

Kaneko, F.H., Sabundjian, M.T., Arf, O., Ferreira, J.P., Gitti, D.D.C., Nascimento, V., Leal, A.J.F. 2015. Análise econômica do milho em função da inoculação com *Azospirillum*, fontes e doses de N em cerrado de baixa altitude. Revista Brasileira de Milho e Sorgo, 14:23-37. http://rbms.cnpms.embrapa.br/index.php/ojs/article/view/556

Kluthcouski, J., Aidar, H., Thung, M., Oliveira, F.R.A. 2006. Manejo antecipado do nitrogênio nas principais culturas anuais. Santo Antônio de Goiás: Embrapa Arroz e Feijão, 64p. (Embrapa Arroz e Feijão. Documentos, 188).

Knoblauch, R., Ernani, P.R., Walker, T.W., Krutz, L.J., Varco, J.J., Gatiboni, L.C., Deschamps, F.C. 2012. Volatilização de amônia em solos alagados influenciada pela forma de aplicação de ureia. Revista Brasileira de Ciência do Solo, 36:813-821. http://www.scielo.br/pdf/rbcs/v36n3/12.pdf

Lara Cabezas, W.A.R., Trivelin, P.C.O., Korndorfer, G.H., Pereira, S. 2000. Balanço nitrogenado da adubação sólida e fluida de cobertura na cultura de milho em sistema plantio direto. Revista Brasileira de Ciência do Solo, 24:363-376. http://dx.doi.org/10.1590/S0100-06832000000200014.

Martin, N.B., Serra, R., Oliveira, M.D.M., Angelo, J.A., Okawa, H. 1998. Sistema integrado de custos agropecuários - "CUSTAGRI". Informações Econômicas, 28:7-28. http://www.iea.sp.gov.br/ftpiea/ie/1998/tec1-0198.pdf

Matsunaga M., Bemelmans, P.F., Toledo, P,D, 1976. Metodologia de custo de produção utilizada pelo IEA. Agricultura em Sao Paulo, 23:123-139. http://www.iea.sp.gov.br/out/verTexto.php?codTexto=11566

Nunes, P.H.M.P., Aquino, L.A., dos Santos, L.P.D., Xavier, F.O., Dezordi, L.R., Assunção, N.S. 2015. Produtividade do trigo irrigado submetido à aplicação de nitrogênio e à inoculação com *Azospirillum brasilense*. Revista Brasileira de Ciência do Solo, 39:174-182. http://www.scielo.br/pdf/rbcs/v39n1/0100-0683-rbcs-39-1-0174.pdf

Raij, B. van, Andrade, J.C., Cantarella, H., Quaggio, J.A. 2001. Análise química para avaliação da fertilidade de solos tropicais. Campinas: IAC, 285 p.

Silva, E.C., Buzetti, S., Lazarini, E. 2005. Aspectos econômicos da adubação nitrogenada na cultura do milho em sistema plantio direto em Latossolo Vermelho distroférrico fase Cerrado. Revista Brasileira de Milho e Sorgo, 4:286-297. http://rbms.cnpms.embrapa.br/index.php/ojs/article/viewArticle/148

Silva, E.C., Muraoka, T., Monteiro, R.O.C., Buzetti, S. 2008. Análise econômica da adubação nitrogenada no milho sob plantio direto em sucessão a plantas de cobertura em Latossolo Vermelho. Acta Scientiarum. Agronomy, 29:445-452. http://dx.doi.org/10.4025/actasciagron.v29i4.395

Tasca, F.A., Ernani, P.R., Rogeri, D.A., Gatiboni, L.C., Cassol, P.C. 2011. Volatilização de amônia do solo após a aplicação de ureia convencional ou com inibidor de urease. Revista Brasileira de Ciência do Solo, 35:493-502. http://www.scielo.br/pdf/rbcs/v35n2/v35n2a18.pdf

Teixeira Filho, M.C.M., Buzetti, S., Andreotti, M., Arf, O., Benett, C.G.S. 2010. Doses, fontes e épocas de aplicação de nitrogênio em trigo irrigado em plantio direto. Pesquisa Agropecuária Brasileira, 45:797-804. http://www.scielo.br/pdf/pab/v45n8/v45n8a04.pdf

Teixeira Filho, M.C.M., Buzetti, S., Andreotti, M., Benett, C.G.S., Arf, O., de Sá, M.E. 2014. Wheat Nitrogen Fertilization Under no Till on the Low Altitude Brazilian Cerrado. Journal of Plant Nutrition, 37:1732-1748. http://dx.doi.org/10.1080/01904167.2014.889150