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Application of coated urea at different phenological stages on second crop corn.

Aplicação de ureia revestida em diferentes estádios fenológicos do milho safrinha.

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Abstract

The response of second crop corn to nitrogen application was evaluated at different stages of development. The experiment was conducted on the São Carlos farm in Vilhena – Rondônia/Brazil. The factors under study included the splitting of N associated with the application of coated urea with NBPT (45-00-00) in top dressing. The control group (witness) showed the highest productivity among all treatments, with 7962 kg ha^{-1}, followed by V3+V7 (7895 kg ha^{-1}) and V4+V8 (7821 kg ha^{-1}). The lowest productivity was 6630 kg ha^{-1} in V5+V9, indicating that the later the urea application in defining the productive potential of the crop (V4), the lower the yields achieved.
Keywords: *Zea mays* L. Subdivision of nitrogen fertilization. Urease inhibitor (NBPT). Corn yield. Agronomic efficiency.

Resumo

Avaliou-se a resposta do milho safrinha à aplicação de nitrogênio em diferentes estádios de desenvolvimento. O experimento foi conduzido na fazenda São Carlos em Vilhena – Rondônia/Brasil. Os fatores em estudo consistiram no parcelamento de N associados a aplicação de uréia revestida com NBPT (45-00-00) em cobertura. A testemunha apresentou a maior produtividade dentre todos os tratamentos, com 7962 kg ha^{-1}, sendo seguida, respectivamente, por V3+V7 (7895 kg ha^{-1}) e V4+V8 (7821 kg ha^{-1}). A menor produtividade foi 6630 kg ha^{-1} ocorrida em V5+V9, indicando que quanto mais tardia for a aplicação de ureia da definição do potencial produtivo da cultura (V4), menores serão os rendimentos alcançados.
Palavras-chave: *Zea mays* L. Parcelamento da adubação nitrogenada. Inibidor de urease (NBPT). Produção de milho. Eficiência agronômica.

Introduction

With the demands of the market, corn (*Zea mays* L.) became the most cultivated crop in the world, exceeding 1 billion tons (ABIMILHO, 2020). In Brazil it is grown in almost all regions of the country (LANDAU et al., 2010), but it depends on the soil and climate conditions of each region (ALVES; AMARAL, 2011). Among the most nutritious foods, corn is rich in protein, carbohydrates, fiber, vitamins and mineral salts. For human consumption it can be an important energy source, but most of what is consumed from production is in animal feed and in some way comes to us through the consumption of beef, pork and poultry (ABIMILHO, 2020). According to CONAB (2021a,b), the State of Rondônia (RO)/Brazil in the 2020 second crop corn had an increase of about 7.6% in the cultivated area and 7% in its production compared to the 2019 harvest.

Nitrogen (N) is the mineral nutrient that provides the greatest effects on corn productivity, influencing several characteristics according to it's availability in the soil, and the growth and development of the plant (COBUCCI, 1991). To obtain yields, high doses of nitrogen fertilizers are applied at responsive stages. Among the nutrients that corn needs most, N is the most complex in relation to its recommendation and management, because of its chemical and biological reactions, besides its strong edafoclimatic requirements for a more efficient absorption by the plant (CANTARELLA; DUARTE, 2004).

According to Cantarella et al. (2008), the best results in reducing ammonia volatilization is the use of urease inhibitors, such as NBPT [N-(n-butyl) triamidathiophosphoric] that inhibits urea hydrolysis in the period of three to fourteen days, which in turn depends on the conditions in which the soil is in moisture content and temperature. This volatilization process involves the hydrolysis of urea by urease, which is an extracellular enzyme produced by bacteria, soil fungi and actinomycetes (REYNOLDS, 1985). In the works conducted by Pereira et al. (2009), Scivittaro et al. (2010) and Marchesan et al. (2013), they found a reduction of losses through volatilization when using urea treated with NBPT in tropical climate countries.

According to Vargas (2010), when nitrogen fertilizer is applied as a top dressing, only a fraction is absorbed by the corn plant. The remainder remains in the soil-plant- atmosphere system and is lost by means of leaching, volatilization, erosion, and denitrification of nitrogen. However, a part of the N stays in the soil in organic form or immobile for a certain time in the soil microbial biomass (BAYER; FONTOURA, 2006).

In relation to the potential losses of N by leaching of nitrate (NO^{-3}) in cultivable soils, this occurs when urea is applied in cover before the phenological stage of greatest demand by the crop. The ammoniacal N (NH^{+4}) due to the conditions at the time of application, such as humidity, soil type and management used may be subject to losses by volatilization (BAYER; FONTOURA, 2006).

In Brazil, it is recommended to apply N at the base, about 10 to 40 kg ha^{-1} and the rest in cover applications that begin in V3 and go until V12 (RAIJ; CANTARELLA, 1996; SBCS/NEPAR, 2017). Being the phenological stages V4 (in which the plant has its production potential defined by the differentiation of the apical meristem, with the definition of reproductive organs and leaves in the thatch) (FORNASIERI FILHO, 2007) and V8 (in which occurs the increase in the growth rate of the cobs, because in this period there is high growth of the root system and, consequently, increased N absorption) (FANCELLI; DOURADO NETO, 2004; FORNASIERI FILHO, 2007) those in which the fractioning of N is commonly performed. Furthermore, Okumura, Mariano and Zacheo (2011) ratify that the application of N between the V12 and V15 stages is essential for the achievement of the productive potential, due to the definition of the number of grains per row.

Debruin and Butzen (2015) state that high-yielding maize plants require a greater contribution of N at the end of their development cycle, because the remobilization of N from the leaves and stalk are not sufficient to meet the demand of the crop at this stage of development. Therefore, it becomes interesting to measure the efficiency of N fractionation at different stages than is usually done, which can, in turn, become an alternative to provide the plant requirement in critical periods, besides maximizing the efficiency of use and reducing the environmental impact (SANGOI; SILVA; PAGLIARINI, 2016).

Due to the socioeconomic importance of corn to Vilhena-RO/Brazil, as well as the local soil and climatic conditions, it is extremely important to establish new management strategies to increase the yield of this crop, especially field studies that identify a better efficiency of nitrogen through the use of controlled release fertilizer. Therefore, the objective of this study was to evaluate, in the second cropping system, the effects of the application of nitrogen in cover at different stages of phenological development, yield components, leaf N content and productivity of crop corn.

Material and methods

The experiment was conducted under field conditions in the commercial area of São Carlos Farm (geographical coordinates 12º47'11.24" S and 60º5'48.55" O), BR 364 - KM 7, in the 2020/2021 harvest of second crop corn (Figure 1). The area is located at 607 m altitude and the type of soil found is Latossolo Vermelho-Amarelo distrófico (Oxisol) of clayey texture, whose granulometric and chemical characterization presented the following values in the 0-0.20 m layer: 59.9% clay, 11.2% silt and 28.9% sand; pH (in H_2O): 5.8; Al^{+3}, Ca^{+2} and Mg^{+2}: 0, 3.4 and 1.0 $cmol_c$ dm^{-3}, respectively; P ($Mehlich^{-1}$) and K+ ($Mehlich^{-1}$): 18.9 and 87 mg dm^{-3}, respectively; organic matter: 29 g dm^{-3}; base saturation (V%): 52%; cation exchange capacity (CEC at pH 7.0): 8.8 $cmol_c$ dm^{-3}.

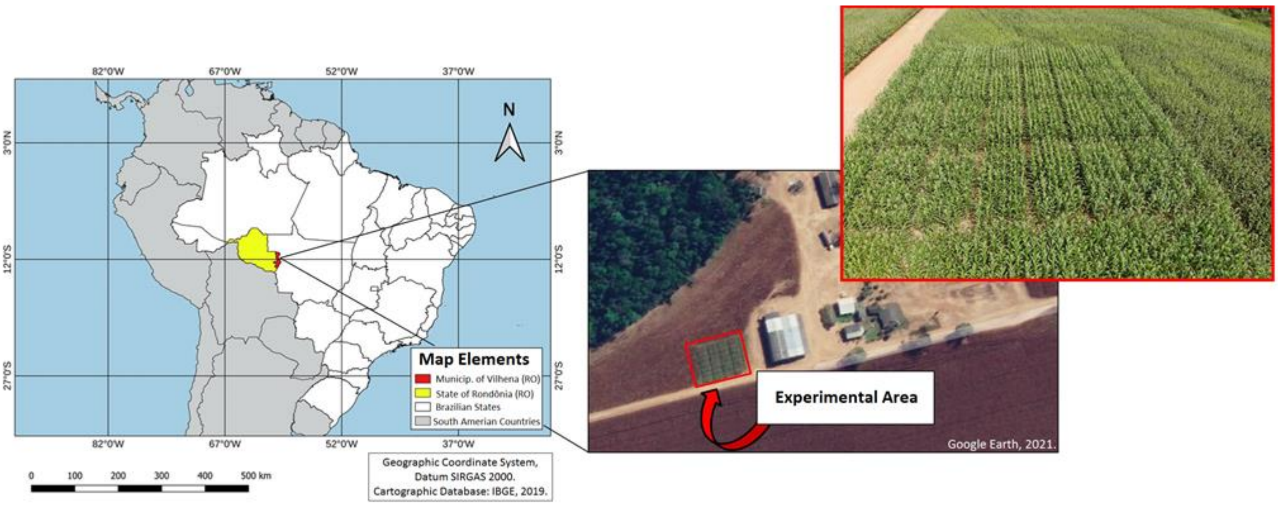

Figure 1 - Location of the experimental area. São Carlos Farm, Vilhena-RO/Brazil, 2021.

The climate, according to Alvares et al. (2013), is type Am, defined as rainy tropical with a well-defined dry season. The average annual precipitation and temperature are 2200 mm and

24.6ºC, respectively. The rainfall data and the maximum and minimum temperatures that occurred during the period of the experiment are presented in Figure 2.

The experimental design adopted was randomized block design (RDB), which considered six treatments + control, with four repetitions each, totaling 28 experimental units (e.u.). The treatments consisted of different times of N application in cover, from the plotting in phenological stages V0+V4, V1+V5, V2+V6, V3+V7, V4+V8 and V5+V9, associated with a source of nitrogen (coated urea) (Figure 3).

Coated urea (45-00-00), commonly called NMaiz, was used as the source of N. The N dose was 222 kg ha^{-1} of urea, according to the recommendations of Sousa and Lobato (2004). The nitrogen fertilizer was applied manually in the cultivation area (without incorporation). All applications occurred at dusk on the following dates: V0 - March 22, V1 - March 29, V2 - April 1, V3 - April 5, V4 - April 8, V5 - April 12, V6 - April 16, V7 - April 20, V8 - April 24, and V9 - April 28. The plots measured 7.5 m x 3.5 m (26.25 m^2) and were composed of seven sowing lines spaced at 0.50 m apart. For the analysis, three central rows were considered, leaving out 0.50 m from each of the headlands of the units.

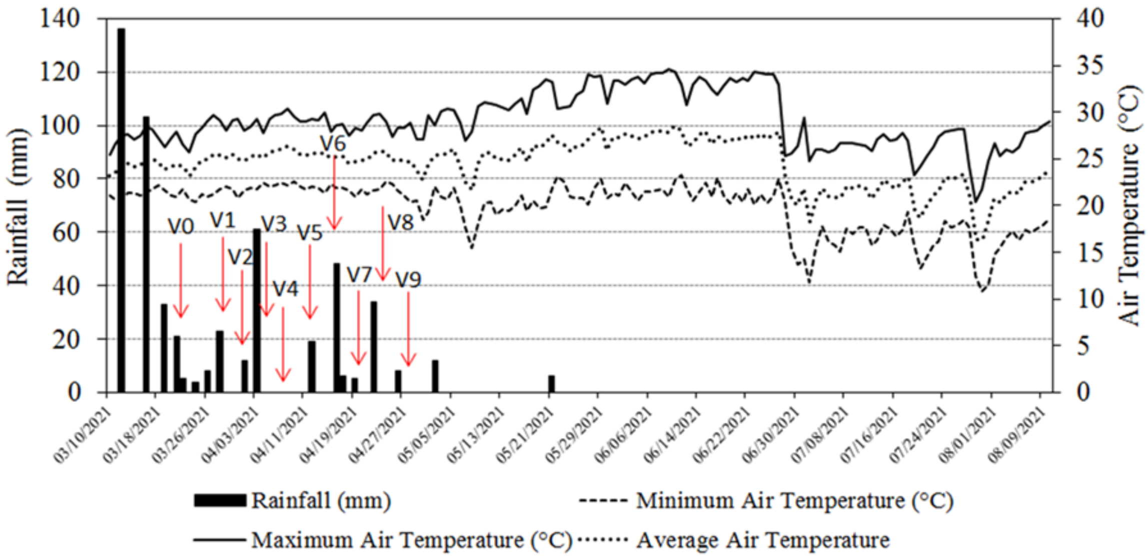

Figure 2 - Rainfall and maximum, minimum and average temperatures during the cycle of second crop corn. São Carlos Farm, Vilhena-RO/Brazil, 2021.

The area has a history of soybean and corn succession for over a decade, with soil analysis performed every three years and liming followed by incorporation with a harrow (minimum cultivation system) and some years later with a scarifier. Over the years, corn started to be intercropped with *Brachiaria ruziziensis*, and in the last "second crop corn" (2019/2020) the area was not sown with the latter.

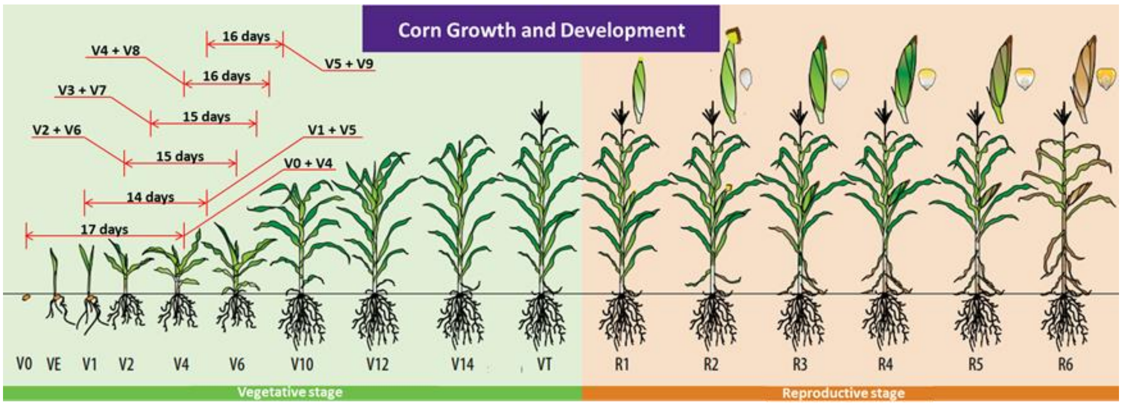

Figure 3 - Number of days after emergence in which nitrogen applications were made in the second crop corn. São Carlos Farm, Vilhena-RO/Brazil, 2021. Source: Adapted from Kansas State University (http://corn.agronomy.wisc.edu/management/pdfs/Corn%20Growth%20and%20Development%20poster.pdf)

The crop was installed in direct seeding system in the soybean stubble, using hybrid LG 36790 PRO3, with an average population of 64000 plants per hectare (3.2 seeds per linear meter). The same was performed on March 19, 2021, adopting base fertilization in the formulation 07-23-23 and dose of 194 kg ha^{-1}, with the harvest occurring on August 3.

Weed control was carried out with the aid of a 10 L backpack pump in the initial stages of development, with the practice of post-emergence, thus in the first application Atrazine 900 WG, Glyphosate and adjuvant was used; the second application was of insecticide using Lambda cilotrina, triflumuron and adjuvant; the third application made use of fungicide (trifloxystrobin and cyproconazole) together with insecticide (Lambda cilotrina, triflumuron), oil and adjuvant; finally, the fourth application was also fungicide (picoxystrobin and cyproconazole), simultaneously with the insecticide Imidacloprid, oil and adjuvant.

On June 9, 2021, randomized leaf collections were made within the plot to determine the nitrogen content in the leaves, according to the recommendations described by Malavolta et al. (1997). Thirty leaves were taken from each plot and placed in paper bags, duly identified, for subsequent delivery to the laboratory where the foliar N content was analyzed.

When the crop reached full maturity (reproductive stage R8) ears were collected for the evaluation of the following variables: number of grain rows per ear (NGRE), number of grains per row (NGR), mass of one thousand grains (MMG) and productivity (PROD). To do this, the cobs present in the three central rows of 5 m of all units were manually harvested.

a) NGRE and NGR: 10 ears were sub-sampled from all e.u. to count their components.

b) MMG: after manual threshing of the 10 cobs, a portion of approximately 500 grams of grains was separated, from which the average of the sum of the weighings of eight sub-samples of one hundred grains was established, with data expressed in grams, corrected to 13% of moisture content. These were used to determine the MMG, which followed the prescriptions of the rules for grain analysis (RAS) of the Ministério da Agricultura, Pecuária e Abastecimento (MAPA) (BRASIL, 2009). The eight sub-samples of 100 grains were used to obtain the variance (V), the standard deviation (SD) and the coefficient of variation (CV) of the values obtained from the weighing of the pure grain portion (ISTA, 1995). Then, the MMG was quantified by multiplying by 10 the average weight obtained from the sub-samples, provided that the CV did not exceed 4%. The mass of 100 grains of all sub-samples, counted manually, were weighed on precision electronic scales.

c) PRODUCTIVITY: for the yield variable, the cobs of the three central rows were harvested, discarding 0.5 m from the headlands of all units, immediately the moment the crop reached the harvest point and moisture content between 11% and 13%. The cobs were threshed manually and the grains were weighed in precision digital scales, where the total weight of grains of each unit was obtained. After that, the relation between the mass of grains in the cobs with moisture content of 13% was performed and adjusted by the final plants population (Equation 1).

$$PROD = grain\ mass\ in\ 15\ linear\ meters * \frac{(100 - current\ grain\ moisture)}{(100 - desired\ moisture\ of\ the\ grains)} \qquad \text{Eq. 1}$$

The data were submitted to analysis of variance, with the means of the N application stages compared by the Tukey test at 5%. The statistical analyses were processed using the AgroEstat software (BARBOSA; MALDONADO JUNIOR, 2015).

Results and discussion

The accumulated rainfall from sowing (March 2021) until harvest of the experiment (August 2021) was 305 mm (Figure 2), which differs from the recommendation of Fancelli and Dourado Neto (2004) who cite thresholds of 350 to 500 mm of rainfall during the corn harvest to reach satisfactory yields. Although the volume of rainfall in the experimental area was below that indicated by the aforementioned authors, the rainfall during the first crop (soybean) was sufficient to allow the full development of the second crop corn, since the accumulated in the respective period was 1139 mm. In addition, in the week before the experiment sowing there was an accumulation of 239 mm of rain, which helped in the germination process of the crop and contributed to maintain an average soil moisture of 0.3446 $m^3\ m^{-3}$ throughout the 138 days of the development cycle of corn plants.

The maximum, minimum and average temperatures observed during the experiment period were, respectively, 34.7ºC, 10.8ºC and 24.5ºC (Figure 2). Acceptable values for the development of the culture and that corroborate with the limits of 40ºC and 10°C mentioned by Fancelli and Dourado Neto (2004).

The experiment used NMaiz urea treated with the NBPT additive, which is a urease inhibitor. A similar application was also performed in the works of Pereira et al. (2009), Scivittaro et al. (2010) and Frazão et al. (2014), who found a reduction in volatilization losses in wet soil by treating urea with this inhibitor. According to Scivittaro et al. (2010), such treatment of urea can reduce volatilization losses by about 88%, while Frazão et al. (2014) indicate yield increases close to 10.8% when NBPT treated urea is used instead of ordinary urea. However, Pereira et al. (2009) found that there was no significant difference in productivity with the use of polymer-coated urea compared with regular urea. This can be reinforced by the work of Civardi et al. (2011), Guareschi et al. (2013) and Maestrelo et al. (2014), which state that the use of polymer- coated urea is not efficient in increasing the productivity of second crop corn.

As shown in Table 1, the yield components analyzed in this experiment, such as the mass of one thousand grains (MMG) and the number of grain rows per ear (NRGE) did not differ statistically with the application of N at different stages. However, it is noted that when there is an advance application of protected urea there is a decrease in the mass of one thousand grains, as occurred at V0 and after V4, since the definition of the productive potential of corn plants occurs between V4 and V6, stages of higher demand for N (SANGOI et al., 2007).

The N plotting influenced the increase in the number of grains per row (NGR) in V1+V5 and decreased in V5+V9. In the other periods, there was no statistical difference in relation to the control (Table 1). NGR can vary among hybrids (FERNANDES et al., 2005; VALDERRAMA et al., 2011), nitrogen doses (CARMO et al., 2012), ear size (KAPPES et al., 2009) and nitrogen sources (ZUCARELI et al., 2014).

The highest MMG values and yields were observed when nitrogen fertilizer was applied at the phenological stages closest to the definition of yield potential and ear size (V4), and were found in the witness (V2+V4), V3+V7 and V4+V8 (Table 1).

Regarding the NRGE and NGR, Gott et al. (2014) state that these parameters were not affected by the different sources of N (ammonium nitrate and urea) and times of application of nitrogen fertilizer (V2, V4, V6 and V8). However, it indicates that there are increases for this parameter when the application of ammonium nitrate and urea is performed there is no statistical difference between treatments. On the other hand, Kappes et al. (2009) evaluated the response of corn to applications of urea, ammonium sulfate and Entec® [slow-release N source: 26% N, being 18.5% in the ammoniacal form and 7.5% in the nitric form, and 13% S (KAPPES et al., 2009)] at the stages V3, V7 and V10, and found that to have a greater number of grain rows it is necessary to make an application with ten expanded leaves (V10).

Sowing in no-till systems (SPD) and the use of nitrogen fertilizer application at V3, according to Kappes et al. (2009), the plant tends to present a greater number of rows and grains due to the good development of the ear. Differing from this author, a reduction of 3.6% in the number of grain rows per ear and an increase of 6.2% in the number of grains per row in relation to the control was obtained when urea was applied early (V0+V4) (Table 1). On the other hand, when the application is made later (V5+V9) there is a decrease of 7.2% and 4.2%, respectively, in the number of grains per row and the number of grain rows per ear. This is confirmed by the phenological scale proposed by Ritchie et al. (1993), which highlights that the definition of the number of grain rows occurs at V8, which may explain the lower productivity among all treatments in the experiment, contrary to the results found by Gott et al. (2014).

Table 1 - Average values of thousand-grain mass (MMG), number of grain rows per ear (NRGE), number of grains per row (NGR), foliar N content (FNC) and productivity (PROD) of second crop corn, as a function of coated urea application at different phenological stages, 2020/21 crop, in Vilhena-RO/Brazil.

Treatments	MMG (g)	NRGE	NGR	FNC (g kg^{-1})	PROD (kg ha^{-1})
Witness	315.08 a	16.90 a	28.60 ab	24.65 a	7962 a
V0+V4	303.70 a	16.30 a	30.38 a	25.68 a	7590 ab
V1+V5	301.43 a	16.33 a	28.33 ab	25.08 a	7446 ab
V2+V6	305.03 a	16.48 a	28.20 ab	23.23 a	7301 ab
V3+V7	318.23 a	16.05 a	28.28 ab	23.78 a	7895 a
V4+V8	310.28 a	16.60 a	28.93 ab	24.10 a	7821 ab
V5+V9	300.10 a	16.20 a	26.55 b	22.18 a	6630 b
F-Value	1.19 ns	0.78 ns	2.02 ns	0.91 ns	2.94*
DMS (5%)	29.83	1.49	3.72	5.78	20.94
CV%	4.15	3.88	5.60	10.27	7.15

Averages followed by the same letter in the column do not differ statistically by Tukey test, at 5% probability level and ns*: not significant and significant at 5%, by F test, respectively.

It is evident that the productivity (PROD) of grains in corn culture is subject to several factors that may interfere in its full development until the plant reaches physiological maturity. For Fancelli and Dourado Neto (2004) these edaphoclimatic and/or genetic environmental factors can have a great influence on the leaf area, photosynthetic activity and also the time that the leaves remain in full activity in the plant. This was observed in the productivity of the treatment that considered the application at V4, because unlike what occurred with the other stages, there was no rainfall in the following six days (Figures 2 and 3). Most likely the yield was not impacted by the fact that the accumulated rainfall in the days preceding the application kept the soil in satisfactory moisture conditions, preventing the abrupt volatilization of urea. Furthermore, it is considered that the 6 mm rainfall on May 23 was fundamental for the good development of the experiment, since the plant was in the transition from R1 to R2, the water bubble grain phase, where grain abortion may occur due to water stress.

The high productivity of the control plant, 7962 kg ha^{-1}, for which urea was applied at V2+V4 (Table 1; Figure 4), is also noticeable. This yield is within normal values for the region, due to the soil and climatic conditions already mentioned, especially the organic matter content of the soil, which is at an average level (2.9%), as well as the contents of P, Ca, Mn, B and Zn according to the soil correction and fertilization manual for the Cerrado (SOUSA; LOBATO, 2004). According to Ciotta et al. (2003), Costa et al. (2004), Rodrigues et al. (2018) and Dhaliwal et al. (2019) organic matter constitutes the main reservoir of N and carbon in the soil. The authors point out that SPD helps to decrease the decomposition rate of organic matter, contributing to its greater permanence in the productive system.

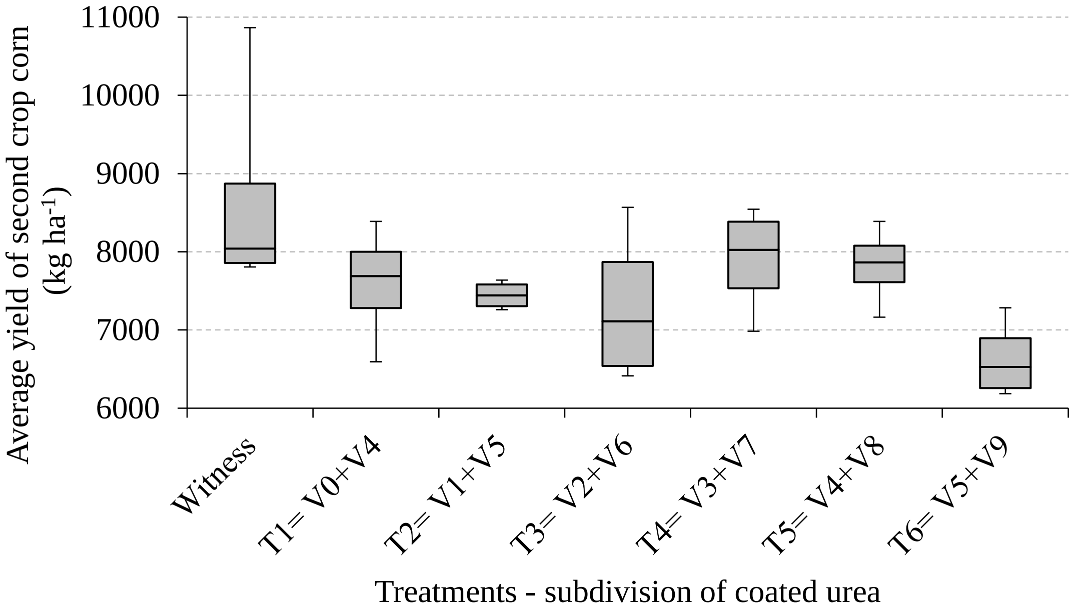

Figure 4 - Boxplot showing the average and quartiles of productivity in relation to the phenological stages in which nitrogen fertilizer was applied to second crop corn. São Carlos Farm, Vilhena-RO/Brazil, 2021.

Compared to the control (witness), it is still noteworthy that when the application of coated urea occurred in V3+V7 there was an increase of 0.99% in MMG and decrease of 0.8% in yield. When it was applied in V4+V8 there was a reduction of 1.52% and 1.8% in MMG and DPR, respectively. This was observed in V5+V9, but with greater intensity, because the observed decreases were 4.75% for MMG and 16.7% for PROD. This is ratified by the lowest average foliar N content (FNC) among all treatments, 22.18 g kg^{-1}, which represented a decrease of 10.02% compared to the control (24.65 g kg^{-1}). These similar results were also obtained by Gott et al. (2014), who, when using urea as a source of N, noted a lower leaf N content when the fertilizer was applied at the V8 phenological stage compared to the application made at the V4 phenological stage of corn.

When FNC was observed, there was no statistical difference between the considered stages (Table 1). Nevertheless, it was found that urea coated with NBPT provides higher foliar N content when supplied between the V1 and V2 stages, since the highest averages were reached in V1+V5 (25.68 g kg^{-1}) and V2+V6 (25.08 g kg^{-1}). This situation may have favored the response of corn to split fertilization rather than single dose applications (post-seeding - V2), since it is already known that these are the conditions favorable to losses, in which split nitrogen fertilization is recommended (LARA CABEZAS et al., 2005).

According to Silva et al. (2005) and Santos et al. (2010), corn productivity is affected by the timing of nitrogen fertilizer application. For them, the application of all N at sowing and at 15 DAE, when the plant is normally at the V4 phenological stage, presents potentially higher crop yields when compared to application at 35 DAE, when the plant is often at the V9 stage. As observed in this experiment, when the application of N was delayed, at V5+V9, there was a reduction in yield, reaching 6630 kg ha^{-1}, the lowest yield of all the treatments performed.

Conclusion

The application of NBPT-coated urea at different phenological stages was shown to be more efficient at applications closer to the definition of the yield potential (V4) and the definition of the number of rows per ear (V8). This was found in the yield components, leaf nitrogen content and productivity of hybrid LG 36790 PRO3. The statistical differences between the plots considered indicated more intense yield reductions between the plots V2+V4 and V5+V9 - 1332 kg ha^{-1}, and V3+V7 and V5+V9 - 1265 kg ha^{-1}. The most appropriate scheduling recommendation for growing conditions similar to the experimental area should contemplate the V2+V4 stages, considered the standard by farmers in the region.

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Conflicts of interest

All authors declare that they have no conflicts of interest.

Authors' contribution

Fabrício da Costa Czarnobay - conceptualization, methodology, prepared the materials and collected the analyzed data, formal analysis, writing - original draft; Marcelo Crestani Mota - writing - review & editing, project administration, commented on and edited previous versions of the manuscript; Karina Galvão de Souza - formal statistical analysis and review; Andressa Gregolin Moreira - formal statistical analysis and review; Sérgio Monteze Alves - conception and design; Francismeire Bonadeu – conception, design and review; Vicente de Paulo Campos Godinho - formal analysis and review.

References

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G. Köppen climate classification map for Brazil. **Meteorologische Zeitschrift**, v. 22, n. 6, p. 711-728, 2013. DOI: https://doi.org/10.1127/0941-2948/2013/0507

ALVES, H. C. R.; AMARAL, R. F. **Produção, área colhida e produtividade do milho no Nordeste**. Informe rural ETENE - Ano V, n. 16, September 2011. https://www.bnb.gov.br/s482-dspace/bitstream/123456789/964/1/2011_IRE_16.pdf

ABIMILHO – Associação Brasileira das Indústrias do Milho. **O cereal que enriquece a alimentação humana**. http://www.abimilho.com.br/milho/cereal

BARBOSA, J. C.; MALDONADO JUNIOR, W. **AgroEstat: sistema para análises estatísticas de ensaios agronômicos**. Jaboticabal, FCAV/UNESP, 2015, 396p.

BAYER, C.; FONTOURA, S. M. V. Dinâmica do nitrogênio no solo, pré culturas e o manejo da adubação nitrogenada na cultura do milho em plantio direto. *In*: FONTOURA, S. M. V.; BAYER, C. (Eds.). **Manejo e fertilidade de solos em plantio direto**. Guarapuava: Fundação Agrária de Pesquisa Agropecuária, p. 59-85, 2006.

BRASIL - Ministério da Agricultura, Pecuária e Abastecimento. **Regras para análises de sementes**. Secretaria de Defesa Agropecuária. Brasília: Mapa/ACS, 2009, 399p. https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/arquivos-publicacoes-insumos/2946_regras_analise__sementes.pdf

CANTARELLA, H.; DUARTE, A. P. Manejo da fertilidade do solo para a cultura do milho. *In*: GALVÃO, J. C. C.; MIRANDA, G. V. (Eds.). **Tecnologia de produção de milho**. Viçosa: Universidade Federal de Viçosa, p. 139-182, 2004.

CANTARELLA, H.; TRIVELIN, P. C. O.; CONTIN, T. L. M.; DIAS, F. L. F.; ROSSETTO, R.; MARCELINO, R.; COIMBRA, R. B.; QUAGGIO, J. A. Ammonia volatilisation from urease inhibitor-treated urea applied to sugarcane trash blankets. **Scientia Agricola**, v. 65, p. 397-401, 2008. DOI: https://doi.org/10.1590/S0103-90162008000400011

CARMO, M. S.; CRUZ, S. C. S.; SOUZA, E. J.; CAMPOS, L. F. C.; MACHADO, C. G. Sources and doses of nitrogen en the desenvelopment of culture endproductivity of sweet corn (Zea mays *convar. saccharata var. rugosa*). **Bioscience Journal**, v. 28, n. 1, p. 223-231, 2012. https://seer.ufu.br/index.php/biosciencejournal/article/view/13246

CIOTTA, M. N.; BAYER, C.; FONTOURA, S. M. V.; ERNANI, P. R.; ALBUQUERQUE, J. A. Soil organic matter and cation exchange capacity increase in a low activity clay soil under no-tillage system. **Ciência Rural**, v. 33, n. 6, p. 1161-1164, 2003. DOI: https://doi.org/10.1590/S0103-84782003000600026

CIVARDI, E. A.; SILVEIRA NETO, A. N.; RAGAGNIN, V. A.; GODOY, E. R.; BROD, E. Slow-release urea applied to surface and regular urea incorporated to soil on maize yield. Pesquisa Agropecuária Tropical, v. 41, n. 1, p. 52-59, 2011. DOI: https://doi.org/10.5216/pat.v41i1.8146

COBUCCI, T. **Efeitos de doses e épocas de aplicação em cobertura do adubo nitrogenado no consórcio milho-feijão**. 94f. Dissertação (Mestrado em Fitotecnia – Produção Vegetal) – Universidade Federal de Viçosa, Viçosa, 1991.

CONAB - Companhia Nacional de Abastecimento. **Acompanhamento da Safra Brasileira de Grãos - Décimo Segundo Levantamento da Safra 2020/21, Setembro 2021**. v. 8, n. 12, p. 1-97, 2021a. https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos

CONAB - Companhia Nacional de Abastecimento. **Acompanhamento da Safra Brasileira de Grãos - Primeiro Levantamento da Safra 2021/22, Outubro 2021**. v. 9, n. 1, p. 1-86. 2021b. https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos

COSTA, F. S.; BAYER, C.; ALBUQUERQUE, J. A.; FONTOURA, S. M. V. No-tillage increases soil organic matter in a South Brazilian oxisol. **Ciência Rural**, v. 34, n. 2, p. 587-589, 2004. DOI: https://doi.org/10.1590/S0103-84782004000200041

DEBRUIN, J.; BUTZEN, S. Nitrogen Uptake in Corn. **Pioneer Crop Insights**, 2015. https://www.pioneer.com/us/agronomy/nitrogen_uptake_corn.html

DHALIWAL, S. S.; NARESH, R. K.; MANDAL, A.; SINGH, R.; DHALIWAL, M. K. Dynamics and transformations of micronutrients in agricultural soils as influenced by organic matter build-up: A review. **Environmental and Sustainability Indicators**, v. 1-2, p. 1-14, 2019. DOI: https://doi.org/10.1016/j.indic.2019.100007

FANCELLI, A. L.; DOURADO NETO, D. **Produção de milho**. 2ª ed. Guaíba: Agropecuária, 2004, 360p.

FERNANDES, F. C. S.; BUZETTI, S.; ARF, O.; ANDRADE, J. A. C. Doses, efficiency and use of nitrogen by six corn cultivars. **Revista Brasileira de Milho e Sorgo**, v.4, n. 2, p. 195-204, 2005. DOI: https://doi.org/10.18512/1980-6477/rbms.v4n02p%25p

FORNASIERI FILHO, D. **Manual da cultura do milho**. Jaboticabal: Funep, 2007, 576p.

FRAZÃO, J. J.; da SILVA, A. R.; da SILVA, V. L.; OLIVEIRA, V. A.; CORRÊA, R. S. Enhanced efficiency nitrogen fertilizers and urea in corn. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 18, n. 12, p. 1262-1267, 2014. DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v18n12p1262-1267

GOTT, R. M.; SICHOCKI, D.; AQUINO, L. A.; XAVIER, F.; SANTOS, L. P. D.; AQUINO, R. F. B. A. Sources and times of nitrogen application in the off season maize. **Revista Brasileira de Milho e Sorgo**, v. 13, n. 1, p. 24-34, 2014. DOI: https://doi.org/10.18512/1980-6477/rbms.v13n1p24-34

GUARESCHI, R. F.; PERIN, A.; GAZOLLA, P. R. Corn yield under polymer coated urea application. **Global Science and Technology**, v. 6, n. 2, p. 31-37, 2013. DOI: http://dx.doi.org/10.14688/1984-3801.v06n02a04

ISTA - International Seed Testing Association. **Handbook of vigour test methods**. Zürich: ISTA, 1995, 117p.

KAPPES, C.; CARVALHO, M. A. C.; YAMASHITA, O. M.; SILVA , J. A. N. Nitrogen influence on double-cropped corn yield after soybean. **Pesquisa Agropecuária Tropical**, v. 39, n. 3, p. 251-259, 2009. https://www.revistas.ufg.br/pat/article/view/5756

LANDAU, E. C.; GARAGORRY, L. F.; FILHO, H. C.; GARCIA, J. C.; DUARTE, J. O.; CRUZ, J. C. Áreas de Concentração da Produção Nacional de Milho no Brasil. *In*: CONGRESSO NACIONAL DE

MILHO E SORGO, 28., 2010, Goiânia. **Anais…** Goiânia: Associação Brasileira de Milho e Sorgo, 2010. CD-ROM.

LARA CABEZAS, W. A. R.; ARRUDA, M. R. de; CANTARELLA, H.; PAULETTI, V.; TRIVELIN, P. C. O.; BENDASSOLLI, J. A. Imobilização de nitrogênio da uréia e do sulfato de amônio aplicado em pré-semeadura ou cobertura na cultura de milho, no sistema plantio direto. **Revista Brasileira de Ciência do Solo**, v. 29, n. 2, p. 215-226, 2005. DOI: https://doi.org/10.1590/S0100-06832005000200007

MAESTRELO, P. R.; BUZETTI, S.; FILHO, M. C. M. T.; GARCIA, C. M. P.; RODRIGUES, M. A. C.; LINO, A. C. M.; ANDREOTTI, M. Topdressing application of coated urea in irrigated corn under no-tillage system. **Revista Brasileira de Ciências Agrárias**, v. 9, n. 2, p. 192-199, 2014. DOI: https://doi.org/10.5039/agraria.v9i2a3708

MALAVOLTA, E.; VITTI, G. C.; OLIVEIRA, S. A. **Avaliação do estado nutricional das plantas: princípios e aplicações**. 2ª ed. Piracicaba: POTAFOS, 1997, 319p.

MARCHESAN, E.; GROHS, M.; WALTER, M.; SILVA, L. S.; FORMENTINI, T. C. Agronomic performance of rice to the use of urease inhibitor in two cropping systems. **Revista Ciência Agronômica**, v. 44, n. 3, p. 594-603, 2013. DOI: https://doi.org/10.1590/S1806-66902013000300023

OKUMURA, R. S.; MARIANO, D. C.; ZACCHEO, P. V. C. Use of nitrogen fertilizer in corn: a review. **Applied Research & Agrotechnology**, v. 4, n. 2, p. 226-244, 2011. DOI: https://doi.org/10.5777/paet.v4i2.1337

PEREIRA, H. S.; LEÃO, A. F.; VERGINASSI, A.; CARNEIRO, M. A. C. Ammonia volatilization of urea in the out-of-season corn. **Revista Brasileira de Ciência do Solo**, v. 33, n. 6, p. 1685-1694, 2009. DOI: https://doi.org/10.1590/S0100-06832009000600017

RAIJ, B. van; CANTARELLA, H.; QUAGGIO, J. A.; FURLANI, A. M. C. **Recomendações de adubação e calagem para o estado de São Paulo**. 2ª ed. Campinas: Instituto Agronômico, 1996, 285p. (IAC. Boletim Tecnico, 100).

REYNOLDS, C. M.; WOLF, D. C.; ARMBRUSTER, J. A. Factors related to urea hydrolysis in soil. **Soil Science Society of America Journal**, v. 49, n. 1, p. 104-108, 1985. DOI: https://doi.org/10.2136/sssaj1985.03615995004900010021x

RITCHIE, S. W.; HANWAY, J. J.; BENSON, G. O. **How a corn plant develops**. Special Report, 48. Ames, Iowa State University of Science and Technology, 1993, 26p.

RODRIGUES, F. J.; BARCAROL, M. A.; ADAMS, C. R.; KLEIN, C.; BERWANGER, A. L. Agronomic efficiency of maize crop under different nitrogen sources in coverage. **Uniciências**, v. 22, n. 2, p. 66-70, 2018. DOI: https://doi.org/10.17921/1415-5141.2018v22n2p66-70

SANGOI, L.; BERNS, A. C.; ALMEIDA, M. L.; ZANIN, C. G.; SCHWEITZER, C. Agronomic characteristics of wheat cultivars in response to the time of nitrogen fertilizer covering. **Ciência Rural**, v. 37, n. 6, p. 1564-1570, 2007. DOI: https://doi.org/10.1590/S0103-84782007000600010

SANGOI, L.; SILVA, P. R. F.; PAGLIARINI, N. H. F. **Estratégias de manejo da adubação nitrogenada em milho na região sul do Brasil**. Lages-SC: Graphel, 2016, 122p.

SANTOS, M. M.; GALVÃO, J. C. C.; SILVA, I. R.; MIRANDA, G. V.; FINGER, F. L. Nitrogen sidedressing and molybdenum application to untilled corn and nitrogen (^{15}N) allocation in the plant. **Revista Brasileira de Ciência do Solo**, v. 34, n. 4, p. 1185-1194, 2010. DOI: https://doi.org/10.1590/S0100-06832010000400018

SBCS - Sociedade Brasileira de Ciência do Solo (SBCS). **Manual de adubação e calagem para o estado do Paraná**. Curitiba: SBCS/NEPAR, 2017, 482p.

SCIVITTARO, W. B.; GONÇALVES, D. R. N.; VALE, M. L. C.; RICORDI, V. G. Nitrogen losses by ammonia volatilization and response of irrigated rice to application of urea treated with the urease inhibitor NBPT. **Ciência Rural**, v. 40, n. 6, p. 1283-1289, 2010. DOI: https://doi.org/10.1590/S0103-84782010000600007

SILVA, E. C.; FERREIRA, S. M.; SILVA, G. P.; ASSIS, R. L.; GUIMARÃES, G. L. Timing and methods of nitrogen application to no-tillage corn on cerrado soil. **Revista Brasileira de Ciência do Solo**, v. 29, n. 5, p. 725-733, 2005. DOI: https://doi.org/10.1590/S0100-06832005000500008

SOUSA, D. M. G. de; LOBATO, E. **Cerrado: correção do solo e adubação**. 2ª ed. Brasília, DF: Embrapa Informação Tecnológica, 2004, 416p.

VALDERRAMA, M.; BUZETTI, S.; BENETT, C. G. S.; FILHO, M. C. M. T. NPK sources and doses on irrigated corn under no-till system. **Pesquisa Agropecuária Tropical**, v. 41, n. 2, p. 254-263, 2011. https://www.revistas.ufg.br/pat/article/view/8390

VARGAS, V. P. **Manejo da adubação nitrogenada na recuperação de estresses em milho**. 145f. Dissertação (Mestrado em Ciência do Solo) – Centro de Ciências Agroveterinárias, Universidade do Estado de Santa Catarina, Lages, 2010.

ZUCARELI, C.; ALVES, G. B.; OLIVEIRA, M. A.; MACHADO, M. H. Agronomic performance of out-of-season maize crop as influenced by time of application and source of nitrogen fertilizers. **Científica**, v. 42, n. 1, p. 60-67, 2014. DOI: https://www.cabdirect.org/cabdirect/abstract/20143184525

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