Australian Journal of Crop Science

AJCS

AJCS 10(4):497-502 (2016) ISSN:1835-2707
DOI: 10.21475/ajcs.2016.10.04.p7229x

# Slow-release stabilized nitrogen fertilizers on initial development and nutrition of coffee plants (*Coffea arabica* L.)

**Vinícius José Ribeiro*[1], Felipe Vaz Andrade[2], Renato Ribeiro Passos[2], Eduardo Sá Mendonça[2], Laís Lemos da Silva[3], Amanda Faé Sartori[3]**

**[1]Soil Department, University Federal of Viçosa-UFV, Viçosa, MG, Brazil**
**[2]Department of Plant Production, University Federal of Espírito Santo-UFES, Alegre, ES, Brazil**
**[3]Agrarian Sciences Center, University Federal of Espírito Santo-UFES, Alegre, ES, Brazil**

***Corresponding author: vj.ribeiro@yahoo.com.br (V. J. Ribeiro)**

**Abstract**

Currently there is interest in aggregating technology to fertilizers in order to increase their efficiency. A good example is the use of slow and steady release nitrogen fertilizers. This study was conducted in a greenhouse to evaluate the efficiency of stabilized, slow-release nitrogen sources in the early development and nutrition of coffee plants (*Coffea arabica* L.). The treatments followed a factorial 6 × 3 being: six nitrogen fertilizer sources (conventional urea – CU; ammonium nitrate – AN; elemental sulfur coated urea - US; elemental sulfur coated urea and polymer - USP; urea combined with organic material - UO, and UO + NBPT - $UO_{NBPT}$); three application times, with four replications. The experiment was conducted for 150 days and the aerial part dry mass production (APDM), that of the leaf (LDM), plus the foliar N concentration and content were evaluated. The use of stabilized slow-release N fertilizers influenced (APDM) and (LDM) production as well as the foliar N concentration and content in coffee plants. The N content in the leaves followed the order: $UO_{NBPT}$ <UO <USP <US < AN <CU, contrary to the beneficial effects regarding N availability of fertilizers with associated technology in relation to the conventional source - Urea.

**Keywords:** Efficiency; fertilizer; polymers; technology; urea.
**Abbreviations:** Ca_calcium; Mg_magnesium; K_ Potassium; P_ phosphorus; N_ nitrogen; H + Al_acidity potential; $NH_3$_ ammonia; CU_ convencional ureia; AN_ammonium nitrate; US_elemental sulfur coated urea; USP_ elemental sulfur coated urea plus polymer; UO_ urea combined with organic material (filter cake); $UO_{NBPT}$_UO + NBPT; APDM_ aerial part dry mass; LDM_leaf dry mass; T1_Time1; T2_ Time2; T3_ Time3.

## Introduction

Coffee cultivation is an important social economic activity for small and medium farmers generating wealth and foreign exchange in Brazil (Pinto et al., 2014), which stands out as the largest producer and consumer of coffee in the world.

Nitrogen (N) stands out among the nutrients needed for the growth and development of plants, by positively affecting its vegetative growth (Yin et al., 2003; Coelho et al., 2012.). N is the macronutrient that provides the highest response regarding coffee plant productivity, it also being the nutrient most in demand for the initial development of seedlings in nurseries and for field crops (Cruz et al., 2014). However, low soil N availability, added to the high demand by plants, makes this element one of the most limiting nutrients to productivity (Braun et al., 2013). Urea is the most widely used nitrogen fertilizer in Bral and its low use efficiency is frequently reported in the literature (Silva et al., 2015) and primarily attributable to losses through denitrification and $NH_3$ volatilization, the latter reaching values near 80% of the N applied (Cabezas, 1997). Various studies are being carried out in Brazil with the use of more efficient fertilizers (stabilized slow-release fertilizers) in the production of various crops (Melo et al., 2001). These fertilizers are also known as coated, intelligent, encapsulated fertilizers. According to Shaviv (2001), these fertilizers provide the nutrients to the plants in a regular and continuous manner, which results in: lower frequency of applications in soils; nutrient loss reduction due to leaching, immobilization, and also volatilization; elimination of root damage by the high salt concentrations; greater fertilizer handling convenienc; contribution to $NO_3$ environmental pollution reduction, providing ecological value to an agricultural activity, and reduced production costs. Reports can be found in the literature on the higher efficiency of these fertilizers in crops such as soybean (*Glycine max*), cotton (*Gossypium* sp.) (Guareschi, et al., 2011), maize (*Zea mays*) (Ribeiro et al., 2011) and coffee (*Coffea arabica*) (Melo et al., 2001). Grohs et al. (2011) found that urea coated with $B^{2+}$ and $Cu^{2+}$ slows and reduces N loss via ammonia volatilization compared with conventional urea, with its efficiency associated with soil conditions and climate, influenced by the rice cultivation system (*Orysa sativa*). For Valderrama et al. (2011), polymer coated fertilizers may not be as efficient compared to conventional fertilizers in regard to foliar N concentration, production components and bean productivity (*Phaseolus vulgaris*). However, works aimed at the use of more efficient fertilizers in coffee plants are still scarce.

This work was carried out to evaluate the aerial part (APDM) and leaf (LDM) dry mass production, as well as the foliar N content and concentration in coffee plants (*Coffea arabica* L.), after application of stabilized slow release nitrogen fertilizers at different times, comparing the effect of these new technologies and of the fertilizer application management on plant development.

**Results and Discussion**

The application of nitrogen fertilizers altered the dry mass production of the aerial part (APDM) and leaf (LDM), as well as the N content and concentration in the aerial part of coffee plants (Fig.2). The results based on the N content were also presented, since the treatments with nitrogen fertilizer provided differentiated growth as to coffee plant LDM and APDM. Treatments in which there is a higher dry mass production lead to a nutrient dilution effect (Jarrell and Beverly, 1981; Partelli et al., 2014). For the C1 contrast (Table 1), that compares conventional fertilizers with other fertilizers with associated technology, there was no difference for APDM and LDM for the conventional source, but there were differences for the content and the concentration of foliar N. For the foliar N content and concentration we observed the following order: CU> AN> US> USP> OU> $UO_{NBPT}$ (Fig. 2), demonstrating the superiority of conventional sources (CU and AN) in relation to the sources associated with technology, according to Contrast C1 (Table 1). Similar results were observed for APDM and LDM (Fig. 2 and Table 1), regardless of the source application time. The use of stabilized slow-release nitrogen fertilizers is, in principle, an alternative for reducing N losses, mainly via $NH_3$ volatilization and increase its availability to plants, steadily and gradually providing N to plants (Almeida and Sanches, 2012), this result allows to question the efficiency of nitrogen fertilizers with associated technology. Polymer-based coatings must have good biodegradability and small dimensions (millimeter scale) to avoid significant variations in fertilizer volume (Guo et al., 2005). For Silva et al. (2012) fertilizers with associated technology, such as encapsulation, may contain a very thick layer of coating with low permeability which impairs the nutrient availability to the soil and hence to the plant. The encapsulation process directly influences the mechanism and intensity of the nutrient release process. Characteristics such as thickness, chemical nature of the coating resin, the amount of microfissures in the coating surface and the fertilizer granule size will also contribute to determine the nutrient release rate (Trenkel, 1997). For Vieira and Teixeira (2004), the release of nutrients from fertilizers with associated technology also depends on temperature and soil moisture. These fertilizers are made up of soluble compounds, surrounded by a water permeable resin, which regulates the nutrient supply process.

The temperature conditions (27°C) and soil moisture (60% field capacity) in our experiment favored the release of N from the fertilizer, leading to a similar effect for conventional fertilizers. Field conditions under which there is no strict temperature and soil moisture control, can lead to different results than those found, increasing the variability of plant responses to these fertilizers used. Fernandes and Fraga Jr. (2010), evaluating doses and nitrogen sources on productivity and maturation of irrigated coffee, concluded that the productivity (84.37 bags $ha^{-1}$) was higher with the use of controlled release N fertilizers. The authors justified the results by the reduction of nutrient losses and their better use by plants compared to the use of urea. For Melo et al. (2001), working with coffee plants (*Coffea arabica*), the application of 473.33 g of controlled release fertilizer caused an increase of 2.47 pairs of leaves on treated plants with respect to conventional fertilizers.

When comparing the physical coating technologies (US + USP) and the organic coating (UO + $UO_{NBPT}$) (Contrast C2, Table 1) we see that the fertilizers coated with physical protection were more efficient in producing APDM, LDM and foliar N content and concentration for the experimental conditions of this study. Fertilizers coated with sulfur and polymers represent a significant fraction of the controlled release fertilizer market. These fertilizers usually have a parabolic N release pattern. This release depends mainly on the quality and thickness of the granule coating (Trenkel, 2010). In Contrast C3 (Table 1), in which US is compared to USP, it was noted that polymer and sulfur-coated (USP) fertilizer did not promote an increase in foliar N concentration. Maestrelo et al. (2014) found no differences in foliar N in corn comparing common urea and polymer-coated urea. For the N, APDM and LDM contents, the US nitrogen fertilizer was more efficient. Various studies have demonstrated that the urea with polymer coating is not efficient in increasing corn grain productivity (Civardi et al., 2011; Guareschi et al., 2013; Maestrelo et al., 2014). These results may be associated with the thick coating over the fertilizer which may delay the release of the nutrient to the plant (Trenkel, 2010). When comparing UO with $UO_{NBPT}$ (C4, Table 1), the UO fertilizer was more efficient in the production of APDM, LDM and N concentration and content. These results are contrary to those obtained by Espíndula et al. (2013) who observed a linear increase in dry mass yield of wheat plants with increased doses of urea treated with NBPT, higher than the yields obtained with urea at doses of 90 and 120 kg $ha^{-1}$ N and those of Garcia et al. (2011), wherein the use of NBPT associated with the urea on coffee (*Coffea arabica* L.) conducted in pots promoted greater use of N with a gain of 18% in the plant dry mass production and 32% in their absorbed N. For the fertilizer application times, all sources behaved in a similar manner (Table 2). The split fertilizer applications led to greater efficiency (or availability) of the nitrogen fertilizer. These results corroborate Amado et al. (2002) and Silva et al. (2005) in which the nitrogen fertilizer parceling and application time constitute an alternative to increase N fertilizer efficiency in the crops and mitigate their losses. This is supported by the better N use, the result of synchronization between applications and the high plant nutrient demand period (Amado et al., 2002).

In contrast, C5 (Table 2), when splitting the application of nitrogen fertilizers there were higher APDM and LDM content,and foliar N concentration. Thus, the results obtained in our study do not corroborate with that indicated by Zabini et al. (2008). These authors, assessed the feasibility of coffee plant fertilization with controlled release N application and found that the fertilizers used, formulated with a controlled release N, are technically feasible to provide N for coffee plants in a single application, with reduced nutrient doses and manpower.

The application of nitrogen sources via parceling in three times led to an increased N content and concentration in leaves (C6, Table 2). Teixeira et al. (2010), applying the rates of 0, 50, 100, 150 and 200 kg $ha^{-1}$ of N as ammonium sulfate, urea and urea with NBPT at two application times (at sowing, along the lines or coverage), observed that the N sources had a similar effect, for both times, on plant height and grain yield in irrigated wheat. These contradictory results reinforce the need for further studies on these coating technologies related to the constant and gradual N supply to plants, considering coating type (Guareschi et al., 2013.); coating quality and thickness (Rodrigues et al., 2013.) and control of the experimental environment, such as soil temperature and moisture concentration (Lanna et al., 2010; Costa et al., 2003). Any changes in these characteristics may reflect in contradictory or inconsistent results and interpretations.

**Table 1.** Contrasts of the averages of aerial part (APDM) and leaf dry mass (LDM) and foliar Nitrogen (N) content and concentration for different N sources.

| Contrasts | APDM | LDM | $N_{content}$ | $N_{concentration}$ |
|---|---|---|---|---|
| C1 | 0.08 | -0.06 | 28.49** | 2.47** |
| C2 | 1.02** | 0.91** | 34.69** | 0.24 |
| C3 | 2.18** | 1.54** | 55.98** | -0.06 |
| C4 | -2.67** | -1.26** | -54.03** | -1.07° |

C1 = (CU + AN) vs (US USP + + + UO UONBPT); C2 = US + USP vs UO + UONBPT; C3 = US vs UPS; C4 = UONBPT vs OU; CU: conventional urea; AN: ammonium nitrate; US: elemental sulfur coated urea; USP: urea coated with elemental sulfur and polymer; UO: urea combined with organic material (filter cake); $UO_{NBPT}$: UO + NBPT; °, * and ** Significant at 10, 5 and 1%, respectively.

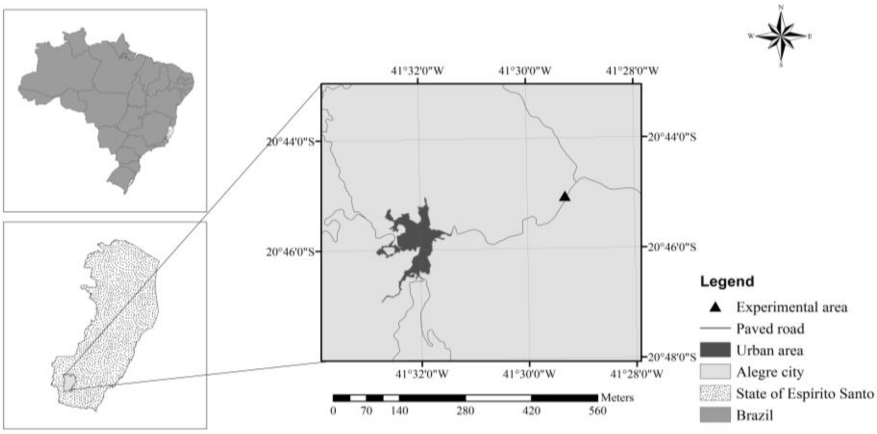


**Fig1.** Location of the study area.

**Materials and Methods**

***Experimental site***

The experiment was conducted in a greenhouse of the Agricultural Sciences Center of the Federal University of Espírito Santo (CCA - UFES) in Alegre - ES. The site is located at an altitude of 250 m, at 20º45'48" South and 41º31'57" West (Fig. 1).

***Soil and climatic characteristics***

The climate in the region is Cwa (subtropical climate, warm and humid in summer and dry in winter) according to the Köppen classification, with average annual rainfall of 1,200 mm and average annual temperature of 23°C. For this experiment, samples were collected from a Latossolo Vermelho Amarelo distrófico (Embrapa, 2013) at a depth of 20-40 cm. Once collected, the samples were air dried, declodded, and passed through a 2.0 mm sieve to obtain fine air-dried soil (FADS). The chemical and physical analyzes of soil samples, performed according to Embrapa (1997) and Almeida et al. (2012), respectively, revealed the following attributes: pH (in $H_2O$) = 4.80; P = 6.34 mg $dm^{-3}$; K = 14.00 mg $dm^{-3}$; Ca = 0.70 $cmol_c$ $dm^{-3}$; Mg = 0.70 $cmol_c$ $dm^{-3}$; $Al^{3+}$ = 0.25 $cmol_c$ $dm^{-3}$; H+Al = 4.29 $cmol_c$ $dm^{-3}$; Sum of Bases = 1.44 $cmol_c$ $dm^{-3}$; CEC capacity = 5.73 $cmol_c$ $dm^{-3}$; CECt = 1.69 $cmol_c$ $dm^{-3}$; V = 25.13%; Sand = 296 g $kg^{-1}$; Silt = 32 g $kg^{-1}$; Clay = 672 g $kg^{-1}$.

***Experimental design***

Different N sources were added to soil samples at different application times. The N sources used were conventional urea - CU; ammonium nitrate - AN; elemental sulfur coated urea - US; urea coated with elemental sulfur and polymer - USP; urea combined with organic material (filter cake) - UO; NBPT and UO + (N-(n-Butyl) thiophosphoric triamide) - $UO_{NBPT}$. The N dose was 75 mg $dm^{-3}$, adapted from Novais et al. (1991), considering the volume of soil used and it was applied at 2 cm of depth.
The treatments followed a factorial 6 × 3 where the factors studied were: six N sources (CU, AN, US, USP, UO, $UO_{NBPT}$) × three application times (Time 1: 100% of the N dose applied at the beginning of the experiment; Time 2: 50% of the N dose applied the beginning of the experiment and 50% after forty-five days, and Time 3: 33.4% of the N dose applied at the beginning of the experiment and two more applications of 33.3% at two forty-five day intervals). The experiment was arranged in a randomized block design (RBD), with four replications.

***Soil preparation and conduction***

Soil samples (2 $dm^3$) were placed in plastic bags for liming by the $Al^{3+}$ neutralization and elevated $Ca^{2+}$ + $Mg^{2+}$ concentration method (Alvarez V and Ribeiro, 1999). Soil moisture was adjusted to 60% of field capacity (Reichardt, 1988). After 21 days of incubation, the soil was air dried, declodded and sieveed in a 2 mm seive (FADS) for mounting the experiment.

Soil samples (FADS) were weighed (10 $dm^3$) and placed in pots with a 12 $dm^3$ capacity, respecting the density of the studied soil. The fertilization (P, K and micronutrients) was performed according Novais et al. (1991) throughout the total soil volume before planting the Arabica coffee seedlings, Red Catuaí IAC 44 cultivar, at the three to four true leaf pair stage. Irrigation of the pots was performed daily according to need, maintaining constant moisture for all pots at 60% of field capacity. The control of weeds, pests and diseases was conducted when necessary.

**Table 2.** Contrasts of the averages of nitrogen source application times for the aerial part (APDM) and leaf (LDM) dry mass and foliar Nitrogen (N) content and concentration.

| Contrasts | Sources | APDM | LDM | $N_{content}$ | $N_{concentration}$ |
|---|---|---|---|---|---|
| C5 | CU | 18.11** | 12.37** | 500.47** | 39.75** |
| | AN | 18.53** | 11.93** | 494.44** | 41.20** |
| | US | 19.35** | 13.81** | 498.14** | 35.82** |
| | USP | 20.65** | 12.54** | 427.79** | 34.18** |
| | UO | 22.71** | 14.56** | 531.20** | 36.94** |
| | $UO_{NBPT}$ | 15.87** | 10.50** | 401.46** | 37.43** |
| C6 | CU | 4.98** | 3.22** | 182.47** | 4.9** |
| | AN | 1.65** | 1.29** | 103.07** | 4.40** |
| | US | 0.39 | 2.39** | 118.75** | 2.48** |
| | USP | -1.10** | -0.71** | -16.04 | 0.70 |
| | UO | -1.76** | -1.49** | -20.49 | 2.41** |
| | $UO_{NBPT}$ | 5.15** | 2.82** | 156.74** | 5.24** |

$C_5$ = Time 2: 50% of the N dose applied at the beginning of the experiment and 50% after forty-five days, plus Time 3: 33.4% of the N dose applied at the beginning of the experiment and two more applications of 33.3% at two forty-five day intervals versus Time 1: 100% of the N dose applied at the beginning of the experiment. C6 = Time 3: 33.4% of the N dose applied at the beginning of the experiment and two more applications of 33.3% at two forty-five day intervals versus Time 2: 50% of the N dose applied the beginning of the experiment and 50% after forty-five days. CU: conventional urea; AN: ammonium nitrate; US: elemental sulfur coated urea; USP: urea coated with elemental sulfur and polymer; UO: urea combined with organic material (filter cake); $UO_{NBPT}$: UO + NBPT; NBPT: N-(n-Butyl) thiophosphoric triamide; °, * and ** Significant at 10, 5 and 1%, respectively.

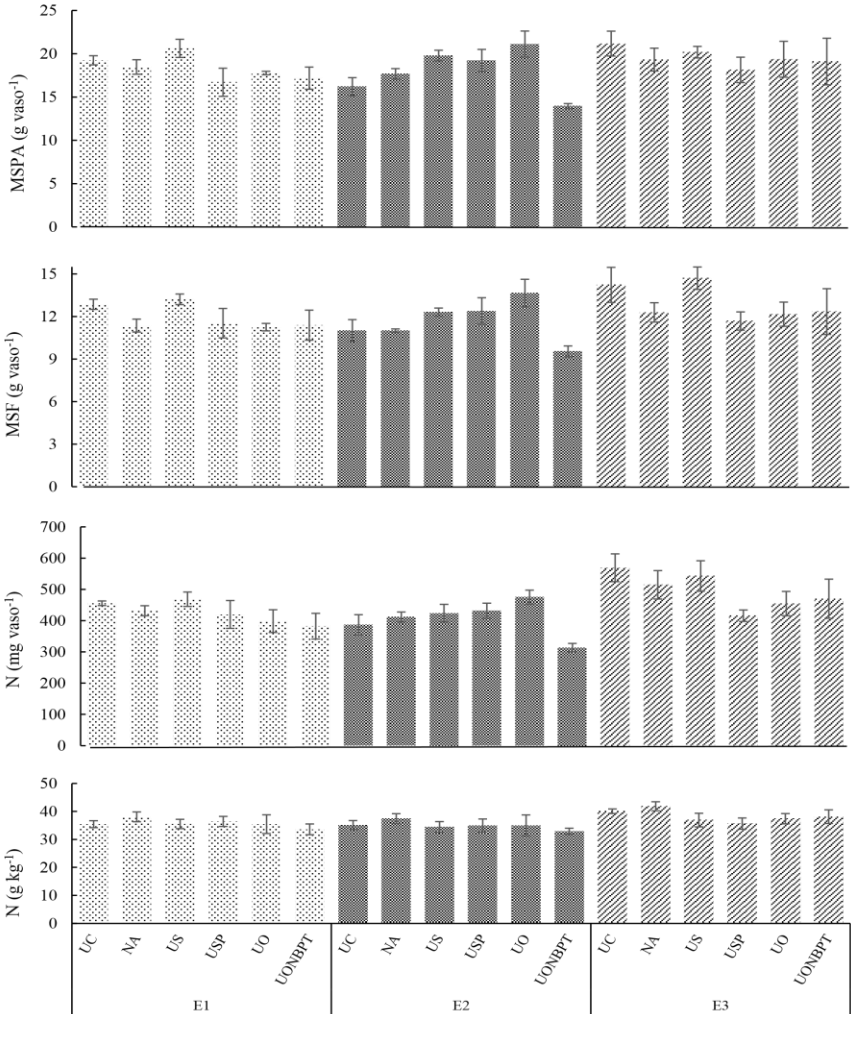


**Fig 2.** Average aerial part (APDM) and leaf dry mass production (LDM) and nitrogen (N) content and concentration in coffee plants (Coffea arabica L.) conducted over a period of 150 days, on different N sources and application times. CU: conventional urea; AN: ammonium nitrate; US: elemental sulfur coated urea; USP: urea coated with elemental sulfur and polymer; UO: urea combined with organic material (filter cake); $UO_{NBPT}$: UO + NBPT; T1: 100% of the N rate applied at the beginning of the experiment; T2: 50% of the N dose applied the beginning of the experiment and 50% after forty-five days; and T3: 33.4% of the N dose applied at the beginning of the experiment and two more applications of 33.3% at two forty-five day intervals. NBPT: N-(n-Butyl) thiophosphoric triamide.

***Variables analyzed***

At the end of the experiment (150 days), the plants were cut about 1 cm from the soil, and stems and leaves separated, which were separately placed in paper bags and brought to a forced-air-circulation oven at a temperature 65°C to determine the leaf (LDM) and aerial part dry mass (APDM), which includes the stem and leaves. The samples were then ground and digested to obtain foliar N content and concentration. The N concentration was obtained by digesting 0.5 g of dry mass, $H_2SO_4$ and $H_2O_2$ plus the digestion mixture ($Na_2SO_4$, $CuSO_4.5H_2O$) followed by Kjeldahl semimicro steam drag distillation according to Tedesco et al. (1995). The leaf N content was calculated by multiplying the N concentration by the respective values of the dry mass weight, obtained in the samples (C = DM x T / 1000, where C = nutrient content (mg $pot^{-1}$); DM = dry weight (g $pot^{-1}$) and T = nutrient concentration (g $kg^{-1}$).

***Statistical analysis***

The results were submitted to analysis of variance using the SAEG program (SAEG, 2007) described by Euclydes (1983), and the effects between the qualitative factors (sources, times) were broken down in the contrasts.

**Conclusions**

The fertilizers with associated technology studied were not effective in increasing the foliar N concentration and content in coffee plants (*Coffea arabica* L.). Urea and ammonium nitrate provided greater foliar N content and concentration in coffee plants (*Coffea arabica* L.). For fertilizers with associated technologies, the increase in foliar N content followed the order: US> USP> OU> $UO_{NBPT.}$ The parceling of nitrogen fertilization provided higher APDM and LDM production and higher foliar N concentration and content in coffee plants (*Coffea arabica* L.), even when using fertilizers with associated technologies.

**Acknowledgement**

To the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the grant award during the Master's course and the Fundação de Amparo à Pesquisa do Espírito Santo (FAPES).

**References**

Almeida BG, Donagemma GK, Ruiz HA, Braida JA, Viana JHM, Reichert JMM, Oliveira LB, Ceddia MB, Wadt PGS, Fernandes RBA, Passos RR, Dechen SCF, Klein VA, Teixeira WG (2012) Padronização de métodos para análise granulométrica no Brasil. Embrapa Solos. 11p.

Almeida RF, Sanches BC (2012) Fertilizantes nitrogenados com liberação lenta e estabilizada na agricultura. Rev Verde Agroecologia Desenvolv Sustent. 7(5):31-35.

Alvarez V VH, Ribeiro AC (1999) Calagem. In: Ribeiro AC, Guimarães PTG, Alvarez V VH. Recomendações para o uso de corretivos e fertilizantes em Minas Gerais - 5ª aproximação. Viçosa, MG. p. 43-60

Amado TJC, Mielniczuk J, Aita C (2002) Recomendação de adubação nitrogenada para o milho no RS e SC adaptada ao uso de culturas de cobertura do solo, sob sistema plantio direto. Rev Bras Ciênc Solo. 26:241-248.

Braun H, Coelho FS, de Castro Silva MC, Fontes PCR, Cecon PR, Busato C (2013) Absorção, metabolismo e diagnóstico do estado de nitrogênio nas plantas de batata. Rev Ciênc Agrár/Amazonian Journal of Agricultural and Environmental Sciences. 56(3):185-195.

Civardi EA, Neto ANS, Ragagnin VA, Godoy ER, Brod E (2011) Ureia de liberação lenta aplicada superficialmente e ureia comum incorporada ao solo no rendimento do milho. Pesqui Agropecu Trop. 41:52-59.

Coelho FS, Fontes PCR, Finger FL, Cecon PR (2012) Avaliação do estado nutricional do nitrogênio em batateira por meio de polifenóis e clorofila na folha. Pesq Agropec Bras. 47(4):584-592.

Costa MCG, Vitti GC, Cantarella H (2003) Volatilização de N-$NH_3$ de fontes nitrogenadas em cana-de-açúcar colhida sem despalha a fogo. Rev Bras Ciênc Solo. 27(4):631-637.

Cruz FJR, De Almeida HJ, Dos Santos DMM (2014) Growth, nutritional status and nitrogen metabolism in Vigna unguiculata (L.) Walp is affected by aluminium. Aust J Crop Sci. 8(7):1132-1139.

Embrapa (1997) Manual methods of analysis of soils. 2th Edition. Rio de Janeiro: Embrapa. 212p.

Embrapa Solos (2013) Sistema brasileiro de classificação de solos. Rio de Janeiro: Embrapa. 353p.

Espíndula MC, Rocha VS. Souza MA, Campanharo M, Paula GS (2013) Rates of urea with or without urease inhibitor for topdressing wheat. Chil J Agr Res. 73(2):160-167.

Euclydes RF. Manual de utilização do programa SAEG (Sistema para Análises Estatísticas e Genéticas). Viçosa: UFV,1983. 53p.

Fernandes ALT, Fraga Junior EF (2010) Doses de fontes nitrogenadas convencionais e nitrogênio polimerizado na produtividade e maturação do cafeeiro irrigado. Fazu em Revista. 7:37-41.

Garcia ALA, Padilha L, Garcia AWR, Mendes ANG, Carvalho CHS (2011) Efeito da ureia com inibidor de urease no crescimento de mudas de cafeeiro (*Coffea arabica L.*). Coffee Sci. 6:1-7.

Grohs M, Marchesan E, Santos DS, Massoni PFS, Sartori GMS, Ferreira RB (2011) Resposta do arroz irrigado ao uso de inibidor de urease em plantio direto e convencional. Ciênc Agrotec. 35:(2): 336-345.

Guareschi RF, Gazolla PR, Perin A, Santini JMK (2011) Adubação antecipada na cultura da soja com superfosfato triplo e cloreto de potássio revestidos por polímeros. Ciênc Agrotec. 35(4):643-648.

Guareschi RF, Perin A, Gazolla PR (2013) Produtividade de milho submetido à aplicação de ureia revestida por polímeros. Glob Sci Technol. 6(2):31-37.

Guo M, Liu M, Zhan F, Wu L (2005) Preparation and properties of a slow-release membrane-encapsulated urea fertilizer with superabsorbent and moisture preservation. Ind Eng Chem Res 44(12): 4206-4211.

Jarrell WM, Beverly RB (1981) The dilution effect in plant nutrition studies. Adv Agron. 34:197-224.

Lanna AC, Silveira PM, Silva MB, Ferraresi TM, Kliemann HJ (2010) Atividade de urease no solo com feijoeiro influenciada pela cobertura vegetal e sistemas de plantio. Rev Bras Ciênc Solo. 34(6):1933-1939.

Cabezas WARL, Korndorfer GH, Motta SA (1997) Volatilização de N-$NH_3$ na cultura de milho: I. Efeito da irrigação e substituição parcial da ureia por sulfato de amônio. Rev Bras Ciênc Solo. 21(3): 481-487.

Maestrelo PR, Buzetti S, Teixeira Filho MCM, Garcia CMP, Rodrigues MAC, Lino ACM, Andreotti M (2014) Aplicação de ureia revestida em cobertura no milho

irrigado sob sistema de semeadura direta. Rev Bras Ciênc Agrár. 9(2):192-199.
Melo B, Mendes ANG, Guimarães PTG (2001) Doses crescentes de fertilizantes de liberação gradual na produção de mudas de cafeeiro (*Coffea arabica* L.). Biosci J. 17:97-113.
Novais RF, Neves JCL, Barros NF (1991) Ensaio em ambiente controlado. In: Oliveira AJ, Garrido WE, Araújo JD, Lourenço S. Métodos de pesquisa em fertilidade do solo. EMBRAPA-SAE, Brasília. pp.189-254.
Partelli FL, Dias JRM, Vieira HD, Wadt PGS, Júnior EP (2014) Avaliação nutricional de feijoeiro irrigado pelos métodos CND, DRIS e faixas de suficiência. Rev Bras Ciênc Solo. 38:858-866.
Pinto LFG, Gardner T, McDermott CL, Ayub KOL (2014) Group certification supports an increase in the diversity of sustainable agriculture network–rainforest alliance certified coffee producers in Brazil. Ecol Econ. 107:59-64.
Reichardt K (1988) Capacidade de campo. Rev Bras Ciênc Solo. 12(2):211-216.
Ribeiro VJ, Souza CHE, Caixeta CG, Souza LF, Castro JS (2011) Avaliação da produção de milho sequeiro adubado com MAP polimerizado na região de Patos de Minas-MG. In: Anais do 33º Congresso Brasileiro de Ciências do Solo, agosto 2011, Uberlândia, MG. Solos nos biomas brasileiros: Sustentabilidade e mudanças Climáticas.
Rodrigues MAC, Buzetti S, Maestrelo PR, Lino ACM, Teixeira Filho MCM, Andreotti M, Garcia, CMP (2013) Cloreto de potássio revestido em efeito residual no feijoeiro de inverno irrigado na região de cerrado. Semina: Ciências Agrárias. 34:1011-1022.
SAEG Sistema para Análises Estatísticas, Versão 9.1 (2007) Fundação Arthur Bernardes - UFV - Viçosa.
SHAVIV A (2001) Advances in controlled-release fertilizers. Advances in Agronomy. 71:1-49.
Silva ADA, Silva TS, Vasconcelos AD, Lana R (2012) Aplicação de diferentes fontes de ureia de liberação gradual na cultura do milho. Biosci J. 28:104-111.
Silva DFD, Pegoraro RF, Medeiros AC, Lopes PAP, Cardoso MM, Maia VM (2015) Nitrogen and plant density in the economic evaluation and fruit quality of pineapple. Pesqui Agropecu Trop. 45:39-45.
Silva EC, Buzetti S, Guimaraes GL, Lazarini E, SÁ ME (2005) Doses e épocas de aplicação de nitrogênio na cultura do milho em plantio direto sobre latossolo vermelho. Rev Bras Ciênc Solo. 29:353-362.
Tedesco M, Gianello C, Bissani CA, Bohnen H, Volkwiss SJ (1995) Análise de solo, plantas e outros materiais. 2. ed. Porto Alegre: Departamento de Solos, UFRGS. 174p.
Teixeira Filho MCM, Buzetti S, Andreotti M, Arf O, Benett CGS (2010) Doses, fontes e épocas de aplicação de nitrogênio em trigo irrigado em plantio direto. Pesqui Agropec Bras. 45(8):797-804.
Trenkel ME (1997) Controlled-release and stabilized fertilizers in agriculture. International fertilizer industry association. Paris: IFA. 156p.
Trenkel ME (2010) Slow and controlled-release and stabilized fertilizers: An Option for Enhancing Nutrient Efficiency in Agriculture. 2.ed. Paris: IFA. 163p.
Valderrama M, Buzetti S, Benett CGS, Andreotti M, Teixeira Filho MCM (2011) Fontes e doses de NPK em milho irrigado sob plantio direto. Pesqui Agropecu Trop. 41(2):254-263.
Vieira BARM, Teixeira MM (2004) Adubação de liberação controlada chega como solução. Revista Campo e Negócios. 41(3):4-8.
Yin X, Lantinga EA, Schapendonk AH, Zhong X (2003) Some quantitative relationships between leaf area index and canopy nitrogen content and distribution. Ann Bot. 91(7):893-903.
Zabini AV, Carvalho M, Barbosa CM (2008) Adubação do cafeeiro com nitrogênio de liberação gradual em lavouras de 1º ano na região das Matas de Minas. In: Anais do 34º Congresso Brasileiro de Pesquisas Cafeeiras, novembro 2008, Caxambu, MG. Rio de Janeiro: MAPA/Procafé. p.226-227.