REVISTA DE CIÊNCIASAGRÁRIAS
Amazonian Journal
of Agricultural and Environmental Sciences
www.ajaes.ufra.edu.br

http://dx.doi.org/10.4322/rca.2013.008

ORIGINAL ARTICLE

# Straw persistence and nutrient release from crambe abyssinica according to the time of management

## *Persistência de palhada e liberação de nutrientes do crambe em função da época de manejo*

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**KEYWORDS**
*Crambe abyssinica*
Nutrient cycling
Biomass decomposition

**PALAVRAS-CHAVE**
*Crambe abyssinica*
Reciclagem de nutrientes
Decomposição de biomassa

**ABSTRACT:** The production and maintenance of plant residues on soil surface as well as the dynamics of nutrient release are fundamental to the success of no-tillage system. The objective of this study was to evaluate the persistence and nutrient release from crambe straw in the municipality of Dourados, State of Mato Graso do Sul, Brazil. The experiment was carried out at the Experimental Farm of the Federal University of Grande Dourados located at 54° 56' W and 22° 12' S, 452 m above sea level. The experimental design used complete randomized blocks with five replications. Treatments consisted of two management times (flowering and harvest) combined with 5 sampling times after management: 0, 15, 30, 45 and 60 days. The dry matter produced by the crambe plants cut at flowering and at harvest is insufficient to properly cover soil surface under no-tillage system. The crambe straw cut at flowering shows high macronutrient levels and low decomposition (low C:N ratio). Conversely, cutting plants at harvest leads to low macronutrient levels and high persistence on soil surface (high C:N ratio). Persistence of crambe residues from plants cut at flowering is low, but straw yield at harvest is high. Potassium, magnesium and sulphur are released from residues right after the cutting of plants; on the other hand, nitrogen, calcium and phosphorus are released later.

**RESUMO:** *A produção e a manutenção de palhada sobre a superfície do solo, e a dinâmica de liberação dos nutrientes são de suma importância para o sucesso do plantio direto. O objetivo deste trabalho foi avaliar a persistência e a liberação de nutrientes de palhada de crambe em Dourados-MS. O experimento foi instalado na Fazenda Experimental de Ciências Agrárias da Universidade Federal da Grande Dourados, no município de Dourados-MS, sob coordenadas de 54° 56' W e 22° 12' S e 452 m de altitude. O delineamento experimental foi em blocos casualizados, com duas épocas de corte (florescimento e colheita) e cinco tempos de coleta após o manejo (0, 15, 30, 45 e 60 dias), com cinco repetições. A massa de matéria seca de plantas de crambe cortadas no florescimento e na colheita é insuficiente para promover a cobertura adequada do solo em plantio direto. A palha de crambe cortada no florescimento apresenta elevado teor de macronutriente e baixa persistência de palhada (baixa relação C:N), enquanto a palha da colheita apresenta baixo teor de macronutriente e alta persistência da palhada (alta relação C:N). A persistência da palha de crambe cortada no florescimento é baixa, enquanto da palha gerada na colheita é alta. Os elementos mais rapidamente liberados após o corte da palhada são K, Mg e S, enquanto N, Ca e P são liberados mais tardiamente.*

Recebido: 15/07/2012
Aceito: 21/12/2012

## 1 Introduction

Phytomass production, maintenance of straw on soil surface, and absence of soil revolvement are important practices for the success of no-tillage systems (NTS), mainly in regions where high levels of temperature and humidity during summer expedite the decomposition process (TEIXEIRA et al., 2009). Ensuring the sustainability of NTSs depends, therefore, on the maintenance of systems capable of generating enough amount of quality dry matter to keep the soil covered throughout the year (KLIEMANN; BRAZ; SILVEIRA, 2006), in addition to allowing the use of recycled nutrients.

The residue decomposition rate of crops and cover plants is important for nutrient cycling, and the knowledge of this dynamics is essential for the understanding of this process (TEIXEIRA et al., 2011). The persistence of vegetation cover on the soil depends on the decomposition rate, which varies according to species and their chemical compositions, climatic factors, the cover management, the initial biomass and the age of vegetables at the time of management (ARAÚJO; RODRIGUES, 2000); while nutrient release depends on the location and the form this nutrient is found in the vegetal tissue (GIACOMINI et al., 2003).

The dynamics of straw nutrient release can contribute to the increased efficiency of nutrient use by subsequent crops, since it makes nutrients available during the periods crops most need them, or even supply crops during times when the demand is smaller (ROSOLEM; CALONEGO; FOLONI, 2003; CRUSCIOL et al., 2005, 2008).

The Brazilian Cerrado region stands out in grain production, with over 50% of the soybean and corn productions of the country, a fact that has aroused concern regarding the use of conservative practices that maintain soil sustainability (PACHECO et al., 2011). In most of this geographic area, in-between crops (during the autumn and winter), the climatic conditions are characterized by reduced rainfall and high temperatures, which hampers the establishment of cover plants (PACHECO et al., 2008). In some regions of the Cerrado, during the second crop (from February to April), it is possible to sow fast-growth species that are reasonably resistant to water deficit.

Crambe (*Crambe abyssinica* Hochst), an oleaginous plant of the family Brassicaceae, native of the Mediterranean region (FALASTA et al., 2010), may be an option for the cropping system in regions whose period for planting crops is limited by climatic conditions.

Crambe is a subshrub that can reach one to two meters in height, depending on the time and intensity of its planting. It presents tap root system with rod-type stem and moderate ramification. Its flowers are white or yellow and blossom in cluster along the stem and branches.

The seeds are spherical, from 0.8 to 2.6 mm in diameter, enveloped by a small capsule that remains after harvest (FONTANA et al., 1998; FALASTA et al., 2010). It presents indehiscent fruit and weight of a thousand seeds is of approximately 6-10 g (FALASTA et al., 2010). In general, the fruits develop at the base of inflorescence predominantly.

Due to its favorable characteristics for second crop cultivation, such as high tolerance to water deficit and low temperatures, precocity (90-day cycle), low production cost, besides accepting mechanized cultivation, this species has attracted the interest of several producers in the midwest region of the country. Thus, crambe has become one more option for cultivation in the second crop, especially in regions whose time gap between crop planting, such as corn, is short (PITOL; BROCH; ROSCOE, 2010). However, literature data on this species as a cover plant are scarce.

The purpose of this study was to assess the straw persistence and nutrient release from crop residues of crambe species cut at flowering and harvest.

## 2 Materials and Methods

The experiment was carried out in 2010 at the Experimental Farm of the Federal University of Grande Dourados, in the municipality of Dourados, state of Mato Grosso do Sul, geographically located at 54° 56' W and 22° 12' S, 452 m above sea level. According to Köppen classification, the climate is characterized as mesothermal humid with rainy summer, Cwa type. The mean temperature and rainfall registered during the experiment are shown in Figure 1.

The soil in the experimental area was classified as very clayey Distroferric Red Latosol (EMBRAPA, 2006). The chemical analysis of the 0-0.20 m layer showed the following results: OM = 26.0 g $dm^{-3}$; pH ($CaCl_2$) = 5.4; P (resin) = 25 mg $dm^{-3}$; H+Al = 58 $mmol_c$ $dm^{-3}$, $K^+$, $Ca^{2+}$ and $Mg^{2+}$ = 8.7; 36.0 and 22.0 $mmol_c$ $dm^{-3}$, respectively; V% = 54; CTC = 124.7 $mmol_c$ $dm^{-3}$, and $S\text{-}SO_4^{-2}$ = 5.6 mg $dm^{-3}$. Particle size analyses were as follows: 645 g $kg^{-1}$ clay, 203 g $kg^{-1}$ silt and 152 g $kg^{-1}$ sand.

A split-plot experimental design with randomized blocks and five replications was adopted. The plots were constituted by the sampling times of the decomposition bags: 0, 15, 30, 45 and 60 days after the cut (DAC) of the plant shoot phytomass, and they were subdivided in two sampling times: flowering and harvest.

The sowing of crambe FMS Brilhante was mechanically performed on April 21, 2010 using a 13-row planter-fertilizer indicated for no-tillage systems; the emergence occurred on April 28, 2010. The area had been under no-tillage system for over 10 years, with corn-soybean succession cropping system, (Zea mays) and (Glycine max) respectively. Crambe seeds were sown on the soybean straw spaced 0.40 m in-between rows with 120 plants per square meter, which is equivalent to approximately 15 kg $ha^{-1}$ seed rate (PITOL; BROCH;

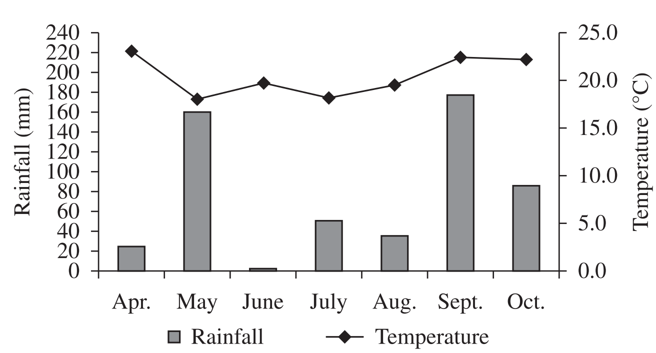


**Figure 1.** Monthly rainfall and mean temperature during the experimental period.

ROSCOE, 2010). The seeds presented 90% germination capacity. As recommended by Pitol (2008), 300 kg $ha^{-1}$ of the formula 08-20-20 were used in the sowing fertilization of the area. A plant grinder, Triton© model, was used for the crambe phytomass cutting process at flowering. Five samplings were performed, with the aid of 1 $m^2$ internal area frame, for the evaluation of biomass production and nutrient accumulation on the cutting days (June 8, 2010 – flowering and August 11, 2010 – harvest).

The plants were cut close to the soil, packed in paper bags, taken to the laboratory, and then chopped with the aid of scissors in 5 cm pieces and dried in forced air circulation oven, at 60 °C, until constant mass was reached. For the plants sampled at harvest, all seeds were removed before fractioning.

In order to evaluate the decomposition rate and nutrient release, we used the method of decomposition bags (AITA; GIACOMINI, 2003), which were manufactured with plastic material (2 mm nylon mesh), 0.04 $m^2$ (20 × 20 cm) dimensions. Twenty kilograms of crambe shoots from the oven-dried composite sample, which were collected with the aid of frames and chopped with scissors, were placed in each bag. The collection of the material that would be placed in the field was considered the zero time; this material was separated and taken to further analysis. Next, eight bags were distributed in each plot; they were collected in their due times – two bags per sampling time were collected from each plot.

The decomposition bags removed from the field were pre-cleaned with size 2, 4, 6 and 8 brushes for removal of adhered dirt. The samples were dried in forced air circulation oven at 60 °C until constant mass was reached; they were then ground in Willey-type mill and submitted to chemical analysis for determination of macronutrients, as described by Malavolta, Vitti and Oliveira (1997); the method by Walkley and Black modified (TEDESCO; VOLKWEISS; BOHNEN, 1985) was used for carbon content determination.

The amount of macronutrient accumulated in the straw was determined by multiplying the dry matter amount by the nutrient levels contained in the corresponding plant residue. With these values, we calculated the nutrient release to the soil from the zero time value minus the amount found on each collection day. Subsequently, the data were submitted to analysis of variance and polynomial regression and math equations were adjusted.

## 3 Results and Discussions

Crambe dry matter yield was greater during flowering (4,070 kg $ha^{-1}$) compared to harvest (2,203 kg $ha^{-1}$) (Figura 2).

The values found for dry matter yield of crambe plants at flowering (4,070 kg $ha^{-1}$) were greater than those obtained by Heinz et al. (2011), who found 2,688 kg $ha^{-1}$ when assessing the same plants at flowering in the municipality of Dourados, state of Mato Grosso do Sul; and the same occurred for the dry matter yield values for plants cut at harvest (2,203 kg $ha^{-1}$), when the value was greater than that obtained by Pitol, Broch and Roscoe (2010) in the municipality of Maracaju, state of Mato Grosso do Sul, who reported yield of 1,742 kg $ha^{-1}$ (Figure 2).

The difference in dry matter yield at flowering observed in this experiment compared to the work by Heinz et al. (2011) for the same region and the same climate, soil and cultivar, may be due to the crop fertilization with 300 kg of the 08-20-20 formula. Increased dry matter yield due to fertilization was also reported by Teixeira et al. (2011), working with BRS 310 sorghum cultivar, who observed dry matter yield smaller than that found by Cruz et al. (2009) for the same cultivar; this fact, according to the authors, is justified by fertilization.

The linear mathematical model was the best fit for the data on straw decomposition rate both for plants cut at flowering and at harvest (Figure 2). At the end of the experiment, 60 days after cut (DAC), 51% of the initial dry matter of crambe plants cut at flowering still remained on the soil surface (Figure 2a), compared to 76% when cut at harvest (Figure 2b). This difference in dry matter quality between plants cut at flowering and at harvest at the end of 60 days occurred due to the greater C:N ratio of plants cut at harvest (Figure 3), as well as to the environmental conditions during the decomposition period.

When analyzing the nutrient release of crambe plant straw cut at flowering, Heinz et al. (2011) observed that, 75 days after cut (DAC), 39% of the initial amount of crambe plant straw still

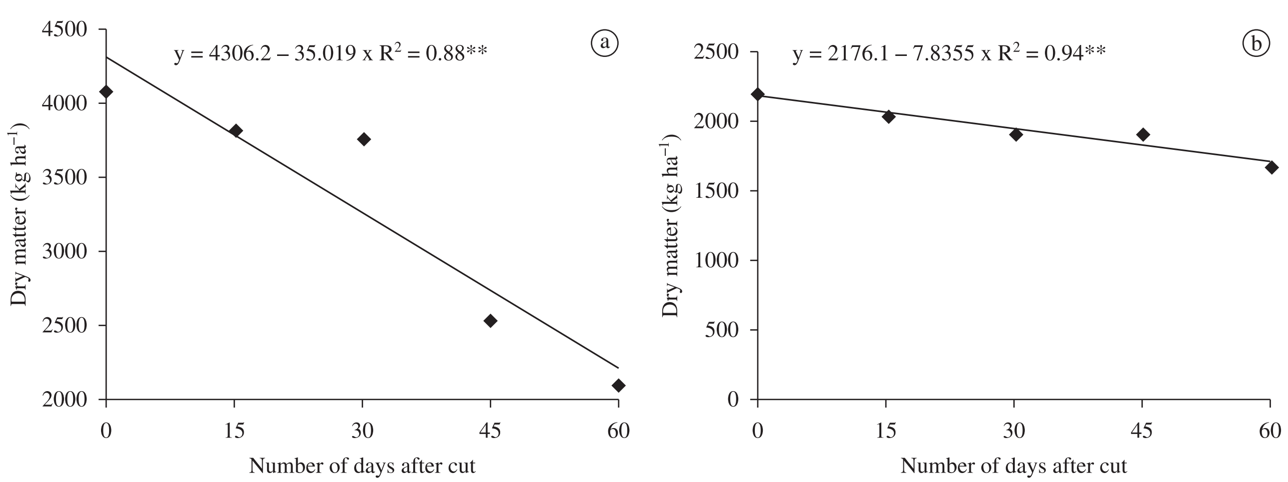


**Figure 2.** Dry matter of crambe plants cut at flowering (a) and harvest (b) in decomposition bags on soil surface in function of time. **Significant at 5% probability by the F test.

remained on the soil surface. The difference in values found for decomposition rate in the present work compared to the study by Heinz et al. (2011) is related to water availability. During the collection of the decomposition bags of plants cut at flowering (Jun 8 to Aug 11), water availability was approximately 95 mm (Figure 1), while in the study by Heinz et al. (2011), it was 295 mm. The biomass decomposition rate is directly related to the humidity and temperature conditions, that is, the higher the temperature and humidity, the greater the phytomass decomposition fraction (KHATOUNIAN, 1999).

It is possible to observe that, 60 days after management (DAM), the crambe plants cut at harvest had decomposed by 23.8% of the initial amount (Figure 2b), indicating high persistence, which is highly desirable for no-tillage systems; diversely, plants cut at flowering had decomposed by 49%. The greater persistence of plants cut at harvest may be related to the C:N ratio of this material, as shown in Figure 3. The main factor inherent to soil cover crops that condition the decomposition rate and nutrient release of their residues is the C:N ratio (HEINRICHS et al., 2001).

For the Cerrado soil and climate conditions, cover species must be of high biomass yield and persistent enough to provide physic protection and nutrients to the soil (NUNES et al., 2006).

Although the straw from crambe plants cut at harvest showed high persistence compared to the straw from those cut at flowering (Figure 3), the values found for dry matter on the day of management (zero time) – 4,070 kg ha$^{-1}$ at flowering and 2,203 kg ha$^{-1}$ at harvest (Figure 2) – are below the 6.0 t ha$^{-1}$ claimed by Alvarenga et al. (2001) and Darolt (1998) as the ideal minimum amount of dry matter yield for crop rotation systems in order to keep the soil properly covered.

A gradual decrease in function of time after cutting was verified in the contents of macroelements in the straw cut at flowering (Figure 4), and the contents of N, P, K, Ca, Mg and S were fitted to linear and quadratic functions.

The highest contents of macronutrients were determined in the straw from plants cut at flowering (Figure 4). This is due to the fact that, until the flowering, the vegetative organs (leaves, stems and branches) are the main drains. Fruit development and leaf senescence begin after the flowering. The fruit becomes the main drain, causing the plant to translocate all its nutrients and photoassimilates to this organ, thus reducing the contents in its vegetative organs, such as leaves, stems and branches. Senescence is an important process for the remobilization of N, P and other minerals from the old leaves to the younger ones and, finally, to the organs (BUCHANAN-WOLLASTON, 1997).

The kinetics of nutrient release from the crambe straw was similar to the decomposition dynamics of phytomass. Comparing the initial contents of macronutrients in the straw from plants cut at flowering to the straw from those cut at harvest (Figure 4), we observed that the straw from plants cut at flowering provided greater accumulation of N, P and K in relation to the straw from those cut at harvest. At the time of cutting, the accumulation of N, P and K was, respectively, 128.8, 27.3, and 17.3 kg ha$^{-1}$ at flowering; and, respectively, 29.5, 4.62, and 3.37 kg ha$^{-1}$ at harvest (Figure 5).

Regarding the release of N of the remaining dry matter, we observed that, at 30 DAC, the straw from plants cut at harvest had released 15.5 kg ha$^{-1}$ or 52.5%, while the straw from plants cut at flowering had released 58.5 kg ha$^{-1}$ or 45.3% (Figure 5). The straw from plants cut at flowering released a smaller percentage of N (smaller C:N ratio); this can be justified by the lower rainfall and temperatures (Figure 1) during the decomposition period, when compared to the decomposition period of the straw cut from plants at harvest. The low humidity in the period provided slower decomposition of the remaining dry biomass and, consequently, lower nutrient release (BOER et al., 2007).

The data on N release from the straw of plants cut at flowering are similar to those found by Heinz et al. (2011): 30 days after the cutting of the crambe plants, they observed the value of 49.4% released N.

Regarding P, we observed, 30 and 45 DAC, release values of 12.3 and 21.37 kg ha$^{-1}$, respectively, for cutting at flowering, and 1.87 and 2.27 kg ha$^{-1}$, respectively, for cutting at harvest (Figure 5). The greater release of P from the straw cut at flowering is probably related to the higher level found for this cutting period. Assessing the decomposition and nutrient

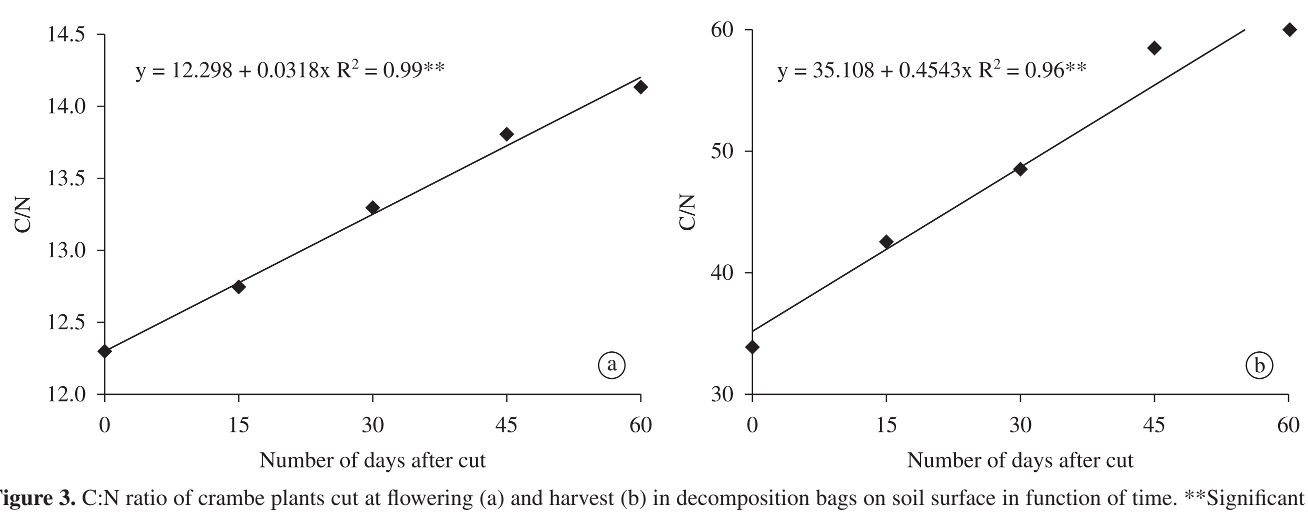


**Figure 3.** C:N ratio of crambe plants cut at flowering (a) and harvest (b) in decomposition bags on soil surface in function of time. **Significant at 5% probability by the F test.

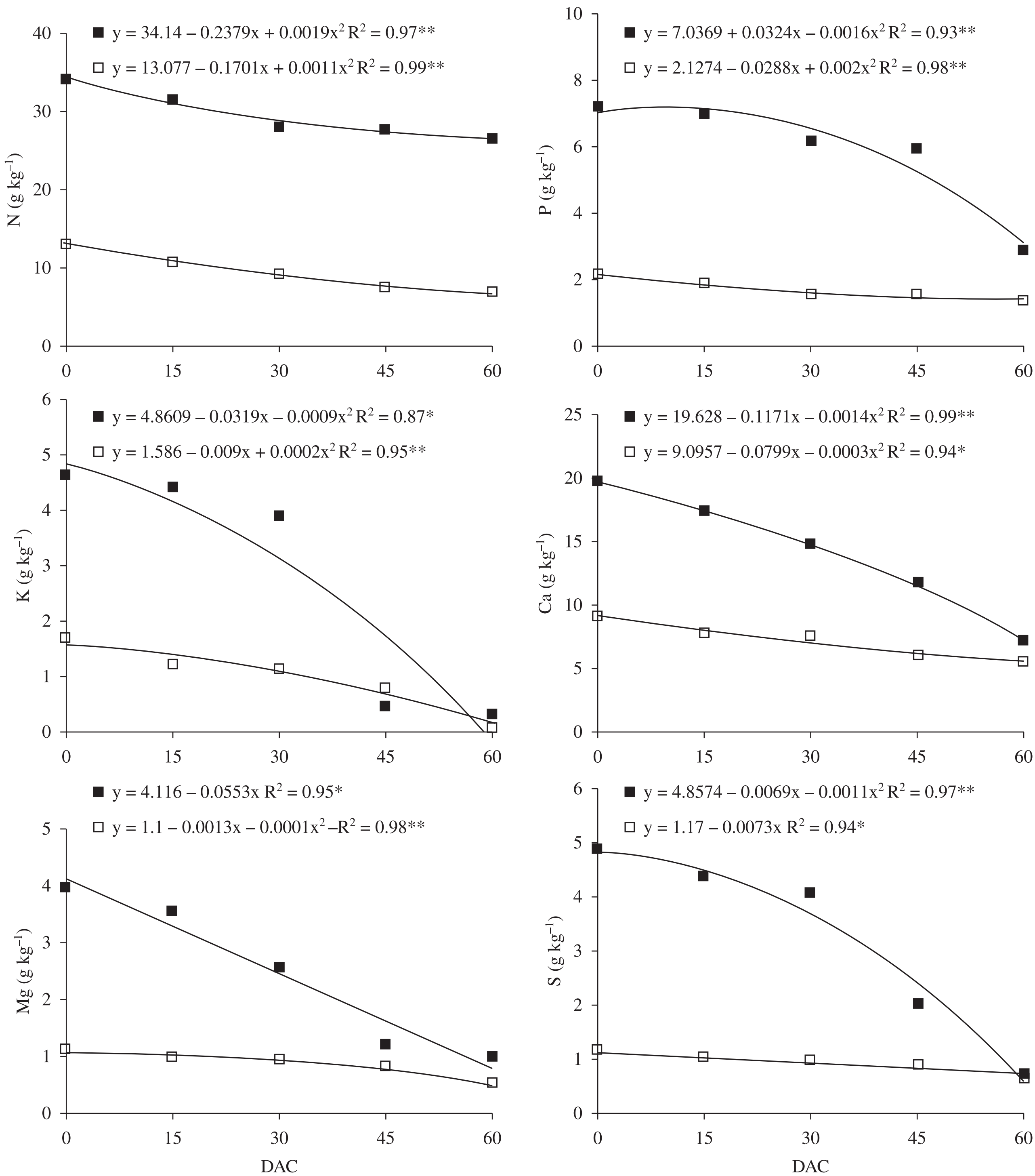


**Figure 4.** Macronutrient levels of crambe plant straw cut at flowering (■) and harvest (□) in decomposition bags on soil surface in function of time. **Significant at 1% and 5% probability, respectively, by the F test.

release from crop residues in Dourados, state of Mato Grosso do Sul, under the same soil and climate condition and with the same cultivar and cutting time of this study, Heinz et al. (2011) verified that, 45 DAC, the crambe straw had released 68.7% of P, which is probably related to the greater water availability during the decomposition period. Phosphorus released from organic tissues structurally linked to protein molecules and compounds related to the transport of energy may be available both for absorption of the subsequent crop root system as well as for immobilization in mineral compounds of difficult solubility (CRUSCIOL et al., 2008).

The kinetics of K release by the straw from crambe plants cut at flowering and at harvest presented linear and quadratic response, respectively. The amount of K released by the straw cut at flowering 45 DAM was approximately 16.8 kg $ha^{-1}$, while the amount released by the straw cut at harvest was

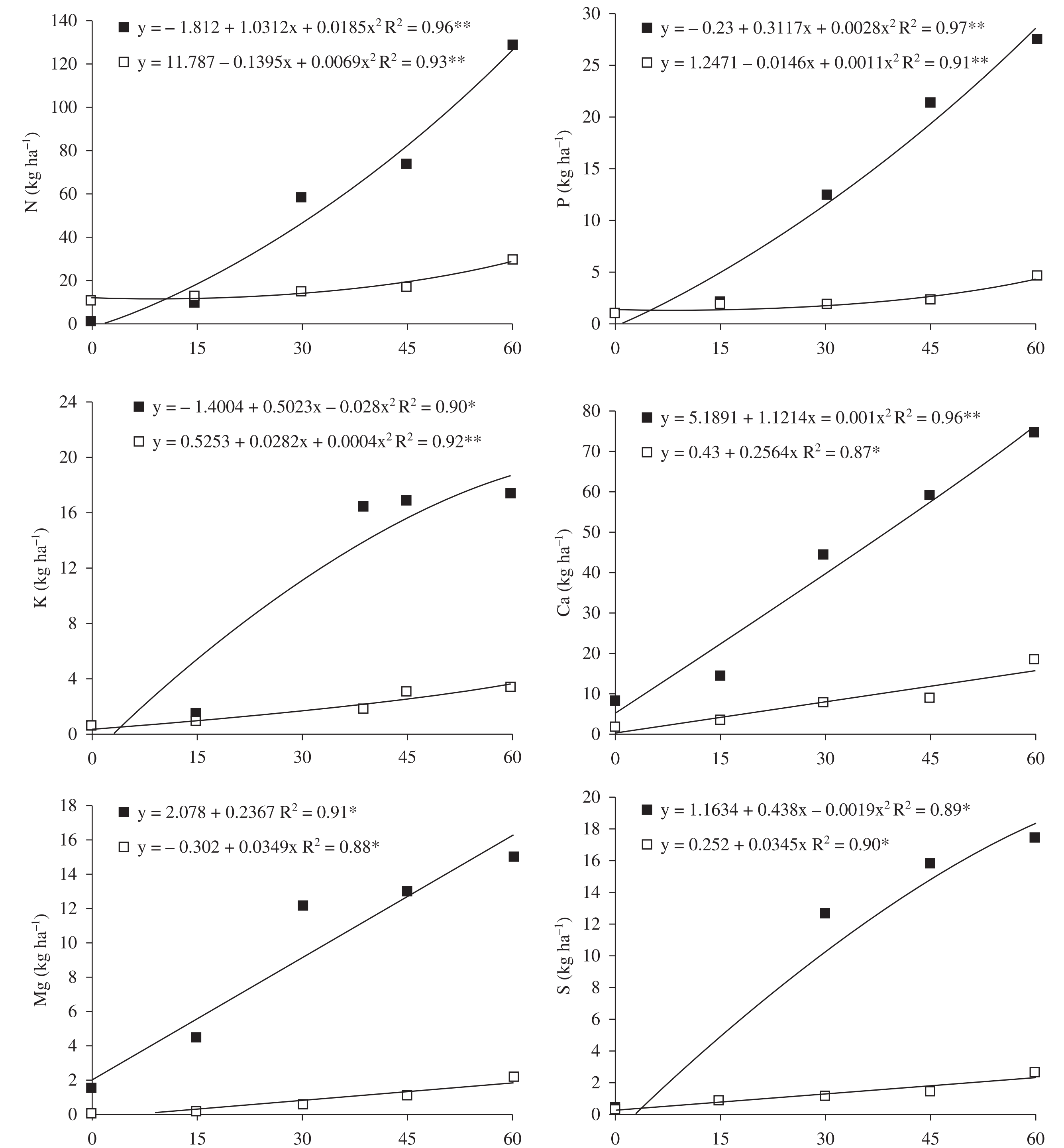


**Figure 5.** Nutrient release in crambe plant straw cut at flowering (■) and harvest (□) in decomposition bags on soil surface in function of time. **Significant at 1% and 5% probability, respectively, by the F test.

3.07 kg ha$^{-1}$, corresponding to 97.1% and 91.0% of the initial value in each cutting time, respectively (Figure 5). These values corroborate Heinz et al. (2011), who observed that, 45 DAC, around 93% of the K of the straw from crambe plants cut at flowering had already been released to the soil. Among the macronutrients, potassium presents the fastest release rate, since the cation $K^+$ is not metabolized in the plant, forming links with easily reversible organic complexes (ROSOLEM; CALONEGO; FOLONI, 2003).

Several authors have reported K as the element more rapidly available to the soil after management in different climatic conditions, types of soil, cutting times and species (ROSOLEM; CALONEGO; FOLONI, 2003; CRUSCIOL et al., 2005, 2008; TEIXEIRA et al., 2011). In terms of straw cut and subsequent crop planting time, potassium is a nutrient for which the implementation period should be as short as possible in order to reduce losses, because of its rapid release (BOER et al., 2007).

Regarding Ca, 45 DAC, about 30.0 kg $ha^{-1}$ or 59.2% of the initial value had already been released by the straw cut at flowering; while this value was 8.6 kg $ha^{-1}$, equivalent to 46.7%, for the straw cut at harvest (Figure 5). Concerning Mg, the values observed 45 days after cut were 12.88 kg $ha^{-1}$ at flowering and 1.12 kg $ha^{-1}$ at harvest, that is, 85.8% and 52.8%, respectively, of the initial accumulated amount (Figure 5). Analyzing the release of nutrients from the biomass of crambe cut at flowering, Heinz et al. (2011) observed that 72% of the Mg from the straw of crambe plants had already been released to the soil 45 DAC.

After Potassium, Magnesium was the element more rapidly released from millet ENA 2 (72%), millet BRS 1501 (71%), and sorghum (81%), 30 DAM, in an experiment carried out by Teixeira et al. (2011). Reduction of 7.4% and 76.8% in Ca and Mg, respectively, was observed by Crusciol et al. (2005) in fodder radish straw 56 DAM. The faster release of Mg compared to Ca, as evinced in the experimental conditions, may be related to the fact that 70% the magnesium in the plant act in the vacuole (MARSCHNER, 1995), thus being quickly released, since this portion is not part of the cell constituents (CRUSCIOL et al., 2008). On the other hand, Ca is an structural element highly concentrated in the middle lamella of cell walls (the apoplast) and on the outer plasma membrane, strengthening them in the form of Ca-pectates (FURLANI, 2004); therefore, more difficult to be mineralized and released in the soil (TEIXEIRA et al., 2011).

The release of sulfur presented different behavior for the two periods: while there was a quadratic response for the flowering, there was a linear response in the harvest (Figure 5). The straw from the crambe plants had released 15.7 kg $ha^{-1}$ or 90% of its initial value in the soil at flowering, against 1.45 kg $ha^{-1}$ or 54.7% at harvest. The difference with respect to the release of S was due to the higher initial nutrient accumulation at flowering.

## 4 Conclusions

The dry matter yield from crambe plants cut at flowering and at harvest is insufficient to properly cover soil surface under no-tillage system.

The straw from crambe plants cut at flowering presents high macronutrients levels and low persistence (low C:N ratio), while the straw from plants cut at harvest presents low macronutrients levels and high persistence (high C:N ratio).

Potassium and sulfur are the elements released in higher percentage in the first 45 days after the cutting of the straw from crambe plants.

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