Revista Ibero-Americana de Ciências Ambientais
*Ibero-American Journal of Environmental Sciences*
Maio 2022 - v.13 - n.5
ISSN: **2179-6858**
**This article is also available online at:**
www.sustenere.co

# *Growth of millet and sorghum in monoculture and consortium under fertilization levels*

The choice of suitable species for maintaining soil protection is a challenge for researchers who work with no-till. Thus, the objective was to evaluate growth and half-life in cover plants, such as millet and sorghum, in monoculture systems and in consortium under three levels of fertilization in the southern region of Tocantins, Brazil. The experiment was submitted to 13 years of cultivation, being: 8 years under a conventional system with plowing and leveling harrows; 2 years under using subsoiler and leveling harrow afterwards and 3 years under no-tillage system, with depth of until 20 cm. The experimental design used was in randomized blocks, with three replications. In the monoculture system, the yield and permanence of millet straw on the soil surface was higher in relation to sorghum, in the intercropped system the sorghum has a higher yield and permanence on the soil surface. It appears that the fertilization for all species expressed higher yield in their development and growth, thus having a greater dry mass. Through the results it is possible to conclude that the use of intercropped sorghum is more advantageous for straw production, in the monoculture the millet stood out, especially with the addition fertilizer.

**Keywords:** Soil fertility; Pannisetum glaucum; Ground cover; Half-life.

# *Crescimento de milheto e sorgo em monocultivo e consorciado sob níveis de adubação*

A escolha de espécies adequadas para manter a proteção do solo é um desafio para os pesquisadores que trabalham com plantio direto. Assim, objetivou-se avaliar o crescimento e a meia-vida de plantas de cobertura, como milheto e sorgo, em sistemas de monocultivo e consorciado sob três níveis de adubação na região sul do Tocantins, Brasil. O experimento foi submetido a 13 anos de cultivo, sendo: 8 anos em sistema convencional com arado e grade niveladora; 2 anos sob uso de subsolador e grade niveladora posteriormente e 3 anos sob sistema de plantio direto, com profundidade de até 20 cm. O delineamento experimental utilizado foi em blocos ao acaso, com três repetições. No sistema de monocultivo, o rendimento e permanência da palha de milheto na superfície do solo foi maior em relação ao sorgo, no sistema consorciado o sorgo tem maior rendimento e permanência na superfície do solo. Verifica-se que a adubação para todas as espécies expressou maior rendimento em seu desenvolvimento e crescimento, tendo assim maior massa seca. Através dos resultados é possível concluir que o uso do sorgo consorciado é mais vantajoso para produção de palha, na monocultura o milheto se destacou, principalmente com a adição de adubo.

**Palavras-chave:** Fertilidade do solo; Pannisetum glaucum; Cobertura do solo; Meia-vida.

Topic: **Engenharia Agrícola**

Reviewed anonymously in the process of blind peer.

Received: **04/05/2022**
Approved: **26/05/2022**

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**DOI:** 10.6008/CBPC2179-6858.2022.005.0001

**Referencing this:**
MAGALHÃES, J. C. S.; MATA, J. F.; MARTINS, H. L.; SIEBENEICHLER, S. C.; SILVA, R. R.; MARTINS, E. S.. Growth of millet and sorghum in monoculture and consortium under fertilization levels. **Revista Ibero Americana de Ciências Ambientais**, v.13, n.5, p.1-9, 2022. DOI: http://doi.org/10.6008/CBPC2179-6858.2022.005.0001

## INTRODUCTION

The cerrado region in Brazil is characterized by low fertility soils, concentration of the rainy season and drought, with great interference in the development of agricultural crops. These characteristics require the application of knowledge and appropriate technologies in the management of the tails, such as the use of forage grasses. Among other basic characteristics that are necessary for the choice of these cultures, there are: good adaptation to different levels of fertility; ease mechanization; resistance to pests and diseases; rapid growth; great resistance to drought; greater mass production; not becoming weeds and that can be used in agriculture (DURÃES et al., 2003).

In order to enable soil cover efficiency through the No-Tillage System (NTS), we seek to discover species that produce large amounts of phytomass. However, the cerrado region does not provide favorable conditions to produce straw in this system, since it has high temperature and humidity during some periods of the year that favor microbial activity, which accelerates the decomposition of plant residues (NEVES et al., 2018). In view of this, plant materials with low lability, that is, high carbon / nitrogen (C / N) ratio, should be used in NTS. The greater this relationship, the longer the decomposition will take, and the longer the residues remain on the soil (CALEGARI et al., 1992; SÁ et al., 2014; AWE et al., 2015).

The millet (*Pennisetum americanum* L.) belonging to the subfamily Panicoideae, family Poaceae, and is an annual summer forage, originated from hot zones, has a short vegetative cycle, 60 to 90 days for early varieties and 100 to 150 days for late varieties. It can be cultivated in sandy or poor in nutritious elements soil, but its productivity increases significantly when an adequate fertilization and irrigation is performed, supplementing the water deficit (ARAÚJO, 2020). This grass is suitable to produce dry matter, as it has a root system that can reach 3.60 m in depth and a great efficiency in the transformation of water and in the production of dry matter through photosynthesis (DURÃES et al., 2003; COSTA et al., 2016; COSTA et al., 2017).

Sorghum (*Sorghum bicolor* (L.) Moench) belonging to the Poaceae family and adapts to different types of soil and climate, being tolerant to acidic soils and with less water availability (CARVALHO et al., 2011).

The decomposition of plant materials added to the soil is characterized by the half-life, which expresses the period required for half the mass of the waste to be decomposed or for half the nutrients contained in that waste to be released (BATISTA et al., 2016; DINIZ et al., 2016; COSTA et al., 2017).

This work aimed to evaluate the growth and half-life of millet and sorghum, in ‘exclusive’ cultivation systems and in consortium under three levels of fertilization in the southern region of Tocantins, Brazil.

## MATERIALS AND METHODS

The work was carried out at Fazenda São Jorge in the municipality of Alvorada in the southern region of Tocantins, located at 12º28'30” S and 49º07'30” W, in an Aw-type climate with dry winter, according to the Köppen classification (ALVARES et al., 2014), average annual temperature and precipitation of 28 °C and 1400 mm, respectively, and concentrated rainy season and high-water deficit between the months of May and September.

The experiment was installed on a typical dystrophic Red Latosol (EMBRAPA 2018), submitted to 13 years of soybean cultivation, being: 8 years under conventional system with the use of plowing and leveling harrows; 2 years under minimum cultivation using subsoiler and leveling harrow afterwards and 3 years under no-tillage system, with the following characteristics at a depth of 0 to 20 cm (table 1).

**Table 1**: Chemical characteristics of the soil where the study was carried out.

| Parameters | Values |
|---|---|
| pH | 5,0 |
| Ca (cmolc dm-3) | 2,5 |
| P. resin (mg dm-3) | 41,0 |
| P honey (mg dm-3) | 35,25 |
| K (mg dm-3) | 85,0 |
| Cu (mg dm-3) | 0,7 |
| Zn (mg dm-3) | 5,8 |
| Fe (mg dm-3) | 490,0 |
| Mn (mg dm-3) | 44,6 |
| CTC (cmolc dm-3) | 6,72 |
| V% | 50,96 |
| M.O (%) | 1,5 |
| Clay Content (%) | 26,0 |
| Silte (%) | 7,0 |
| Sand (%) | 77,0 |

**Table 2:** Equation parameters X = X0e-kt adjusted to the values of dry matter and half-life for the material incubated on the soil surface for 120 days under different levels of fertilization.

| **Species** | **Fertilization levels** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **0%** | | | **20%** | | | **40%** | | |
| | $X_0$ | **k** | $t_{1/2}$ (1) | $X_0$ | **k** | $t_{1/2}$ (1) | $X_0$ | **k** | $t_{1/2}$ (1) |
| | **g** | **day$^{-1}$** | **day** | **g** | **day$^{-1}$** | **day** | **g** | **day$^{-1}$** | **day** |
| Millet | 35,17 aAB | 0,01155 | 60 | 26,50 bB | 0,01172 | 59 | 46,67 aA | 0,01901 | 36 |
| Sorghum | 20,33 bA | 0,01341 | 52 | 30,67 abA | 0,01301 | 53 | 21,33 cA | 0,01032 | 67 |
| C. Millet (2) | 38,50 aA | 0,01262 | 55 | 29,83 bA | 0,01123 | 62 | 28,33 bcA | 0,00806 | 86 |
| C. Sorghum (3) | 30,17 abB | 0,01229 | 56 | 44,00 aA | 0,01226 | 57 | 37,00 abAB | 0,00749 | 93 |

CV=32

(1) t1 / 2 = half-life. (2) Millet and sorghum consortium, analyzing millet. (3) Millet and sorghum consortium, analyzing sorghum.

(2) (2) X0 = amount of dry matter or initial nutrient; K = decomposition constant; t1 / 2 is the half-life of dry matter or nutrient.

*****Means followed by the same uppercase letter in the row and lowercase in the column do not differ, by the Tukey test, at the level of 5% probability.

The experimental design used was randomized blocks (DBC), with three replications. Each block consisted of 12 treatments obtained by the 2x2x3 factorial combination, the factors being two grasses, two cultivation systems and three levels of fertilization. The grasses used were: Millet (*Pennisentum americanum*) 12 kg of seed ha-1; Sorghum (*Sorghum vulgare pers*) 10 kg of seed ha-1; and the Milheto / Sorghus consortium with 12 kg of seed ha-1 and 10 kg of seed ha-1, respectively. The three fertilization levels were 0%, 20% and 40% of the fertilization recommendation for the soybean crop, which will be the subsequent crop, according to the soil analysis at the time of planting (400 kg ha$^{-1}$ de 5-25-15 NPK). Each treatment was installed in plots of 60 m2 (6 x 10 m). Planting fertilization was carried out by hauling according to the fertilization level for each treatment. On the same day, grasses were sown.

To evaluate the height, three plants per plot were measured at 32, 46, 60 and 72 days after emergence (DAE), and two plants per plot were collected to quantify the dry mass of leaves, stem and panicle. These were placed in a forced ventilation oven at 65 °C, until reaching constant mass.

For evaluations of the decomposition of straw on the soil surface after desiccation of the plots, the straw contained in an area of 0.0625 m2 was collected and weighed in plastic bags (litter bags) with dimensions of 0.25 x 0, 25 m (0.0625 m2) of black color with 1 mm mesh, which were distributed over the surface of the plots in the field in their respective places of origin in the experiment in contact with the soil. The decomposition was calculated according to the material remaining in the litter bag as a function of the amount of initial material contained therein (MATA et al., 2011). At the day 120 of experiment, three replicates per treatment were collected, totaling 12 litter bags.

To express the rate of decomposition of the residues, the exponential model used was the one created by Rezende et al. (1999): X = X0 e-kt, where X = amount of dry matter or nutrient remaining after the period of time in days; X0 = amount of dry matter or initial nutrient; K = decomposition constant; t = time period in days, being possible to calculate the half-life using the equation: t1 / 2 = ln 2 / k, where t1 / 2 is the half-life of dry matter or nutrient (PADOVAN et al., 2006). The results obtained were subjected to analysis of variance, and the plant height averages, and fertilization levels were compared using the Tukey test, at the level of 5% probability, and the regression was applied to plant height at each fertilization level, according to the adjustments of the models that were made based on their significance and the coefficient of determination (R2), at the level of 5% probability.

## RESULTS AND DISCUSSION

When analyzing the production of leaf dry mass in monoculture and in consortium, there is a tendency for millet to present higher production in monoculture, mainly with fertilization in 40% of the recommendation. Sorghum yield was higher in the consortium and at fertilization levels of 20% and 40% of the recommendation. As for soil fertilization levels, millet in monoculture and intercropping did not differ in the production of leaf dry matter. The production of dry mass from intercropped millet did not differ from millet in monoculture with 0% fertilization (Figure 1).

The intercropped sorghum tended to accumulate greater dry mass in the colmo, except in the treatment without fertilization (Figure 2), similar to what was observed for the dry mass of the leaves. For dry stem mass, the highest value was found in millet in monoculture with 40% of the fertilization recommendation. When in intercropped cultivation the largest accumulation of dry matter of the stem was observed with 0% fertilization of the recommendation, not differing from the level of 20%, and it can be inferred that the millet when in consortium accumulates the photoassimilates in greater quantity in the stem (Figure 2). In this cultivation system, sorghum may have been favored by some internal mechanism that benefited its growth.

Regarding the dry mass of the panicle, it can be inferred that in monoculture the millet had a better performance, and in consortium the production of dry mass of the panicles was, in general, higher for sorghum, showing that an effect may have occurred allele-chemical of sorghum when intercropped (Figure

3) (VIDAL et al., 2004; BRAGA et. al., 2017).

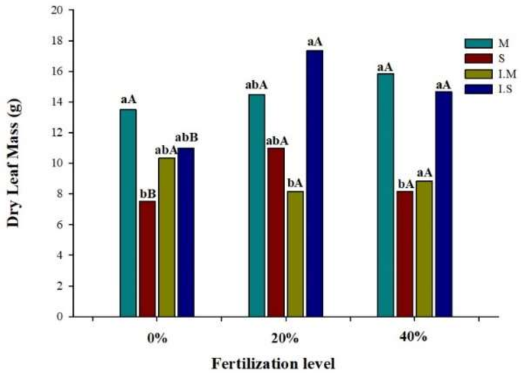


**Figure 1**: Production of dry leaf mass (g) of millet (M), sorghum (S) and intercropping of millet (I.M) and sorghum (I.S) as a function of chemical fertilization (0, 20 and 40%) at 46 DAE.

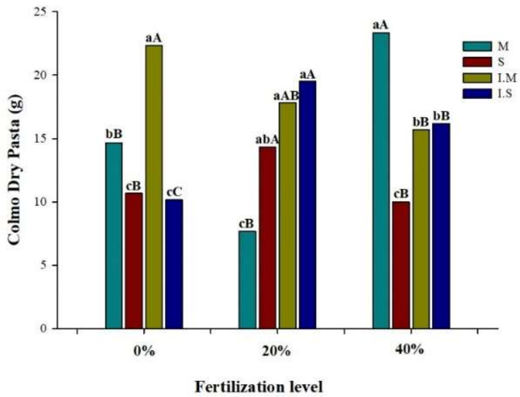


**Figure 2**: Production of dry mass of colmo (g) of millet (M), sorghum (S) and intercropping of millet (I.M) and sorghum (I.S) depending on chemical fertilization (0, 20 and 40%) at 46 DAE.

* Averages followed by the same lowercase letter within each fertilization level and uppercase for each system between fertilization levels, by the Tukey test, at the level of 5% probability.

In a study by Correa et al. (2004), the dry mass values of the panicle in consortium with castor bean obtained higher values in relation to the monoculture. This increase in the mass of the panicle, perhaps reflects the predominance of sorghum over castor, even though in matters of structure castor (C3) has a slower development in relation to sorghum (C4). Thus, the dominance that sorghum had over it may show the superiority of sorghum in consortium with millet in the production of panicle dry mass.

Regarding fertilization levels, sorghum in monoculture and in intercropping presented a better performance at the level of 20% for the production of panicle dry mass (Figure 3). The dry mass of the millet panicle was greater with 40% fertilization when grown alone, and this did not differ from 0% fertilization, probably due to the high fertility of the soil, since it received chemical fertilization.

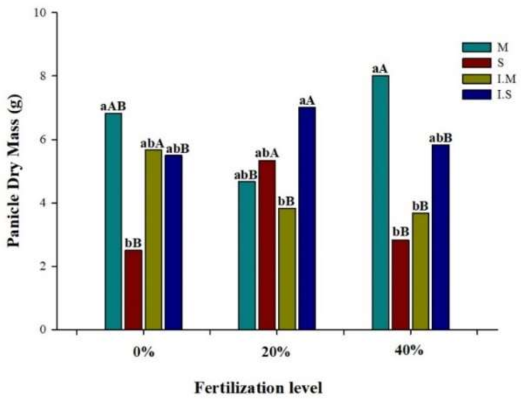


**Figure 3:** Production of dry mass of the panicle (g) of millet (M), sorghum (S) and intercropping of millet (I. M) and sorghum (I. S) as a result of chemical fertilization (0, 20 and 40%) at 46 DAE

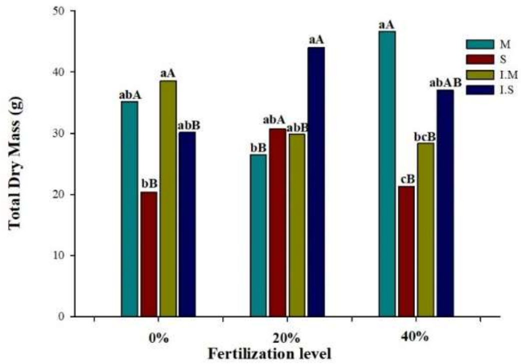


**Figure 4:** Production of total dry mass (g) of millet (M), sorghum (S) and intercropping of millet (I.M) and sorghum (I.S) as a result of chemical fertilization (0%, 20% and 40%) at 46 DAE.

* Averages followed by the same lowercase letter within each fertilization level and uppercase for each system between fertilization levels, by the Tukey test, at the level of 5% probability.

Regarding the total dry mass, it can be observed that the intercropped millet was better at the level of 0% fertilization and the production of dry matter of this in monoculture was higher with 40% fertilization, however it did not differ from 0%. (Figure 4). According to Pereira Filho et al. (2003) the production of dry millet phytomass, even in conditions of low fertility, has been shown to be more productive than other cover crops, thus being able to deduce the use of millet in conditions of low fertility.

Regarding the total dry matter of sorghum, fertilization of 20% was favorable to its development both in monoculture and in intercropping, and the production of total dry matter in the intercrop was greater than in monoculture at the level of 40% of the recommended fertilization (Figure 4).

In general, the total dry mass of the grass system in monoculture and intercropping (Figure 4) reflected the response observed in the plant portions alone (Figures 1, 2 and 3).

As expected, the plants showed an increase in their height throughout their development cycle. Regarding the fertilization level, it was observed that with 0 and 20% of fertilizer, millet in monoculture presents the highest height and the highest growth speed (α = 3.09 and 4.36, respectively) (Figure 5). With the development of the plant, the effect of 20% fertilization was more significant, as millet in monoculture with this fertilization reached the highest height (Figure 5). For the 40% fertilization, it was observed that the intercropped millet had the highest height and growth speed (α = 3.20) (Figure 5).

Sorghum, in monoculture and in intercropping, presented the lowest height and the slowest growth rate in all evaluated fertilization levels, and intercropping showed better performance than monoculture (Figure 5).

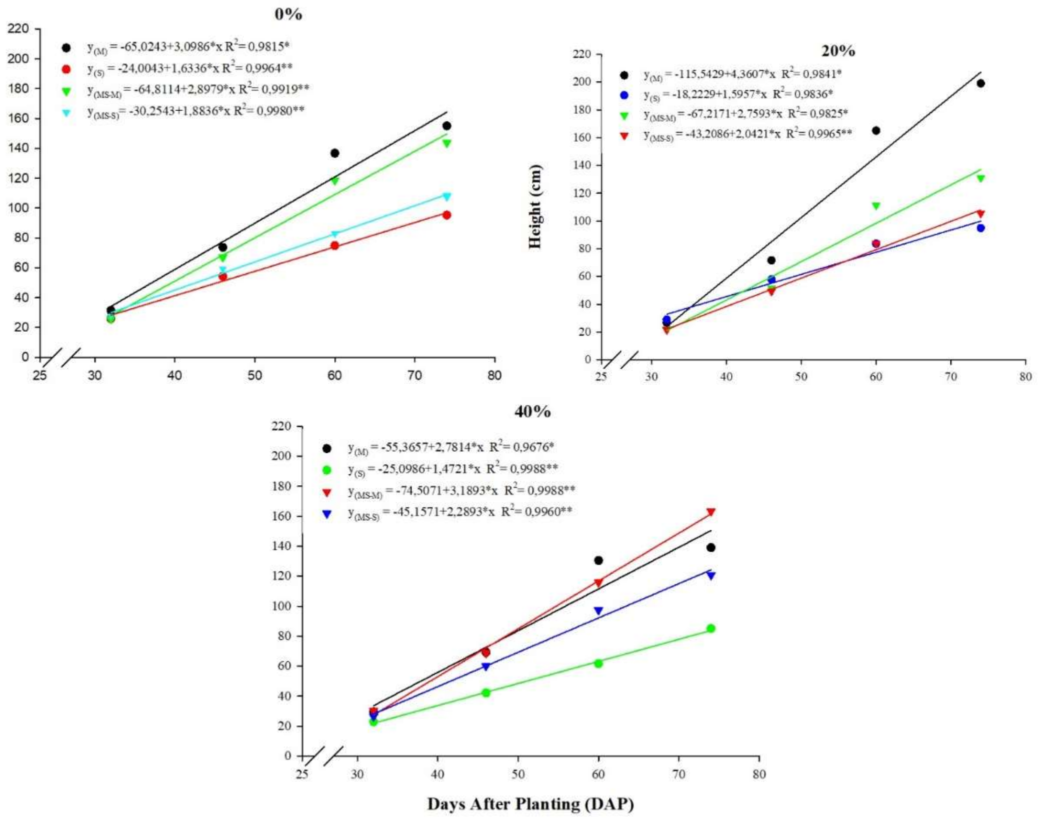


**Figure 5:** Plant height (cm) in days after planting (DAP) of millet (M), sorghum (S) and intercropped millet (I.M) and sorghum (I.S) cultivated in monoculture and intercropped throughout their cycle vegetative growth without fertilization: 0%, 20% and 40%.
** (P <0.01) significant at 1%; * (0.01≥P <0.05) significant at 5% probability. ns (P≥0.05) not significant.

In the vegetative growth phase, the plants showed a higher percentage of dry mass invested in the leaves (70 to 90%) (Figure 6). When comparing the dry mass ratio of the colmo between the cultivation systems, it can be observed that in the monoculture and in the intercropping, sorghum tends to present a greater increment of photoassimilates in the colmo (Figure 6), the same was observed in the plants in reproductive stage (Figure 7).

The final distribution of dry matter in the leaf, stem and panicle varies widely in millet, depending on the variety. In some varieties, however, 50% or more of the dry weight can be in the culms, with a maximum of 20-30% in the panicle, thus, the culm serves as a storage organ for excess carbohydrates and at another time as a source of grain filling carbohydrates (DURÃES et al., 2003) (Figure 7).

The intercropped millet has a distribution of photoassimilates differentiated from the monoculture (Figures 6 and 7), it was observed that in intercropping there was a greater dry mass in the stem than the leaves during the reproductive period. In general, there is a greater initial increase in leaves and then an increase in the dry mass of the stems, or else the proportional growth between stems and leaves, since the accumulation of reserve occurs due to the photosynthesis performed by the leaves (LARCHER, 2006).

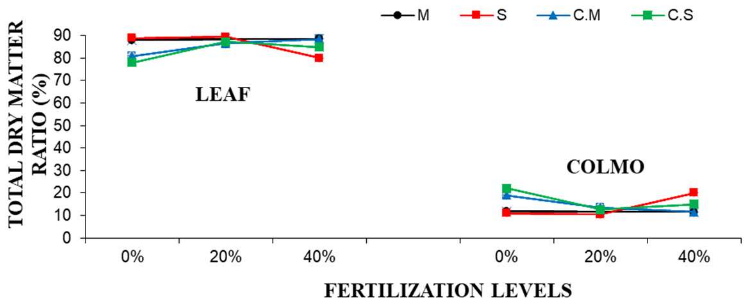


**Figure 6**: Ratio of total dry mass (%) of leaf and stem of plants of millet (M), sorghum (S) and consortium of millet and sorghum (I.M), and sorghum and millet (I.S) depending on the level of fertilization (0, 20 and 40%) at 46 days after emergence (DAE).

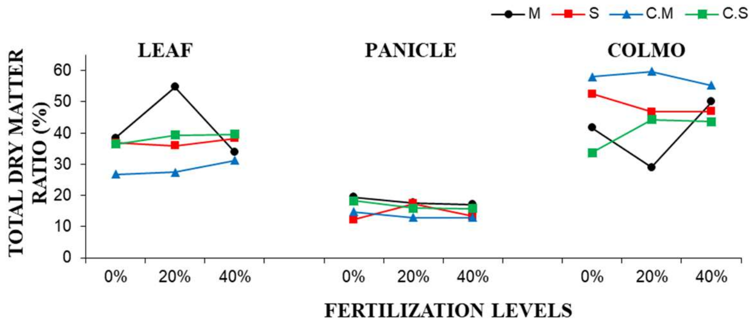


**Figure 7**: Total dry matter ratio (%) of stem, leaf and panicle of millet (m), sorghum (s) and intercropped millet (I.M) and sorghum (I.S) as a function of chemical fertilization (0, 20 and 40%) at 72 days after emergency (DAE).

The mulch on the soil surface has decreased for all plant materials, so those materials that have lower decomposition rates and higher initial dry mass production, consequently, obtain a higher half-life value, these will then be the best materials for covering the soil, for having half its dry mass production over a longer period of time. The higher decomposition rates are justified by the loss of soluble labile compounds that are easily decomposed by these materials (LUPWAYI ET al., 1998, citado por ESPÍNDOLA et al., 2006). The climate of the southern region of Tocantins (high temperatures and seasonal periods) can contribute to the decomposition of materials.

Sorghum (0 and 20%) and millet (40% of fertilization), both in monoculture, showed higher decomposition constants, while the opposite was observed for millet in monoculture with 0% fertilization, millet intercropped with 20% and sorghum with 40% fertilization (Table 1). It was noticed that the other vegetable coverings showed an intermediate response. The decomposition of the residues was slower for most of the intercropped roofs and with 40% fertilization, probably due to the accumulation of cellulose in the tissues that increases the stiffness of the mass to be decomposed.

In these conditions, it appears that the material with the greatest recalcitrance estimated by the half-life in the treatment with 0% of fertilization was millet in monoculture, with 20% it was intercropped millet, and with 40% it was intercropped sorghum. It was estimated for sorghum (0 and 20%) and millet (40% of fertilization), both in monoculture, easier for carbon biodegradation.

According to Larcher (2006), fertilization contributes to an increase in the production rate, which can be expressed as an increase in dry mass through assimilation products, thus, it can be observed that fertilization increased the half-life of intercropped grass systems, which would allow the soil cover to be maintained for a longer time.

The decomposition of the residues was slower for the millet and sorghum consortium at 40% fertilization levels. The result is satisfactory for straw production in the southern region of Tocantins. It is suggested that residual fertilization of soybeans may assist in maintaining soil cover.

## CONCLUSIONS

In the monoculture system, millet performed better for dry matter and decomposition rate, mainly with the addition of fertilizer. The use of sorghum in an intercropped system proved to be more advantageous for the production of straw. The fertilization of production systems can favor the maintenance of straw in the soil for a longer period.

## REFERENCES

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G.. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, v.22, n.6, p.711-728, 2014.

ARAÚJO, I. S.; SOUZA, T. A. F.; FOSTALL-SOSA, K. S.; LUCENA, E. O.; SILVA, S. A. I.; SANTOS, D.. *Pennisetum glaucum* (L.) R. Br. vs. *Mucuna pruriens* (L.) DC.: efeito do cultivo de espécies de plantas não leguminosas e leguminosas sobre a comunidade de fungos micorrízicos nativos de solos arenosos. **Acta Biológica Catarinense**, v.7, n.2, p.48-57, 2020.

AWE, G. O.; REICHERT, J. M.; WENDROTH, O. O.. Temporal variability and covarianc estructure sof soil temperature in a sugarcane fieldunder different management practices in southern Brazil. **Soil and Tillage Research**, Amsterdam, v.150, p.93-106, 2015.

BATISTA, F. C.; CAMILO, B. G.; OLIVEIRA, M. C.; MATTOS, B. B.; SANTOS, F. C.; MARRIEL, I. E.; OLIVEIRA, C. A.. Atividade microbiana do solo em cultivo de milheto adubado com fertilizantes organominerais enriquecidos com microrganismos e submetidos a diferentes temperaturas de secagem. In: REUNIÃO BRASILEIRA DE FERTILIDADE DO SOLO E NUTRIÇÃO DE PLANTAS, 32; REUNIÃO BRASILEIRA SOBRE MICORRIZAS, 16; SIMPÓSIO BRASILEIRO DE MICROBIOLOGIA DO SOLO, 14; REUNIÃO BRASILEIRA DE BIOLOGIA DO SOLO, 11. **Anais**. Goiânia: Rumo aos novos desafios; Viçosa: Sociedade Brasileira de Ciência do Solo, 2016.

CALEGARI, A.; FERRO, M.; GRZESIUK, F.; JACINTO JUNIOR, L.. **Plantio direto e rotação de culturas:** experiência em Latossolo Roxo/1985-1992. Curitiba: IAPAR; COCAMAR; ZENECA Agrícola, 1992.

CORREA, M. L. P.; SILVA, C. S. A.; TAVORA, F. J. A. F.. Avaliação de cultivares de mamona em sistema de consórcio com caupi e sorgo granífero. In: CONGRESSO BRASILEIRO DE MAMONA: ENERGIA E SUSTENTABILIDADE, 1**. Anais**. Campina Grande, 2004. p.5.

CARVALHO, E. R.; REZENDE, P. M.; ANDRADE, M. J. B.; PASSOS, A. M. A.; OLIVEIRA, J. A.. Fertilizante mineral e resíduo orgânico sobre características agronômicas da soja e nutrientes no solo. **Revista Ciência Agronômica**, v.42, n.4, p.930-939, 2011.

COSTA, R. R. G. F.; COSTA, K. A. P.; SANTOS, C. B.; SEVERIANO, C. E.; EPIFANIO, P. S.; SILVA, J. T.; TEIXEIRA, D. A. A.; SILVA, V. R.. Production and nutritional characteristics of pearl millet and Paiaguas palisadegrass under different forage systems and sowing periods in the offseason. **African Journal of Agricultural Research**, v.11, n.19, p.1712-1723, 2016.

COSTA, R. R. G. F.; COSTA, K. A. P.; SEVERIANO, C. E.; SANTOS, C. B.; ROCHA, A. F. S.; SOUZA, W. F.; BRANDSTETTER, E. V.; CASTRO, W. A.. Nutrients cycling and accumulation in pearl millet and Paiaguas palisadegrass biomass in different forage systems and sowing periods. **Revista Scientia Agraria**, v.18, n.4, p.166-178, 2017.

DINIZ, G. F. D.; PINHO, J. M. R.; SANTOS, F. C.; GOMES, E. A.; MARRIEL, I. E.; OLIVEIRA, C. A.. Avaliação da atividade enzimática em cultivo de milheto adubado com fertilizantes organominerais. In: REUNIÃO BRASILEIRA DE FERTILIDADE DO SOLO E NUTRIÇÃO DE PLANTAS, 32; REUNIÃO BRASILEIRA SOBRE MICORRIZAS, 16; SIMPÓSIO BRASILEIRO DE MICROBIOLOGIA DO SOLO, 14; REUNIÃO BRASILEIRA DE BIOLOGIA DO SOLO, 11; **Anais**. Goiânia: Rumo aos novos desafios; Viçosa: Sociedade Brasileira de Ciência do Solo, 2016.

DURÃES, F. O. M.; MAGALHÃES, P. C.; SANTOS, F. G.. **Fisiologia da planta de milheto**. Sete Lagoas: EMBRAPA Milho e Sorgo, 2003.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. **Sistema Brasileiro de Classificação de Solos**. 5 ed. Brasília: Embrapa Solos, 2018.

ESPÍNDOLA, J. A. A.; GUERRA, J. G. M.; ALMEIDA, D. L.; TEIXEIRA, M. G.; URQUIAGA, S.. Decomposição e liberação de nutrientes acumulados em leguminosas herbáceas perenes consorciadas com bananeira. **Revista Brasileira de Ciência do Solo**, Viçosa, v.30, n.2, 2006.

LARCHER, W.. **Ecofisiologia vegetal**. São Carlos: RIMA, 2006.

MATA, J. F.; SILVA, R. R.; CHAGAS, J. F. R.; FREITAS, G. A.. Produção, decomposição e meia-vida da palhada de coquetéis de gramíneas sob diferentes níveis de adubação para sistema de plantio direto no cerrado. **Pesquisa Aplicada & Agrotecnologia**, v.4, n.1, p.97-106, 2011.

NEVES, R. C.; VILAR, C. C.; USHIWATA, S. Y.; COSTA, A. C.; HARTWIG, C. F. V.; CHAVES, J. S.. Persistência de palhada de *Urochloa ruziziensis* em sistema de plantio direto e convencional no município de Nova Xavantina - MT. Gl. **Sci Technol**, v.11, n.03, p.110-122, 2018.

PADOVAN, M. P.; ALOVISI, A. M. T.; CESAR, M. N. Z.; SILVA, E. E.. Decomposição da palhada e liberação de nitrogênio pela soja, para fins de adubação verde, num sistema sob manejo orgânico. **Fertbio**, Bonito, v.1, n.1, 2006.

PEREIRA FILHO I. A.; FERREIRA, A. S.; COELHO, A. M.; CASELA, C. R.; KARAM, D.; RODRIGUES, J. A. S.; CRUZ, J. S.; WAQUIL, J. M.. **Manejo da cultura do milheto**. Sete Lagoas: Embrapa Milho e Sorgo, 2003.

REZENDE, C. P.; CANTARUTTI, R. B.; BRAGA, J. M.; GOMIDE, J. A.; PEREIRA, J. M.; FERREIRA, E.; TARRÉ, R.; MACEDO, R.; ALVES, B. J. R.; URGUIAGA, S.; CADISH, G.; GILLER, K. E.; BODDEY, R. M.. Litter deposition and disappearance in *Brachiaria* pastures in the Atlantic Forest region of the south of Brazil. **Nutrient Cycling in Agroecosystems**, Dordrecht, v.54, p.99-112, 1999.

SÁ, J. C. M.; TIVET, F.; LAL, R.; BRIEDES, C.; HARTMAN, D. C.; SANTOS, J. Z.; SANTOS, J. B.. Long-termtillage systems impactson soil C dynamics, soil resilience and agronomic productivity of a Brazilian Oxisol. **Soil and Tillage Research**, v.136, p.38-50, 2014.

VIDAL, R. A.; TREZZI, M. M.. Potencial da utilização de coberturas vegetais de sorgo e milheto na supressão de plantas daninhas em condição de campo: I - plantas em desenvolvimento vegetativo. **Planta Daninha**, v.22, p.217-233, 2004.