

## WATER USE EFFICIENCY AND YIELD OF BROCCOLI CULTIVATED UNDER NO-TILLAGE WITH DIFFERENT TYPES OF SOIL COVER STRAW AND IRRIGATION SYSTEMS

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### 1 ABSTRACT

This study aimed to evaluate the water use efficiency and yield of broccoli, irrigated by surface and subsurface drip and cultivated with no-till vegetable system (NTVS), using different species of cover plants for straw formation. The experimental design was completely randomized, in a 4 x 2 factorial arrangement (4 soil covers and 2 types of drip irrigation: surface and subsurface). The treatments related to the cultivation system were: control treatment, cultivated under conventional tillage and uncovered soil (CT), and three treatments cultivated in NTVS varying the residual straw species used as soil cover, namely: straw from intercropping of *Crotalaria ochroleuca* and *Brachiaria ruziziensis* (NT1), straw from only *C. ochroleuca* (NT2) and straw from only *B. ruziziensis* (NT3). Treatments with NTVS obtained yield levels higher than or similar to that of the control treatment. NT1, with straw from the intercropping of *C. ochroleuca* and *B. ruziziensis*, stood out with a 27% increase in marketable yield of inflorescence (18.68 t ha<sup>-1</sup>) and higher water use efficiency (17.57 kg m<sup>-3</sup>), being 54% more efficient than the treatment with conventional tillage.

**Keywords:** water consumption, green manure, drip irrigation, microirrigation.

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EFICIÊNCIA NO USO DA ÁGUA E PRODUTIVIDADE DE BROCOLI CULTIVADO  
SOB PLANTIO DIRETO COM DIFERENTES TIPOS DE PALHADA DE  
COBERTURA NO SOLO E SISTEMAS DE IRRIGAÇÃO

## 2 RESUMO

Este trabalho teve como objetivo avaliar a eficiência do uso da água e a produtividade em plantas de brócolis, irrigado por gotejamento superficial e subsuperficial, cultivado no sistema de plantio direto (SPD), em que foram utilizadas diferentes espécies de plantas de cobertura para formação de palhada. O delineamento experimental foi inteiramente casualizado em arranjo fatorial 4 x 2 (4 coberturas de solo e 2 sistemas de irrigação por gotejamento: superficial e subsuperficial). Os tratamentos relacionados ao sistema de cultivo foram: tratamento testemunha, cultivado sob preparo convencional e solo descoberto (CT), e três tratamentos cultivados em SPD variando as espécies residuais de palhada utilizadas como cobertura do solo, sendo: palhada do consórcio de *Crotalaria ochroleuca* e *Brachiaria ruziziensis* (NT1), palhada somente de *C. ochroleuca* (NT2) e palhada somente de *B. ruziziensis* (NT3). Os tratamentos com SPD obtiveram níveis de rendimento superiores ou semelhantes ao tratamento controle. O NT1, com palha proveniente do consórcio de *C. ochroleuca* e *B. ruziziensis*, destacou-se com aumento de 27% na produtividade comercial da inflorescência (18,68 t ha<sup>-1</sup>) e maior eficiência no uso da água (17,57 kg m<sup>-3</sup>), sendo 54 % mais eficiente que o tratamento com preparo convencional.

**Keywords:** consumo de água, adubação verde, irrigação por gotejamento, microirrigação.

## 3 INTRODUCTION

No-tillage system (NTS) has been a practice used on a large scale in several agricultural production systems, being considered an adequate option for soil conservation (TELLES *et al.*, 2020). In the NTS, the straw absorbs the impact of raindrops on the soil, reducing its disaggregation, promoting water infiltration and reducing surface runoff and erosion. In addition, it smooths the thermal amplitude of the soil, incorporates organic matter into the soil (BRANCO *et al.*, 2017; COELHO *et al.*, 2013; COUTINHO *et al.*, 2010; SILVA; MARIA, 2011) and reduces production costs (FERREIRA, FREITAS and MOREIRA, 2015).

In Brazil, the spread of the no-till vegetable system (NTVS) is still incipient. Nevertheless, there are some studies related to its application for the cultivation of lettuce (HIRATA *et al.*, 2014; NESPOLI *et al.*, 2017), chives (ARAÚJO NETO *et al.*, 2010), broccoli (BRANCO *et al.*, 2017; JOKELA; NAIR, 2016; MELO; MADEIRA; PEIXOTO, 2010; YADAV *et*

*al.*, 2014) and coriander (TAVELLA *et al.*, 2010). Melo, Madeira and Peixoto (2010) observed no difference between the yields of broccoli cultivated in a conventional system and in NTVS, but the latter was recommended due to its various benefits.

Broccoli, belongs to the genus Brassica, this genus, in general, presents in its constitution several properties beneficial to human health, mainly due to the presence of antioxidants and high concentrations of vitamins (SOEGAS *et al.*, 2011). Broccoli is a vegetable highly demanding in water, which in Brazilian conditions mostly comes from the practice of irrigation. Thus, research with the crop becomes relevant to improve sustainable practices in irrigated cultivation of this crop (OLIVEIRA *et al.*, 2016a).

The challenges for using the NTVS in broccoli cultivation include choosing the previous crop to form the straw that will cover the soil. Straw maintains or improves soil physical, chemical and biological attributes and, therefore, its quality. It is important that straw have slow decomposition to remain covering the soil

during the cultivation of broccoli and, after its decomposition, enable the return of good and balanced amount of nutrients to the soil (BRANCO *et al.*, 2017; GIACOMINI *et al.*, 2003; SALTON; HERNANI; FONTES, 1998). Diniz *et al.* (2017) highlighted that, when the previous cover species decomposes very fast, nutrients are added to the soil, but there is rapid reduction of the protective cover, exposing the soil to the adverse effects of sun and torrential rains. There are several species used to form straw and they can be divided between grasses (Poaceae family) and legumes (Fabaceae family).

While grasses generally have higher biomass production and straw with greater resistance to decomposition (MELO; MADEIRA; PEIXOTO, 2010; SALTON; HERNANI; FONTES, 1998), legume species tend to provide nutrients more readily for the crop and have more aggressive root systems, which can break through compacted soils (ALVAREZ; STEINBACH; PAEPE, 2017; BRANCO *et al.*, 2017; DINIZ *et al.*, 2017). The intercropping of grasses and legumes aims to take advantage of the benefits of both, so that straw is formed with intermediate C/N ratio compared to the values obtained when the species are cultivated as sole crop (SALTON; HERNANI; FONTES, 1998; SCHELLENBERG; MORSE; WELBAUM, 2009), providing gradual nutrient supply, long-lasting cover and improved water use efficiency (GIACOMINI *et al.*, 2003).

The irrigation system also influences yield and water consumption in broccoli cultivation. Thus, systems that promote higher crop yield per unit of water volume applied via irrigation should be selected (ADEYEMI *et al.*, 2017; OLIVEIRA *et al.*, 2016a). However, studies on the feasibility of the practice of irrigation in NTVS are scarce. The drip system has presented itself as a feasible option for localized water application in vegetables, and it can be

installed either in surface or in subsurface. In subsurface, it can promote reduction of evaporation losses (MARQUES; FRIZZONE; TEIXEIRA, 2006), lower moisture variation close to plant roots (SOUZA; COELHO; PAZ, 2007) and greater water use efficiency (GEISENHOF *et al.*, 2015).

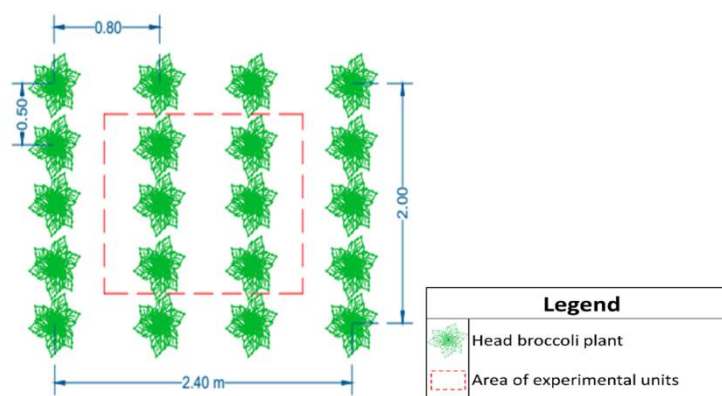
Therefore, this study aimed to evaluate the water use efficiency and yield of broccoli, irrigated by surface and subsurface drip and cultivated in no-till vegetable system, using different species of cover plants for straw formation.

#### 4 MATERIAL E MÉTODOS

The study was conducted in the experimental irrigation area of the Faculty of Agricultural Sciences (FCA), belonging to the Federal University of Grande Dourados (UFGD), located in Dourados, Mato Grosso do Sul, Brazil. The average altitude is 446 m, with coordinates: 22° 13' 16" South latitude and 54° 48' 20" West longitude. The broccoli experiment began on March 15, the end of summer.

According to Köppen's classification, the climate of the region is Cwa (humid mesothermal), with rainy summer and dry winter, and with an average annual temperature of 22 °C. The soil of the area was described as Latossolo Vermelho distroférico (Oxisol), with very clayey textural class (SANTOS *et al.*, 2018).

The crop used in this study was head broccoli (*Brassica oleracea* var. *italica*), Avenger hybrid. The field experiment was conducted in a completely randomized design, in a factorial arrangement. Each plot contained 20 plants at spacing of 0.80 m between rows and 0.5 m between plants. The usable area consisted of six plants, which corresponded to the experimental units, disregarding the borders (Figure 1).

**Figure 1.** Scheme of a plot highlighting the area of the experimental units.

**Source:** The authors (2021)

The treatments related to the cultivation system were: control treatment, cultivated with conventional tillage and with uncovered soil (CT), and three treatments cultivated in NTVS varying the residual straw species used as soil cover, namely: straw from the intercropping of *Crotalaria ochroleuca* and *Brachiaria ruziziensis* (NT1), straw from only *C. ochroleuca* (NT2) and straw from only *B. ruziziensis* (NT3). These treatments were irrigated separately, using surface and subsurface drip systems, resulting in eight treatments evaluated, with four replicates each.

In the treatment with conventional cultivation (CT, control), soil tillage was initially performed with one subsoiling operation and then one light harrowing operation.

In treatments with NTVS, the soil cover species, rattlepod (*Crotalaria*

*ochroleuca*) and Congo grass (*Brachiaria ruziziensis*), were sown 145 days before the transplantation of broccoli seedlings (October 30, 2014) at spacing of 0.45 m between rows and 40 plants  $m^{-1}$ . In the treatment with intercropping, plants were sown by interspersing one row of *B. ruziziensis* and one row of *C. ochroleuca*. When the plants were beginning flowering, 108 days after sowing, desiccation was performed using the herbicide glyphosate (10 mL  $L^{-1}$  of active ingredient). Then, the plants were mowed close to the soil (15 days before the transplantation of broccoli seedlings), forming the vegetation cover of the soil.

Before the transplantation of broccoli seedlings, soil chemical analysis was performed in the 0-20 cm layer, using disturbed samples (Table 1).

**Table 1.** Results obtained in soil chemical analysis in the 0-20 cm layer in each treatment.

Treatments	pH	OM	P <sub>resin</sub>	H+Al	Ca	Mg	N	V
	CaCl <sub>2</sub>	g kg <sup>-1</sup>	mg dm <sup>-3</sup>	cmol dm <sup>-1</sup>			(%)	(%)
<i>C. ochroleuca</i> + <i>B. ruziziensis</i> cover	5.0	27.0	3.1	4.3	6.3	1.9	0.10	66
<i>C. ochroleuca</i> cover	5.4	24.4	2.8	3.6	6.7	2.0	0.10	61
<i>B. ruziziensis</i> cover	5.4	23.5	2.2	4.2	7.7	2.1	0.11	61
Conventional cultivation	5.7	22.4	7.3	3.7	9.0	2.5	0.11	77

**Source:** The authors (2021)

Broccoli seedlings were transplanted to 0.10-m-deep pits on March 16, 2015. Before transplanting, fertilization was performed with 150 kg ha<sup>-1</sup> of N in the form of urea, 300 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub> in the form of single superphosphate and 180 kg ha<sup>-1</sup> of K<sub>2</sub>O in the form of potassium chloride.

Top-dressing fertilization consisted of 100 kg ha<sup>-1</sup> of N (in the form of agricultural urea with 45% N) and 200 kg ha<sup>-1</sup> of K<sub>2</sub>O in the form of potassium chloride, being 30%, 40% and 30% at 15, 30 and 45 days after transplantation. During the cultivation period, foliar fertilization was carried out every 7 days. The composition of the applied product was: 11% N; 11% P; 11% K; 2% Mg; 10% S; 0.15% B; 0.30% Cu; 0.11% Fe; 0.26% Mn; 0.04% Mo and 0.50% Zn (1.0 g L<sup>-1</sup>) (GEISENHOF *et al.*, 2015).

Plants were irrigated using the surface and subsurface drip irrigation systems. Drip tapes with emitters spaced apart by 0.5 m were used in both systems. With an operating pressure of 10 m, the corresponding flow rate of the emitters was 1.5 L h<sup>-1</sup>, with one emitter per plant. In the subsurface system, the drip tapes were buried at 0.10 m depth. In the first 12 days after transplantation, in order to optimize the initial growth of seedlings, the plants were irrigated using the Santeno® system, applying water depths of 16.5 mm every two days, which resulted in the application of 66.02 mm of water in all treatments.

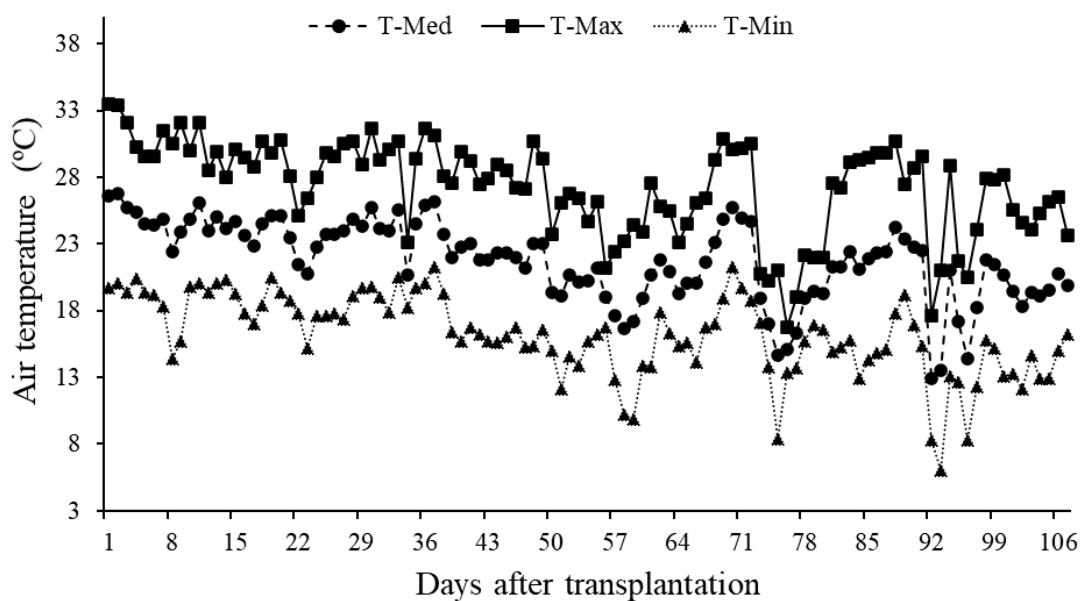
Irrigation management was performed based on volumetric soil moisture, using tensiometers to monitor soil water tension, and soil water retention curve equation fitted by the Van Genuchten (1980) model (Equation 1).

$$\theta_a = 0.2133 + \frac{0.3667}{\left[1 + \left(0.2906 |\psi_m|^{1.7254}\right)\right]^{0.4204}} \quad (1)$$

Three tensiometers were installed in each plot (0.20 m depth). Irrigations were performed for each treatment independently, whenever at least two tensiometers exceeded the matric potential of -15 kPa (0.3354 m<sup>3</sup> m<sup>-3</sup>). Tensiometer readings were performed twice a day (at 09:00 and 15:00 h). Irrigations were carried out in order to increase the matric potential to -6 kPa (0.4270 m<sup>3</sup> m<sup>-3</sup>).

During the experiment, the weather conditions were monitored using data from the automatic station of the BRAZILIAN AGRICULTURAL RESEARCH CORPORATION (EMBRAPA-CPAO), located in Dourados, MS, Brazil. This meteorological station is about 15 km from the area where the experiment was worked out. The average daily temperature along the experimental period ranged from 12.95 to 26.75 °C (Figure 2), which promoted ideal conditions for germination and crop development (LALLA *et al.*, 2010).

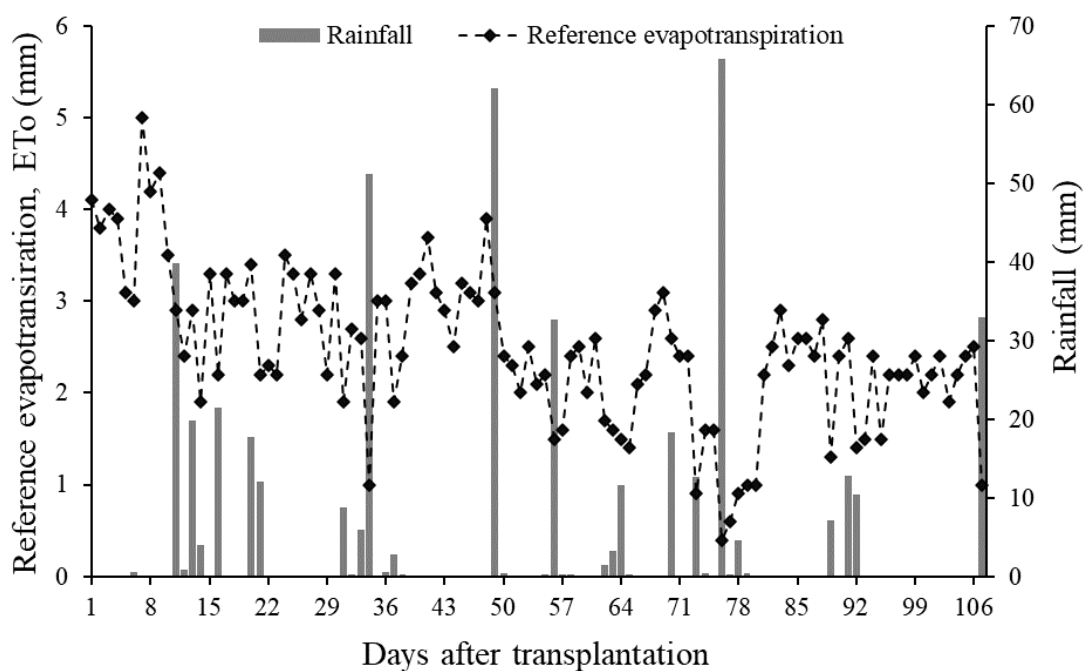
**Figure 2.** Mean (T-Mean), maximum (T-Max) and minimum (T-Min) temperatures during the cultivation period.



Source: The authors (2021)

Rainfall and reference evapotranspiration showed accumulated values of 463.8 and 265.8 mm throughout the crop cycle, respectively (Figure 3).

**Figure 3.** Reference evapotranspiration (ET<sub>o</sub>) and daily rainfall observed during the cultivation period.



Source: The authors (2021)

The experiment was harvested 80 days after transplantation (June 30, 2015). Inflorescence diameter (cm), marketable yield of inflorescence ( $\text{t ha}^{-1}$ ), water depth applied via irrigation (mm) and water productivity ( $\text{kg m}^{-3}$ ) were determined to compare the treatments.

Inflorescence diameter (ID) was obtained based on the circumference of the inflorescences collected, measured with a measuring tape, and on the relationship between the circumference and the value of  $\pi$ . The marketable yield of inflorescence (MYI) was obtained by extrapolating the yield obtained in the usable area to the plant

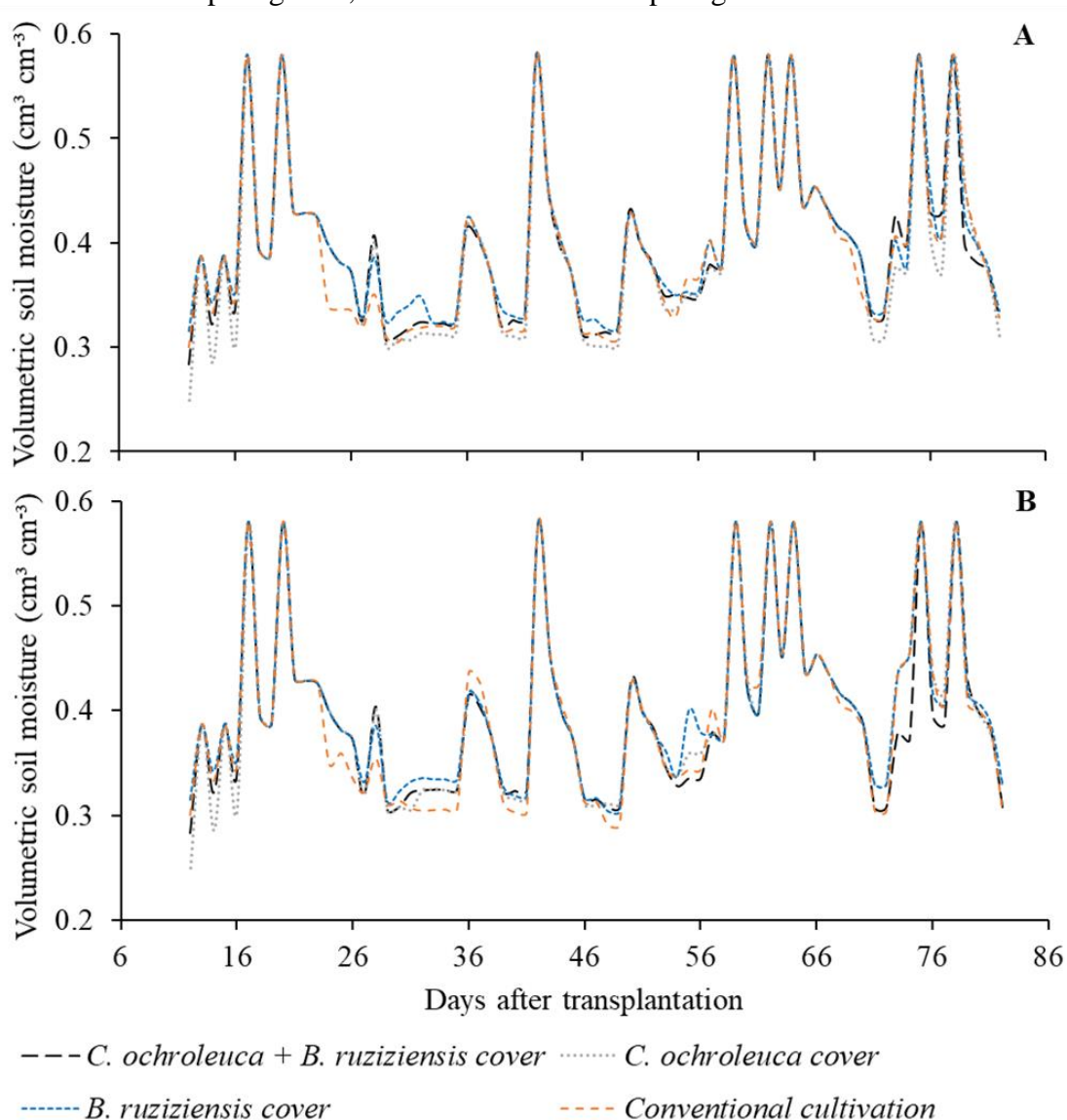
## 5 RESULTS AND DISCUSSION

According to the values of soil moisture throughout the period of broccoli cultivation, it is observed that the cover with *C. ochroleuca* and *B. ruziziensis* intercropping, in general, kept the soil wetter for a longer period of time. Regardless of the

population per hectare. The plants did not show injuries or malformation, so all the harvested plants were considered marketable. The water depths applied by irrigation (IRRIG) in each treatment were recorded at each irrigation event to calculate the volume of water throughout the cycle. Water productivity (WP) was obtained by the ratio between inflorescence mass and volume of water applied via irrigation. The results were subjected to analysis of variance by F test and subsequent comparison of means, by Tukey test, at 5% probability level.

irrigation system, the conventional cultivation had several moments with lower soil moisture compared to the other treatments. For the surface drip system, this occurred mainly from 24 to 30 and from 67 to 71 days after transplantation. For the subsurface drip system, the lowest values of soil moisture occurred mainly between 24 and 35 and between 39 and 41 days after transplantation (Figure 4).

**Figure 4.** Volumetric soil moisture in each treatment during the experimental period. A - with surface drip irrigation; B - with subsurface drip irrigation.



Source: The authors (2021)

As the irrigation events are performed according to the soil moisture content, the number of irrigations (NI) and the irrigation depth applied (IRRIG) in the treatment with conventional soil tillage were higher compared to the treatment with *C. ochroleuca* and *B. ruziziensis* cover, under both irrigation systems. In the CT treatment, 123.62 mm and 133.72 mm were applied in 29 and 30 irrigation events in the surface and

subsurface drip systems, respectively, while in the NT1 treatment 104.22 mm and 108.42 mm were applied, both in 25 irrigation events, respectively (Table 2). Thus, the soil surface cover directly contributed to the conservation of its soil moisture, reducing the number of irrigation events and the total water depth applied via irrigation. Similar effect of soil cover with straw was observed by Almeida *et al.* (2019).



**Table 2.** Irrigation depths applied (IRRIG) and number of irrigations (NI) for head broccoli in different cultivation systems under surface and subsurface drip irrigation.

Treatments	Surface drip		Subsurface drip	
	IRRIG (mm)	NI	IRRIG (mm)	NI
<i>C. ochroleuca</i> + <i>B. ruziziensis</i> cover (NT1)	104.22	25	108.42	25
<i>C. ochroleuca</i> cover (NT2)	91.62	25	88.42	25
<i>B. ruziziensis</i> cover (NT3)	118.12	26	123.32	26
Conventional tillage (CT)	123.62	29	133.72	30

Source: The authors (2021)

The irrigation depths applied varied in the NTVS as a function of the amount of dry matter in the treatments related to the cultivation system. The average straw dry matter (SDM) for the treatments NT1, NT2, NT3 and CT were 8.2, 11.2, 8.0 and 0.0 t ha<sup>-1</sup>, respectively. The cover with only *C. ochroleuca* had greater amount of SDM on the surface, contributing to a lower application of irrigation during broccoli cultivation under both irrigation systems, 91.62 mm and 88.42 mm, respectively. When intercropped with *B. ruziziensis*, this crop promoted less soil cover, with the second lowest irrigation depth (102.22 mm and 108.42 mm, respectively).

The straw layer, when covering the soil surface, makes crusting more difficult, allowing greater infiltration of water into the soil profile, depending on the channels opened by the roots (SALTON; HERNANI; FONTES, 1998). In addition, it reduces losses by evaporation (ALMEIDA *et al.*, 2019), contributing to the increase in the water use efficiency of crops. However, the effect of cover plants on the water stored in the soil depends on the depth considered, and the positive effects are more evident in the more superficial layers (ALVAREZ; STEINBACH; PAEPE, 2017), mainly benefiting crops with superficial root system, such as vegetables. Yadav *et al.* (2014) reported water saving of 71% in the

cultivation of broccoli in NTVS compared to conventional cultivation. Several studies also highlight the importance of NTS for crops, especially in regions with water restrictions (FAROOQ *et al.*, 2011; PITTELKOW *et al.*, 2015; RUSINAMHODZI *et al.*, 2011).

According to the F test ( $p < 0.05$ ), there was no statistical interaction between the cultivation systems and irrigation systems, and the irrigation systems were similar to each other. Thus, the means of treatments with surface and subsurface drip irrigation were statistically equal, regardless of the cultivation system and parameter evaluated. Broccoli yield parameters and water productivity were significantly influenced by the cultivation systems, differing by F test ( $p < 0.05$ ), with the highest values of yield and higher water use efficiency in the treatments with NTVS.

Statistical difference was observed by the F test ( $p < 0.05$ ) between treatments in relation to inflorescence diameter (ID). The NTVS positively influenced the increase in broccoli ID, with increments from 1 to 12% in size compared to the diameters obtained in the control treatment, conventional cultivation (CT). The highest increments were observed in treatments NT1 and NT2, which had *C. ochroleuca* as a cover plant (Table 3).

**Table 3.** Mean values of inflorescence diameter (ID), marketable yield of inflorescence (MYI) and water productivity (WP) for broccoli grown in different cultivation systems.

Treatments	ID (cm)	MYI (t ha <sup>-1</sup> )	WP (kg m <sup>-3</sup> )
<i>C. ochroleuca</i> + <i>B. ruziziensis</i> cover (NT1)	18.88 a	18.68 a	17.57 a
<i>C. ochroleuca</i> cover (NT2)	18.57 b	16.51 ab	18.34 a
<i>B. ruziziensis</i> cover (NT3)	17.87 b	15.50 b	12.84 b
Conventional tillage (CT)	17.71 b	14.67 b	11.40 b

\*Values followed by the same letters in the column do not differ from each other, by Tukey test ( $p < 0.05$ ). Source: The authors (2021)

The largest inflorescence diameter was obtained in the NT1 treatment (19.88 cm), and similar value of diameter was observed in NTVS using residues from the intercropping of *C. ochroleuca* and millet (19.45 cm), reported by Nespoli *et al.* (2013). The other treatments showed no significant differences between them, with the smallest inflorescence diameter obtained in the treatment with conventional cultivation (17.71 cm). In conventional cultivation, Lalla *et al.* (2010) also obtained values of diameter similar to those reported in the present study in the CT treatment, with a maximum diameter of 16.6 cm. In general, the inflorescence diameters obtained in this study are considered of satisfactory size and commercially acceptable, based on the diameters reported in several studies (INFANTE; MORSE, 1996; JOKELA; NAIR, 2016; MELO; MADEIRA; PEIXOTO, 2010; OLIVEIRA *et al.*, 2018; SCHELLENBERG; MORSE; WELBAUM, 2009).

Regarding the marketable yield of inflorescence (MYI), the gains obtained by the NTVS were significant and ranged from 5.5% to 27% compared to the yields obtained in the control treatment with conventional soil cultivation, with a statistical difference between treatments by the F test ( $p < 0.05$ ). Treatments that had *C. ochroleuca* (NT1 and NT2) as cover plant in the NTVS obtained the highest marketable yields of inflorescence (Table 3).

The highest marketable yield of inflorescence was observed in the NT1 treatment (18.68 t ha<sup>-1</sup>) and the lowest value

in the treatment with conventional cultivation (14.67 t ha<sup>-1</sup>). The yields obtained in this study were high compared to those reported in studies involving the cultivation of broccoli with other approaches (INFANTE; MORSE, 1996; JOKELA; NAIR, 2016; MELO; MADEIRA; PEIXOTO, 2010; OLIVEIRA *et al.*, 2018; SCHELLENBERG; MORSE; WELBAUM, 2009).

Regarding water use efficiency, represented in this study by water productivity (WP), the NTVS positively influenced the increase in water use efficiency in broccoli cultivation, with increments of 12% to 54% compared to the control treatment. In addition, a statistical difference was observed between treatments by the F test ( $p < 0.05$ ). The treatments with *C. ochroleuca* as a cover plant in the NTVS obtained the highest water use efficiency. NT1 was statistically similar to NT2. The results of both were higher than and statistically different from those of the treatments NT3 and CT, which were similar to each other (Table 3).

The higher values of WP obtained in NT1 and NT2 are attributed to the higher values of crop yield and higher water saving in these treatments, since the water depths applied in these treatments were 17% and 30% lower, respectively, compared to the CT treatment. Thus, the amount of SDM had a direct effect on water use efficiency, promoting higher results when compared to previous experiments conducted in the same experimental area using the conventional system for broccoli cultivation

(GEISENHOFF *et al.*, 2015; OLIVEIRA *et al.*, 2016b).

The WP parameter has an economic character (GEISENHOFF *et al.*, 2015), as it considers the water depth applied and, consequently, the energy consumption for such activity (LIMA JUNIOR *et al.*, 2016; OLIVEIRA *et al.*, 2016a). From the WP values, it can be observed that 116 L of water were applied to produce 1 kg in the CT, while 67 L of water were applied in NT1, i.e., the NTVS generated a 42% saving in the volume applied by irrigation.

In relation to the marketable yield of inflorescence (MYI), statistical difference was observed between treatments according to the F test ( $p < 0.05$ ). The increase in yield occurred in the first cycle of cultivation. In major crops such as rice, cotton, corn, soybeans and wheat, the benefits promoted by the NTS in general are more pronounced in the long term (ALVAREZ; STEINBACH; PAEPE, 2017; LAMAS *et al.*, 2016; PINTO *et al.*, 2016; SILVEIRA; STONE, 2003).

In the cultivation of vegetables, obtaining increments in yield in the first cycle can be a decisive factor for greater adoption of NTVS because, even when adopted with temporal discontinuity, the NTVS can promote significant benefits, reducing the processes of erosion caused by excessive soil turning, smoothing the peaks of soil temperature, increasing the supply of nutrients to the soil and reducing phytosanitary problems and weed infestation (COELHO *et al.*, 2013; CORRÊA; SHARMA, 2004; COUTINHO *et al.*, 2010; MELO; MADEIRA; PEIXOTO, 2010; SILVA; MARIA, 2011). Considering that vegetables produce little or no straw, the maintenance of straw becomes a challenge and require greater planning for sowing the straw-forming crop (JOKELA; NAIR, 2016; SALTON; HERNANI; FONTES, 1998).

Despite promising results of yield in the cultivation of vegetables in NTVS, the adoption of NTVS is still low in Brazil,

possibly due to the tradition of cultivating in a conventional system, with soil turning and formation of beds. There is also a fear that the system will cause losses of yield (MELO; MADEIRA; PEIXOTO, 2010). The different responses that the NTS promotes can vary widely according to the category of the crop. However, several studies have shown that the NTVS in the cultivation of broccoli promotes increased yields (DINIZ *et al.*, 2017; INFANTE; MORSE, 1996; WYLAND *et al.*, 1996) or even similar yields to that of the conventional system (BRANCO *et al.*, 2017; JOKELA; NAIR, 2016; MELO; MADEIRA; PEIXOTO, 2010; SCHELLENBERG; MORSE; WELBAUM, 2009).

However, considering the reduction in production costs (FERREIRA; FREITAS; MOREIRA, 2015) and the benefits provided for the soil by the NTS (BRANCO *et al.*, 2017; COELHO *et al.*, 2013; COUTINHO *et al.*, 2010; SILVA; MARIA, 2011), the adoption of this system becomes feasible from the moment when the yield is equal to or higher than that of the conventional cultivation system. Thus, the practice of broccoli cultivation in NTVS can be considered adequate for the region of Dourados, MS, Brazil, as it was observed that the yields were higher than that obtained in conventional cultivation.

The results observed in this study demonstrate that the selection of straw-forming species for the NTVS is an extremely relevant factor to obtain high marketable yield of broccoli and save water and energy in irrigation. During the formation and maintenance of the NTVS system, grasses and legumes should be intercropped, integrating their benefits, so that the rapid decomposition of legume residues gradually supplies nutrients to plants (GIACOMINI *et al.*, 2003) and the durability of *B. ruziziensis* straw keep the soil surface covered for a longer period during broccoli cultivation (DUDA *et al.*,

2003; SALTON; HERNANI; FONTES, 1998).

## 6 CONCLUSÃO

Regarding the irrigation systems (surface and subsurface dripping), it was observed that there was no significant difference on the productivity parameters of head broccoli. Although, in relation to crop management systems, no-tillage with straw from the intercropping of *Crotalaria ochroleuca* and *Brachiaria ruziziensis* showed better water use efficiency and higher crop productivity, being more suitable for the cultivation of head broccoli.

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