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Thermal and Soil Moisture Amplitude of Intercropped Crops

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Authors' contributions

This work was carried out in collaboration among all authors. Author JDB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PSLF and RD managed the analyses of the study. Author RD managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Conservation systems of production are promoting yields and profitability, intercropping systems aim at sustainable maximization of soil and water use, and have become an alternative for regions characterized by relatively short rainy periods and high temperatures. The objective of this work was to evaluate the influence of the intercropping system between maize (*Zea mays* L.) and C. juncea (*Crotalaria juncea* L.) on soil temperature and humidity for the municipality of Tangará da Serra in Brazil. The treatments consisted of the single crop of maize and crotalaria, as well as their intercrop cultivation, the soil temperature was evaluated at depths of 0.10, 0.20, 0.30 and 0.40 m and soil moisture at depths of 0.20 and 0.40 m. The components of grain production and yield of maize were

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also evaluated, for crotalaria, height, diameter and dry mass of the plants were evaluated. The highest soil temperature occurred at 14 h with an average of 21°C for all three treatments. The intercropping of maize with crotalaria gave the soil a lower amplitude of the soil temperature and kept the soil moisture high with values of 0.3 m^3 m^{-3} in the depth of 0.20 m. The development stage presented the lowest mean thermal amplitude and higher humidity for the intercrop system. The yield of maize in an intercrop was reduced by 42.7% compared to a single crop.

Keywords: Thermal amplitude; crop intercrop; TDR; thermocouples.

1. INTRODUCTION

The maize (*Zea mays* L.), is one of the most important plants cultivated in Brazil and worldwide, stands out in terms of economic importance and, besides, has wide adaptation to the Brazilian edaphoclimatic conditions, cultivated in the first and second harvests with high productive potential even under adverse conditions [1].

According to National Supply Company – CONAB [2], for the state of Mato Grosso, the average yield of maize 2nd crop in the 2018/19 crop year, considering the total area sown, was 6,150 kg ha^{-1}, yield 4.72% higher than the 5,860 kg ha^{-1} that occurred in the crop (2017/18), an increase due to the increased use of new technologies by producers in the state and the greater regularity of the region rainfall over the past year.

In search of new practices to optimize land use in periods between seasons, is the second crop intercropping, which aims to insert two crops that do not compete for water and nutrient, to take advantage of the end of the rainy season that for the state is between May to September [3].

The maize and *Crotalaria juncea* (*Crotalaria juncea* L.) intercropping are being a major ally in soil quality regarding microorganisms and nutrient cycling. *C. juncea* belongs to the Fabaceae family and together with the other species of the genus are used as green manure crops and in intercropping systems [4]. In addition, *C. juncea* species have a high capacity for biomass production and nitrogen fixation [5].

Production systems that consider socioeconomic and environmental aspects should be prioritized in order to enable the conservation of natural resources, and are increasingly recommended to replace conventional production systems [6].

The best benefits have been found with the use of legumes such as *C. juncea* due to the great contribution in soil nutrition, adaptability to light conditions, rapid early growth and suppression of unwanted plants [6,7,8].

Another advantage of intercropping maize-*C. juncea* cropping is the maintenance of soil surface biomass that reduces the intensity of solar radiation, soil absorptivity, and reflectivity. [9].

Vegetation cover has benefits in all soil chemical-physical dynamics, however, management systems such as intercropping influence soil temperature [10]. Vegetation cover plays an important role in soil temperature since vegetation cover is responsible for the exchange and storage of thermal energy in terrestrial ecosystems [9].

In research evaluating the soil temperature and humidity in-depth, it was observed that the solar energy after being absorbed by the soil is transmitted to the deeper layers and this process is dependent on the thermal properties of the soil, such as specific heat, thermal conductivity. and the relationship between these properties (thermal diffusivity). These changes are greatest in layer 0.0 - 0.10 m, which also concentrates most roots and activity of microorganisms [11].

When determining soil temperature, with and without vegetation cover, Carneiro, et al. [9] found that soil moisture is critical because the presence of water affects the heat flux in the soil, ie the presence of moisture in the soil modifies the temperature range at surface level upon evaporation.

Heat flux depends on soil capacity and thermal conductivity, which vary with soil composition, density, and water content. Soil warming can reduce soil moisture, which affects micro-organism's respiration and root growth [12].

Thus, we aimed to evaluate the effect of monoculture and maize-*C. juncea* intercropping on soil temperature and soil moisture at depth, crop development and yield.

2. MATERIAL AND METHODS

2.1 General Description

The experiment was carried out at the experimental field of the University of Mato Grosso State (UNEMAT), Brazil, in the facilities of the Technological Center of Geoprocessing and Remote Sensing applied to Biodiesel Production (CETEGEO-SR), from April to August 2018.

Near the experimental area is an automatic weather station from the Campbell Scientific, installed at the geographic coordinates of 14º65' 00" S, 57º43' 15" W with elevation of 440 m, from which we obtained the meteorological data used to estimate the reference evapotranspiration - ETo, Penman-Monteith method - FAO 56 [13].

2.1.1 Climate characterization

The regional climate is classified as tropical megathemic humid (AW) (Köppen classification), with high temperatures, a dry season from May to September, and a rainy season from October to April, with an annual average rainfall of 1,830 mm and average air temperature 26.1ºC [3]. The soil is classified as an Oxisol, very clayey texture [14].

2.2 Experimental Design

The experiment consisted of six lysimeters so that two lysimeters were used for each of the three treatments, as follows: T1 - maize; T2 - *C. juncea* and T3 - intercropping. A draw was made to determine which of the lysimeters would receive each treatment. All plants of each lysimeter were collected, where each plant corresponded to one repetition.

To better understand the variations of soil temperature and humidity during the experiment period, the crop cycle was divided into 3 phases: Initial (I): planting up to 10% soil cover (sowing up to V7); Development (II): end of early phase until beginning of maturation (V8 to R5); Final (III): from the beginning of maturation until harvest (R6 until harvest), according to the methodology described by Allen, et al. (2006).

2.3 Procedure Experimental

The experiment was carried out on six high precision weighing lysimeters, existing in the experimental area, with an area of 2.25 m² (1.50 x 1.50 m) and 1.20 m deep, described by Fenner, et al. [15]. These were previously calibrated to control the water inputs and outputs of the system through evapotranspiration, irrigation, precipitation, and drainage.

The sensors used to measure ground temperature were type "K" thermocouples. In the central area of each treatment, 4 horizontal sensors were installed, with the depths of 0.10, 0.20, 0.30 and 0.40 m.

To monitor soil moisture, two time-dominance reflectometry probes (TDR), model CS-616, were installed at a depth of 0.20 and 0.40 m, also horizontally at the center of each treatment.

Both temperature and humidity sensors were installed 15 days after the maize crop emerged. Both were connected to a multiplexer card, connected to a Campbell Scientific CR1000 datalogger, programmed to collect data every 30 seconds, storing the average every 15 minutes.

The sowing in the lysimeters was done manually (04/12/2018), and in the surroundings with the aid of a maize border seeder, totaling an experimental area of 3,600 m^2. The cultivar Fórmula Viptera 2, super early cycle, was sown with 3 plants m^{-1}, spaced 0.50 m between rows, totaling 60,000 plants per hectare. Simultaneous planting of *C. juncea* was done by row, manually, with 30 seeds per m^2, totaling 600,000 plants per hectare. All cultural treatments were carried out according to the recommendations for the cultures [16,17].

The soil in the region under study has moisture in the field capacity (CC) and permanent wilting point (PMP), in the values of 0.361 and 0.232 m^3 m^{-3} respectively [18].

Fertilization and soil pH correction was performed according to soil analysis (Table 1). Before sowing, soil correction was performed with 1.49 t ha^{-1} of dolomitic limestone only in the surrounding area, in the lysimeters not required according to soil analysis. The basic fertilization consisted of 500 kg ha^{-1} of NPK mineral fertilizer, formula 5-25-15, applied in the sowing line. Two applications of nitrogen (N) totaling 200 kg ha^{-1} of N were carried out when the crop was in stage V4 and V7, with urea being the source used. Crotalaria culture was conducted without fertilization.

2.4 Irrigation Management

The required irrigation depth was determined by evapotranspiration of the crop counted on the lysimeters, and applied by a sprinkler irrigation system consisting of 8 sprinklers (Eco 232 Frabrimar) with 4.0x2.8 mm nozzles spaced

Table 1. Chemical characteristics of the soil at a depth of 0.0 - 0.20 m from the lysimeters (A) and the experimental area around (B) of the State University of Mato Grosso (UNEMAT), in Tangará da Serra, Brazil, before the experiment

Sample	pH		P	K	Ca+Mg	Ca	Mg	Al	H	CEC	V %
	H2O	CaCl2	-- mg/dm³ --		------------------ Cmolc/dm³ ------------------						
A	6.10	5.60	4.85	21.60	3.36	2.35	1.01	0.00	2.12	5.54	61.73
B	5.70	5.00	1.60	84.60	2.44	1.82	0.62	0.00	3.25	5.91	45.01

**PLANTE CERTO – Analysis of Soil, limestone, water, nematodes, fertilizer, ration, salt, and leaf tissue LTDA, Varzea Grande – MT. (February/2018)*

12x12 m, with a distribution uniformity coefficient of 83% under 30 m.c.a. pressure, providing an applied water depth of 8.20 mm h^{-1} with a flow rate of 1.41 $m^3 h^{-1}$ per sprinkler.

Soil moisture values obtained by TDR probes were adjusted by the equation proposed by Vasconcelos, et al. [19], where the quadratic equation best fits data relating temperature to soil moisture.

2.5 Harvesting and Analyzed Variables

At the end of the maize crop cycle, the harvest was performed at 123 days after sowing (DAS), manually, in which the variables analyzed were: plant height; ear insertion height; dry mass; number of rows per ear; number of grains per row; average number of grains per ear; 1.000 grain mass and productivity.

2.6 Statistical Analysis

The data of the production components were subjected to analysis of variance (ANOVA) by the F test, and the means compared by the Tukey test at 5% probability. For data analysis, we used the computer program SISVAR version 5.6 [20].

3. RESULTS AND DISCUSSION

During the experimental period, the precipitation and irrigation values were 122.2 and 560 mm, respectively, totaling 682.2 mm during the cycle (Fig. 1).

Summing up the irrigation and precipitation occurred in the initial phase of maize crop up to 40 DAS, 267.6 mm, in the development phase until 98 DAS, 334.4 mm and in the final phase until 124 DAS, 80.2 mm, providing the culture ideal conditions of water availability.

Maize cultivation requires minimum consumption of 350 to 500 mm of water to ensure satisfactory production without the need for irrigation. When grown under hot and dry weather conditions, the crop will rarely exceed 3 mm d^{-1} of water consumption [21].

Maize crop in the monoculture system demands 387.1 mm in the whole cycle. In another study performed [22], Souza, et al. [6], report that the total water consumption in the maize crop cycle was 394.1 mm, with an average of 3.46 mm d^{-1}. Thus, the sum of the precipitated water volume and that provided by irrigation during the conduction period of this experiment, meet the water demand demanded by maize crop.

The maximum, average and minimum temperature values were respectively 29.82, 22.94 and 17.09ºC. It can be observed that there is a direct relationship between precipitation and air temperature, where on days when precipitation occurred, the minimum, maximum and average temperature values were relatively lower. Fenner, et al. [23] observed this same behavior in research conducted in the Tangará da Serra. Another inversely proportional relationship was observed in solar radiation and relative humidity, showing that on days of low radiation to an increase in relative humidity.

3.1 Soil Temperature Variation

The temperature variation in the soil profile shows that at greater depths the thermal amplitude tends to be smaller, independent of the cropping system, so for the depth of 0.30 and 0.40 m the temperature variation is close to those found in the treatments. In intercrop and single (Fig. 2).

The variation of soil moisture was smaller for *C. juncea* cultivation because it has a higher number of plants per square meter and for this single treatment did not present competition for light its development was higher and with higher water consumption (transpiration).

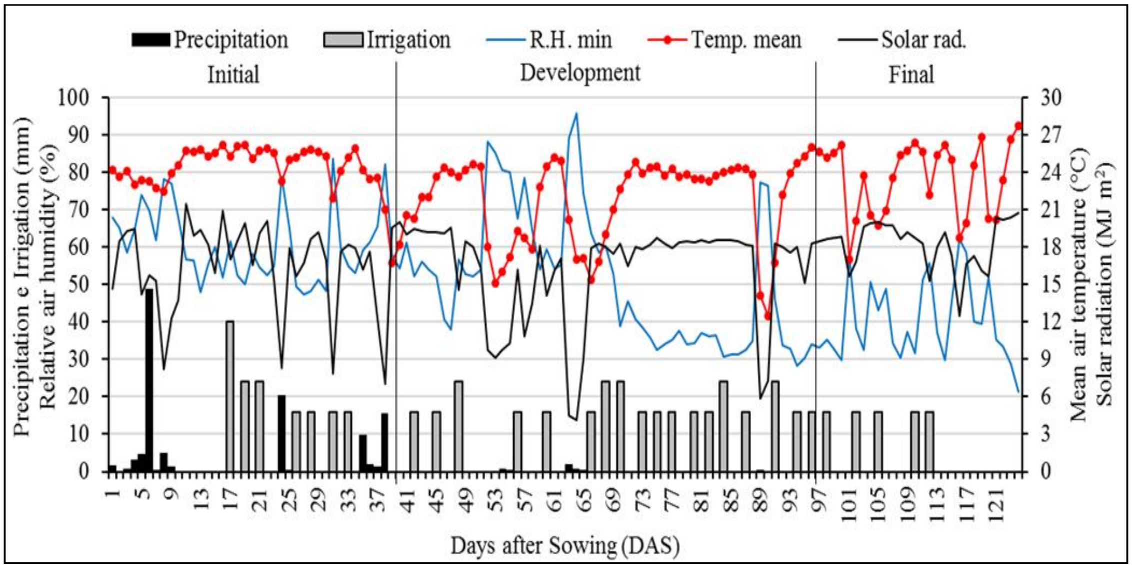

Fig. 1. Mean air temperature, precipitation, irrigation, solar radiation and relative air humidity, during the experimental period in Tangará da Serra, 2018

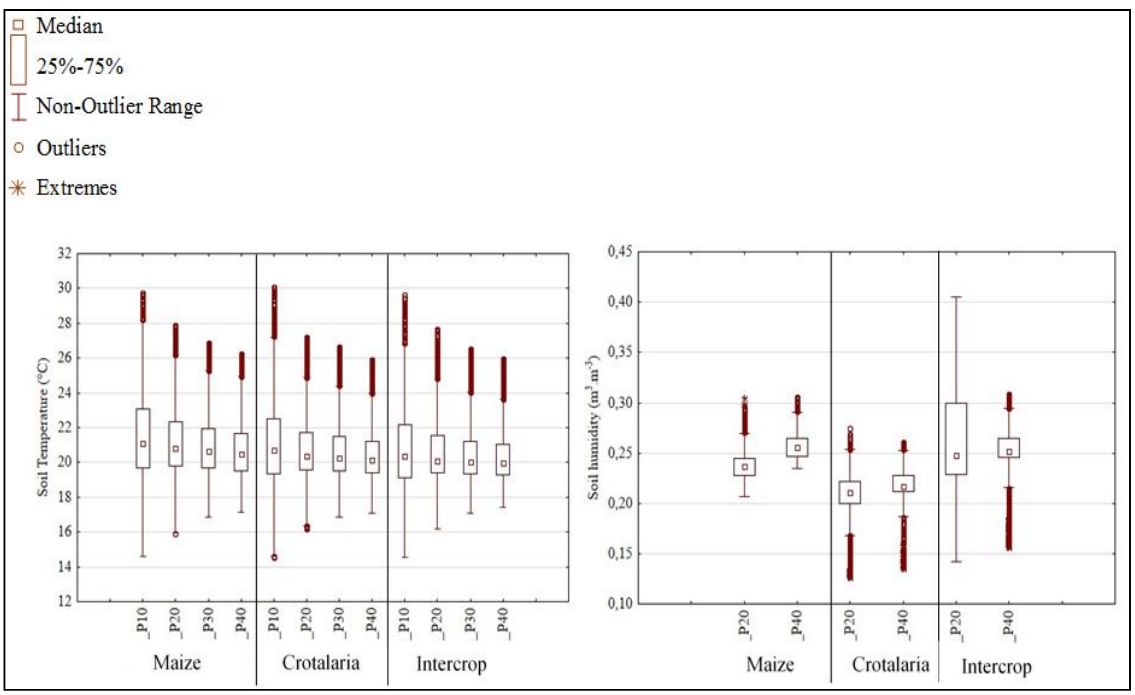

Fig. 2. Variation of soil air temperature and humidity values in-depth in the soil profile for maize, crotalaria, and intercropping systems

For the intercrop treatment, the variation of the moisture in the 0.20 m layer was higher due to light competition and, consequently, lower rate and transpiration. In intercropping systems, leaf cover is shorter in time compared to monoculture systems and this gives the soil a lower rate of water evaporation.

Soil temperature and humidity are inversely related, as humidity is of paramount importance, as the presence of water in the soil affects the heat flux of the soil, ie the presence of moisture in the soil modifies the temperature values in the soil evaporation function [9].

Despite few studies from the perspective of minimizing the amplitude of the soil temperature, appropriate management can change this scenario, such as the use of mulch in the ground cover and intercropped crops, aiming for greater ground cover and shading. Soil temperature has direct effects on plant development, especially on germination, since all seeds need an induction for germination, the most common being temperature, but normal plant development also needs an adequate temperature [24].

The average soil temperature suitable for sowing crops such as soybeans, maize, and beans are between 20 and 30ºC, with 25ºC ideal for rapid and uniform emergence. Sowing in soil with an average temperature below 18ºC can result in a drastic reduction in germination and emergence rates and temperatures above 40ºC can also be harmful [21]. In a study by Rodrigues [25], the author finds that the optimal soil temperature for seed germination is in the range of 25 to 30ºC and for nodulation and nitrogen fixation between 27 and 32ºC.

The maximum soil temperature occurred between 12 and 15 h and the minimum between 3 and 6 h, following the air temperature variation, as expected. However, in intercropping systems, the soil temperature decreased with maximum values of 22.08ºC at 3 pm, for this same time the maximum values for maize and crotalaria were 28.7 and 22.4ºC. Respectively (Fig. 3). Corroborating these results [26] obtained values of 28.5 and 27.8ºC at 14 and 15 h, respectively, for uncovered soil; and 24.9 and 24.8 for covered soil, showing an average reduction of 3.3ºC with the use of cover.

Temperature in the soil profile varied as a function of depth (Fig. 3), corroborating the results found by Dantas, et al. [27], which allows us to infer that at greater depths, in addition to the smaller thermal amplitude, the times in which the maximum temperature values occur are different in each soil layer. Such behavior is valid for both January and June.

Soil and air temperature showed a positive correlation only at the surface and depth of 0.10 m, and a negative correlation at the lower layers (0.30 and 0.50 m), showing the direct influence of the air temperature on the surface. Generates a slow but gradual heat flux into the ground [26].

Soil temperature varied in relation to the cropping system (maize, *C. juncea* and intercropping), and also in relation to the developmental stages (initial, development and final), it is observed that the thermal amplitude for intercropping is smaller than for monocultures, due to shorter soil shading provided by intercropping.

The *C. juncea* cultivar studied has a plant height similar to the maize height. This is a factor to consider for intercropping, but it is recommended that the main crop in case the maize presents the largest size so that no shading occurs. Nevertheless, the crop *C. juncea* has great advantages for intercropping systems such as N fixation, has rich P, K and Ca biomass, has branched and deep root system, facilitating nutrient recycling in soil and making nematode proliferation difficult [27].

Cortez, et al. [28] evaluating soil temperature and humidity in pre-sowing tillage management systems observed that systems in the corn crop, that preserve the high soil cover index provide higher moisture values and lower temperatures. This data variation is more pronounced in the initial phase of the V3 and V8 crop, where there is a low leaf area index, allowing direct interception of radiation to the soil.

The thermal amplitude of the soil decreases when the depth of the ground observation increases, regardless of the type of crop or cover, which is explained by the heat transfer in the soil that occurs predominantly by conduction, a slow process [29]. Because the soil has a porous fraction, which is partly filled with water and partly air (poorly conductive), thermal energy transfers slowly to the ground, reducing heating and cooling as it deepens [30].

The relationship of the cropping systems with the maize and *C. juncea* cultivation stage cultivated in monoculture and in intercropping, it is observed that in depth of 0.30 and 0.40 m do not present significant differences for thermal amplitude, which is explained by Silva, et al. [30] assessing the relationship between climate and depth at ground temperature found that regardless of the amount or type of coverage, the thermal amplitude at depths greater than 0.30 m is low and indifferent (Table 2).

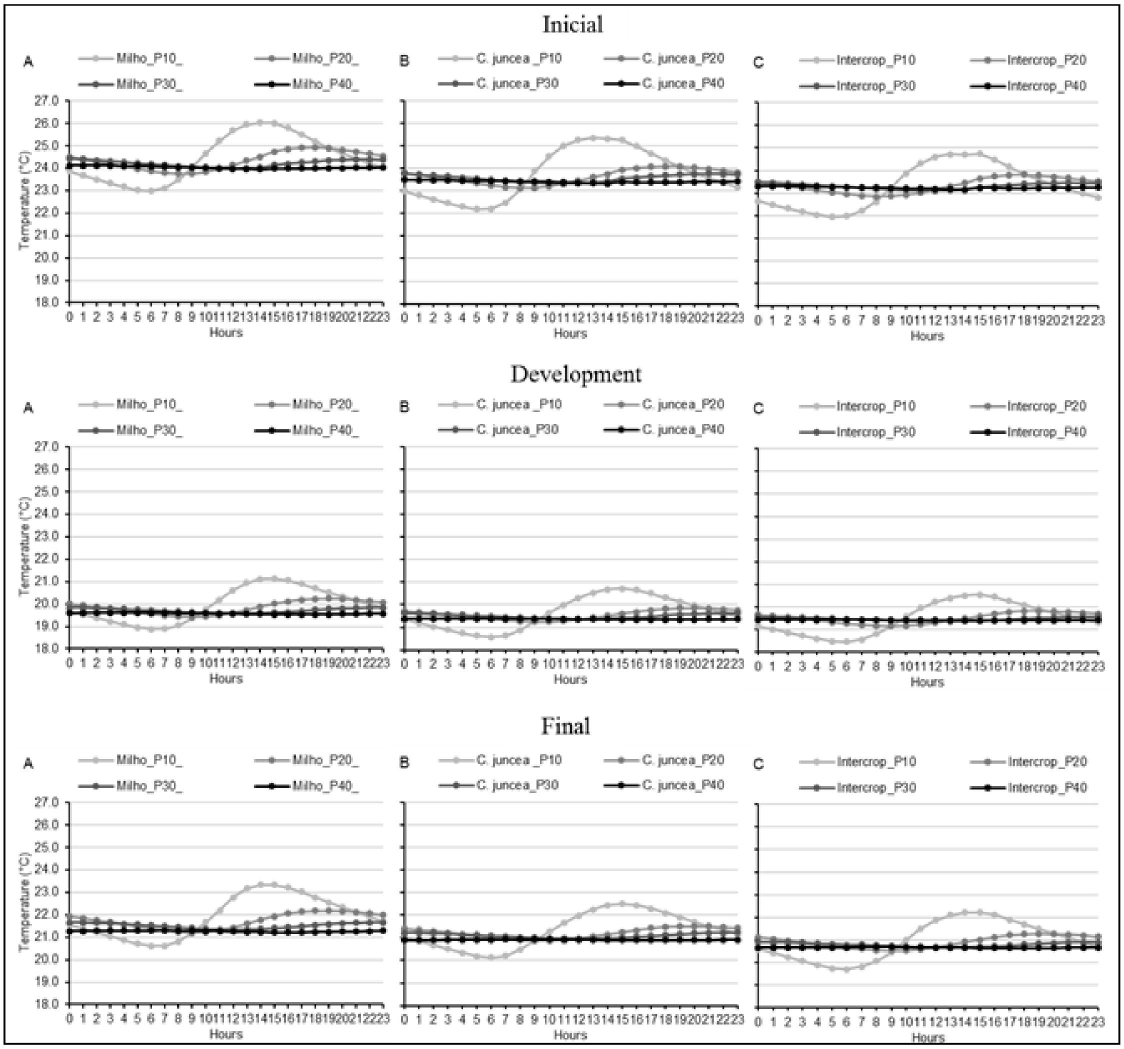

Fig. 3. Hourly variation of the soil temperature at depths 0.10, 0.20, 0.30 and 0.40 m, in (A) maize, (B) *C. juncea* and (C) intercropping systems, in relation to phenological stages of culture, initial, development and final, *local hour (GMT +4:00)

Table 2. Analysis of the depth soil temperature amplitude related to the cropping systems and the maize crop phase

Systems	Phenological stage	Soil temperature (°C)				DMS
		Depth 0.1 m	Depth 0.2 m	Depth 0.3 m	Depth 0.4 m	
Maize	Initial	3.19aA	1.26bA	0.54cA	0.27cA	0.27
	Development	2.39aC	1.01bAB	0.48cA	0.28cA	0.22
	Final	2.76aB	1.11bB	0.49cA	0.26cA	0.25
C. juncea	Initial	3.42aA	1.02bA	0.54cA	0.25dA	0.27
	Development	2.26aC	0.80bA	0.46cA	0.25cA	0.22
	Final	2.60aB	0.85bA	0.46cA	0.24cA	0.25
Intercrop	Initial	3.08aA	1.04bA	0.46cA	0.26cA	0.27
	Development	2.09aC	0.79bB	0.37cA	0.21cA	0.22
	Final	2.66aB	0.99bAB	0.41cA	0.22cA	0.25
	DMS	0.22	0.22	0.22	0.22	

Means followed by the same uppercase letter in the column and lowercase in the row do not differ by the Tukey test at 5% probability. DMS - Difference minimum significant

At a depth of 0.10 m, the soil temperature presents its greatest amplitude at the initial stage of development, but we observe that the intercropping system reduces the thermal amplitude for all stages. This is because germination is concomitantly covering a larger soil area than in monoculture systems. The average amplitude difference found for maize monoculture and in intercropping is 0.3ºC, considering that the light culture 55 days to complete this phase accumulated 16.5ºC difference between the systems.

Furlani [31] found a temperature lower than 0.05 m deep in no-tillage soil compared to conventional tillage, reaching a difference of 4.7ºC during peak daily temperature. Ribas, et al. [32] also evaluated mulching to reduce soil thermal amplitude and concluded that this practice provides yield gains in general crops, as well as preventing erosion and leaching of the richest soil layer.

The maize crop completed its cycle in 123 days after sowing, being distributed in the initial phase, development, intermediate and final, reaching each phase at 20, 55, 108, 123 days.

The soil temperature is higher in the initial phase of the crop until 35 DAS, from that time the soil temperature keeps oscillating between 19 and 23ºC, except in cases where the air temperature drops below 13ºC. It is observed that the daily amplitude of the soil temperature is greater in the depth of 0.10 m and occurs in the initial phase where there is a low leaf area index, but increasing and in the final phase of the crop, where the leaves senescence and reduction of the leaf area index.

3.2 Soil Moisture Variation

Observations of soil moisture were performed at depths of 0.20 and 0.40 m (Figs. 4 and 5) for intercropping and monoculture cropping systems of maize and *C. juncea*. It is clearly noted that the moisture variation is smaller at depth 0.40 m, this is due to the physical-water characteristics of the soil, which directly influence the evaporative water losses that are related to the soil structure, mainly density and porosity, which interfere with water retention and its liquid and gaseous fluxes in the soil profile [33].

The unsaturated hydraulic conductivity plays an important role in the water supply to the soil surface to maintain the evaporation process. Water, oxygen, temperature and mechanical resistance are factors that are associated with the emergence and root growth, directly acting on plant growth [34].

The variation of soil water content is presented in hourly values so we can observe the variation throughout the day between irrigation events, it is observed that in the initial phase of the crops (40 DAS), the variation of moisture between the systems are similar close to 0.25 m^3 m^{-3}, while the crop is established, there is an increase in soil moisture for the intercropping system, this is due to the increased soil shading provided by both crops, contributing to the reduction of soil water evaporation. At the end of the maize crop cycle and irrigation suspension, where it is in the senescence phase, the soil water content for this treatment remains superior to the other systems, this is explained by the fact that the *C. juncea* crop is in full phase. Maximum evapotranspiration rate, so for these systems soil moisture is reduced.

It is noted that at a depth of 0.40 m the humidity variation between the systems remains close to 0.25 m^3 m^{-3}, and as previously mentioned the humidity is reduced from 112 DAS, in the systems where the crotalaria is inserted because it is still in the reproductive phase.

Soil moisture variation during 24 h of each day after 15 DAS was analyzed, and as observed in Table 3, for the depth of 0.40 m there was no significant difference between the systems. For the depth of 0.20 m, the humidity variation is greater because in this fraction of the soil occurs the gas exchange and the water losses by evaporation and transpiration of the plants. The soil moisture in the initial phase of the crops had an amplitude of 0.0275, 0.0242 and 0.0351 m^3 m^{-3} for maize, *C. juncea* and intercropping systems, respectively.

For the maize crop this amplitude decreased during the development of the crop, because the architecture of the maize plant presents high height with low leaf numbers, allowing the interception of sunlight to the soil, reducing the evaporation of soil water and, concomitantly, the plant under development carries out perspiration, thereby reducing soil moisture values.

For the intercropping system, it is observed that the amplitude increases in the development phase, differing statistically from the final phase, because the vegetation cover in this system is higher, providing greater soil shading reducing evaporation. In this case, plant transpiration is the main mechanism for removing water from the soil.

3.3 Analyzed Variables Response

Table 4 shows the average tests for maize monoculture and intercropping; however, they were performed in two repetitions, lysimeters, and field, with the field represented as the border for lysimeters. We observed that for the maize monoculture, all the analyzed variables were superior when compared to the intercropping, being the most relevant variable for the maize the yield difference was 2959 and 2168 kg ha^{-1}, for lysimeters and field respectively.

This drop-in productivity was also observed by Chieza, et al. [4], studying the same cultivar of *C. juncea* in intercropping with maize, showing that simultaneous sowing reduces maize productivity because the competition for light occurs in the initial phase until 30 DAS.

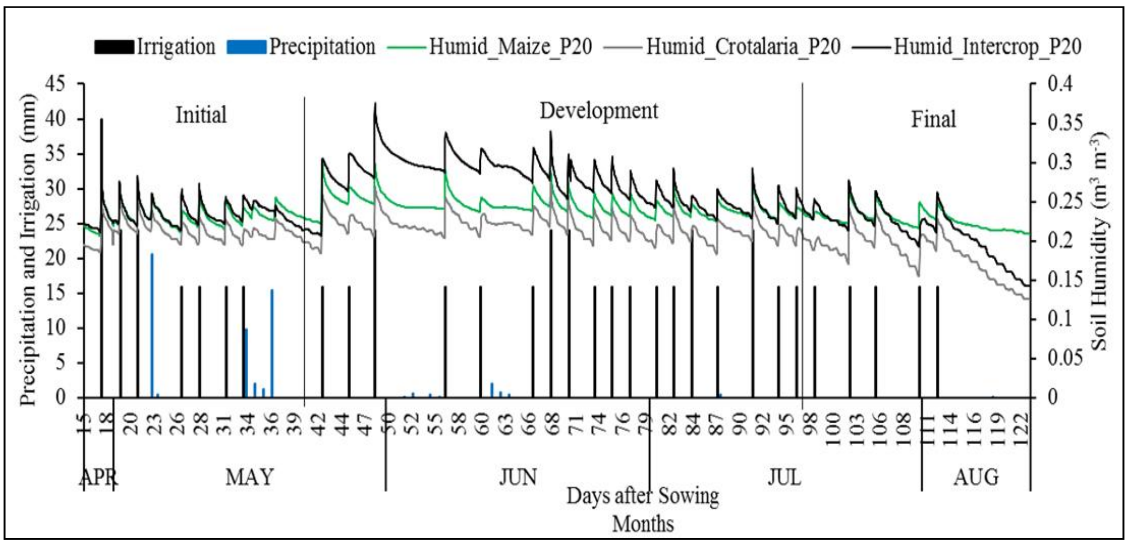

Fig. 4. Soil moisture variability at a depth of 0.20 m and accumulated precipitation and irrigation during the crop cycle

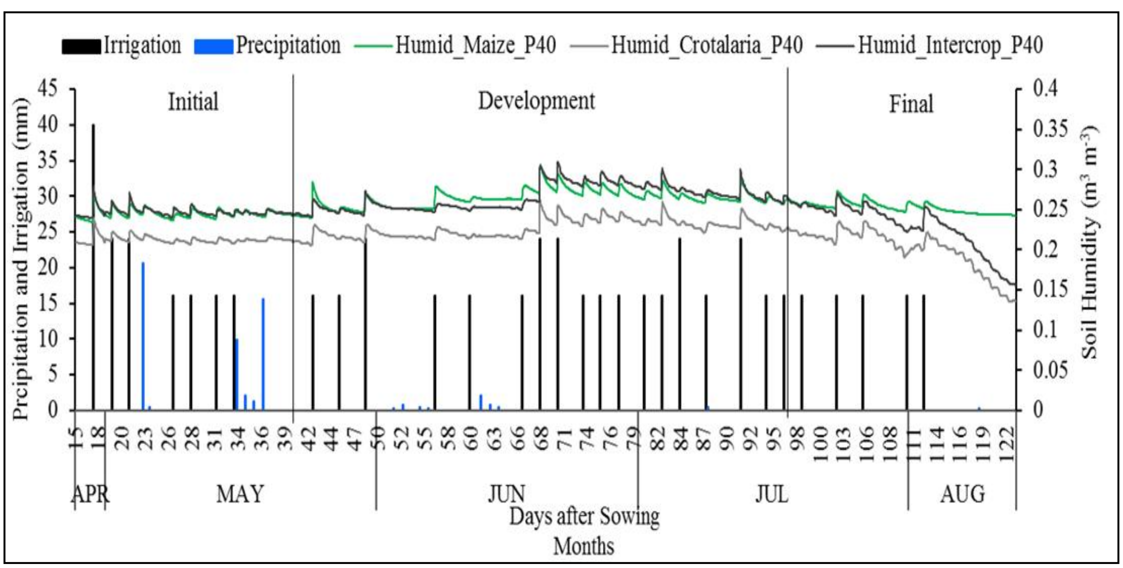

Fig. 5. Soil moisture variability at a depth of 0.40 m and accumulated rainfall and irrigation during the crop cycle

Table 3. Analysis of soil moisture amplitude in-depth, related to cropping systems and crop phase

System	Phenological stage	Soil moisture (m^3 m^{-3})		DMS
		Depth 0.2 m	Depth 0.4 m	
Maize	Initial	0.0275aA	0.0134bA	0.0101
	Development	0.0216aAB	0.0129bA	0.0082
	Final	0.0139aB	0.0077aA	0.0094
C. juncea	Initial	0.0242aA	0.0079bA	0.0101
	Development	0.0239aA	0.0096bA	0.0082
	Final	0.0239aA	0.0095bA	0.0082
Intercrop	Initial	0.0351aAB	0.0120bA	0.0101
	Development	0.0416aA	0.0116bA	0.0082
	Final	0.0252aB	0.0128bA	0.0094
	DMS	0.0111	0.0111	

Means followed by the same uppercase letter in the column and lowercase in the row do not differ by the Tukey test at 5% probability. DMS - Difference minimum significant

Table 4. Mean test for all variables analyzed in single maize and in *C. juncea* intercropping, in lysimeters and in the field

Variable	Lysimeters		Field		DMS
	Maize	Intercrop	Maize	Intercrop	
Plant height (cm)	170.33c	165.75c	204.43a	191.93b	9.08
Stem diameter (mm)	19.72a	15.18c	21.03a	18.19b	1.42
Insertion height (cm)	63.33c	67.81c	93.43a	85.25b	4.83
Number of rows per ear	16.55ab	16.18ab	17.56a	16.06b	1.40
Number of grains per row	27.44a	18.31b	27.30a	21.25b	4.56
Number of grains per ear	452.88a	299.31b	480.52a	342.25b	85.73
Ear length (cm)	12.75a	10.06b	12.50a	10.56b	1.59
Ear diameter (mm)	47.95a	43.47b	47.22a	44.11b	2.55
Mass of 1000 grains (g)	223.93	190.36	206.51	205.12	34.60
Yield (kg ha^{-1})	6920.02a	3961.33b	6739.26a	4571.85b	1190.05
Shoot dry mass (g)	95.17a	68.88c	94.82a	79.63b	10.61

Means followed by the same letter on the line do not differ statistically from each other by Tukey test at 5% probability of error. DMS - Difference minimum significant

Table 5. Average test for all variables analyzed in single Crotalaria and maize intercropping, lysimeters and field

Variable	Lysimeter		Field		DMS
	C. juncea	Intercrop	*C. juncea*	Intercrop	
Plant height (cm)	192.0b	196.2b	218.9a	216.1a	10.77
Stem diameter (mm)	6.36	6.16	6.87	6.47	0.79
Shoot dry mass (g)	340.3a	238.7b	222.5b	129.79c	29.89

Means followed by the same letter on the line do not differ statistically from each other by Tukey test at 5% probability of error. DMS - Difference minimum significant

Gitti, et al. [35] also reported that when sown simultaneously with *C. juncea*, maize had its production compromised. However, these authors also observed that *C. juncea* sown 25 days after maize did not influence cereal production.

Santos, et al. [36], evaluating the intercropping of maize and crotalaria, observed that for simultaneous sowing of crops the minimum row spacing should be 0.8 m to avoid light competition, their results showed no differences in maize yield.

Some studies show that intercropping with *C. juncea* increases maize productivity if the crotalaria is cut when the maize has the eighth leaf expanded this promotes a greater nutrient utilization of green manures by maize [37]. Since the use of a Fabaceae as cover plants provides atmospheric N input to the system via symbiotic fixation [38], reducing the C/N ratio of the straw and increasing its decomposition rate, thus providing a faster nutrient release [39].

Table 5 shows the average tests for the plant height variables that showed no differences between the monoculture and intercropping systems, but between the lysimeters and field, showed differences, which can be explained by soil conditions, which in the lysimeters there is less compaction facilitating the rooting of the plants, and consequently the absorption of water and nutrients and due to the arrangement of the plants there is a slight variation in the spacing between lines allowing greater use of sunlight, as also observed by Mendonça, et al. [40], who emphasize the observation of the bouquet effect on lysimeters caused by the surrounding plants.

Dry mass production by crotalaria plants was higher in the monoculture system, results also observed by Gitti, et al. [35], where they evaluated the same cultivar of crotalaria for intercropping and monoculture systems, reported an increase of 8 t ha^{-1} for exclusive systems.

4. CONCLUSION

The average temperature during the hottest hours of the day is reduced by intercropping by 1.3ºC, which provides a reduction in thermal amplitude by reducing the evaporation rate of soil water. At depths greater than 0.20 m no variations in temperature are observed between the evaluated systems.

Intercropping of maize and crotalaria provides the soil with a lower temperature range and maintenance of soil moisture (0.3 m^3 m^{-3}) at a depth of 0.20 m.

Intercropping maize yield decreased 42.7%, but the gain with dry mass for the cover was higher when adding maize and *C. juncea*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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