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Physiological parameters and CO2 efflux in areas cultivated with beans and maize

Alécio Rodrigues Pereira
Doctor Scientiae

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2024

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Thesis submitted to the Applied Meteorology Graduate Program of the Universidade Federal de Viçosa in partial fulfillment of the requirements for the degree of *Doctor Scientiae*.

Adviser: Jackson Martins Rodrigues

Co-adviser: Flavio Barbosa Justino

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Assent:

Alécio Rodrigues Pereira
Author

Jackson Martins Rodrigues
Adviser

To my parentes José de Assis and Lúcia
To my sisters Elaine and Edlaine.
To my family.
To my friends.

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First of all, to God. Author of life and all knowledge, for always taking care of me and enlightening my thoughts.

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The difficulties of life
They should not be a cause for despair,
But opportunities to become
Victorious people...
Life is an adventure
Where the days are pages
The months chapters
And the years of books
In which we can register
A beautiful love story
(Alécio Rodrigues)

ABSTRACT

PEREIRA, Alécio Rodrigues, D.Sc., Universidade Federal de Viçosa, June, 2024. **Physiological parameters and CO2 efflux in areas cultivated with beans and maize**. Adviser: Jackson Martins Rodrigues. Co-adviser: Flavio Barbosa Justino.

The present study has the objective of estimating the of carbon dioxide efflux (CO_2) in an area cultivated with bean and maize. The experiment was conducted at the experimental irrigation and drainage unit of the Department of Agricultural Engineering, located at the Federal University of Viçosa. The crops used were Ouro of Mata bean and maize (BM270) during two cultivation cycles as well as carioca bean (VC25) in a single cropping cycle. CO2 efflux was measured using an infrared gas analyzer (IRGA), attached to the LC-PRO+ portable system, manufactured by the company ADC BIO Scientific. To read soil respiration and the ecophysiological parameters, IRGA was coupled to the soil and photosynthesis chamber, respectively. The ecophysiological parameters photosynthesis (A), stomatal conductance (gs), transpiration (E), internal carbon concentration (Ci), instantaneous water use efficiency (EiUA) and instantaneous carboxylation efficiency (EiC) were monitored. In the area cultivated with Ouro of Mata bean the mean soil respiration during the two crop cycles was 1.02 and 1.65 µmol m^{-2} $s^{-1,}$ respectively. For the maize area between 1.24 and 1.25 µmol m^{-2} s^{-1}, in the first and second cycle, respectively. For the carioca bean crop the mean for the entire crop cycle were 1.44 µmol m^{-2} s^{-1}. For Ouro of Mata bean the ecophysiological parameters In the first cultivation cycle the mean values of 27.97 µmol m^{-2} s^{-1} (A), 0.61 mol of H2O m^{-2} s^{-1} (gs), 5.93 mol of H_2O m^{-2} s^{-1} (E), 297.09 µmol mol^{-1} (Ci), 4.60 µmol mol^{-1} of H_2O (EiUA) and 0.095 mol m^{-2} s^{-1} (EiC) and in the second cycle 25.74 µmol m^{-2} s^{-1} (A) , 0.28 mol of H_2O m^{-2} s^{-1} (gs), 4.38 mol of H_2O m^{-2} s^{-1} (E), 293.30 µmol mol^{-1} (Ci), 5.87 µmol mol^{-1} of H_2O (EiUA) and 0.091 mol m^{-2} s^{-1} (EiC). In the first maize crop cycle the following values were observed 52.07 $µmol.m^{-2}$ s^{-1} (A), 0.52 mol of H_2O m^{-2} s^{-1} (gs), 7.68 mol of H_2O m^{-2} s^{-1} (E), 211.95 µmol mol^{-1} (Ci), 6.78 µmol mol^{-1} of H_2O (EiUA) and 0.245 mol m^{-2} s^{-1} (EiC), and in the second cycle 26.85 $µmol.m^{-2}$ s^{-1} (A), 0.30 mol of H_2O m^{-2} s^{-1} (gs), 3.66 mol of H_2O $m^{-2\ s-1}$ (E), 222.05 µmol mol^{-1} (Ci), 7.96 µmol mol^{-1} of H_2O (EiUA) and 0.130 mol m^{-2} s^{-1} (EiC). For the Carioca bean crop, the mean values of 23 µmol m^{-2} s^{-1} (A), 0.30 mol of H_2O m^{-2} s^{-1} (gs), 3.78 mol of H_2O m^{-2} s^{-1} (E), 311.04 µmol mol^{-1} (Ci), 6.02 µmol mol^{-1} of H_2O (EiUA) and 0.080 mol m^{-2} s^{-1} (EiC).

Keywords: soil respiration; photosynthesis; bean; maize; co_2

RESUMO

PEREIRA, Alécio Rodrigues, D.Sc., Universidade Federal de Viçosa, junho de 2024. **Parâmetros fisiológicos e efluxo de CO2 em áreas cultivadas com feijão e milho**. Orientador: Jackson Martins Rodrigues. Coorientador: Flavio Barbosa Justino.

A presente pesquisa teve como objetivo estimar o efluxo do dióxido de carbono (CO_2) em área cultivada com feijão e milho. O experimento foi conduzido na área experimental de irrigação e denagem pertencente ao departamento de engenharia agrícola, localizado na sede da Universidade Federal de Viçosa. As culturas utilizadas foram o feijão Ouro da Mata e milho (BM270) durante dois ciclos de cultivo, bem como feijão carioca (VC25) em ciclo único. O efluxo de CO2 foi mensurado usando um analisador de gás por infravermelho (IRGA) acoplado ao sistema LC-PRO+, fabricado pela empresa ADC BIO Scientific. Para leitura da respiração do solo e parâmetros ecofisiológicos o IRGA foi acoplado com as câmaras de solo e fotossintese, respectivamente. Os parâmetros ecofisiológicos fotossintese (A), condutância estomática (gs), transpiração (E), concentração interna de carbono (Ci), eficiência no uso da água (EiUA) e eficiência instantânea de carboxilação (EiC) foram monitorados. Em área cultivada com feijão Ouro da Mata a respiração media durante os dois cicloes de cultivo foi 1,02 e 1,65 µmol m^{-2} s^{-1}, respectivamente. Para área com milho 1,24 e 1,25 µmol m^{-2} s^{-1}, no primeiro e segundo ciclo de cultivo, respectivamente. Para o feijão carioca a média para o ciclo da cultura foi 1,44 µmol m^{-2} s^{-1}. Para o feijão Ouro da Mata os valores médios dos parâmetros ecofisiológicos no primeiro ciclo de cultivo foi 27,97 µmol m^{-2} s^{-1} (A), 0,61 mol de H_2O m^{-2} s^{-1} (gs), 5,93 mol de H_2O m^{-2} s^{-1} (E), 297,09 µmol mol^{-1} (Ci), 4,60 µmol mol^{-1} de H_2O (EiUA) e 0,095 mol m^{-2} s^{-1} (EiC), no Segundo ciclo 25,74 µmol m^{-2} s^{-1} (A) , 0,28 mol of H_2O m^{-2} s^{-1} (gs), 4,38 mol de H_2O m^{-2} s^{-1} (E), 293,30 µmol mol^{-1} (Ci), 5,87 µmol mol^{-1} de H_2O (EiUA) e 0,091 mol m^{-2} s^{-1} (EiC). No primeiro ciclo de cultivo do milho foi observado os valores 52,07 µmol.m^{-2} s-^{1} (A), 0,52 mol de H_2O m^{-2} s^{-1} (gs), 7,68 mol de H2O m^{-2} s^{-1} (E), 211,95 µmol mol^{-1} (Ci), 6,78 µmol mol^{-1} de H_2O (EiUA) e 0,245 mol m^{-2} s^{-1} (EiC), no segundo ciclo 26,85 µmol.m^{-2} s^{-1} (A), 0,30 mol de H2O m^{-2} s^{-1} (gs), 3,66 mol de H_2O m^{-2} s^{-1} (E), 222,05 µmol mol^{-1} (Ci), 7,96 µmol mol^{-1} de H_2O (EiUA) e 0,130 mol m^{-2} s^{-1} (EiC). Para a cultura do feijão carioca os valores médios foram 23 µmol m^{-2} s^{-1} (A), 0,30 mol de H2O m^{-2} s^{-1} (gs), 3,78 mol de H_2O m^{-2} s^{-1} (E), 311,04 µmol mol^{-1} (Ci), 6,02 µmol mol^{-1} de H_2O (EiUA) e 0,080 mol m^{-2} s^{-1} (EiC).

Palavras-chave: respiração do solo; fotossintese; feijão; milho; co_2

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LIST OF ACRONYMS AND ABBREVIATIONS

CONAB - Companhia Nacional de Abastecimento
DAE - Days after emergence
EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária
GDP - Gross Domestic Product.
iEC - Instantaneous carboxylation efficiency
iEWU - Instantaneous water use efficiency
IPCC - Intergovernmental Panel on Climate Change
IRGA - Infrared Gas Analyzer.
MAPA - Ministério da Agricultura e Pecuária
UFV - Universidade Federal de Viçosa

LIST OF SYMBOLS

A	- Photosynthesis
B	- Boron
C_i	- Internal carbon concentration
^oC	- Degrees Celsius
$cmol_c\ dm^{-3}$	- Centimol by cubic decimeter
CO_2	- Carbon dioxide
E	- Transpiration
g/L	- Grams by liter
g_s	- Stomatal conductance
$g\ cm^{-3}$	- Gram by cubic centimeter
H	- Hours
H_3BO_3	- Boric Acid
K	- Potassium
KCl	- Potassium Chloride
$Kg\ kg^{-1}$	- Kilogram by kilogram
L/ha	- Liters by hectare
m	- Meter
mm	- Milimiter
m^2	- Square meter
$m^3\ m^{-3}$	- Cubic meter by cubic meter
Mg	- Magnesium
$mg\ dm^{-3}$	- Milligram by cubic decimeter
MAP	- Monoammonium Phosphate
N	- NItrongen
P	- Phosphorus
Ppm	- Part by million
R	- Coefficients of correlation
r^2	- Coefficients of determination
Zn	- Zinc
$mol\ m^{-2}\ s^{-1}$	- Mol by square meter per second
mol of $H_2O\ m^{-2}\ s^{-1}$	- Mol of water by squere meter per second

µmol mol^{-1} - Micromol by mol

µmol m^{-2} s^{-1} - Micromol by square meter per second

µmol mol^{-1} of H_2O - Micromol by mol of water

SUMMARY

1. INTRODUCTION

The intensification of greenhouse gas emissions, primarily carbon dioxide (CO_2), by anthropogenic activities, has caused mean global warming, which in turn has resulted in changes in atmospheric and oceanic circulation, implying a change in the climate. According to the IPCC (2021) climate change is already affecting every inhabited region in the world, with a tendency to intensify even more as the temperature rises. More frequent extreme events have been observed or projected in various parts of the world, such as more severe droughts (Leng et al., 2015; Zhan et al., 2016; IPCC, 2021), intense rainfall (O'Gorman et al., 2015; Abiodun et al., 2017; IPCC, 2021), frosts (Mosedale et al., 2015; Meier et al., 2018) and hailstorms (Brimelow et al., 2017; Rãdler et al., 2019; Trapp et al., 2019; Raupach et al., 2021).

The process of climate change will trigger alterations in meteorological variables such as air temperature and rainfall. Since these are variables that influence emergence, growth, on the development and yield of agricultural crops, the process of climate change will impact food production and distribution on a global scale. According to Lipper et al. (2014) climate change is responsible for reducing global maize and wheat yields by 3.8% and 5.5%, respectively. Globally, climate variability accounts for around a third (32-39%) of yield variability (Ray et al., 2015).

Air temperature has both a direct and indirect influence on agricultural crops. Directly, the air temperature contributes to less or more heating of the soil and plants, which in turn influences seed germination, plant growth and development, in the photosynthesis process and, finally, on crop yields. The increase in temperature results in greater evaporation of the water present in the soil and in water bodies, an increase in crop water demand and a reduction in the volume of water available for irrigation.

Furthermore, crops have optimum temperatures for their growth and development and when these are not within the ideal range, crop yields are compromised. In addition to the ideal range, there is a lower and upper basal temperature, when the air temperature is not within this range the plants do not grow and die, with a total loss of productivity. For bean, the ideal range is between 17 and 25 ºC, with a lower basal temperature 10 ºC and the upper basal 35 ºC. For maize the ideal range is between 26 and 34 ºC, with a lower basal temperature 8 ºC and the upper basal 44 ºC.

In the bean crop temperatures above the ideal range reduce crop yields by causing pollen grain sterility, a reduction in the rate of flower fertilization and flower and pod abortion (Gross and Kigel, 1994; Porch e Jahn, 2001). In addition to affecting different metabolic processes, where according to Wahid et al. (2007) high temperatures influence photosynthesis, respiration, water relations, fluidity and stability of membrane systems. According to EMBRAPA (2021) below ideal temperatures cause a reduction in the formation of lateral branches, seed abortion, failures in the formation and physiology of reproductive structures, a lower percentage of pollen grain germination and a reduction in the fertilization rate.

In maize the EMBRAPA (2021) reports that temperatures below or above the ideal range lead to reduced germination and flowering of the crop. Even at high temperatures the pollen germination is reduced and there is a decrease in the activity of the nitrate reductase enzyme, which can alter not only the yield, but also the protein composition of the grains.

In general, for all crops, high temperatures cause an increase in leaf respiration, which reduces the net photosynthetic rate. Low temperatures affect seed germination and plant metabolism. In both cases the growth and development of crops is impaired, which will result in reduced productivity.

The greater frequency of extreme events tends to cause more severe crop damage than any pest or disease, given that extreme events lasting only a short time (sometimes a few minutes) are enough to devastate a crop. According to Liu et al. (2018) the greater the heat stress, the greater the risk to the crop. Kim et al. (2016) point out that intense frosts are responsible for entire crop losses in agriculture. Research in the south-west of England Mosedale et al. (2015) have seen an increase in the risk of frost during the spring, which will compromise grape production. The increase in the probability of frost occurring in a climate change scenario, in certain regions and at certain times of the year, was also observed by Molitor et al. (2014) and Meier et al. (2018). Gobo et al. (2018) report that frost is the main reason why producers in Central-Southern Brazil buy crop insurance and Wrege et al. (2018)

emphasize that frost, by causing economic losses over a long period, must be taken into account when planning agricultural production.

Intense rainfall (precipitation of a large volume of water in a short period of time) in arable areas is harmful to the crop, since the large volume of precipitation usually exceeds the soil's capacity to infiltrate water, resulting in the formation of puddles of water in the field and mud. Strong gusts of wind cause crops to dry out, causing grains to rot when they come into contact with the soil. In addition, excess humidity is a favorable environment for the proliferation of diseases that affect crops and hinders root respiration.

The hailstorms is responsible for causing severe damage to agricultural crops. According to Allen (2018) hailstones over 2 cm in diameter are responsible for causing serious damage. According to Botzen et al. (2010), damage to agriculture due to hailstorms could increase by 25 to 48 % by 2050 compared to 1990. The projection of greater frequency and intensity of hailstorms has been obtained from different scientific studies (Kapsch et al., 2012; Mezher at al., 2012; Diffenbaugh et al., 2013; Gensini et al., 2014; Allen et al., 2015; Mohr et al., 2015; Brimelow et al., 2017; Rãdler et al., 2019; Trapp et al., 2019).

The increase of 1.5 ºC in the global average temperature predicted to be reached by 2050 (IPCC, 2021), regardless of the climate change scenario assumed, is enough to cause an increase of around 2 ºC in the mean temperature in practically all of South America. The precipitation in response to this increase in temperature is expected to be reduced by between 10% and 20% in coastal regions in northern South America and in the Southwest.

In Brazil, a rise in temperature is expected, where according to the IPCC (2021) if the average global temperature rises by 2°C in Brazil, an increase of between 3 and 3.5°C is expected. With regard to rainfall, more intense and frequent droughts are expected in the Northeast and the Eastern Amazon region, which should show a reduction in rainfall of between 10 and 20%. On the other hand, the southern region of the country should see an increase in precipitation and related extremes, an increase in total rainfall of between 10 and 20% is expected. The northeast and south of the country are the regions most exposed to the weather in

Brazil, the Northeast due to drought and the South due to extreme rainfall events and frosts, where according to Silveira et al. (2018) frost is responsible for the majority of agricultural accidents in the Center-South of Brazil.

In the country it is estimated that extreme weather events were responsible for a loss of US$ 1.7 billion, representing 0.06% PIB of the country (Eckstein et al., 2017). Dias et al. (2021) report that drought events are already more frequent and severe in Brazil, where between 2012 and 2017 there was one of the worst droughts in the last 50 years in the Brazilian semi-arid region. The increased frequency and severity of drought events has been observed and is likely to intensify over the coming decades in different regions of the globe (Marengo, 2014; Leng et al., 2015; Nam et al., 2015; Kelley et al., 2015; Martins e Magalhões, 2015; Zhan et al., 2016; Dai et al., 2018; Mukherjee e Mishra, 2018).

In Brazil The IPCC Special Report on Extremes (Managing the Risks of Extreme Events and Disasters to Advance Climate Chance Adaptation – SREX) indicates that the Northeast will experience more intense and longer dry spells (Marengo, 2014). Dias et al. (2021) emphasize that the semi-arid region will be vulnerable to the risks of climate change, as this region has intrinsic nuances of sensitivity to drought, as well as the unsustainable use of natural resources and degrading agricultural practices. França and Moreno (2017) report that in the semi-arid region of Rio Grande do Norte, due to droughts in recent years, there has been a 50% drop in crop yields.

Different studies using atmospheric models to simulate future climate have found a higher probability of extreme rainfall events in the rainy season for the state of Minas Gerais (Salviano et al., 2016; Natividade et al., 2017; Rebota et al., 2018; Reis et al., 2018). Due to the fact that more intense and frequent extreme events have been observed in recent years in Brazil, there has been a greater take-up of agricultural insurance by producers, According to MAPA (2019) the number of agricultural claims policies went from 21,783 in 2006 to 63,554 in 2018, practically tripling the number of policies.

In terms of agricultural yields in Brazil for maize, it is expected that there will be a reduction in productivity with an increase in mean temperature above 2 ºC

(Lipper et al.,2014; Kassie et al., 2015; Renato et al., 2018). For the bean crop, according to the MCTL (2016), temperatures above 34 ºC could result in a 39% reduction in yields in the first crop and a 50.4% reduction in yields in the second crop. Various other studies evaluating climate change scenarios for Brazil have shown that an increase in mean temperature of between 1 and 3 ºC is sufficient to reduce, in a significant way, the yield of important crops for the country (Siqueira et al., 2000; Assad et al, 2004; Camargo et al., 2010; Luppi et al., 2014; Santi et al., 2017; Texeira et al., 2021).

The MCTI (2016) produced a report that included agroclimatic zoning in a climate change scenario for an intermediate scenario (projected CO_2 concentration of 650 ppm and a 3 °C rise in temperature by 2100) and a pessimistic scenario (projected CO_2 concentration of around 1,000 ppm and a 6 °C rise in temperature by 2100). For maize grown without irrigation, the loss of low-risk area reaches 70.4% in the intermediate scenario and in the pessimistic scenario, the restriction of production is limited to practically the entire national territory. The maize grown in the irrigated system will show a smaller reduction in suitable areas, although it is expected to suffer a 22.2% decrease in a pessimistic scenario. For first crop bean the loss of low-risk areas for the intermediate and pessimistic scenarios varies between 39.4 and 57.1 %, respectively. For the second harvest, the loss is even more significant with low-risk areas being reduced by 50.4 and 71.9% for the intermediate and pessimistic scenarios, respectively.

The Brazil, a country whose economic base is agribusiness, will suffer a major impact. Faria and Haddad (2017) analyzed the impact of climate change on Brazil's PIB for two IPCC scenarios, being A2 and B2, which project CO_2 increases of 1250 ppm and 800 ppm, respectively, by 2100 and respective temperatures of 3.4 and 2.4°C. A reduction in PIB is expected by 2050 of 0.5% in the B2 scenario and 2.3% in the A2 scenario. According to the same authors, the expected loss for the period between 2070 and 2099 is R$ 8,157.8 million in the A2 scenario and R$ 5,336.6 million in the B2 scenario.

Whether the process of climate change has an impact on agriculture, the agriculture, in turn, is of preponderant importance in terms of the extent to which the climate can be modified. The increase in temperature should exert a positive feedback on CO_2 emissions in areas occupied by agricultural crops. According to Rakotavao et al. (2017) among the main emitting activities, soil preparation techniques for agricultural cultivation stand out as one of the main operations that accelerate CO_2 emissions. The increase in temperature tends to accelerate this emission even more, as it stimulates microbial activity, accelerating the process of cycling organic matter and, consequently, intensifying CO_2 emissions by increasing respiration in the soil microfauna.

The soil is the largest active reservoir of terrestrial carbon (Kumar e Sharma, 2016), then disturbances in that environment, including its temperature, should result in higher CO_2 emissions. It has been observed that an increase in soil temperature causes an increase in CO_2 emissions in different studies (Torres et al., 2006; Siqueira et al., 2009; Ussiri e Lal, 2009; Oertel et al., 2016; Melillo et al., 2017; Souza et al., 2019). On the other, an atmosphere enriched in CO_2 can stimulate greater photosynthetic activity, especially in C3 plants, helping to regulate the concentration of this gas in the atmosphere. Thus, areas cultivated for agricultural purposes both contribute to the emission and absorption of CO_2, It is essential to understand this efflux in agricultural areas in order to understand its real impact on the process of climate change.

2. Methodology

2.1. *Location of the experimental area and soil characteristics*

The experiment was carried out at the experimental irrigation and drainage unit of the Department of Agricultural Engineering, located at the Federal University of Viçosa (UFV) (-20°46'7”S and -42°51'44”), southeastern Brazil. The climate of the region is warm and temperate, according to the Köppen and Geiger (Cwa), with an mean annual temperature of 20.6 ºC and annual rainfall total of 1,229 mm. Precipitation and temperature climatology for period between 1991 – 2020 Viçosa – MG are represented in Figure I. The rainiest quarter is from November to January and the least rainy quarter is from June to August. The temperature varied from 16.4 °C in the coldest month July, and 22.5°C for December.

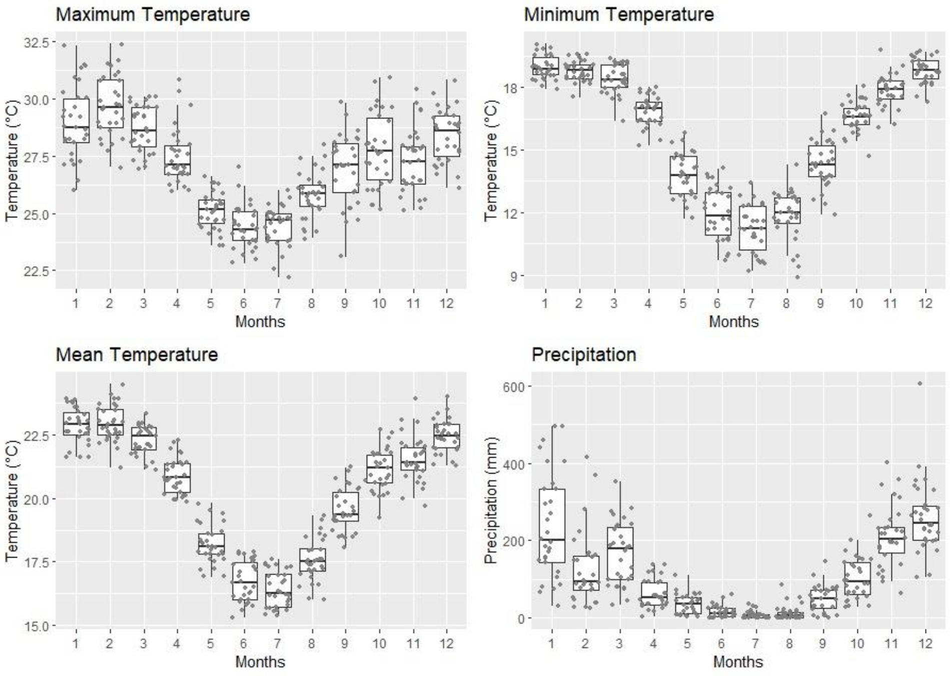


Figure I – Climatological normal of temperature and precipitation in the period from 1991 to 2020 for the county of Viçosa - MG.

The soil was collected according to the methodology proposed by Santos et al. (2015) and taken to the laboratory for physical and chemical analysis. Each sampled area was traversed in a zigzag pattern, and random soil samples were collected along the way with the aid of the tractor, from depths between 0 to 20 cm. A total of 15 samples were taken from each cultivated area. At the end of the sampling process, the samples were mixed and standardized to form a representative sample for each cultivated area. These samples were then taken to the laboratory for physical and chemical analyses (Tables I and II, respectively).

Table I – Physical analysis of the soil.

Coarse sand	**Thin sand**	**Silt**	**Clay**	**ADA**	**Dp**	**Ds**	**Type**
kg/kg					g/cm^3		
0.254	0.125	0.137	0.484	0.204	2.53	1.02	Clayey

Table II – Soil chemistry analysis.

pH H_2O	**P**	**K**	**Na**	**Ca^{2+}**	**Mg^{2+}**	**Al^{3+}**	**H + Al**	**SB**	**t**	**T**	**V**
	mg/dm^3			cmol$_c$/dm^3							%
6.13	24.7	131	-	2.80	0.75	-	3.1	3.89	3.89	6.99	55.7

According to the textural classification, the soil was classified as clayey (with 48.4% clay). According to the results of the soil's chemical attributes, it is acidic, with a pH of 6.13, which is within the ideal range for most crops of agricultural importance. Levels of the macronutrients phosphorus and potassium in the order of 24.7 mg/dm^3 and 131 mg/dm^3 have been found, and a base sum of 3.89 cmol$_c$/dm^3.

2.2. Crops

During the first growing cycle were cultivated beans (Phaseolus vulgaris L.), Ouro of Mata, and corn (Zea mays L.) BM270. In the second crop cycle, a plot was added with carioca beans, cultivar VC25. These cultivars are adapted to the soil and climate conditions of Viçosa - MG. In the first cultivation cycle, Ouro of Mata bean were sown on 08/17/2020 and harvested on 11/12/2020. Maize was sown on 09/02/2020 and harvested on 01/23/2021. In the second crop cycle, Ouro of Mata and carioca beans were sown on 04/01/2021, the first being harvested on 07/01/2021 and the second on 07/29/2021. Maize was sown on 04/21/2021 and harvested on 10/01/2021.

2.3. cultural practices

The cultivated area was mechanized where for both cycles plowing and harrowing were carried out. Sowing fertilization was carried out with Nitrogen, Phosphorus and Potassium (NPK), in formulation 4-14-8 and proportion of 700 kg/ha. Throughout the crop cycle, fertirrigation is conducted to meet nutritional demands of the crops. For the common beans, 5 fertirrigation hae been utilized distributed throughout the crop cycle, with applications of Monoammonium Phosphate (160 kg/ha), Potassium Chloride (90 kg/ha), Urea (20 kg/ha) and Magnesium (50 kg/ha). Turning to maize, 9 fertirrigations were carried out, in both crop cycles, using Monoammonium Phosphate (160 kg/ha), Potassium Chloride (90 kg/ha), Urea (20 kg/ha), Boron (7.7 kg/ha), Zinc (7.7 kg/ha) and Boric Acid (11.5 kg/ha).

To meet the water demand of the crop a drip irrigation system was adopted. The irrigation amount was calculated through the evapotranspiration of the crop (ETc), the soil moisture (SM) and crop needs throughout the phenological phase. Soil moisture was monitored using tensiometers, four of which were installed in each cultivated area at a depth of 20 cm. Daily SM was taken based on the mean of readings obtained from the tensiometers. Invasive plants were controlled through mechanical methods, with the aid of a hoe, and chemical, where applications were made with herbicides Flex (1 L/ha), Select (0.9 L/ha) e Atrazina (6.5 L/ha). For chemical pests control application of Connect (0.5 L/ha), Lannat (0.4 L/ha), Klorpan (1.5 L/ha) e Premium (0.1 L/ha) have been done. To manage diseases through chemical methods, were used the fungicides Score (0.3 L/ha), Amistar Top (0.3 L/ha), Sumilex (100 g/100 L of water) e Supera (2 L/ha).

2.4. Experimental area design

In both cultivation cycles the experimental area with beans were arranged in dimensions of 10 x 10 meters (100 m^2). Whereas for maize, the dimensions were 10 x 13 meters (130 m^2). Spacing adopted for beans was 0.5 m between rows and 0.1 m between plants (0.4 m x 0.5 m), resulting in 10 plants per linear meter. For maize, the spacing was 0.8 m between rows and 0.1 m between plants (0.8 m x 0.2 m), resulting in 5 plants by linear meter. In the first crop cycle, two areas were cultivated with Ouro of Mata bean and with maize. In the second crop cycle, three areas were cultivated with Ouro of Mata bean, carioca bean and maize. During the second cycle, in addition to the cultivated areas, an uncultivated area was prepared aiming at measuring soil respiration under the absence of beans and maize.

2.5. Soil respiration measurements

The soil respiration was measured using an Infra Red Gas Analyzer (IRGA), coupled to the LC-PRO+ portable system, manufactured by ADC BIO Scientific. The soil chamber was used to read.

Four reading points were distributed throughout each experimental area. A cylinder was installed in the ground at each point, with dimensions of 110 mm in diameter and 70 mm in height, each cylinder was buried with a 20 mm edge above the soil surface. The cylinders have the function of properly fitting the IRGA chamber to the soil. The two edge rows of the cultivated areas were disregarded, in order not to be influenced by the effect of the border. The collection points were distributed, at random, within cultivated areas and between planting rows, in order to minimize advective air flows.

The soil respiration reading readings were taken between 09:00 and 12:00 h. After calibrating the reading, which took between 5 and 8 minutes, five readings were taken, where the mean of these was considered the reading per point and the mean of all the points the mean value observed. The soil respiration readings were accompanied by soil moisture monitoring, with the aid of tensiometers, and temperature, with the aid of a geothermometer. The soil respiration (NCER) is given in μmol m^{-2} s^{-1}.

2.6. Photosynthesis and ecophysiological measurements

The gas exchange readings were performed with the IRGA attached to the leaf chamber. Readings were taken between 09:00 and 12:00 h. Each analysis verified 10 plants located inside the cultivated plot were randomly selected. For each selected plant, the reading was performed on the third fully expanded and healthy leaf from the apex. After calibrating the reading, 5 readings were taken per plant. The mean of these readings is considered the value per plant and the mean of the plants are assumed to be the mean daily photosynthesis value.

In the IRGA configuration the camera adopted for reading the bean photosynthesis was the Narrow, whereas for corn the Broad has been used. The flux density adopted for bean was 1,000 μmol m^{-2} s^{-1}, which provides an incidence of saturating photosynthetically active light for the bean crop (Armand et al., 2016; Mathobo et al., 2017; Androciolo et al., 2020). For the maize crop, the density used was 1,200 μmol m^{-2} s^{-1}, as adopted in different studies such as Henry et al., (2015); Zhan et al., (2015) and Zhao et al., (2016). Collected variables were photosynthesis (A – μmol m^{-2} s^{-1}), stomatal conductance (gs – mol of H_2O m-^{2} s^{-1}), transpiration (E – mol of H_2O m^{-2} s^{-1}), internal carbon concentration (Ci – μmol mol^{-1}). The instantaneous efficiency of water use (iEWU – μmol mol^{-1} of H_2O), and the instantaneous efficiency of carboxylation (iEC – mol m^{-2} s^{-1}) were obtained by equations 1 and 2, respectively.

$$iEWU = \frac{A}{E} \tag{1}$$

Where: iEWU is the instantaneous water use efficiency (μmol mol^{-1} of H_2O); A is net photosynthesis (μmol m^{-2} s^{-1}); E is transpiration (mmol of H_2O m^{-2} s^{-1}).

$$iEC = \frac{A}{C_i} \tag{2}$$

Where: iEC is the instantaneous carboxylation efficiency (mol m^{-2} s^{-1}); A is the net photosynthesis rate (μmol m^{-2} s^{-1}); C_i is the internal concentration of carbon (μmol mol^{-1}).

2.7 Phenological stages and statistical treatment

The phenological phases of the crops were divided into three: from germination to the beginning of flowering (phase I); from the beginning of flowering to the beginning of maturation (phase II); and phase III goes from maturation to the end of the crop cycle. The data obtained were treated and statistically analyzed in the R (version 3.6.1) and Python (version 2.7) programs. They were submitted to analysis of variance by the F test ($p < 0.05$), and when significant they were compared by the Tukey test (Tukey, 1953) at 5% probability.

3. RESULTS

3.1. Phenological phases, precipitated water depth and irrigated.

In table III there are shown the days corresponding to each phenological phase of the Ouro of Mata bean and Carioca bens and maize as well as the amount of water irrigated and precipitated during the first and second crop cycle.

Table III – Phenological stages of Ouro of Mata and Carioca beans and maize during e first and second crop cycle, irrigated water depth and precipitated.

	Phenological phases	**Period (DAE*)**	**Number of days**	**Irrigation (mm)**	**Precipitation (mm)**
Ouro of mata bean first crop cycle	I	1 – 38	38	151	51.6
	II	39 – 67	29	44	97.8
	III	68 – 79	12	-	99
	Total		**79**	**195**	**248.4**
Maize (BM270) first crop cycle	I	1 – 51	51	72	203.6
	II	52 – 82	31	-	195
	III	83 – 134	52	-	263.8
	Total		**134**	**72**	**662.4**
Ouro of mata bean second crop cycle	I	1 – 33	33	63.8	40.4
	II	34 – 68	35	69.1	25.7
	III	69 – 84	16		1.8
	Total		**84**	**132.9**	**67.9**
Carioca bean (VC25)	I	1 – 43	43	108.3	41.8
	II	44 – 84	41	73	25.6
	III	85 – 112	28	-	1.8
	Total		112	181.3	69.2
Maize (BM270) second crop cycle	I	1 – 83	83	124	26.4
	II	84 – 126	43	100.4	19.4
	III	127 – 154	28	-	33
	Total		**154**	**224.4**	**78.8**

***DAE** – Days after emergence.

In Ouro of Mata bean during the first crop cycle the phenological phases I, II and III lasted 38, 29 and 12 days, respectively, with the crop completing its cycle 79 days after emergence. A total of 195 mm of water was irrigated, distributed between the first and second phenological stages of the crop, in the third phase as the crop was senescing, there was no irrigation. The total rainfall throughout the crop cycle was 248.4 mm, where there were precipitation events at all phenological stages.

During the second crop cycle the phenological phases I, II and III lasted 33, 35 and 16 days, respectively, completing its cycle 84 days after plant emergence. A total of 132.9 mm of water was irrigated, distributed between the first and second phenological stages of the crop, being suspended in the third phase. The total preciptation for the entire crop cycle was 67.9 mm, with the highest volume occurring between the first and second phases, corresponds to 97.35% of the total precipitation.

In the carioca bean crop, phenological phases I, II and III lasted 43, 41 and 28 days, respectively, completing the cycle 112 days after plant emergence. A total of 181.3 mm was irrigated, distributed between phenological stages I and II. In the third phase, as the crop was senescing, there was no irrigation. The total precipitated throughout the crop cycle was 69.2 mm. Although preciptation events occurred in all the phenological stages of the crop, the greatest volume precipitated occurred between the first and second phase, added together corresponds to 97.35% of the total precipitated during the entire crop cycle.

In the maize during the first crop cycle the phenological phases I, II and III stages lasted 51, 31 and 52 days, respectively, completing the cycle 134 days after plant emergence. As a result of abundant precipitation events, throughout all the phenological stages of the crop, only 72 mm was irrigated, in the first phenological phase. The total precipitation was 662.4 mm. During the second crop cycle the phases I, II and III lasted 83, 43 and 28 days, respectively, completing the cycle 154 days after plant emergence. Irrigations were distributed between the first and second phenological phases of the crop, corresponding to a total volume of 224.4 mm. Preciptation events were well distributed throughout the crop cycle, corresponding to a total rainfall of 78.8 mm.

3.2. Soil temperature and humidity

Soil temperature and humidity during soil respiration readings in the area cultivated with Ouro of Mata and Carioca and beans and maize during the first and second crop cycle are represented in figure II.

In Ouro of Mata bean during the first crop cycle (a) most days the temperature remained between 20 and 25 ºC, with a mean of 22.6°C. The temperature range was high, ranging from 17.6 to 30.5ºC. Soil moisture showed increased, considering that as the crop developed the irrigation shift and the irrigated blade also increased, to meet the growing demand for water, until the end of the second phenological phase of the crop. During the senescence phase the soil moisture remained high, even after stopping irrigation, due to precipitation events that occurred during this phase. Soil moisture varied between 0.35 e 0.47 m^3 m^{-3}, where the mean 0.41 m^3 m^{-3}. During the second cycle (c) the soil temperature remained above 20 °C on most days, with the mean for the whole series being 20.4 ºC. Temperature ranged between 17.5 and 24 °C. Soil moisture initially showed slight oscillations and a decreasing behavior towards the end of the serie, since irrigation was suppressed during the crop is senescence phase and rainfall events were scarce during this phase, which led to a loss of soil moisture. The humidity ranged from 0.31 and 0.48 m^3 m^{-3}, the mean being 0.43 m^3 m^{-3}.

The soil temperature and humidity for the dates when soil respiration was measured in the area cultivated with carioca bean (d) most of the period the temperature varied between 20 and 21.5 ºC with the mean for the whole period being 20.5 ºC. In terms of amplitude the temperature ranged from 17.5 e 24 ºC. Soil moisture was irregular and decreasing at the end of the evaluation period. Since irrigation was suspended during the crop is senescence phase and there were few significant rainfall events during this phase, resulting in a loss of soil moisture. Soil moisture varied between 0.34 e 0.48 m^3 m^{-3}, being the mean for the whole period 0.42 m^3 m^{-3}.

In maize the during the first crop cycle (b) the temperature oscillated considerably, ranging between 17.6 and 27.7 °C and with a mean of 23.3 °C. Soil moisture also behaved similarly to temperature during the maize cycle, ranging from 0.36 to 0.49 m^3 m^{-3}, for a mean of 0.43 m^3 m^{-3}. The second cycle (e) in terms of amplitude the temperature varied between 11.7 and 29.1 °C, being the mean for the whole period 18.2 °C. The lower mean temperature during the maize cycle was due to a cold front entering the region while the crop was in the field. The Soil moisture fluctuated and showed a slight downward trend. Unlike what was seen for the Ouro of Mata and carioca bean crops, soil moisture did not show a marked reduction in humidity, even when irrigation ceased at the end of the crop cycle, since there were significant rainfall events in all phenological stages of the maize. The humidity ranged from 0.38 and 0.48 m^3 m^{-3}, being the mean for the whole series 0.43 m^3 m^{-3}.

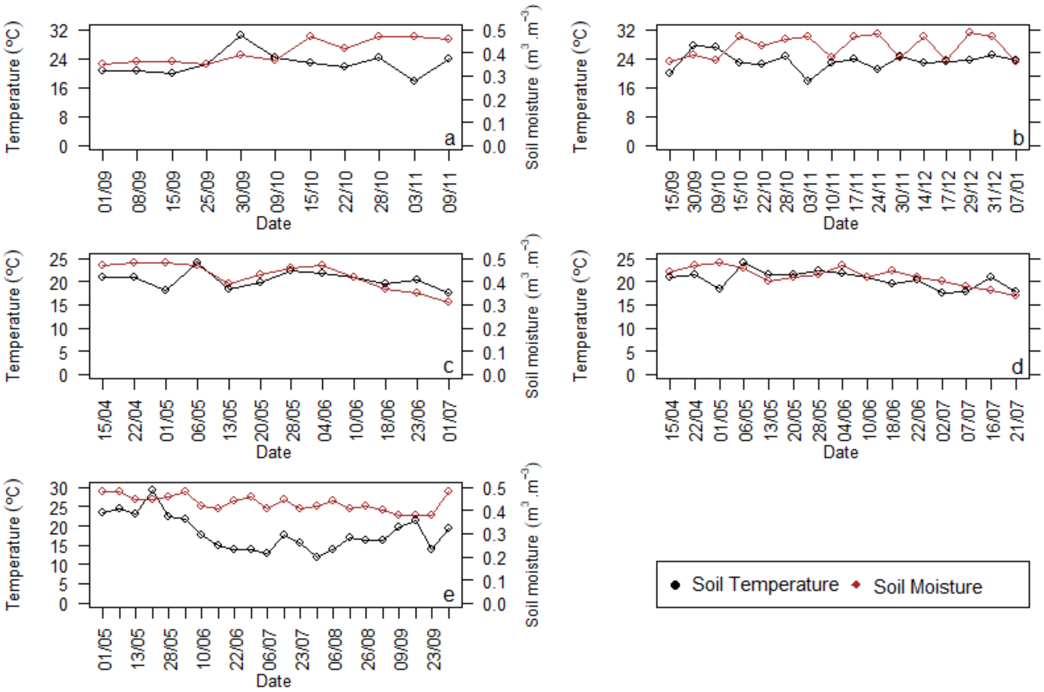


Figure II – Soil temperature and humidity in the area cultivated with Ouro of Mata bean, Carioca bean (VC25) and maize (BM270) during soil respiration reading.

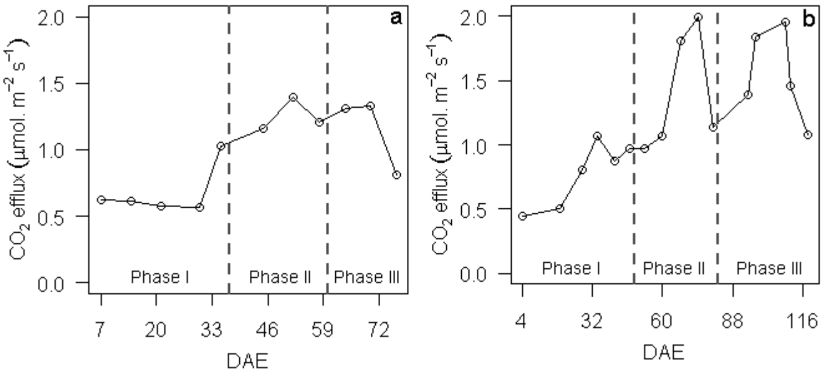
The Pearson correlation (r) according to Callegari (2003) in Ouro of Mata bean during the first crop cycle of soil respiration with temperature and soil moisture were 0.16 and 0.77, respectively, and their respective coefficients of determination (r^2) were 0.02 and 0.59. The correlation between respiration and soil temperature is statistically classified as positive and weak, while the correlation between respiration and soil moisture was positive and strong. During the second cycle The Pearson correlations of soil respiration in relation to temperature and soil moisture were 0.16 and - 0.25, respectively, and their respective coefficients of determination 0.03 e 0.06. The correlation between respiration and soil temperature is statistically classified as positive and weak, while the correlation between respiration and soil moisture was negative and weak.

The Pearson correlation according to Callegari (2003) in Carioca bean of respiration with temperature and soil moisture were 0.44 and 0.25, respectively, and their respective coefficients of determination 0.19 and 0.06. Both correlations are statically classified as positive and weak.

The Pearson correlation according to Callegari (2003) in maize during the first crop cycle of soil respiration with temperature and soil moisture were - 0.11 and 0.50, respectively, with their respective coefficients of determination being 0.01 and 0.25. The correlation between respiration and soil temperature is statistically classified as negative and weak, the correlation between respiration and soil moisture as positive and moderate. During the second cycle the correlations of respiration with temperature and soil moisture were - 0.58 and - 0.41, respectively, with their respective coefficients of determination being 0.34 and 0.16. Both correlations are statistically classified as negative, the first being moderate and the second weak.

3.3 *Soil respiration*

The respiration in areas cultivated with Ouro of Mata bean and Maize during the first crop cycle are represented in Figure III a and b. In both cultivated areas soil respiration delivered increasing trend between the first and second phenological phases of the crop, but a decreasing trend at the end of the third phase.



DAE* - Days After Emergency.

Figure III – Behavior of soil respiration in the area cultivated with Ouro of Mata bean (a) and maize (BM270) (b) during the first crop cycle.

The lowest mean daily value of soil respiration during the first crop cycle was 0.57 µmol m^{-2} s^{-1}, obtained in the first phenological phase, with the highest value being 1.39 µmol m^{-2} s^{-1}, during the second phenological phase. In the area cultivated with maize during the first crop cycle, the lowest mean daily value soil respiration was 0.45 µmol m^{-2} s^{-1}, obtained in the first phenological phase. The highest value obtained was 1.99 µmol m^{-2} s^{-1}, obtained in the second phenological phase.

In Table IV are describe soil respiration mean obtained in each phenological phase and for the entire cycle in areas occupied with bean and maize.

Table IV – Mean soil respiration for phenological phases and for the entire cycle Ouro of Mata bean and maize (BM270) during the first crop cycle.

Culture	Phase I	Phase II	Phase III	Mean
	- - - - - - - - - - - - - -	μmol m^{-2} s^{-1}	- - - - - - - - - - - - - -	
Ouro of mata bean	0,68	1,25	1,15	**1,02 a***
Maize (BM270)	0,78	1,40	1,54	**1,24 a**

* Equal letters do not differ by the F test at 95% significance.

In the area cultivated with Ouro of Mata bean, the lowest and highest mean soil respiration (0.68 and 1.25 μmol m^{-2} s^{-1}) were achieved in the first and second phenological phases, respectively. For maize the lowest and highest mean between the phenological phases (0.78 and 1.54 μmol m^{-2} s^{-1}) were observed in the first and third phases, respectively. Although, for the entire crop cycle, the mean of the area cultivated with maize (1.24 μmol m^{-2} s^{-1}) was higher than that observed in the area cultivated with beans (1.02 μmol m^{-2} s^{-1}), this difference was not statistically significant by the F test at 95% significance.

The soil respiration in the areas cultivated with Ouro of Mata bean, carioca bean and maize during the second crop cycle, as well as the area without plants, are represented in figure III a, b and c. In the area cultivated with Ouro of Mata bean (Figure IV a), carioca bean (Figure IV b) and maize (Figure IV c) reveal upward trend until the reproductive phase of the culture, and decreasing trend in the senescence phase typical. Although for the area cultivated with Ouro of Mata beans, the highest mean soil respiration was reported in the beginning of the third phenological phase characterized by the decreasing trend.

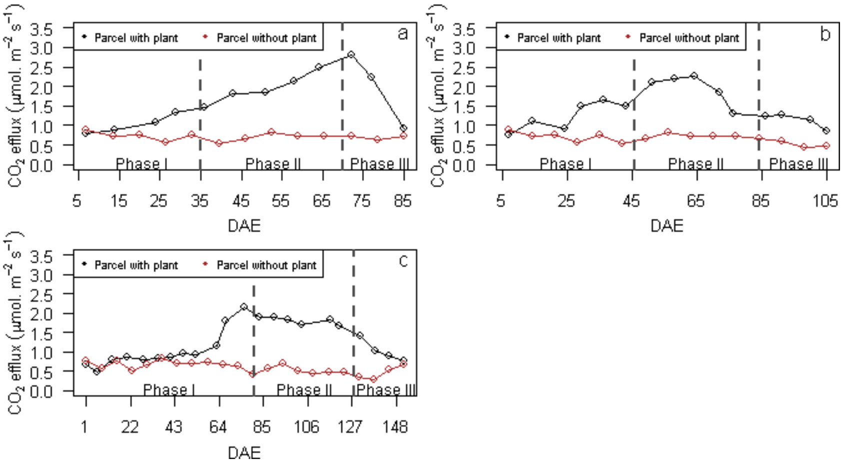


Figure IV – Behavior of soil respiration in the area cultivated with Ouro of Mata bean (a), carioca bean (VC25) (b) and maize (BM270) (c) during the second crop cycle and in an area without plants.

Throughout the Ouro of Mata bean cycle the lowest mean daily value of soil respiration ranged from 0.79 μmol m^{-2} s^{-1}, obtained in the first phenological phase, to 2.80 μmol m^{-2} s^{-1}, obtained in the third phenological phase. For the carioca bean and maize, the lowest mean daily efflux has been obtained in the first phenological phase, 0.77 and 0.49 μmol m^{-2} s^{-1}, respectively. This has been higher in the second phase, and in areas occupied by both cultures the efflux was 2.27 μmol m^{-2} s^{-1}.

In table V are described soil respiration mean obtained in each phenological phase and for the entire cycle in the areas vegetated with Ouro of Mata bean, carioca bean and maize, as well as in the area without the crops. For this area, the mean was calculated taking into account the days on which readings were also taken in areas with crops.

Table V – Mean soil respiration for the phenological phases and for the entire cycle of areas vegetated with crops and mean efflux of the area without plants.

Culture	Phase I	Phase II	Phase III	Mean
	- - - - - - - - - - - - - -	μmol m^{-2} s^{-1}	- - - - - - - - - - - - - -	
Carioca bean (VC25)	1.23	1.94	1.12	**1.44 a**
Ouro of Mata bean	1.02	1.94	1.99	**1.65 a**
Maize (BM270)	1.04	1.80	1.04	**1.25 a**
Area without plant	-	-	-	**0.53 b**

The highest and lowest mean soil respiration in the area cultivated with Ouro of Mata bean was obtained in the first and third phases, respectively, with their respective values being 1.02 and 1.99 μmol m^{-2} s^{-1}. For the area cultivated with carioca bean, it was lower for the period comprising the third phenological phase of the crop, 1.12 μmol m^{-2} s^{-1}, and higher in the second phase, 1.94 μmol m^{-2} s^{-1}. In the area cultivated with maize, the lowest mean was obtained in the first and third phenological phases, with a mean of 1.04 μmol m^{-2} s^{-1} in both phases, whereas in the period comprising the second phenological phase, the highest mean was obtained, being its value 1.80 μmol m^{-2} s^{-1}.

Regarding the mean soil respiration by the entire data series, the lowest CO_2 emission was observed in the area without plants, 0.53 μmol m^{-2} s^{-1}, followed by areas cultivated with maize 1.25 μmol m^{-2} s^{-1}, carioca bean 1.44 μmol m^{-2} s^{-1} and Ouro of Mata bean 1.65 μmol m^{-2} s^{-1}. There was a significant difference by the F test, at 95% of significance, and by the Tukey test, at 5% of probability, the difference was significant between soil respiration occurred in the area without plants in relation to the areas vegetated with bean and maize. Differences in means between areas occupied by crops during the second crop cycle were not statistically significant. Comparing the mean obtained between the cultivation cycles, only the area cultivated with Ouro of Mata bean, when compared with itself, showed off a significant difference, with the mean of the first and second cycles being 1.02 and 1.65 μmol m^{-2} s^{-1}, respectively.

3.4. *Photosynthesis and ecophysiological parameters*

In figure V are represent photosynthesis and other ecophysiological variables observations for Ouro of Mata bean during the first cycle of crop cultivation. The photosynthesis (a) showed an increasing pattern between the first and second phenological phases, and a decreasing trend for the third phase. The same behavior was observed for stomatal conductance (b), transpiration (c) and instantaneous carboxylation efficiency (f). The internal carbon concentration (d) was growing throughout the development of the crop. The behavior of instantaneous water use efficiency (e) was irregular throughout the crop development.

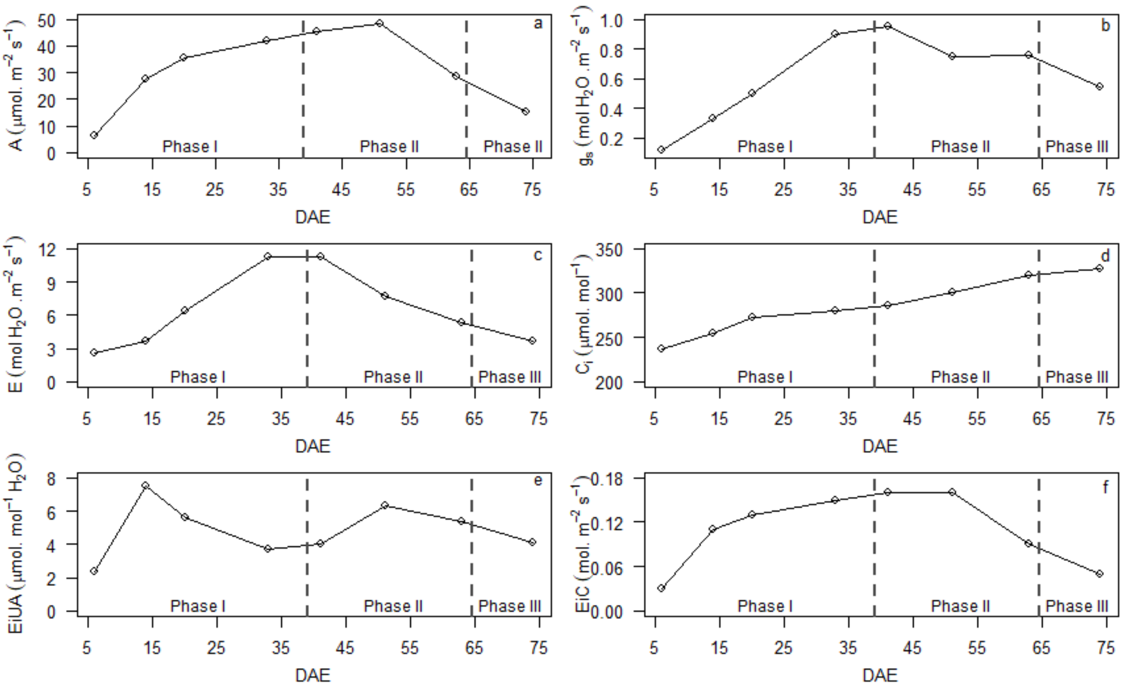


Figure V – Photosynthetic (a), stomatal conductance (b), transpiration (c), internal carbon concentration (d), instantaneous water use efficiency (e) behavior along the phenological phases of Ouro of Mata bean in the first crop cycle.

In the Ouro of Mata bean crop, the mean photosynthesis per reading date varied between 6.16 µmol m^{-2} s^{-1}, obtained in the first phase, and 48.40 µmol m^{-2} s^{-1}, obtained in the second phase. For stomatal conductance, transpiration and instantaneous carboxylation efficiency, the lowest values were observed in phase I, 0.12 mol of H_2O m^{-2} s^{-1}, 2.59 mol of H_2O m^{-2} s^{-1} and 0.026 mol m^{-2} s^{-1}, respectively, and higher values in phase II, 0.95 mol of H_2O m^{-2} s^{-1}, 11.29 mol of H_2O m^{-2} s^{-1} and 0.161 mol m^{-2} s^{-1}, respectively. For the internal carbon concentration, the lowest value was observed in phase I, 237.34 µmol mol^{-1}, and the highest in phase III, 328.05 µmol mol^{-1}. For instantaneous water use efficiency, the lowest and highest values were observed in the phase I, 2.38 µmol mol^{-1} of H_2O and 7.47 µmol mol^{-1} of H_2O, respectively.

In figure VI are shown photosynthesis and other ecophysiological variables observations for Ouro of Mata bean during the first cycle of crop cultivation. In the maize crop the photosynthesis (a) increased until phase II and decreased in phase III, followed by stomatal conductance (b) and transpiration (c). The internal carbon concentration (d) increased throughout all the phenological stages of the crop. Water use efficiency (e) showed irregular behavior until phase II, with a downward trend in phase III. Instantaneous carboxylation efficiency (f) showed a downward trend throughout the crop is development.

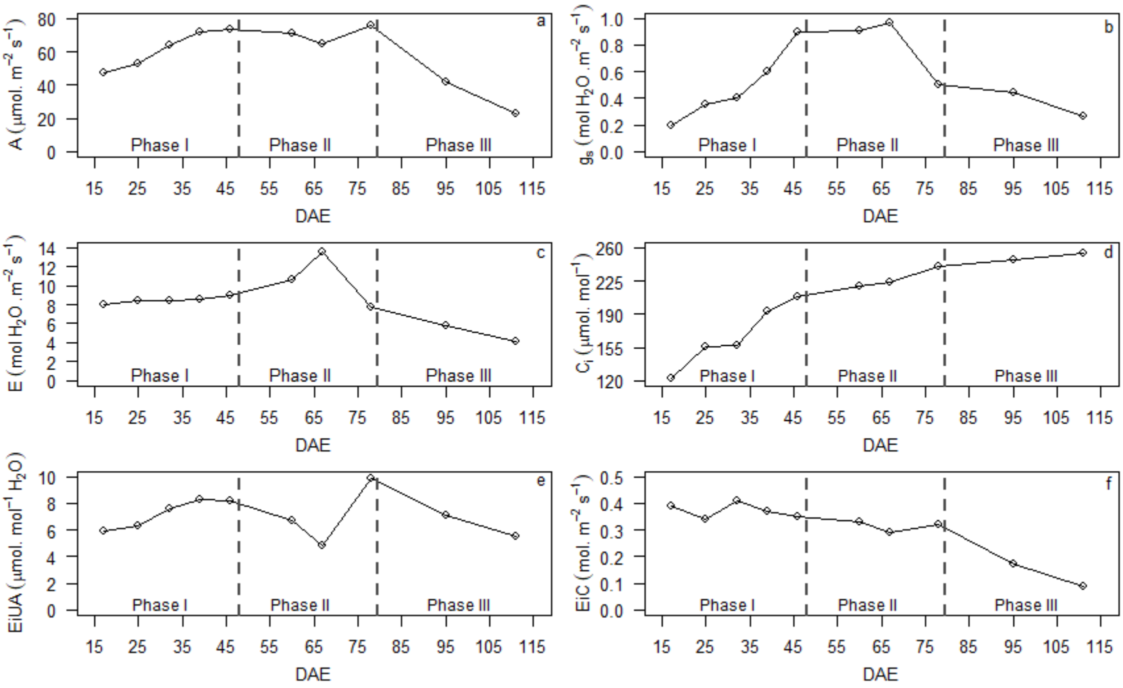


Figure VI – Photosynthetic (a), stomatal conductance (b), transpiration (c), internal carbon concentration (d), instantaneous water use efficiency (e) behavior along the phenological phases of maize (BM270) in the second first cycle.

For maize, mean daily photosynthesis varied between 23 μmol m^{-2} s^{-1}, obtained in the third phenological phase, and 76.08 μmol m^{-2} s^{-1}, obtained in the second phase. Stomatal conductance varied from 0.20 to 0.97 mol of H_2O m^{-2} s^{-1}, observed in phase I and II, respectively. For transpiration the lowest value was 4.18 mol H_2O m^{-2} s^{-1}, observed in phase III, and the highest value was 13.57 mol H_2O m^{-2} s^{-1}, observed in phase II. The internal carbon concentration varied between 122 and 253.9 μmol mol^{-1}, obtained in phases I and III, respectively. For instantaneous water use efficiency, the lowest and highest values occurred in phase II, 4.79 and 9.92 μmol mol^{-1} of H_2O, respectively. Instantaneous carboxylation efficiency fluctuated between 0.091 mol m^{-2} s^{-1}, obtained in phase III, and 0.406 mol m^{-2} s^{-1}, obtained in phase I.

In table VI described the mean behavior of photosynthesis and ecophysiological variables by phenological phase for the Ouro of Mata bean and maize crops obtained in the first cultivation cycle.

Table VI – Mean photosynthesis (A – μmol m^{-2} s^{-1}), stomatal conductance (g_s –mol of H_2O m^{-2} s^{-1}), transpiration (E – mol of H_2O m^{-2} s^{-1}), internal carbon concentration (Ci – μmol mol^{-1}), instantaneous water use efficiency (EiUA – μmol mol^{-1} of H_2O) and instantaneous carboxylation efficiency (EiC – mol m^{-2} s^{-1}) for Ouro of Mata bean and Maize (BM270) during the first crop cycle.

	Phenological phases	**A**	**gs**	**E**	**Ci**	**EiUA**	**Eic**
Ouro of mata bean first crop cycle	**I**	27.86	0.54	5.98	260.28	4.66	0.106
	II	40.84	0.82	8.11	302.20	5.03	0.133
	III	15.20	0.46	3.70	328.10	4.11	0.046
	Total	**27.97**	**0.61**	**5.93**	**297.09**	**4.60**	**0.095**
Maize (BM270) first crop cycle	**I**	61.81	0.49	8.47	167.17	7.29	0.369
	II	70.85	0.79	10.65	227.40	6.65	0.311
	III	32.24	0.36	5.02	250.45	6.42	0.128
	Total	**52.07**	**0.52**	**7.68**	**211.95**	**6.78**	**0.245**

For Ouro of Mata bean the photosynthesis was highest in phase II in relation to the different phenological phases, obtaining an mean of 40.84 μmol m^{-2} s^{-1}. As expected stomatal conductance, transpiration and instantaneous water use efficiency, associated with photosynthesis, also showed higher values in this phase, being 0.82 mol of H_2O m^{-2} s^{-1}, 8.11 mol of H_2O m^{-2} s^{-1} e 5.22 μmol mol^{-1} of H_2O. respectively. The internal carbon concentration showed an increasing behavior over the course of the phenological cycles, with the mean of 260.98 μmol mol^{-1} in phase I and 238.10 μmol mol^{-1} in phase II. The carboxylation efficiency also showed an increasing behavior until the second phase and a decreasing behavior in the first phase, with the highest and lowest mean obtained in the second and third phases, respectively, with their respective values 0.133 and 0.046 mol m^{-2} s^{-1}. The mean for the entire cycle were 27.97 μmol m^{-2} s^{-1} (A), 0.61 mol of H_2O m^{-2} s^{-1} (g_s), 5.93 mol of H_2O m^{-2} s^{-1} (E), 297.09 μmol mol^{-1} (C_i), 4.60 μmol mol^{-1} of H_2O (EiUA) and 0.095 mol m^{-2} s^{-1} (EiC).

The behavior of photosynthesis in maize was followed by stomatal conductance and transpiration, increasing until phase II and decreasing in phase III. The highest means were obtained in phase II, where the values of 70.85 μmol m^{-2} s^{-1}, 0.79 mol of H_2O m^{-2} s^{-1} and 10.65 mol of H_2O m^{-2} s^{-1}, respectively. The internal carbon concentration showed an increasing behavior throughout the crops development, varying between the first and third phases of 167.17 μmol mol^{-1} for 250.45 μmol mol^{-1}, respectively. The behavior of instantaneous water use efficiency and instantaneous carboxylation efficiency decreased throughout the crops phenological stages, with their respective values 7.29 µmol mol^{-1} of H_2O and 0.369 mol m^{-2} s^{-1}, in phase I, 6.42 µmol mol^{-1} and 0.128 mol m^{-2} s^{-1}, in phase III. For the entire crop cycle the mean observed were 52.07 µmol m^{-2} s^{-1}(A), 0.52 mol of H_2O m^{-2} s^{-1}(g_s), 7.68 mol of H_2O m^{-2} s^{-1} (E), 211.95 µmol mol^{-1} (C_i), 6.78 µmol mol^{-1} (EiUA) and 0.245 mol m^{-2} s^{-1} (EiC).

In figure VII are represented the photosynthesis for the Ouro of Mata bean during the second crop cycle. Photosynthesis (a) showed an increasing behavior at the beginning of phase I and decreased at the end of this phase, stabilizing in phase II and decreasing again in phase III. This behavior was similar to that shown by instantaneous water use efficiency (e) and instantaneous carboxylation efficiency (f). Stomatal conductance (b) and transpiration (c) showed an increasing behavior until phase II and a decreasing behavior in phase III. The internal carbon concentration (d) increased throughout the crop is development.

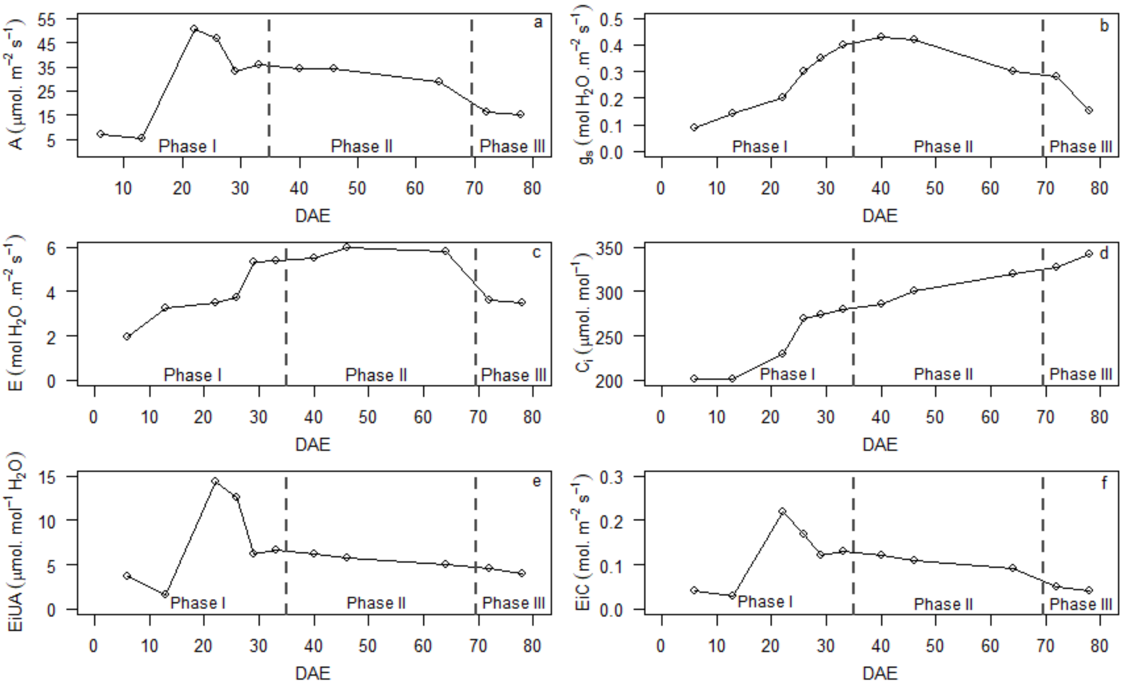


Figure VII – Photosynthetic (a), stomatal conductance (b), transpiration (c), internal carbon concentration (d), instantaneous water use efficiency (e) behavior along the phenological phases of Ouro of Mata bean in the second crop cycle.

The mean photosynthesis for Ouro of Mata bean ranged from 5.22 and to 50.28 µmol m^{-2} s^{-1}, with all readings obtained in the first phenological phase of the culture. For stomatal conductance and transpiration, the lowest values were obtained in the phase I, 0.09 mol of H_2O m^{-2} s^{-1} and 1.94 mol of H_2O m^{-2} s^{-1}, respectively, and higher values in the II, 0.43 mol of H_2O m^{-2} s^{-1} and 5.98 mol of H_2O m^{-2} s^{-1}, respectively. The internal carbon concentration fluctuated between 200.60 μmol mol^{-1} and 342.40 μmol mol^{-1}, observed in phase I and II, respectively. Instantaneous water use efficiency and instantaneous carboxylation efficiency showed lower and higher values in the first phenological phase, ranging from 1.61 μmol mol^{-1}of H_2O and 0.026 mol m^{-2} s^{-1}, respectively, to 14.37 μmol mol^{-1} of H_2O and 0.219 mol m^{-2} s^{-1}, respectively.

In figure VIII are represented the photosynthesis for the Carioca bean. The photosynthesis showed an increasing behavior until the beginning of phase II and atypically decreased throughout this phase, maintaining the decreasing behavior in phase III. This behavior was also observed in transpiration. Stomatal conductance showed an increasing trend until the beginning of phase II, where it stabilized throughout this phase, and a decreasing behavior in phase III. The internal carbon concentration maintained its standard behavior, increasing throughout the crop is development. Instantaneous water use efficiency and instantaneous carboxylation efficiency showed similar behavior, increasing in the first half of phase I, at which point they began to decrease until the end of the crop cycle.

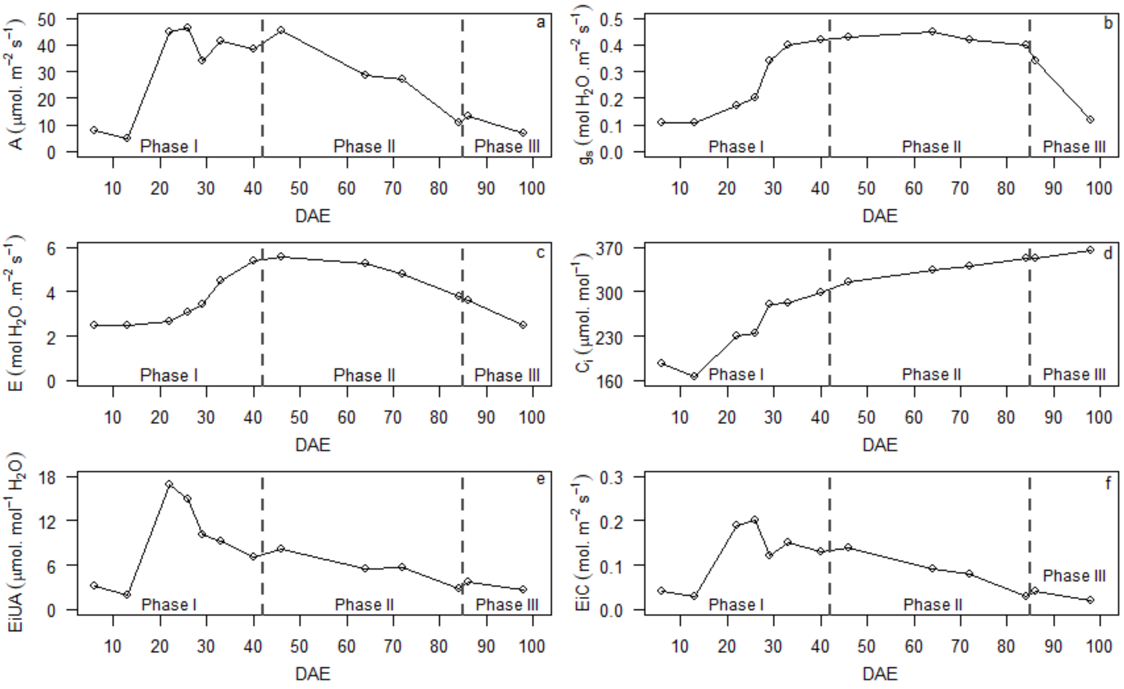


Figure VIII – Photosynthetic (a), stomatal conductance (b), transpiration (c), internal carbon concentration (d), instantaneous water use efficiency (e) behavior along the phenological phases of Carioca bean.

In the carioca bean crop, photosynthesis fluctuated between 4.66 and 46.22 μmol m^{-2} s^{-1}, both values observed in phase I. The same behavior was observed for instantaneous water use efficiency, which varied from 1.86 to 16.82 μmol mol^{-1}, also observed in phase I. Stomatal conductance and transpiration were lower in phase I, 0.11 mol of H_2O m^{-2} s^{-1} and 2.48 mol of H_2O m^{-2} s^{-1}, respectively, and higher in phase II, 0.45 mol of H2O m^{-2} s^{-1} and 5.30 mol of H2O m^{-2} s^{-1}, respectively. The internal carbon concentration varied between 186.70 and 364.58 μmol mol^{-1}, obtained in phases I and III, respectively. Instantaneous carboxylation efficiency was lowest in phase III, 0.018 mol m^{-2} s^{-1}, and highest in phase II, 0.197 mol m^{-2} s^{-1}.

In figure IX are represented the photosynthesis for the maize during the second crop cycle. The maize also showed atypical photosynthetic behavior, decreasing even in phase II, reflected in stomatal conductance and transpiration, which also showed a reduction in the corresponding period. The internal carbon concentration showed a characteristic increasing behavior throughout the crop is development. Water use efficiency decreased between the end of phase I and the beginning of phase II and then stabilized until the end of the cycle. Instantaneous carboxylation efficiency, with the exception of a few periods of oscillation, showed a downward trend throughout the phenological stages.

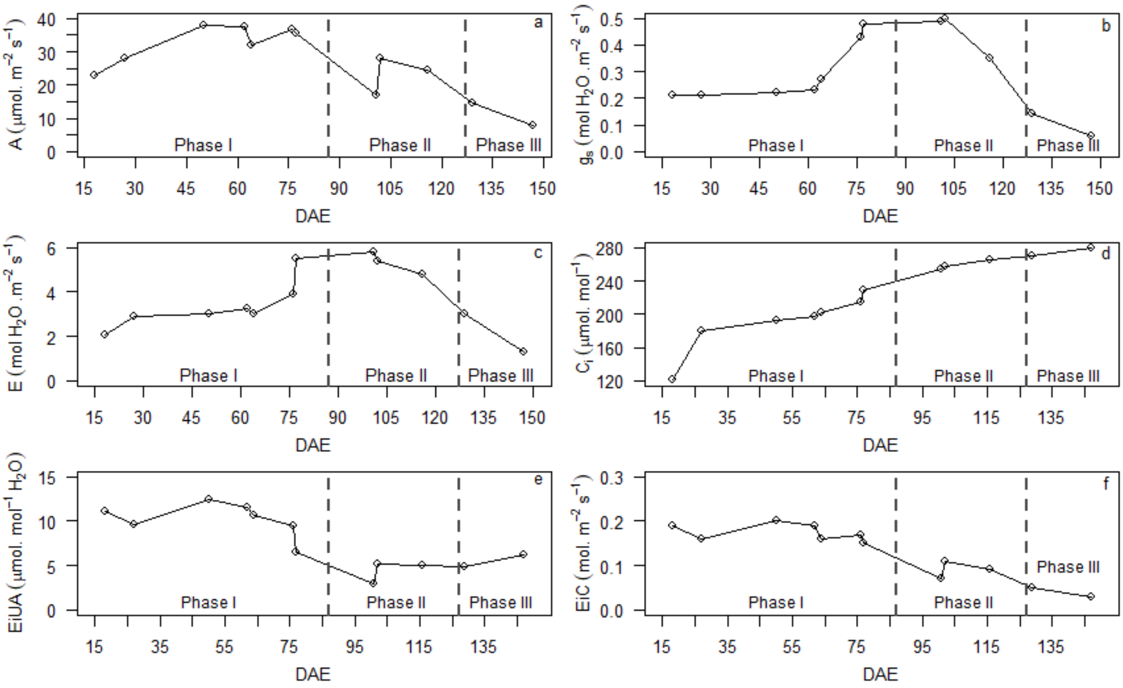


Figure IX – Photosynthetic (a), stomatal conductance (b), transpiration (c), internal carbon concentration (d), instantaneous water use efficiency (e) behavior along the phenological phases of maize (BM270) in the second crop cycle.

The photosynthesis and instantaneous carboxylation efficiency were lower in phase III, 8.04 µmol m^{-2} s^{-1} and 0.029 mol m^{-2} s^{-1}, respectively, and higher in phase I, 37.87 µmol m^{-2} s^{-1} and 0.197 mol m^{-2} s^{-1}, respectively. Stomatal conductance and transpiration were lower in phase III, 0.06 mol of H_2O m^{-2} s^{-1} and 1.30 mol of H_2O m^{-2} s^{-1}, respectively, and higher in phase II, 0.50 mol of H_2O m^{-2} s^{-1} and 5.80 mol of H_2O m^{-2} s^{-1}, respectively. The internal carbon concentration fluctuated between 121.97 and 280 µmol mol^{-1}, obtained in phases I and III, respectively. Water use efficiency was lowest in phase II, at 2.92 µmol mol^{-1} of H_2O, and highest in phase I, at 12.44 µmol mol^{-1} of H_2O.

In table VII described the mean behavior of photosynthesis and ecophysiological variables by phenological phase for the Ouro of Mata bean, Carioca bean and maize crops obtained in the second cultivation cycle.

Table VII – Mean photosynthesis (µmol.m^{-2} s^{-1}), stomatal conductance (g_s – mol of H_2O m^{-2} s^{-1}), transpiration (E – mol of H_2O m^{-2} s^{-1}), internal carbon concentration (Ci – µmol mol^{-1}), instantaneous water use efficiency (EiUA – µmol mol^{-1} of H_2O) and instantaneous carboxylation efficiency (EiC – mol m^{-2} s^{-1}) for Ouro of Mata bean, Carioca (VC25) bean and maize (BM270) during the second crop cycle.

	Phenological phases	A	gs	E	Ci	EiUA	Eic
Ouro of mata bean first crop cycle	**I**	29.63	0.25	3.85	242.49	7.69	0.122
	II	32.39	0.38	5.75	302.17	5.63	0.107
	III	15.20	0.22	3.55	335.23	4.28	0.045
	Total	**25.74**	**0.28**	**4.38**	**293.30**	**5.87**	**0.091**
Carioca bean (VC25)	**I**	31.04	0.25	3.43	239.41	9.05	0.129
	II	28.10	0.43	4.87	335.19	5.77	0.084
	III	9.92	0.23	3.05	358.52	3.25	0.027
	Total	**23**	**0.30**	**3.78**	**311.04**	**6.02**	**0.080**
Maize (BM270) second crop cycle	**I**	32.90	0.29	3.38	191.15	10.18	0.173
	II	23.10	0.45	5.33	258.86	4.39	0.089
	III	11.29	0.10	2.15	275.00	5.52	0.041
	Total	**26.85**	**0.30**	**3.66**	**222.05**	**7.96**	**0.130**

In the second crop cycle of Ouro of Mata beans, the standard behavior of the ecophysiological variables remained the same, with photosynthetic behavior being followed by stomatal conductance and transpiration. For these variables, the highest values were obtained in the second phenological phase, being 32.39 μmol m^{-2} s^{-1}, 0.38 mol of H_2O m^{-2} s^{-1} and 5.75 mol of H_2O m^{-2} s^{-1}, respectively. The lowest values were observed in the third phase, 15.20 μmol m^{-2} s^{-1}, 0.22 mol of H_2O m^{-2} s^{-1} and 3.55 mol of H_2O m^{-2} s^{-1}, respectively. The internal carbon concentration showed an increasing behavior throughout the development of the crop, varying between 242.49 and 335.23 μmol mol^{-1}, obtained, respectively, in the phases I and III. The behavior of instantaneous water use efficiency and instantaneous carboxylation efficiency decreased throughout the crop cycle, where the values of 7.69 μmol mol^{-1} of H_2O and 0.122 mol m^{-2} s^{-1}, respectively, in the phase I and the values of 4.28 μmol mol^{-1} of H_2O and 0.045 mol m^{-2} s^{-1}, respectively, in the phase III. The mean for the entire crop cycle was 25.74 μmol.m^{-2} s^{-1} (A), 0.28 mol of H_2O m^{-2} s^{-1} (g_s), 4.38 mol of H_2O m^{-2} s^{-1} (E), 293.30 μmol mol^{-1} (C_i), 5.87 μmol mol^{-1} of H_2O (EiUA) and 0.091 mol m^{-2} s^{-1} (EiC).

In the Carioca bean crop the standard behavior was maintained, with photosynthesis, stomatal conductance and transpiration increasing until phase II and decreasing in phase III. In the second phenological phase, the mean were 31.04 μmol.m^{-2} s^{-1}, 0.43 mol of H_2O m^{-2} s^{-1} and 4.87 mol of H_2O m^{-2} s^{-1}, respectively. In the third phase, the mean were 9.92 μmol m^{-2} s^{-1}, 0.23 mol of H_2O m^{-2} s^{-1} and 3.05 mol of

H_2O m^{-2} s^{-1}, respectively. The internal carbon concentration increased throughout crop development, varying between phases I and II from 239.41 μmol mol^{-1} and 358.52 μmol mol^{-1}, respectively. Instantaneous water use efficiency and instantaneous carboxylation efficiency decreased throughout the phenological phases, ranging from 8.17 μmol mol^{-1} of H_2O 0.117 mol m^{-2} s^{-1}, respectively, in phase I and 3.25 μmol mol^{-1} of H_2O 0.027 mol m^{-2} s^{-1}, respectively, in phase III. The mean obtained for the entire crop cycle was 23 μmol m^{-2} s^{-1} (A), 0.30 mol of H_2O m^{-2} s^{-1} (gs), 3.78 mol of H_2O m^{-2} s^{-1} (E), 311.04 μmol mol^{-1} (Ci), 5.93 μmol mol^{-1} (EiUA) and 0.078 mol m^{-2} s^{-1} (EiC).

In the second maize crop cycle, photosynthesis and instantaneous carboxylation efficiency showed a downward trend, varying from 32.90 μmol m^{-2} s^{-1} and 0.172 mol m^{-2} s^{-1}, respectively, in phase I, to 11.29 μmol m^{-2} s^{-1} and 0.041 mol m^{-2} s^{-1}, respectively, in phase III. Stomatal conductance and transpiration increased up to phase II, with mean of 0.45 and 5.33 mol of H_2O m^{-2} s^{-1}, respectively, and decreased in phase III, with values of 0.10 and 2.15 mol of H_2O m^{-2} s^{-1}, respectively. The internal carbon concentration creased throughout the crop's development, varying between 191.15 and 275 μmol mol^{-1}, obtained in phases I and III, respectively. Instantaneous water efficiency was highest in phase I, at 9. μmol mol^{-1} of H_2O, and lowest in phase II, at 4.33 μmol mol^{-1} of H_2O. The mean for the entire cycle was 22.43 μmol m^{-2} s^{-1} (A), 0.28 mol of H_2O m^{-2} s^{-1}, (gs), 3.62 mol of H_2O m^{-2} s^{-1} (E), 241.67 μmol mol^{-1} (Ci), 6.43 μmol mol^{-1} of H_2O (EiUA) and 0.101 mol m^{-2} s^{-1} (EiC).

4. DISCUSSION

4.1. *Soil moisture and temperature*

Soil moisture and temperature can influence soil respiration (Cueva et al., 2015; Vargas et al., 2018), because moisture and soil temperatures may stimulate microbial activity and the decomposition of organic matter, which result in higher CO_2 emissions, as observed in different studies (Borges et al., 2015; Lamaguti et al., 2015; Mitra et al., 2019; Silva et al., 2019). However, in the present study, a significant correlation was only found between humidity and soil respiration in the area cultivated with Ouro of Mata beans in the first crop cycle. However, in the area cultivated with maize positive correlation is found in the first crop cycle and a negative correlation in the second cycle.

The negative correlation between soil temperature and CO_2 emissions during the second cultivation cycle in the maize-growing area can be explained by the occurrence of cold fronts, in which the mean soil temperature in the first cycle was 17.6 ºC, and in the second cycle was only 11.7 ºC. However, despite the low temperature, soil humidity combined with root growth and development contributed to a greater soil respiration. According to Vargas et al. (2018) the effect of humidity is dominant over soil temperature in the soil respiration process.

4.2. Soil respiration

The soil respiration in the cultivated areas is characteristic of areas cultivated with annual crops, showing an increasing trend between the first and second phenological phase, that decreases at the end of the third phase. This pattern occurs due to the growth of its roots and greater interaction with the soil microfauna as the crop develops. This leads to higher soil respiration and consequent higher concentration of CO_2 in the medium (Bloemen et al., 2016; Goncharova et al., 2019).

Another factor that contributes to this increase is that the root system secretes photo assimilated to the soil, which serves as energy for microbial activity. According to Cardoso and Androete (2016) and Zocolotto et al. (2016), plants are capable of secreting up to 40% of photoassimilates into the soil, significantly increasing microbial activity and CO_2 production. In both crop cycles in the area cultivated with Ouro of Mata, soil respiration remained high at the beginning of the third phenological phase, possibly due to the high emission of leaves on the soil in this phase, which resulted in the contribution of organic matter, and greater microbial activity. It was observed that the performance of microorganisms in the process of decomposition of organic matter increases the emission of CO_2 in different studies (Carey et al., 2016; Castellano et al., 2017; Veeck et al., 2018).

The lowest mean soil respiration in the maize crop during the first crop cycle was 0.78 μmol.m^{-2} s^{-1}, obtained in the first phenological phase of the culture. Result similar to that obtained by Santos et al. (2019). This later study obtained a lower mean value of 0.72 μmol m^{-2} s^{-1}. In the second maize cycle the mean has been 2.27 μmol m^{-2} s^{-1}. Result similar to that observed by Boguzas et al. (2018) and Santos et al. (2019), where they obtained efflux of 2.27 and 2.04 μmol m^{-2} s^{-1}, in area cultivated with maize, respectively.

With the exception of the beginning of the observed period, CO_2 emissions in areas with plants were substantially higher than in areas without plants. In terms of mean, the greatest difference was obtained on measurements taken during the second phenological phase of the crop. The period in which the root system is fully developed and active. On the first collection date, the soil respiration in the cultivated areas was similar to the area without vegetation, since plants in the cultivated area were underdeveloped exerting little influence on soil respiration. In addition, the plowing and harrowing carried out two days before planting, by removing the soil, kept the soil respiration high in the first days of observation in the area without plants. According to Robertson et al. (2015), management practices that remove soil and organic matter disturb the soil ecosystem and result in higher carbon emissions. This may explain the higher CO_2 emissions in the second cycle, since in the first cycle the plowing and harrowing operations were carried out three months before planting.

4.3. *Photosynthesis and Ecophysiological parameters*

In the first cycle of cultivation the photosynthesis of the cultures presented a standard behavior of annual cultures, increasing between the vegetative and reproductive phases, period in which the crop needs to synthesize maximum amount of energy, way photosynthesis, to develop, grow and produce grain. In the third phenological phase, there was a marked reduction in photosynthesis, because it is the phase of yellowing and senescence of the leaves, with consequent reduction of photosynthetic activity and death of the plant. This pattern of photosynthesis behavior was observed in different studies (Miller et al., 2000; Thakur et al., 2016; Wu et al., 2020; Sakuraba et al., 2021).

The photosynthesis observed in Ouro of Mata beans during the first growing cycle was higher than that observed for the bean crop in other studies. Pessôa et al. (2017), evaluating photosynthesis in cowpea, observed that it varied between 20.09 and 20.63 μmol m^{-2} s^{-1} for plants grown under weed control, and a photosynthetic mean of 17.36 μmol m^{-2} s^{-1} for plants grown without weed control. Also evaluating photosynthesis in cowpea Melo et al. (2018) and Santos et al. (2019) obtained mean values of 23.57 and 26.71 μmol m^{-2} $s^{-1,}$ respectively. This difference can be explained by the fact that there was a difference in the cultivar used in the respective experiments, as well as the plants being subjected to different soil, climate and growing conditions

With regard to cultivars, those with better leaf architecture, in order to intercept more light and less shading between leaves tend, to have a higher photosynthetic rateMore productive cultivars need a greater amount of photo assimilates for the growth and development of pods/ears and grains, showing greater photosynthesis to the detriment of less productive cultivars. The photosynthetic rate is directly influenced by the interception of solar radiation by the leaves, the adequacy of the canopy and the shape of the production arrangement can optimize this process (Caetano et al., 2005).

When the plant is grown in fertile or well fertilized soil it tends to have a higher photosynthetic rate, since some nutrients are important for the photosynthesis process (chlorine, copper and manganese) and in the regulation of the opening and closing of stomata (potassium and chlorine). It is important that the soil has enough moisture for these nutrients to be absorbed, via soil solution, since under conditions of water stress, in addition to limiting the absorption of nutrients, plants close their stomata to prevent the loss of water, resulting in a lower photosynthetic rate (Santos et al., 2014; Crosa et al., 2021; Ferreira et al., 2024).

With regard to climatic factors, mainly temperature and light influence the behavior of photosynthesis. Low temperatures tend to limit plant photosynthesis (Taiz and Zeiger, 2013; Kluge et al., 2015). In relation to light, when it is intense, it promotes greater degradation of chlorophyll to the detriment of its synthesis (photo-oxidation), with equilibrium established at a low concentration (Streit et al., 2005), inducing less photosynthesis, since chlorophyll is related to the photosynthetic efficiency of plants (Kramer e Koslowsk, 1979).

The behavior of transpiration in the present study was similar to that observed by Coelho et al. (2014) and Rezende et al. (2021), where in research with different types of beans they also observed values varying between 5 and 9 mol of H_2O m^{-2} s^{-1} and between 4 and 7 mol of H_2O m^{-2} s^{-1}, respectively. Rezende et al (2021) obtained lower values for the internal carbon concentration, where they observed a variation between 180 and 250 μmol mol^{-1}. Similar results were obtained for instantaneous water efficiency by Melo et al. (2018), where values varied between 4 and 5 μmol mol^{-1} of H_2O.

In the first corn crop cycle, photosynthesis varied between 23 and 73.44 μmol m^{-2} s^{-1}. These results are higher than those observed by Moreira et al. (2020), who analyzed the behavior of photosynthesis in maize crops subjected to different growing conditions and observed photosynthesis ranging from 14.08 to 51.58 μmol m^{-2} s^{-1} in different treatments. Vera et al. (2015) obtained photosynthesis in the maize crop ranging from 20 to 45 μmol m^{-2} s^{-1} for the control treatment. In research with maize grown without salt stress, Henry et al. (2015) observed even lower photosynthesis, with the maximum recorded being around 32 μmol m^{-2} s^{-1} for maize grown without stress. The mean photosynthesis for the entire crop cycle was similar to that observed by Moreira et al. (2020), who obtained an mean photosynthesis of 51.58 μmol m^{-2} s^{-1} for maize grown in soil fertilized with tanned cattle manure and polymer. The mean transpiration for the entire cycle was close to that observed by Henry et al. (2015), who obtained transpiration of around 7.70 mol of H_2O μmol m^{-2} s^{-1} for maize grown without salt stress.

In both crops during the first growing cycle the stomatal conductance, transpiration and water use efficiency followed the behavior of photosynthesis in a characteristic way, increasing until the reproductive phase and decreasing in the senescence phase. This is because as the plant increases its photosynthetic rate (between phases I and II) it means that a greater number of stomata remain open and for longer in a condition of greater stomatal conductance, since this measures the opening of the stomata and indicates the capacity of the leaves to carry out gas exchange (Bianchi et al., 2007). When the stomata are open, water is lost through transpiration (Bianchi et al., 2007). On the other hand, the more the photosynthetic rate increases to the detriment of the water that is consumed in this process, the greater the efficiency of water use. The internal concentration of carbon increases throughout the development of the crop, since in this process a greater amount of carbon is needed to make up the structure of the plant and to be used in physiological processes.

In the second cycle of cultivation, atypically, a decreasing behavior of photosynthesis was observed in the second phenological phase of the cultures. This behavior must have occurred due to the action of cold fronts, since lower temperatures may result in reduced photosynthesis (Medlyn et al., 2002; Kluge et al., 2015; Dusenge et al., 2019).

According to Taiz and Zeiger (2013) it is necessary that the air temperature is within optimal ranges for the greatest induction of photosynthetic activity to occur. Kluge et al. (2015) emphasizes that the environmental factors limiting photosynthesis are CO_2, luminosity and the temperature, being that for the same luminous intensity the photosynthetic rate is higher as the temperature increases.

In the Ouro of Mata bean crop, while the air temperature, at the time the photosynthesis reading, was taken during the first cycle varied between 12.5 and 20.5 ºC and the mean for all the reading days was 16.3 ºC, in the second crop cycle the temperature varied between 9.2 and 16.7 ºC, with the mean being 13.4 ºC. For Carioca beans, the temperature varied between 9.2 and 18 ºC, the mean being 13.8 ºC. However, according to EMBRAPA, the ideal temperature range for beans is 17 to 25 °C. For corn, while in the first cycle the temperature varied between 16.3 and 20.8 ºC, for an mean of 18.7 ºC, in the second cycle it varied between 10.6 and 16.5 ºC, the mean being 12.7 ºC. And according to EMBRAPA the ideal air temperature range for maize is between 26 and 34 °C.

In the second cycle, the photosynthesis observed for the Ouro of Mata bean was higher than that observed in different studies for two different bean varieties, the carioca bean (Casaroli and Van Lier, 2015; Pérez-Bueno et al. 2015; Rezende et al. 2021) and the caupi bean (Pessôa et al., 2017; Melo et al. 2018; Santos et al. 2021). The fact that the bean species are different and subject to different environmental and growing conditions may have contributed to the differences observed. A similar result was observed by Santos et al. (2021), where they found photosynthesis of 26.71 μmol m^{-2} s^{-1}. The mean stomatal conductance observed throughout the crop cycle was higher than that obtained by Androcioli et al (2020), where for carioca beans they obtained a mean conductance of 0.29 mol of H_2O m^{-2} s^{-1}. A similar result to this research was observed for transpiration by Pessôa et al. (2021), who observed transpiration of 4.86 mol of H_2O m^{-2} s^{-1} for beans. The mean internal carbon observed was higher than that obtained by Pessôa et al. (2017) where, for cowpea grown under mechanical and chemical weed control, they obtained values of 249.62 and 251.50 μmol mol^{-1}, respectively.

The photosynthesis observed in this research for Carioca bean was higher than that obtained by Casaroli and Van Lier (2015), where they observed maximum mean photosynthesis for Carioca beans ranging from 15.6 to 18.7 μmol m^{-2} s^{-1}, for plants grown in clay and sandy soil, respectively. This research also obtained photosynthesis higher than that obtained by Pérez-Bueno et al. (2015) and Androcioli et al. (2020), who obtained photosynthesis of 16 and 16.4 μmol m^{-2} s^{-1} for common carioca bean, respectively. The fact that all these experiments were conducted in a greenhouse (closed environment) may have contributed to lower photosynthesis, since the plants is subject to the effect of greater shading compared to plants grown in the field.

In shaded conditions, plants no longer receive light in the photosynthetically active range and the reduction in stimuli leads to stomata closing. This results in lower photosynthetic activity. The effect of shading on the reduction of photosynthesis for the common bean crop was observed by Coelho et al. (2014), where for Cowpea bean significant reduction in photosynthesis was observed by increasing shading. Filgueiras (2002) obtained for the cowpea cultivars BRS Guariba and BRS Marataoã, grown without shading, increment of photosynthesis in the order of 34.5 and 26.7%, respectively, when compared with their respective crops under shading conditions.

For Carioca bean the photosynthesis values close to these were obtained by Casaroli and Van Lier (2015), who obtained photosynthesis for Carioca beans of 20 μmol m^{-2} s^{-1}, for plants subjected to an intensity of photosynthetically active radiation of 1000 μmol m^{-2}. Evaluating the behavior of ecophysiological variables for Carioca beans without the application of microorganisms (control treatment), Rezende et al. (2021) obtained photosynthesis of 13 μmol m^{-2} s^{-1}, a value lower than the mean for the entire crop cycle obtained in this research, however transpiration was similar, the authors observed transpiration of 5 mol of H_2O m^{-2} s^{-1}. The same authors also observed stomatal conductance and internal carbon in the order of 0.2 mol of H_2O m^{-2} s^{-1} and 225 μmol mol^{-1}, values which were also lower than the mean obtained for the entire crop cycle in the present experiment.

In the second maize cycle, photosynthesis was lower than that observed by Moreira et al. (2020), where in an experiment with corn, photosynthesis varied between 14.08 and 51.58 μmol m^{-2} s^{-1}. Vera et al. (2015) obtained photosynthesis in the maize crop for the control treatment ranging from 20 to 45 μmol m^{-2} s^{-1}. The result closest to the present study was observed by Henry et al. (2015), where for maize grown without salt stress, maximum photosynthesis was around 32 μmol m^{-2} s^{-1}. Transpiration in the second maize crop cycle was also lower than that observed in other studies Henry et al. (2015) obtained transpiration of 7.78 mol of H_2O m^{-2} s^{-1} for maize. The mean internal carbon was higher than that observed by Ban et al. (2017), who observed internal carbon of 163 μmol mol^{-1} for maize in the control treatment.

Though Ouro of Mata bean and maize showed a lower photosynthetic mean during the second crop cycle, compared to that obtained in the first cycle, only the difference obtained for the corn crop was statistically significant by the F test at 5% probability. Atypically the mean photosynthesis of maize during the second cycle of cultivation was even lower than those obtained for Ouro of Mata and Carioca bean. This behavior must have occurred because maize it is a C4 plant is more likely to be affected by lower temperatures when compared to bean, because it is a C3 plant. Furthermore, considering the air temperatures, at the time the photosynthesis readings were taken, the lowest mean was observed for the corn cycle, 13.9 °C, while for the Carioca bean and Ouro of mata crops it was 14.7 and 15.2 °C, respectively.

Although Ouro of Mata bean and maize showed lower mean photosynthesis during the second growing cycle compared to the first cycle, only the difference obtained for maize was statistically significant according to the F test at 5% probability. Atypically, the mean photosynthesis of maize during the second growing cycle was even lower than that obtained for Ouro of Mata and carioca beans. This behavior may have occurred because corn, being a C4 plant, has a higher ideal temperature range compared to beans, being a C3 plant. In addition, the temperatures during the photosynthesis readings throughout the second maize growing cycle were even lower than those observed for the bean cultivars.

5. CONCLUSION

With the execution of this research, it is concluded that:

a) Soil respiration in a cultivated with annual crops is influenced by the growth of the roots, increasing until the full development of the root system, where it stabilizes, and decreasing when the roots of the plants section their activity and die;

b) Soil respiration in a cultivated with annual crops is significantly higher compared to areas without plants;

c) Plowing and harrowing operations aimed at soil preparation during the second crop cycle contributed to increase CO_2 emissions in subsequent days;

d) In annual crops photosynthesis showed off an increasing behavior between the vegetative and reproductive growth phases, as well as a decreasing behavior in the maturation and senescence phases;

e) Low temperatures during the second cultivation cycle must have contributed to lower photosynthetic rates of cultures when compared to their respective values obtained in the first cultivation cycle;

f) Regarding photosynthesis maize was the crop most affected by low temperatures;

g) The soil preparation for agricultural purposes and the presence of plants contribute to greater CO_2 emissions from the soil. On the other hand, photosynthetic activity throughout the crop cycle absorbs a higher concentration of CO_2 from the atmosphere. However, part of the absorbed CO_2 returns to the atmosphere when the leaves enter senescence and stimulates the action of soil microorganisms. On the other hand, the part of the carbon that is absorbed by the plant and starts to compose the soil, depending on the management of the same aiming at subsequent plantings, can be quickly emitted into the atmosphere.

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7. ATTACHMENT

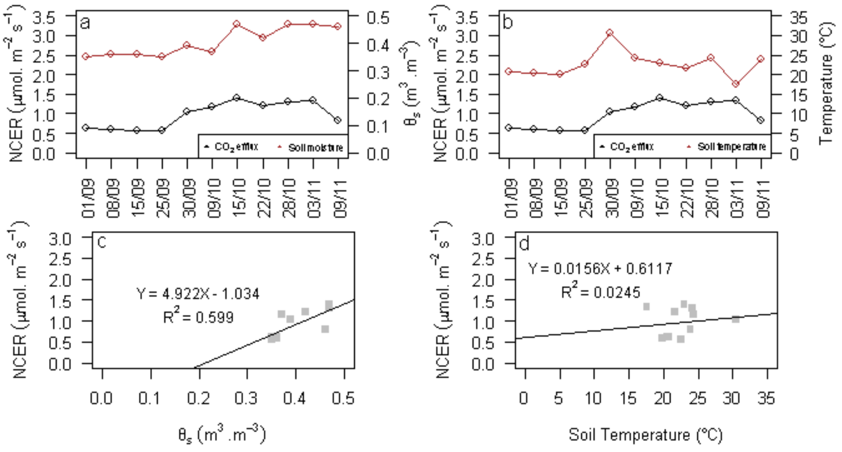

Figure I – Behavior of CO_2 efflux in relation to soil moisture (a) and soil temperature (b), correlation of CO_2 efflux with soil moisture (c) and soil temperature (d) in the area cultivated with Ouro da Mata bean during the first crop cycle.

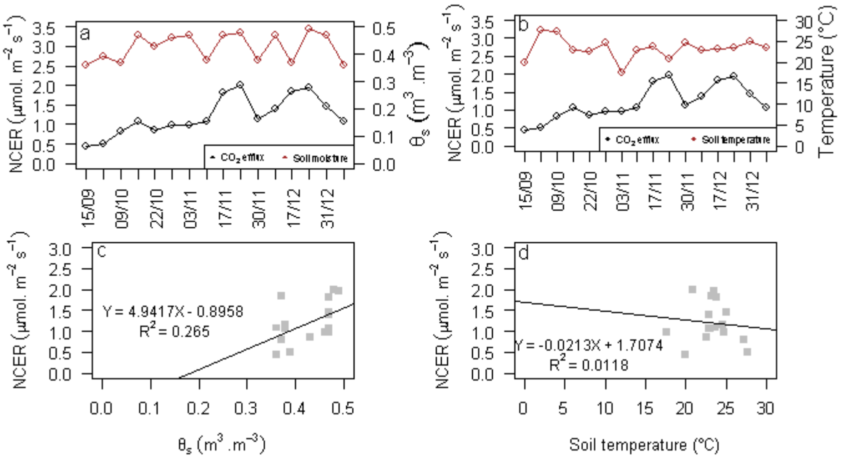

Figure II – Behavior of CO_2 efflux in relation to soil moisture (a) and soil temperature (b), correlation of CO_2 efflux with soil moisture (c) and soil temperature (d) in the area cultivated with Maize (BM270) during the first crop cycle.

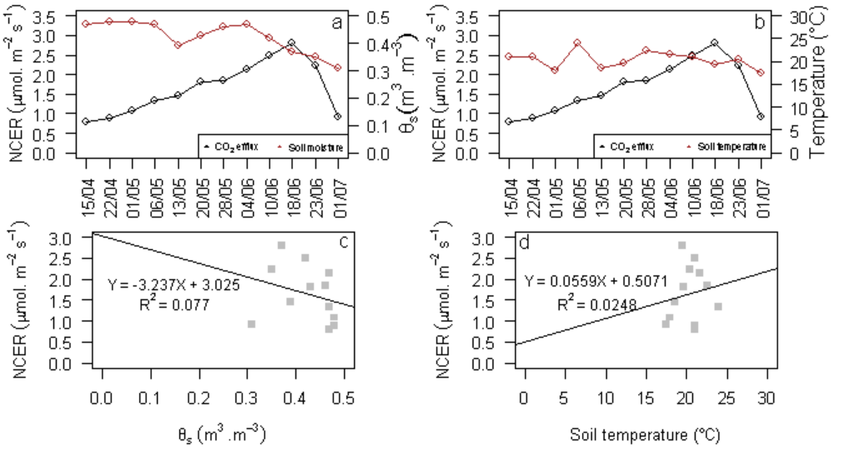

Figure III – Behavior of CO_2 efflux in relation to soil moisture (a) and soil temperature (b), correlation of CO_2 efflux with soil moisture (c) and soil temperature

(d) in the area cultivated with Ouro da Mata bean during the second crop cycle.

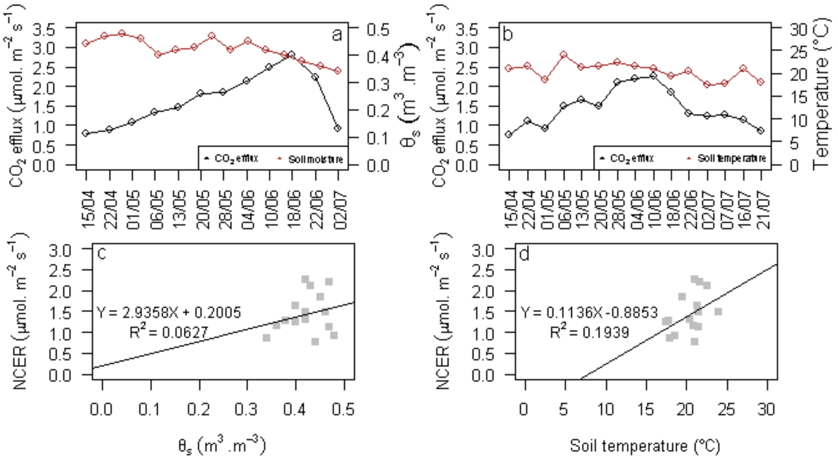

Figure IV – Behavior of CO2 efflux in relation to soil moisture (a) and soil temperature (b), correlation of CO2 efflux with soil moisture (c) and soil temperature (d) in the area cultivated with Carioca bean.

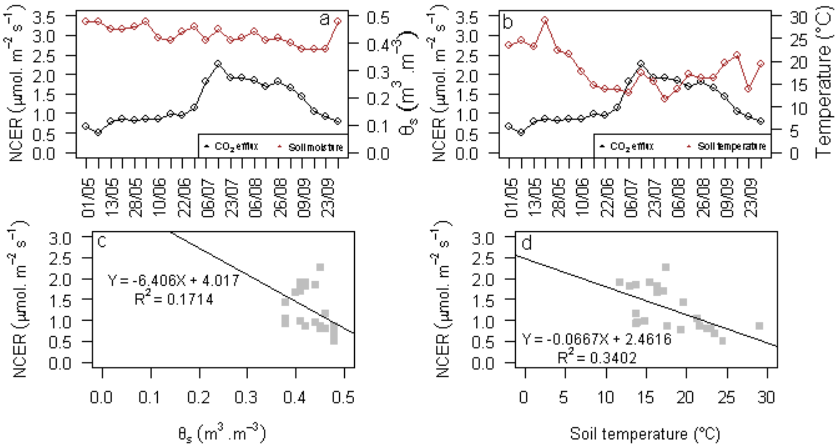

Figure V – Behavior of CO2 efflux in relation to soil moisture (a) and soil temperature (b), correlation of CO2 efflux with soil moisture (c) and soil temperature (d) in the area cultivated with Maize (BM270) during the second crop cycle.