English Version

Behavior of climatic characteristics for the management of agricultural crops in Guarapuava, central south of the state of Paraná

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Abstract

The variations on the water and climate regimes are the factors which act the most to limit the agricultural production. The region which covers the municipality of Guarapuava is characterized by a wide potential of production of winter and summer crops, mainly cereals, due to seasons of the year which are well defined and high annual index of rainfall. The objective of the work was to evaluate the behavior of climatic characteristics as rainfall, temperature, relative humidity of the air, sun radiation and wind speed, aiming to interpret its variations and make the information of the management of agricultural crops in Guarapuava – PR available. The analysis was performed based on an historical and continuous series of average daily climatologic data for the period of twenty four years, from 1984. The data used were temperature and relative humidity of the air, rainfall, sun radiation and wind speed accumulated at 10 m of height. It was determined the monthly average distribution of the climatic variables and the specific coefficient of variation, the climatic water balance by the method proposed by Thornthwaite and Mather and the reference evapotranspiration (Eto) estimated by the method of Penman-Monteith, pattern model FAO. It was verified that the months of June, July and August are those which present the lower index of rainfall, being in the month of august the highest possibility of occurrence of water stress for winter crops. It was verified that the average water balance do not present the occurrence of defined periods of water stress. The beginning of September indicates the beginning of water reposition, considering the months of October and December those which present the highest rainfall levels. The risks of lack of water are lower for summer crops than winter crops. Compared to other components, rainfall presents the highest historical index of variability.

Key words: climatic characteristics; agriculture; water balance; evapotranspiration.

Introduction

The variations on the water and climate regimes are the factors which act the most to limit the agricultural production. According to Ortolani and Camargo (1987), the inappropriate frequency and distribution of the rainfall are responsible for 60 to 70% of the final variability of the agricultural production. For the authors, it is of major importance the historical knowledge of climate conditions to conduce the planning of the crops and management to be performed during the crop cycle, observing carefully the behavior of the rainfall and intensity of the evapotranspiration, aiming to avoid or reduce at a maximum the occurrence of water deficit.

The appropriated development of the agricultural crops is dependent on interactions between the factors referent to the dynamics of the systems of the soil, plant and atmosphere. Frizzone et al. (2005) describe the occurrence of a functional relation between theses factors and the crop production, being the latter dependent on the environmental conditions, in which the inappropriate water availability may suppress the effect of genetic and management factors as soil fertility and crop treatments restricting the productive potential of the crop.

In relation to the water regime, ASSIS (1996) reports that in the tropical regions the rainfall amounts are not harmoniously distributed around

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the average, but in an irregular way, which may, in many cases, makes the crop and the agricultural production in non irrigated crops impracticable. For this author, concerning the rainfall for the agriculture, in general the frequency must be considered as an aspect more important than the total volume of rainfall. About this, SILVA et al. (1998) affirm that studies of the rainfall distribution and the intensity of the potential evapotranspiration must be considered for the crop implantation, enabling to estimate the water availability and the possible condition of water during the crop cycle.

In their researches, BARNI and MATZENAUER (2000) identified the rainfall as the main climate variable which over the years determined variations in grain production, in different regions of the state of Rio Grande do Sul. According to BERLATO and FONTANA (1999), the rainfall from December to March explains approximately 80% of the interannual variation of the crop yield in the state. In different researches it was observed that the distribution of the rainfall was the climate variable which caused most part of the reductions in the agricultural production in Rio Grande do Sul in the last thirty years.

The planning of the agricultural activities based on the analysis of climate elements is very defended in the technical community. NIED et al. (2005) affirm that it is necessary the knowledge of a minimum interval of data of rainfall so it can be reflected about the environmental conditions of one region in relation to a certain agricultural crop, because since rainfall is a phenomenon of random occurrence, its quantity, distribution and intensity may vary considerably.

In a simplified form, the word climates are classified in three main divisions – the climate from the low, medium and high latitudes. In climatology, these three divisions are subdivided in 14 climatic regions, still adding the climate of high temperature, in which the altitude comes as a dominant controller. According to this theory, Guarapuava, as well as all the South region of Brazil fits into the classification of "Climates of medium latitudes – climates controlled by tropical and polar air masses".

Considering the climate classification by KÖPPEN (1948), the region of Guarapuava is characterized by presenting a Humid Subtropical Mesothermic climate (Cfb), which have as main characteristics the occurrence of fresh summers (average temperature inferior to 22 °C), winters with events of severe and frequent frost (average temperature superior to 3 °C and inferior to 18 °C) and absence of dry season. Altitude, which ranges between 1000 m and 1200 in relation to the sea level, combined with latitude of 25° guarantees a mild climate in most part of the year. According to MENDONÇA (1997), the climate conditions are characterized by influences of the intertropical atmospheric systems (Atlantic tropical mass, continental tropical mass and equatorial continental mass) and polar (Atlantic polar mass), and they have, however, moderate participation in the intertropical systems and more effective participation in the extratropical system, which gives to the region a climate with subtropical characteristics.

The state of Paraná, although with great annual water availability in most of the regions, it presents wide variation in the time and space distribution of the rainfall. In the region of Guarapuava – PR, the period recommender for the crop seeding is between September 21 and November 10 (CARAMORI, 2003).

The climate water balance, developed by Thornthwaite and Mather (1955) is one of the several ways to monitor the variation of water storage in soil. This determination provides an estimate of ranges in the content of water in the soil of a local considering the accounting of the entrance of water by the rain (P) and from the atmospheric demand, by the reference evapotranspiration (Eto), trough the process which considers the maximum volume of water which can be stored in certain depth of the profile, by knowing the available water capacity (AWC). The estimate of the water balance by this method enables also the determination of other related variables.

The Sequential Water Balance enable us to estimate the probability of occurrence of water deficiencies or excesses in different types of soils, trough the study of long series of climate data. For Assis et al. (1996), the longest the series, the best is the adjustment of the functions of distribution and the most accurate is the estimate of probability of occurrence.

The water balance is important as tool to evaluate the intensity of the enter and input and outgoing water in soil and, consequently, to define the most likely periods of water scarcity for plants, related to the knowledge of the factors which compose it (evapotranspiration, rainfall, internal drainage or capillary rise and variation of the water storage in the soil). For CARAMORI (1991), the knowledge of the plant characteristic, mainly, from its phenology, which represents the starting point for the coherent interpretation of the results of the balance.

For the study of the water regime from a place, evapotranspiration is an essential factor as integrant of the process of water flow from soil to atmosphere. For FERREIRA and PEREIRA (1998), evapotranspiration is one of the main compounds of the water balance in the soil, and has wide utility in climatology, either for climate classification, or for quantify the regional available water trough the comparison of the rainfall against the variation on the content of water in soil.

Among different methods of estimates evapotranspiration evaluated, Sediyama (1996) considers that the combined model of Penman-Monteith is one of the most advanced. In the improvement of the method, Monteith developed based on the Penman equation, a model which not only conciliates the aerodynamic and thermodynamic aspects, but also includes the resistance of the air to the flow of sensible heat (RAH) and water vapor (RAV) and the resistance of the vegetated surface (RC) to the transference of the water vapor to the atmosphere.

The objective of the work was to evaluate the behavior of climate characteristics as rainfall, temperature, relative humidity of the air, sun radiation and wind speed aiming to interpret their variations and make the information available for the management of agricultural crops in Guarapuava – PR.

Material and methods

The analysis was performed based of an historical and continuous series of average daily climatologic data for the period from 1984 to 2008, which were compiled from the archie from the meteorological station of the Universidade Estadual do Centro Oeste – UNICENTRO (State University of Mid West), in Guarapuava – PR, located in the latitude 25°23’02” S, longitude 51° 29’43” W, at 1026 meters of altitude, and information of the achieve of the Instituto Agronômico do Paraná – IAPAR (Agronomic Institute of Paraná).

The data used were temperature and air relative humidity, rainfall, sun variation and wind speed accumulated at 10 m of height. Considering the methodology by Köppen (1948), the regional climate is classified as Cfb Humid subtropical mesothermic.

The climate water balance was determined by the method composed by Thornthwaite and Mather (1955). It began in the month of July 1984, in the moment that the soil presented the conditions of superior limit of water storage (field capacity – FC) due to the large period of high rainfall index, and it was calculated without interruption until May 2008. To calculate this, it was considered the value of available water capacity in soil (AWC) of 100 mm, which according to what is understand of Grego and Vieira (2005), is the most usual pattern when the objective is the average characterization of the sequential water availability of a certain parcel of the soil.

The reference evapotranspiration (Eto) was estimated by the Penman-Monteith method, pattern model FAO (ALLEN et al., 1998)(Equation 1).

$$Eto = \frac{0,408 \times s \times (Rn - G) + \dfrac{y \times 900 \times U_2 \times (es - ea)}{T + 275}}{s + y \times (1 + 0,34 \times U_2)} \quad (1)$$

in which:

Eto – Reference evapotranspiration in mm d^{-1}:

Rn - Total daily net radiation (MJ m^{-2} d^{-1});

G – Flow of the heat in the soil (MJ m^{-2} d^{-1});

900 – Factor of conversion

γ - Psychrometric constant (0, 063 kPa °C^{-1}):

T – Average temperature of the air (°C);

U2- Wind speed at 2 m (m s^{-1});

es – Saturation vapor pressure (kPa °C^{-1}), calculated by:

$$es = 0,6108 \times 10^{(7,5T/237,3+T)}, \quad (1.1)$$

ea - Partial vapor pressure (kPa), calculated by:

$$ea = (es \times UR)/100 \quad (1.2)$$

Declivity of the pressure curve of vapor in the temperature of the air (kPa), calculated by:

$$s = \frac{4098 \times es}{(T + 237,3)^2} \quad (1.3)$$

The average wind speed measured at 10 m of height (U_Z with Z=10) was converted to 2 m, through the following relation (Allen et al., 1998):

$$U_2 = U_Z \frac{4,87}{\ln(67,8(Z) - 5,42)} \quad (1.4)$$

The statistic evaluation of the data was performed by analysis of variance and test of average comparison by the method of Tukey at the level 5% of probability, using the statistic software Assistat version 7.5 beta.

Results and discussion

From the evaluation of the climate data it was determined the monthly average distribution of the rainfall along the year aiming to observe the limits of the rainfall volume and available water for the crops in condition of open field (Figure 1).

The results show that the months of spring and summer are those which present the highest index of rainfall, always superior to 160 mm, being January and October the months with higher average with index superior to 200 mm. The months of fall presented the lower values that are always inferior to 130 mm, with an emphasis to the month of August that has 88 mm, which is the lowest monthly index.

The high index of the coefficient of variation for this parameter, always superior to 40% and may reach 80% in months from fall and winter, and may be interpreted as indication that this range along the months of the year may be also expressive along the years, with the occurrence of discrepancy in the monthly averages, fact that is directly linked with the productive behavior of the agricultural crops, according to what is emphasized by DALLACORT et al. (2006) and representing higher risk of occurence of periods with water scarcity for fall and winter crops, for example wheat, barley, oat, among others.

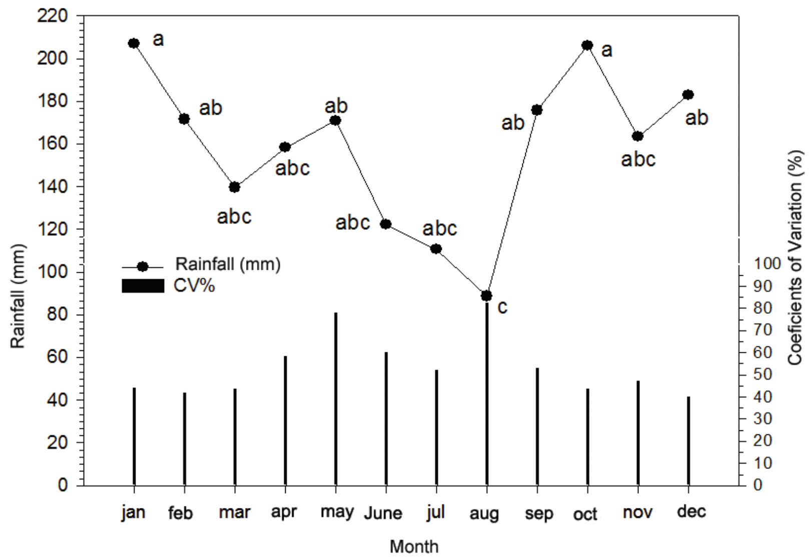

Figure 1. Monthly rainfall determined based on data from the period from 1984 to 2008 in Guarapuava – PR.

About the distribution of rainfall it can be verified that the summer months tend to have the reduction of the rain volume, from the beginning to the end of the season, as well as winter, being noteworthy the inverse behavior of the fall months with is the increasing period of water replacement. The highest monthly range is verified in the period August-September whose index vary more than 100%, ranging from less than 90 mm in August to approximately 180 mm in September.

These results demonstrate that although it is verified lower index of rainfall from June to August, the rainfall average of the month of September indicates a period of water replacement. In the case of spring and summer crops, as for instance maize, beans and others, this result represents reduction of the risks of lack of soil humidity for seeding and occurrence of water scarcity. These crops develop their cycle in later period, when the index of rainfall are higher, however, the coefficient of variation for this parameter demonstrate that the rainfall distribution presents irregularities along the years, with risks of occurrence of periods of draught even in spring and summer, in which there is also the highest losses of water for the atmosphere due to the increase of the average temperature.

The evaluation of the behavior of the reference evapotranspiration (Eto) is presented in Figure 2, in which it can be observed a wide range in the monthly external values from less than approximately 75 mm in June, to 150 mm in December.

It can be verified that the period with highest potential of extraction of ground water occurs from October to March, whose index range from approximately 130 to 160 mm per month. The months of April to September presented the lower values which are between approximately 70 to 100 mm per month, with the lowest averages for the months of June and July.

The coefficients of variation for this parameter are inferior than 20% and, approximately, well distributed along the year, demonstrating that the behavior of the potential of loss of water from the soil to the atmosphere is less variable that the replacement by the rainfall. This data can represent a preoccupation in terms of non irrigated agricultural crops; constant losses of water to the atmosphere, when associated to the possibility of occurrence of dryer periods due to lower index of rainfall, may cause damages by water stress to the crops, according to FRIZZONE et al. (2005).

Based on the availability of data of rainfall and evapotranspiration it was determined the annual water balance (Figure 3). With this balance it is possible to extract information for a better interpretation of the behavior of the water distribution and of its inter-

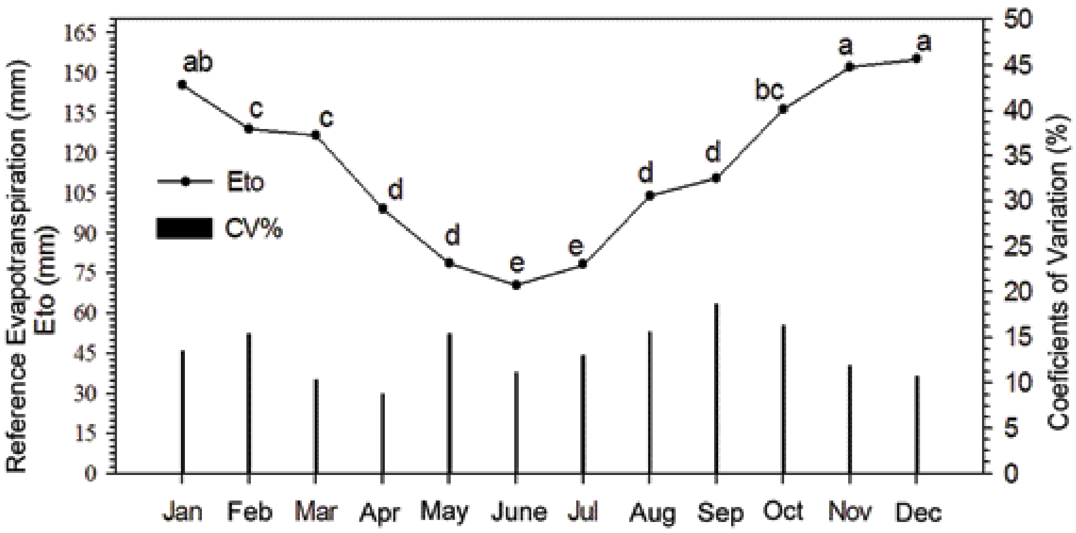

Figure 2. Reference evapotranspiration by month along the year determined based on climatic data in the period from 1984 to 2008 in Guarapuava – PR.

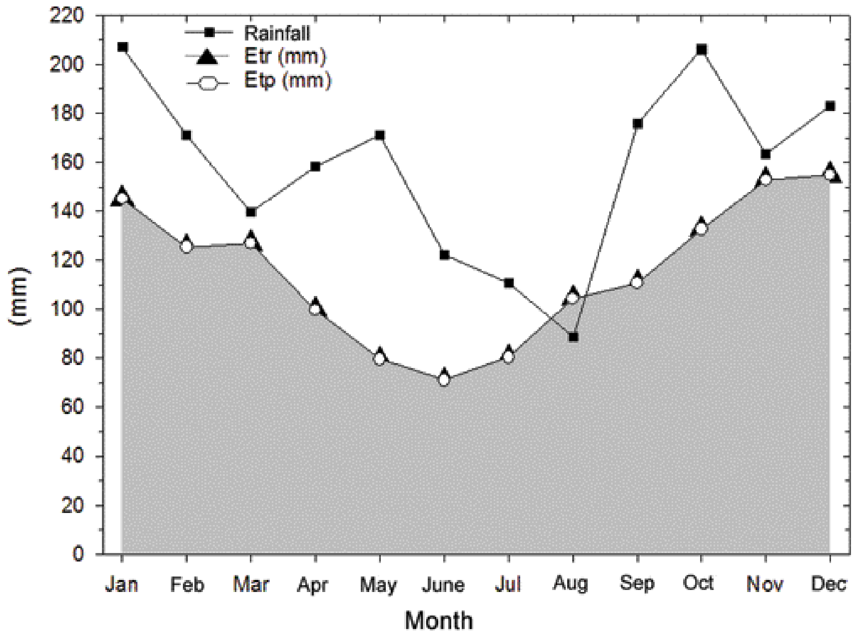

Figure 3. Sequential water balance by the method of Thornthwaite-Mather (1955), based on climatic data of the period from 1984 to 2008 in Guarapuava – PR.

relations with the Eto along the year and, specially, to visualize the average pattern of the water conditions during the year or specific periods of interest for the agricultural crops in the region.

In the evaluation of the monthly behavior of the water balance it can be verified that the income of water in the soil by the rainfall is superior to the outgoing by evapotranspiration for all the months of the year, except in August, which is also the only month in which it is not verified the existence of water exceeding, which is represented by the positive value of the difference between the rainfall volume is superior to the outgoing by evapotranspiration for all the months of the year, except in August, which is also the only month in which it is not verified the existence of water exceeding, which is represented by the positive value of the difference between the rainfall volume and the Eto. However, in this case, it is also not verified the existence of water scarcity, which would be interpreted by the occurrence of values of real evapotranspiration (Etr) lower than the Eto. This occurs because the method presupposes that in the first period of occurrence of values of rainfall lower than those from Eto, the storage of the water on the soil which had maximum values, may supply without restrictions the potential demand of the evapotranspiration.

In this sense, OLIVEIRA (1996) describes that the most restrictive effects caused by soil in relation to the outgoing of water will increase sequentially, together with the reduction of the water storage, being generally null when the soil presents conditions close to the superior limit of its capacity of water storage.

With these results, it is possible to infer about the great agricultural potential of the region, with characteristics of temperature and water distribution that, in a general way, may satisfy the necessities of most of the agricultural crops which develop in different periods of the year. However, it must be considered that these are average values, obtained from an historical series of climatic information, whose evaluation represents probability, and whose monthly intervals may be wide when it comes to water availability for agricultural crops, whose water supply must consider as more important the distribution than the total amount of rainfall.

The average behavior of the climatic characteristics temperature and relative air humidity, wind speed and sun radiation, used for the determination of the Eto are presented in Figure 3. It can be verified that the average temperature ranges from approximately 13 and 22 °C, with the highest averages verified for the period from October to March, between 18 and 22 °C, being January the month which presents the highest average of temperature of the year. The period from April to September present the lowest averages with the temperatures inferior than 16 °C, being the month of July the coldest, with average temperature inferior to 13 °C. These data, if associated to the averages of rainfall, collaborate to the climatic characterization of Guarapuava as Cfc climate, temperate moderate rainy, according to the model of climate classification by KOEPPEN (1948).

The sun radiation presents behavior similar to those presented to air relative humidity and temperature, with highest values in spring-summer and lowest in fall-winter, which is normal for these periods of the year, according to Caramori (2003). The coefficients of variation for this climatic characteristics are always inferior to 15%, however, in relation to temperature, it can be verified that the winter period tend to present higher variation, especially in the months of June and July, indicating that in some years it may occur winters with lower average temperatures and with more intense cold, influencing in an atypical way the crops which developed in this period.

For agricultural crops cultivated in spring-summer, it is observed that when the seeding is performed in the end of the recommended period, the crop tends to develop its vegetative cycle in conditions with higher temperature, especially the phenological phases of the vegetative stage, when compared to earlier seeding. For the soybean crop, for instance, which is seeded from November, the temperatures in average do not represent risks to the cultivation, and the highest uncertainties may be associated to the irregularities in the rainfall.

The average values of air relative humidity range from 70 to 80%, being considered high values according to what is emphasized by Silva and Guetter (2003). However, this behavior may be interpreted as consequence of the regional characteristics with temperatures that tend to be mild and annual rainfall index superior to 1800 mm. However, it is verified that there is a tendency that the lowest average values of this parameter are grouped in the period from August to November. In this case, it is possible that the highest averages of wind speed, which also tended to be presented in this period, collaborate with the removal of the air humidity.

In relation to the wind speed, it can be observed that the average values range from 11 to 16 km h^{-1}, considered high according to Sansigolo (2005). This behavior, besides being directly associated to the variations of humidity and be essential component to the variations of the Eto, acts also over the behavior of the agricultural crops in general, and may affect the physiologic behavior, specially when related to the transpiration, including possible physic damages in plants.

Besides, CUNHA et al. (2007) emphasize that in regions with more constant winds the operations of application of products by spraying tend to be less efficient and must be performed with more attention and planning. It is also verified in Figure 4 that in the case of the crops with planting recommended in the beginning of spring there is the coincidence that most part of the vegetative cycle occurs during the months of highest average of wind in the region. This is an important factor to be considered in the planning of the agricultural activities, aiming to reduce the impacts and improve the results.

Conclusions

The months of June, July and August are those which present the lowest index of rainfall, with August as the month with higher probability of occurrence of water stress for winter crops.

The water balance does not represent, on the average, the occurrence of defined periods of water deficiency. The month of September marks the period of beginning of water replacement, being the months of October and December those which presented the highest rainfall volumes. The risks of water deficiency are lower for summer crops than for winter crops.

Compared to other components, rainfall presents the highest historical index of variability.

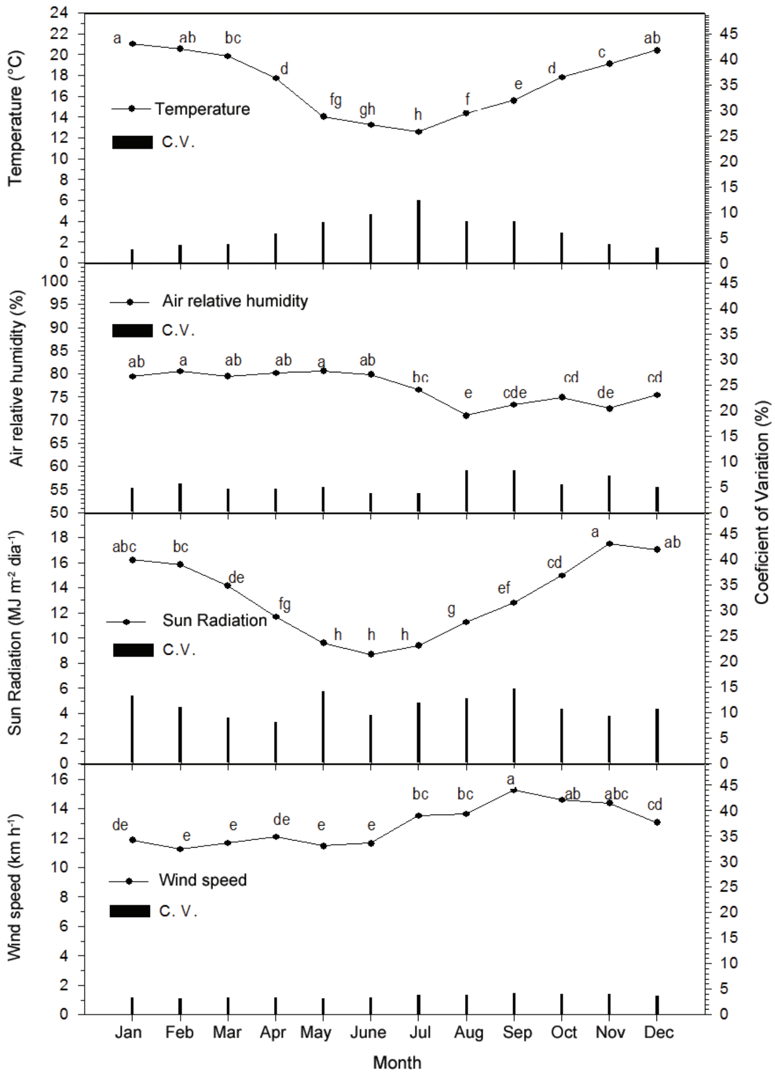

Figure 4. Air temperature, air relative humidity, Wind speed and Sun radiation along the year, determined based on climatic data in the period from 1984 to 2008 in Guarapuava – PR.

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