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Scientific paper

Evaluation of corn crop phenology cycle in Guarapuava, South of Brazil based on the thermal sum

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Abstract

The thermal availability has a direct influence on the phonological development of plants, so that local or warmer periods provide more rapid development of them. The objective was to evaluate the climate behavior in order to establish the probable duration of phenological phases and the full cycle of development of the corn crop for the region of Guarapuava-PR, based on thermal sum. The study was developed based on a historical series of average daily meteorological data for the period from 1984 to 2008 compiled from the collection of the meteorological station of the Universidade Estadual do Centro Oeste - UNICENTRO in Guarapuava-PR. In the study, it was used the agricultural zoning of the State of Paraná, recommended by the Agronomic Institute of Paraná - IAPAR, where it considers suitable for the sowing of the corn crop sowing of the period of September 21 to 10 of November. The treatments consisted of estimates of the sowing dates of 1) Sept 21, 2) Oct 01, 3) Oct 11, 4) Oct 21, 5) Oct 31 and 6) Nov 10. The calculation of the thermal sum in degree-days (DD) was performed from the mean air temperature minus the base temperature. It was assumed that the development of the plants was constant between the base temperature below 10°C and temperatures above 32° as base. The use of the thermal method is a practice that can be used to estimate the duration of phenological phases and the cycle of development of the corn crop. When the cultivation of corn is held within the period recommended as agricultural zoning of Paraná, the cycle of cultural development between sowing and physiological maturity varies between approximately 114 and 122 days.

Keywords: water balance, water deficit, Cfb climate.

Introduction

The effect of the temperature over the vegetal development has been described using the conception of heat units, as degree-days, which assume that the development is Constant in a thermal range between a minimum temperature or base temperature and a maximum temperature (STEWART et al., 1998), below and above which the plant does not develop and, if it does so, it will be in very reduced rates.

During the last decades agriculture went trough expressive changes, and the production and the productivity reached levels increasingly high. However, AYOADE (1998) describes that despite the technological and scientific advances, climate is still the most important variable in the agricultural production, due to the potential of limiting the crop yield and by the influences that it has over all the stages of the agricultural production chain, including harvesting, storage, transport and commerce.

It must be always considered that a climatic variable may change facing other variable. OMETO (1981) emphasizes that the climate variables are inter-related in the influence that it has over the crop, with expression the daily, seasonal and annual variables. For the author, the choice of the crop to be developed begins from the climatic local characteristics, since each culture depends on the soil, on the sun radiation, rainfall, relative humidity, besides seasonality.

In relation to the climate over the corn crop, it must be considered that the relative influence of the factors which affect the season of the crop growth ranges according to the specific characteristics of each region. DOORENBOS and KASSAN (1994) recommend regionalized study about the relation between fall of relative yield and relative deficit of evapotranspiration, with test of the factors of response of the production to the water deficit, since

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the conditions of production during the crop cycle are specific of the place and variety used.

The phenological stages appeared aiming to ease the detailing in the steps of plant development. For BERGAMASCHI (2006) it is the transformation that will occur in the processes of plant growth and development, as germination, sprouting, flowering, silking, maturation and their knowledge that will help to improve the description of the crop cycle. The author adds that phenological stages may have subdivisions (subperiods). A subperiod is defined as time passed between two consecutive phases, considering that, along them, the necessities and structures of the plant are practically constant. Some subperiods are easily observed, with the appearance and disappearance of organs, while others, since they are invisible (organs), are only perceptible trough detailed exams, as microscopy or chemical analysis.

According to MATZENAUER (1997), the prevision of the phenological stages is important in the planning of the best periods of seeding and also in the study of adaptation of cultivars. For MATZENAUER (1997) the application of the phenology would be in order to determine the critical periods of the crops to water deficiency, aid in the periods in which there is higher demand or necessity of water, in the elaboration of agricultural zoning, for periods with best application of fertilizers, for the classification of cultivars concerning the precociousness and in the plague management.

FANCELLI and DOURADO NETO (2000) adapted the scale from HANWAY (1966) in conformance with the development cycle of the maize crop, subdividing it in five periods: (1) germination and emergence; (2) vegetative growth; (3) flowering; (4) fructification and; (5) physiological maturation.

In Table 1, it is presented the phenological stages of the corn crop, adapted from RITCHIE et al. (1993).

The concept of degrees-day (DD) and accumulated degrees-day (ADD) was introduced in order to overcome inappropriateness in the calendar to predict phenological events, as well as to the agro climatic zoning of the crops, since they are independent on the period and place of cultivation of the plant. The thermal availability has direct influence over the phenological development of plants, so that hotter places or periods determine their faster development. Thus, in hotter regions or even periods, there is more precociousness in the plant development (BERGAMASCHI, 2006). Therefore, GADIOLl et al. (2000) emphasize that in the corn development, the duration of the cycle in days is inconsistent, due to the fact of the duration of sub periods and plant cycles are associated to the variations of the environmental conditions and not to the number of days.

Temperature is the most important climate element to predict the phenological events of the crop, as long as there is no water deficiency. In relation to the base-temperature, BERLATO and MATZENAUER (1986) emphasize that in general it must be considered the base temperature inferior to 10 °C in order to calculate the thermal sum of the corn crop. For MALUF et al (2000), the thermal demands of most of the corn genotypes may range for the processes of germination and growth, however a few develop in temperatures below 10 °C. RITCHIE and NESMITH (1991) consider that estimates of the superior threshold or maximum temperature for corn are from 19 to 34 °C.

The objective of the work was to evaluate the climatic behavior aiming to establish the probably duration of the phenological phases and the total

Table 1. Phenological stages of one corn plant. Guarapuava-PR, 2011.

Vegetative stages	Reproductive stages
VE- emergence	A- anthesis
V1- first leaf	R1- flowering and fecundation
V2- second leaf	R2- Milk grain
V3- third leaf	R3- Dough grain
V6- sixth leaf	R4- Soft grain
V9- ninth leaf	R5- Hard dough
V12- twelfth leaf	R6- Physiological Maturity (PM)
V15- fifteenth leaf	
V18- eighteenth leaf	
VT- tasseling	

Source: adapted from RITCHIE et al. (1993).

cycle of development of corn crop for the region of Guarapuava (PR), based in the accumulated thermal sum.

Material and methods

The study was developed based in an historical series of average daily meteorological data for the period from 1984 to 2008 compiled from the acquis of the meteorological station of the Universidade Estadual do Centro Oeste – UNICENTRO (State University of Mid West), located at 25°23'02" S, 51° 29'43" W, with altitude of 1026 meters. It was considered for the study the Zoneamento Agrícola do Estado do Paraná (Agricultural Zoning of the State of Paraná), recommended by the Instituto Agronômico do Paraná – IAPAR (Agronomic Institute of Paraná). CARAMORI (2003) considers as recommended for the seeding of the corn crop the seeding period from September 21 to November 10.

The treatments were prediction of seeding in 1) Sept 21, 2) Oct 01, 3) Oct 11, 4) Oct 21, 5) Oct 31 and 6) Nov 10. After the determination of the seeding periods, they were subdivided and their phenological stages were characterized, following the classification adapted and their phenological stages characterized, according to the classification adapted and recommended by FANCELLI (1986): 1) VE-V6, 2) V7-V10, 3) V10-VT, 4) VT, 5) A-F (R1), 6) R2, 7) R3, 8) R4 and 9) R6, being briefly the sub periods (V) correspondent to the number of leaves completely developed present in the plant, VT (tasseling), A-F (antheis and fecundation) and R (reproductive period with phases of grain development, considering R4 – soft grain) and R6 physiological maturation.

The calculation of the thermal sum in degrees-day (DD) was performed from the average air temperature subtracted from the base temperature. It was assumed that the plant development was constant between the inferior base temperature 10 °C and superior base temperature 32 °C according to MONTEITH and ELSTON (1996).

It was considered the equation 1:

$$UTD = \sum_{i=1}^{n} \left[\frac{(Tmáx + T\min)}{2} - Tb \right] \qquad (1)$$

In which: UTD = Daily thermal unit (°C); Tmáx = maximum temperature of the considered day (°C); Tmin = minimum temperature of the considered day (°C); Tb = Inferior base temperature.

The average thermal sum needed in the sub period between the emergence (E) and Anthesis (A) used for the corn crop early group was 857 Daily Thermal Unit (UTD), in general applied for cultivars of normal cycle from the anthesis (considering that, in this case, the cycle length increases in the sequence for early, normal and late cultivar, respectively).

It was used an accumulation of 293 UTD and 835 UTD in order to estimate the final date of the sub period with the occurrence of Milky maturation (MM) and Physiological Maturation (PM), respectively, considering results taken by NIED (2003), for the sub periods emergence to stage V6 (six leaves), stage V7 to pre-tillering, stage VT (tillering) and stage R2 (milky grain), it was considered an accumulation from 0 to 295 UTD, 295 to 470 UTD, 470 to 660 UTD and 1010 UTD, respectively, considering the results (GADIOLI, 2000). The results were submitted to the statistical analysis of variance and test of average comparison.

The statistic analysis was performed using the software Sisvar. It was performed the analysis of variance and Tukey test for average comparison with probability 95%. The descriptive analysis was performed by the grouping in Quartis of percentage according to PIMENTEL GOMES (1990).

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

Results and discussion

The results of the evaluation of the thermal sum for the phenological characterization of the corn crop in Guarapuava (PR), determined from average climate values of 24 years are represented in Table 2, and the graphic dispersion of the temporal length of different phenological phases is presented in Figure 1. In order to complete the length of the development cycle until the physiological maturation, it was added the period of six days from the seeding period, necessary for the germination.

The data referent to the vegetative cycle presented in Table 2 extends to the physiological maturation. Accordingly, the elaboration of inference considering the seeding - harvest cycle, it must be considered that from the physiological maturation the crop still needs time in the field for the reduction of the content of humidity in the grain,

Table 2. Average length of the phenological staged of the corn crop determined based on the thermal sum for the climate conditions of Guarapuava (PR).

Seeding period	Length of the phenological stages (days)*								Total vegetative cycle (days)
	VE-V6	V7	V10	VT	A-F(R1)	R2	R3	R4-MF	
Sept 21	22.33a	12.66a	12.95a	12.70a	9.50a	7.37a	11.70a	22.45ab	121.91a
Oct 01	21.33b	12.08ab	12.08b	12.37ab	9.70a	7.41a	11.37a	22.45ab	119.50b
Oct 11	20.66bc	11.95abc	12.33ab	12.16ab	9.75a	7.16a	11.16a	22.50ab	117.50c
Oct 21	20.04cd	11.66bc	11.70b	12.29ab	9.58a	7.08a	11.08a	22.41b	115.87d
Oct 31	19.37de	11.33bc	11.79b	11.95b	9.29a	7.04a	11.33a	22.58ab	114.70e
Oct 10	18.87e	11.16c	11.58b	11.70b	9.25a	7.04a	11.04a	23.16a	113.83e
Average	20.43	11.81	12.07	12.20	9.54	7.18	11.28	22.59	117.25
Dms	0.97	0.85	0.79	0.73	0.52	0.57	0.68	0.74	0.94
C.V. %	5.70	8.61	7.87	7.22	6.59	9.51	7.28	3.94	1.01

** In the column, averages followed by the same letter do not differ by Tukey test at probability (p < 0.01).*

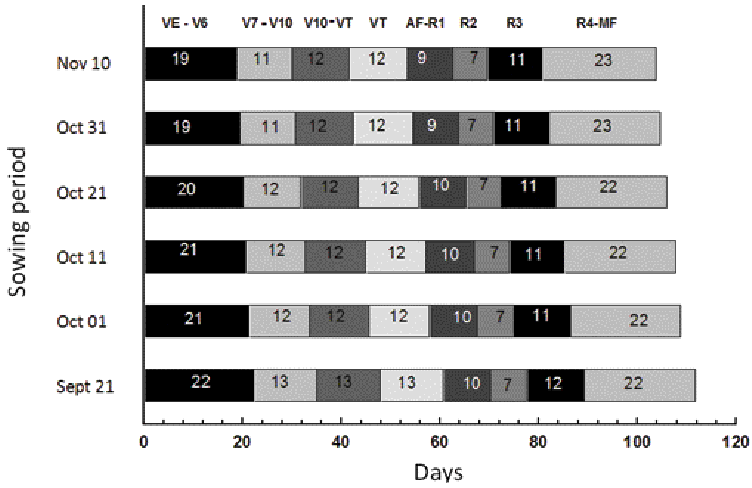

Figure 1. Length of phenological phases of the corn crop in function of the thermal sum in Guarapuava (PR). (Average *1984 -2008).*

in this case, according to MATZENAUER (1997) for approximately 20 to 25%, which in normal climate conditions occur in approximate period of 15 days after the physiological maturation.

It is verified that the total estimated vegetative cycle ranges between 114 and 122 days, approximately, with sequential shortening for later seedlings in relation of the recommended period from September 21.

The total shorten of the cycle among the extreme data of seeding was approximately 8 days. This difference may be larger in regions with different climatic characteristics, according to what was emphasized by authors as FORSTHOFER (2004) and GADIOLI et al. (2000). However, the climate characteristics of the region of Guarapuava (PR), with climate Cfb mesothermic humid, do not present thermal amplitude with values of extreme variation during the crop cycle which may cause great ranges in the accumulation of thermal sum and higher acceleration of the crop cycle.

When analyzing the total length of the phenological phases of the vegetative period (VE to VT) it is noted that they extended by a period which ranged between, approximately, 60 and 53 days for seeding performed in September 21 and November 10, respectively. These results may be considered the main responsible for the differences verified in the total vegetative cycle length, since for the stages of the reproductive period the differences are not very expressive and have no statistic significance.

In Figure 2 it is presented the data about the behavior of the maximum and minimum temperatures with the respective pattern deviation in relation to the average. It is verified an increasing behavior of the temperature until approximately the end of the month of November. It may be observed that the daily thermal units (UTD) presented lower values for earlier seeding and, together with the advance of the seedlings in the periods, the UTD increased in accordance with the temperature rise, which caused the shorten of the period needed to complete the accumulation of the thermal sum of the phases of the vegetative period. Similar results are described by BRUNINI et al. (2006), who verified that the increase in the average temperature accelerated the phenological development of corn plants.

By Figure 2, it can be noticed that the temperature range tend to concentrate the values in the development band of the corn crop, considering that until close to October 15 the line which determines the minimum average pattern deviation presents values that are not in the limit of the inferior base temperature.

These determinations consider climatic data from several years for the composition of average values, thus, it is expected that the amplitude of the temperatures reach more extreme values in specific years. In this sense, it can be inferred that the region presents mild summers, however, the minimums of some winter days and including spring reach commonly negative values, in this case, possibly the phenological development of the culture in the region is more frequently affected by temperatures below the inferior base that above the superior. This behavior is determined by the climate conditions of the South region, where the climate subtropical and temperate prevail, according to the description by VILLA NOVA and PEREIRA (2006).

This process is more evident for the phenological phases of the vegetative period for seeding until October 21, reducing the proportions of the differences in relation to the seeding of October 31 and November 10, since they develop in period where there is the stabilization of the daily averages. For the reproductive period, the crop seeded in September 21 will reach the anthesis approximately in November 30 (70 days after the seeding), demonstrating that independent on the seeding period, the phonologicals of the reproductive period will tend to range less

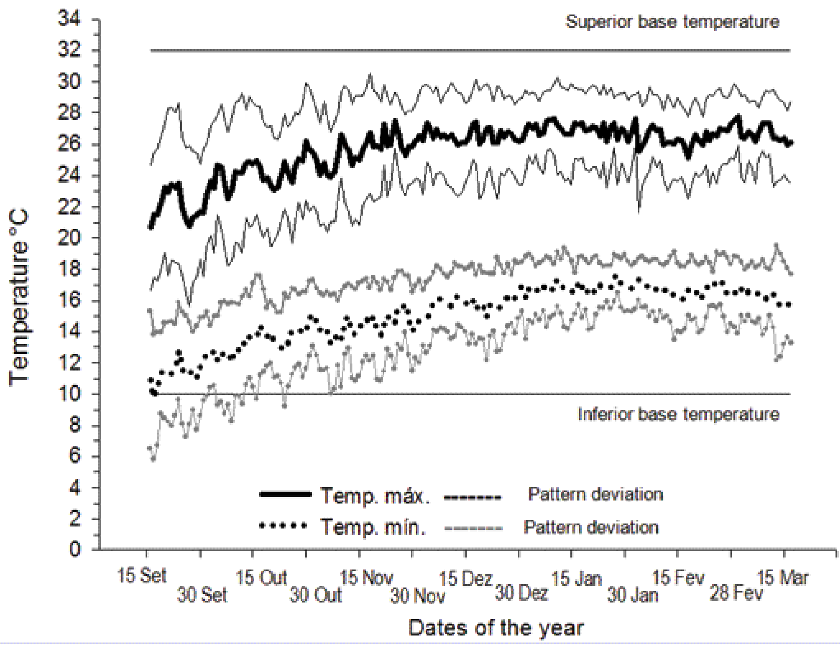

Figure 2. Average maximum (Máx.) and minimum (Mín.) air temperature with pattern deviation of the average, along the period of cultivation of the corn crop in Guarapuava (PR) (Average 1984 – 2008).

their extension because they occur in more stable thermal conditions. Thus, even though the extreme dates are separated in 53 days in time, the average climate variation from the month of December are not as expressive as those which occur in September, October and November.

In the region of Ponta Grossa (PR), located geographically close to Guarapuava and presenting thermal conditions approximately close to Guarapuava (PR), QUIRRENBACH (2007) concluded that the phenological development in the productive period of the corn is less sensible to the thermal sum in relation to the vegetative period. Thus, possibly, even that the tendency of increment of the temperature was maintained from December, possibly the responses in relation to the duration of the total vegetative cycle would maintain the same behavior.

In relation to the results of the statistic evaluation, it is noticed in Table 2 that the coefficients of variation for length of the phenological phases present values inferior than 10%, which besides providing the expression of significant statistic differences also shows that the thermal sum in the period recommended for the cultivation of crop in the region is a parameter which presents consistence along the years, indicating that this is a tool of high accuracy for the planning of the corn crops.

From the result, it may be inferred that with the use of the evaluation of the thermal sum it is possible to predict the corn crop cycle length, however, several research results, as those presented by GADIOLI (2000) and NIED et al. (2005) have showed that other factors of climate origin, mainly the occurrence of period of water deficiency may affect the phenological development and the total cycle of the corn crop.

Conclusions

Considering the climate conditions occurred in the period between 1984 and 2008 in the region of Guarapuava (PR), it is concluded that:

The use of thermal sum is the practical methodology which may be used for the prevision of the duration of the phenological stages and of the development cycle of the corn crop.

When the cultivation of crop is performed in the recommended period according to the agricultural zoning of Paraná, the cycle of development of the crop between seeding and physiological maturation ranges between approximately 114 and 122 days.

The most expressive days in the temporal duration of the different phenological phases of corn occur during the period of vegetative development and less markedly in the reproductive period of the crop cycle.

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