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SWITCH CORN A-7573 PHENOLOGY AS A FUNCTION OF SOIL MOISTURE TENSION

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ABSTRACT

The present study had the objective of evaluating the effect of soil moisture tension on the phenological behavior of sweet corn hybrid A-7573 under conditions of controlled irrigation. Four different soil moisture tension treatments were applied, irrigating the crops when tension increased to -5 kPa, -30 kPa, -55 kPa, and -80 kPa. Manometer tensiometers were used to measure soil moisture tension, installing the capsule at a depth of 30 cm, immediately below the irrigation tape. Nine phenological stages were evaluated: three vegetative (V6, V9, and V12), and six reproductive ones (R1, R2, R3, R4, R5, and R6). No differences were observed between the more humid treatments regarding the time necessary to reach the vegetative or reproductive phenological stages, nor in the number of growing degree days required (GDD10). On the other hand, in the treatments corresponding to the higher tensions, differences were observed in the times needed to reach the vegetative and the reproductive phenological stages, as well as the accumulation of GDD10, both between themselves as with the more humid treatments. Moisture deficiency in the soil delayed the appearance of the phenological stages corresponding to vegetative development, but accelerated the appearance of the phenological stages corresponding to reproductive development. Crop harvest was delayed four and six days in treatments -55 and -80 kPa, respectively, according to the more humid treatments.

Key words: irrigation, degree-days, phenological model, water stress, temperature

FENOLOGIA DO MILHO VERDE A-7573 COMO FUNÇÃO DA TENSÃO DE ÁGUA NO SOLO

RESUMO

O presente estudo teve como objetivo avaliar o efeito da tensão de umidade no solo sobre a fenologia do milho verde, híbrido A-7573, em condições de irrigação controlada. Foram aplicados quatro tratamentos diferentes de tensão de umidade no solo, com a irrigação sendo realizada quando a tensão atingiu -5 kPa, -30 kPa, -55 kPa e -80 kPa. Foram usados tensiômetros com manômetro para medir a tensão de umidade no solo, cujas cápsulas foram instaladas a 30 cm de profundidade, imediatamente abaixo da faixa de irrigação. Foram avaliados nove estádios fenológicos: três vegetativos (V6, V9 e V12) e seis reprodutivos (R1, R2, R3, R4, R5 e R6). Não foram observadas diferenças entre os tratamentos mais úmidos em relação ao tempo necessário
para atingir os estádios fenológicas vegetativos e reprodutivos, nem no número de graus dias de desenvolvimento requeridos (GDD10). No entanto, nos tratamentos referentes às tensões mais altas foram observadas diferenças no tempo para atingir as etapas fenológicas vegetativas e reprodutivas, bem como na acumulação dos GDD10. A deficiência de umidade no solo atrasou o aparecimento dos estádios fenológicos do desenvolvimento vegetativo, mas antecipou o aparecimento dos estádios fenológicos do desenvolvimento reprodutivo. A colheita da cultura foi atrasada em quatro e seis dias respectivamente nos tratamentos de -55 e -80 kPa, em relação aos tratamentos mais úmidos.

Palavras chave: irrigação, graus dia, modelo fenológico, estresse hídrico, temperatura base

INTRODUCTION

Knowledge of the evolution of the phenological stages of corn is important in some practical processes of agronomy, since it simplifies the creation of irrigation programs (Kar & Verma, 2005) and facilitates the programming of agricultural activities (Kiniry & Bonhomme, 1991) by giving the dates when diverse physiological processes will occur. It also allows to predict the decrease in yield during the flowering and grain filling stages, caused by biotic and abiotic stresses (Hodges, 1991), as well as establishing the harvest date, and defining the best time for sowing. Under field conditions, the development ratio of corn crops can be modified by several factors such as light period, soil moisture, solar radiation, soil fertility, and, most importantly, temperature (Hodges, 1991).

Nevertheless, a water deficit in any growth stage of the plant affects many anatomical, morphological, physiological, and biochemical processes (Kramer, 1983). Doraiswamy & Thompson (1982) and Dale & Daniels (1995) argue that water stress during the early development of the corn plant delays flowering and maturity. Wong et al. (1983) observed that water stress accelerated flowering stage an average 2.2 days in 49 sorghum genotypes, while at the same time decreased the duration of the flowering. Bennouna et al. (2004), on the other hand, reported that the appearance of the ligule in the corn leaf is delayed as a consequence of water stress.

Moreover, Bolaños & Edmeades (1993) state that water deficit reduces photosynthesis given that plants close their stomata. When this reduction occurs during the development and growth of the reproductive structures of corn, the silk is more affected than the tassel, since the expansion of the stigmas is delayed, which increases the duration of flowering (Salinas et al. 1993), resulting in a lack of synchronicity between them. Soler et al. (2007) mention that hybrid corns differ among themselves in maturity times, and water stress possibly affects the different phenological periods. Many studies show that corn grain yield is sensibly affected by water stress in a period comprehended between flowering and grain filling (Smith & Ritchie, 1992; Norwood, 1995; Norwood & Currie, 1997; Kipkorir & Raes, 2002).

In the southeast of Mexico, the information available on phenological studies on sweet corn is quite limited. Therefore, considering its importance, this research was carried out to evaluate the effect of soil moisture tension at the irrigation time on the phenology of sweet corn, hybrid A-7573, under conditions of controlled irrigation.
MATERIAL AND METHODS

1. Field experiment

The experiment was carried out from April to June, 2007, in the experimental field of the Colegio de Postgraduados, Campus Campeche, in Champoton, state of Campeche, Mexico; coordinates: 19°29'55" north latitude, 90°32'45" west longitude. Sowing was done on April 13th in a plot with calcic Vertisol soils. The plant material used was sweet corn (Zea mays L.) hybrid A-7573, which was irrigated with a tape drip system.

2. Studied factors

Two factors were studied: soil moisture tension at the irrigation time, and phosphate fertilization. This paper focuses only on the effect of soil moisture tension on the phenology of the crop. The soil moisture tension factor had four degrees: -5, -30, -55, and -80 kPa, which were defined based on studies done by Lu et al. (2000), Kang et al. (2004), and Wang et al. (2007), and tried to explore the response of corn to humid and relatively dry levels in the soil. The factor of phosphate fertilization had three levels: 60, 80, and 100 kg ha\(^{-1}\). Through the use of the simplified model (Rodriguez, 1988) the optimum fertilization dose of 80 kg ha\(^{-1}\) was estimated, exploring also a lower and a higher level. Using the same model, the fertilization doses were estimated for nitrogen and potassium, using only the optimum doses for these two nutrients. A more detailed description of the fertilization applied to the crop can be found in Rivera-Hernandez et al. (2009).

3. Treatments

The combination of the levels of the two studied factors resulted in 12 treatments (Table 1).

Table 1. Soil moisture tension and phosphate dose treatments on phenology response of sweet corn hybrid A7375 in Campeche, Mexico.

<table>
<thead>
<tr>
<th>Moisture tension (kPa)</th>
<th>Phosphate Dose (\text{P}_2\text{O}_5) (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>60</td>
</tr>
<tr>
<td>-5</td>
<td>80</td>
</tr>
<tr>
<td>-5</td>
<td>100</td>
</tr>
<tr>
<td>-30</td>
<td>60</td>
</tr>
<tr>
<td>-30</td>
<td>80</td>
</tr>
<tr>
<td>-30</td>
<td>100</td>
</tr>
<tr>
<td>-55</td>
<td>60</td>
</tr>
<tr>
<td>-55</td>
<td>80</td>
</tr>
<tr>
<td>-55</td>
<td>100</td>
</tr>
<tr>
<td>-80</td>
<td>60</td>
</tr>
<tr>
<td>-80</td>
<td>80</td>
</tr>
<tr>
<td>-80</td>
<td>100</td>
</tr>
</tbody>
</table>

4. Experimental design

A divided plot design (DPD) was used, where the levels of the irrigation factor (treatments) were located in the larger plots in a random full block design (RFBD) with three replications, and the phosphate fertilization factor levels (subtreatments) were located within the larger plots in a
totally random design (TRD) (Heinkelmann & Kemphorne, 1994; Martinez, 1996).

The larger plots (96 m²), were made up of eight rows of plants, 20 m long, 0.6 m between rows, and 0.3 m between plants, and a plant density of 55,500 plants ha⁻¹. Each larger plot was sub-divided into three parts for the fertilization sub treatments, thus the experiment was made up of 36 experimental units, 32 m² each.

5. Application of treatments

The control of the irrigation treatments, applied to the larger plots, was done through individual valves connected to each tape at the beginning of the corn rows, with drip holes every 0.3 m. The time of irrigation was determined according to the soil moisture tension corresponding to each treatment, determined with manometer tensiometers installed in the middle of each larger plot, and whose porous capsule was installed at a depth of 0.3 m, immediately below the irrigation tape. The irrigation treatments started on May 5th, when the corn plants reached a height of 0.3 m. Before this, all the experimental units were irrigated homogeneously to guarantee seed germination and plant emergence. To establish the fertilization treatments, a physical mixture of urea, potassium chloride, and triple calcium superphosphate was used. Given the reactivity of the P and the dynamics of N, the fertilizer was fractioned in two applications: the first at the time of sowing, and the second one 20 days later.

6. Crop management

The agronomical labors of the corn crop were done according to the recommendations of corn production technological package for the state of Campeche (INIFAP, 2007).

7. Pest control

During the experiment, there was an incidence of army worm (Spodoptera frugiperda Smith) and cutworm (Agrotis spp.). These pests were controlled with the use of cypermethrin in doses of 0.5 L ha⁻¹ applied once, at the time the populations of both pests reached the economic threshold.

8. Evaluated phenological stages

The effect of moisture tension on the plants' phenology was analyzed in the treatment with an applied fertilization dose of 80 kg P₂O₅ ha⁻¹, since the treatment with a dose of 60 kg P₂O₅ ha⁻¹ showed significantly lower values both in cob yield and in yield component variables, and the treatments with doses of 100 and 80 kg P₂O₅ ha⁻¹ showed no significant statistical differences in these variables (Rivera-Hernandez et al. 2009). The crop cycle was divided into five vegetative (V) and six reproductive (R) stages of sweet corn A-7573 (Table 2).

| Table 2. Vegetative (V) and reproductive (R) phenological stages of sweet corn plants (*) |
|-------------------------------|-------------------------------|
| **Vegetative (V)**            | **Reproductive (R)**          |
| 0. Sowing (S0)                | 1. Appearance of silk (R₁a 50%) |
| 1. Emergence (E)              | 2. Appearance of stigma (R₂ a 50%) |
| 2. Appearance of third specific leaf (V₃) | 3. Appearance of tassel (R₃ al 50%) |
| 3. Appearance of sixth leaf (V₆) | 4. Pearl grain (R₄ al 50%) |
| 4. Appearance of ninth leaf (V₉) | 5. Crystal grain (R₅ al 50%) |
| 5. Appearance of twelfth leaf (V₁₂) | 6. Milky grain (R₆ al 50%) |
| (*) After Hanway, (1982).     |                                |
The beginning of each development stage was defined by carrying out continuous samplings, until more than 50% of the plants were in the same stage (Hanway, 1982). Since the soil moisture tensions were imposed from stage V3, to establish the effect of the irrigation treatments on the phenology in the vegetative stage, the evaluation was done only on stages V6, V9, and V12.

The growing degree days (GDD) for each stage were estimated through the standard method described by Harpal & Tupper, (2004) with the expression:

$$GDD = \sum_{n=1}^{n} \left[ \frac{T_{\text{max}} + T_{\text{min}}}{2} - T_{\text{base}} \right]$$

Where:
- $T_{\text{max}}$ = Maximum daily temperature ($^\circ$C)
- $T_{\text{min}}$ = Minimum daily temperature ($^\circ$C)
- $T_{\text{base}}$ = Base temperature for the crop ($^\circ$C)
- $n$ = Number of days of the stage.

The base temperature ($T_{\text{base}}$) was calculated through the minimum variation coefficient method by Arnold (1959), which consists of evaluating expression one using an arbitrary given base temperature ($T_{\text{base}}$), and then calculating the variation coefficient of the values obtained for GDD. The procedure is repeated with another arbitrary value for $T_{\text{base}}$, until a $T_{\text{base}}$ is found which shows the lowest value for the variation coefficient in the GDD values. This is then stated as the final $T_{\text{base}}$.

Once the GDD for each stage were estimated, the linear phenological models were generated ($Y = a + b \times X$) considering as the dependent variable ($Y$) as the number of development stages from sowing to milky grain, and the independent variable ($X$) as the degree day accumulated for each phenological stage, similar to those generated by Robertson (1984).

Linear equations were also generated for the development ratio ($Td$) of each phenological stage with the following model.

$$Td = a + b \times T$$

Where:
- $Td$ = Development ratio in the phenological stage.
- $b$ = Inverse of the growing degree days accumulated per stage (1/GDDS)
- $T$ = Average temperature of the stage duration ($^\circ$C).
- $a$ = Product of coefficient $b$ times the base temperature ($T_{\text{base}}$).
RESULTS AND DISCUSSION

The maximum daily temperature registered ranged between 32 and 40°C, minimum temperature was between 20 and 28°C, and the average amplitude was 12.3°C (Figure 1). The base temperature \( T_{\text{base}} \) calculated for the corn hybrid A-7573 was 10°C, for all the development stages in all four moisture tensions, which agrees with Cross and Zuber (1972) and Cutforth & Shaykewich (1989) as the optimum base temperature for corn growth and development.

![Figure 1. Daily pattern of the maximum and minimum temperatures at the experimental site (Sihochac, Campeche, Mexico), during the crop growth.](image)

No significant differences were seen in chronological time, nor in the growing degree days required for the appearance of the phenological stages corresponding to the vegetative and reproductive development between treatments -5kPa and -30kPa (Table 3). In both treatments, the appearance of the symptoms used to define the change in stage was simultaneous, thus the evaluation of equation one had exactly the same results. Differences were observed only between the drier and the more humid treatments, and between these latter (Table 3).

Considering the phenological stages of the vegetative growth, stage V12 showed the greatest number of delayed days between treatments of -55 kPa and -80 kPa, with 3 and 6 days (63 and 126 GDD\(_{10}\)), with regard to the more humid treatments (-5 kPa and -30 kPa).

Similar results were reported by Traore et al. (2000) in transgenic hybrid corn resistant to Ostrinia nubilalis (Hübner). The delay in the appearance of leaves could be due to the low water content in the plants, which caused low turgidity of the cells, affecting the division and elongation ratios, thus delaying the development of the leaves (Abo-El-Kheir & Mekk, 2007).

There is one day difference in the appearance of the V9 vegetative stage (20 GDD\(_{10}\)) between the most humid treatment and the two drier ones. Later, in stage V12, the difference increased to 6 days (126 GDD\(_{10}\)) increasing even more in stages R1 and R2 up to 10 days (198 GDD\(_{10}\)), and in R3 to 12 days (244 GDD\(_{10}\)) (Table 3). The greatest moisture tension delayed the appearance of stages V9 and R3; however, in stages R4 to R6, the 12 day difference decreased to 6 days (123 GDD\(_{10}\)). This means that moisture tension accelerated development of the last stages. This suggests that water stress delays vegetative stages, but accelerates reproductive ones of hybrid A-7573.
Table 3. Effect of soil moisture tension on the duration of chronological and physiological times of the phenological stages of corn hybrid A-7573 in the state of Campeche, Mexico.

<table>
<thead>
<tr>
<th>Phenological Stages</th>
<th>Accumulated days</th>
<th>GDD&lt;sub&gt;10&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-5kPa, -30kPa</td>
<td>-80kPa</td>
</tr>
<tr>
<td>S0</td>
<td>S=0 (13 April)</td>
<td>S=0 (13 April)</td>
</tr>
<tr>
<td>VE</td>
<td>S + 7</td>
<td>S + 7</td>
</tr>
<tr>
<td>V3</td>
<td>S + 13</td>
<td>S + 13</td>
</tr>
<tr>
<td>V6</td>
<td>S + 21</td>
<td>S + 21</td>
</tr>
<tr>
<td>V9</td>
<td>S + 30</td>
<td>S + 31</td>
</tr>
<tr>
<td>V12</td>
<td>S + 37</td>
<td>S + 40</td>
</tr>
<tr>
<td>R1</td>
<td>S + 43</td>
<td>S + 49</td>
</tr>
<tr>
<td>R2</td>
<td>S + 51</td>
<td>S + 57</td>
</tr>
<tr>
<td>R3</td>
<td>S + 53</td>
<td>S + 61</td>
</tr>
<tr>
<td>R4</td>
<td>S + 60</td>
<td>S + 66</td>
</tr>
<tr>
<td>R5</td>
<td>S + 66</td>
<td>S + 71</td>
</tr>
<tr>
<td>R6</td>
<td>S + 71 (27 June)</td>
<td>S + 75 (1 July)</td>
</tr>
</tbody>
</table>

GDD<sub>10</sub>= Growing degree days base ten; S0=Sowing; VE= Emergence stage; V3= Appearance of third specific leaf; V6= Appearance of sixth leaf; V9= Appearance of ninth leaf; V12= Appearance of twelfth leaf; R1= Appearance of silk; R2 = Appearance of stigma; R3= Appearance of tassel; R4= Pearl grain; R5= Crystal grain; R6= Milky grain.

Similarly, the number of GDD<sub>10</sub> required for the appearance of the phenological stages varies as the soil moisture tension increased, making necessary to have more GDD<sub>10</sub> as moisture tension got higher, which was registered from the V9 vegetative phenological stage, although the effect was more notorious in the R6 reproductive stage. In treatments whose soil moisture tension at the time of irrigation was -55 kPa and -80 kPa was observed the need for 82 and 123 GDD<sub>10</sub> more than in treatments with -5 kPa and -30 kPa, respectively, to reach the milky grain stage (Table 3).

From the V3 phenological stage to the silk stage (R1) a 6 and 10 day delay was observed, equivalent to 122 and 203 GDD<sub>10</sub>, respectively, in treatments with -55 kPa and -80 kPa when compared with treatments with -5 kPa and -30 kPa. Soler et al. (2007); Abrecht & Carberry, (1993) report similar delay effects in the appearance of the silk, and Scout et al. (1978) report it in the appearance of the panicle in sorghum (Sorghum bicolor L.). The lack of moisture in the soil delayed the appearance of the phenological stages corresponding to the vegetative development, which indicates that the growth of the hybrid A-7573 is limited by water availability in the soil.

In the reproductive phenological stages from the appearance of the silk (R1) to that of milky grain (R6) in the treatments corresponding to the lower moisture tensions, the corn plant used a greater number of days to go from one stage to the next than did the treatments were greater tensions were applied (2 and 5 more days than treatments with -55 kPa and -80 kPa, respectively), and required more growing degree days, 40 and 80 GDD<sub>10</sub>. Similar results have been reported by Karam et al. (2003) in Manuel corn variety. The acceleration in the appearance of the phenological stages corresponding to the reproductive development when the crop is subject to water stress has been reported by Rosales-Serra et al. (2004) as an escape adaptive mechanism of crops to water stress.
Considering most of the crop cycle, from the V3 vegetative stage to milky grain (R6), moisture tensions of -55 kPa and -80 kPa delayed corn harvest by 4 and 6 days more than a tension of -20 kPa. Dale & Daniels (1995); Payner et al. (2006) reported similar effects in the delay of the harvest by effect of water stress.

However, although in this experiment the same behavior pattern of maturity delay was present, it differs in the time of harvest. On the other hand, Farré & Faci (2006) found a delay of 12 and 5 days in corn and sorghum to reach maturity, respectively. These differences could be due to, among other things, to the intensity and duration of water stress to which the plants are subject, their genotype, and the crop management (McMaster et al. 2005).

On the other hand, the development models constructed for each evaluated vegetative stage, according to soil moisture tension that the crop was subject to, are different for each phenological stage (Table 4), as well as for the different soil moisture tensions that the plant was submitted to, with the exception of stages VE, V3, and V6, which show the same development model for all moisture tensions, since soil moisture tension was imposed on the crop starting on stage V3. Stage V6 shows the same development model for all four moisture tensions, since no notorious effects from the moisture treatments can be seen, given that at this stage the treatments had just begun.

**Table 4.** Development models for corn hybrid A-7573 with different soil moisture tensions in the state of Campeche, Mexico.

<table>
<thead>
<tr>
<th>Phenological stages</th>
<th>-5kPa and -30kPa</th>
<th>-55kPa</th>
<th>-80kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>VE</td>
<td>Td = -0.074019 + 0.007402*T</td>
<td>Td = -0.074019 + 0.007402*T</td>
<td>Td = -0.074019 + 0.007402*T</td>
</tr>
<tr>
<td>V3</td>
<td>Td = -0.040486 + 0.004049*T</td>
<td>Td = -0.040486 + 0.004049*T</td>
<td>Td = -0.040486 + 0.004049*T</td>
</tr>
<tr>
<td>V6</td>
<td>Td = -0.023574 + 0.002357*T</td>
<td>Td = -0.023574 + 0.002357*T</td>
<td>Td = -0.023574 + 0.002357*T</td>
</tr>
<tr>
<td>V9</td>
<td>Td = -0.016340 + 0.001634*T</td>
<td>Td = -0.015813 + 0.001581*T</td>
<td>Td = -0.015813 + 0.001581*T</td>
</tr>
<tr>
<td>V12</td>
<td>Td = -0.012809 + 0.001281*T</td>
<td>Td = -0.011848 + 0.001185*T</td>
<td>Td = -0.011022 + 0.001102*T</td>
</tr>
<tr>
<td>R1</td>
<td>Td = -0.011456 + 0.001146*T</td>
<td>Td = -0.010053 + 0.020408*T</td>
<td>Td = -0.009295 + 0.009295*T</td>
</tr>
<tr>
<td>R2</td>
<td>Td = -0.009873 + 0.000987*T</td>
<td>Td = -0.008834 + 0.000883*T</td>
<td>Td = -0.008255 + 0.000825*T</td>
</tr>
<tr>
<td>R3</td>
<td>Td = -0.009263 + 0.000926*T</td>
<td>Td = -0.008048 + 0.000805*T</td>
<td>Td = -0.007553 + 0.000755*T</td>
</tr>
<tr>
<td>R4</td>
<td>Td = -0.007709 + 0.000771*T</td>
<td>Td = -0.007008 + 0.000701*T</td>
<td>Td = -0.006703 + 0.000670*T</td>
</tr>
<tr>
<td>R5</td>
<td>Td = -0.007037 + 0.000704*T</td>
<td>Td = -0.006542 + 0.000654*T</td>
<td>Td = -0.006363 + 0.000636*T</td>
</tr>
<tr>
<td>R6</td>
<td>Td = -0.006837 + 0.000684*T</td>
<td>Td = -0.006472 + 0.000647*T</td>
<td>Td = -0.006304 + 0.000630*T</td>
</tr>
</tbody>
</table>

T = Mean temperature °C; Td = Development ratio; VE= Emergence stage; V3= Appearance of third specific leaf; V6= Appearance of sixth leaf; V9= Appearance of ninth leaf; V12= Appearance of twelfth leaf; R1= Appearance of silk; R2 = Appearance of stigma; R3= Appearance of tassel; R4= Pearl grain; R5= Crystal grain; R6= Milky grain.

In stage V9, it is seen that in the lower tensions (-5 kPa and -30 kPa) models for the development rate were different from those under higher tensions, but remain the same between these last two. From stage V12 to stage R6 all the development models are different for each moisture tension, which indicates the clear effect that water deficit has on the growth and development of sweet corn A-7573. On the other hand, the different soil moisture tension treatments at the time of irrigation originated different lineal phenological models (Table 4) among the number of development stages and the accumulated degree days(GDD_{10}).
According to Máthé-Gáspár & Kovács (2003) the development of the plants is highly correlated with the moisture content in the soil. As the humidity decreases, the development ratios also decrease, thus causing a delay in harvest, originating different development ratios and, consequently, different phenological models. To this regard, Oktem et al. (2003) reported a positive linear correlation of $R^2 = 0.98$ between water consumption and grain yield for Merit hybrid sweet corn, and Payero et al. (2006) report a correlation of $R^2 = 0.95$ for DeKalb C57-40 RR hybrid corn.

In the obtained phenological models, a clear effect can be seen of the moisture tension on the development of the hybrid A-7573, this is, as soil humidity increases, the plants require a greater number of GDD$_{10}$ to reach the milky grain stage. Similar results to this have been reported by Bennouna et al. (2004) when relating GDD with the number of leaves in corn ev Raissa and by Traore et al. (2000) in transgenic corn.

The $b$ parameter (line slope) of the general phenological model proposed by Robertson (1984) (Figures 2, 3 and 4) to predict phenological stages in corn, which presents the development ratio of the crop, varies with the soil moisture tension. Therefore, it can only be used to predict the phenological stages of the hybrid A-7573 under optimum moisture conditions for the crop (low moisture tensions). This result is contrasting with the phenological model suggested by Robertson (1984), where a unique model is proposed for corn crops, since the mentioned author assumes a crop without water stress. Nevertheless, when the corn crop is submitted to different moisture tensions (Figures 3 and 4), this unique model is no longer valid for the crop. In both figures can be appreciated that the relationship between GDD and the appearance of phenological stages is not perfectly linear, there being a slight delay in the appearance of the vegetative phenological stages, and a drastic advance in the appearance of the reproductive stages, which becomes more apparent in the last stage.
Figure 2. Phenological model of Hybrid A-7573 for the soil moisture tension treatment of -5 and -30 kPa.

Figure 3. Phenological model of Hybrid A-7573 for the soil moisture tension treatment of -55 kPa.

Figure 4. Phenological model of Hybrid A-7573 for the soil moisture tension treatment of -80 kPa.
CONCLUSIONS

No significant differences were observed in the times of appearance of the phenological stages corresponding to the vegetative development of corn between the moisture tension treatments with -5 kPa and -30 kPa, and therefore no difference in the number of growing degree days required.

In the case of the soil moisture tension treatments with -55 kPa and -80 kPa, a delay was observed in the appearance of the vegetative phenological stages.

Moisture tension treatments with -55 kPa and -80 kPa accelerated the appearance of the phenological stages corresponding to the reproductive development.

The development ratio of hybrid A-7573 in the vegetative stage is delayed as the soil moisture tension increased from -30 kPa to -80 kPa and accelerates in the reproductive stages.

There is no unique phenological model for hybrid A-7573 when it is submitted to moisture tensions greater than 30 kPa.

REFERENCES


