EMERGENCE AND EARLY GROWTH OF PLANT AND RATOON CANE CROPS UNDER DIFFERENT TEMPERATURE REGIMES

By

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Abstract

The purpose of this research was to evaluate the effects of temperature on emergence and early growth of plant and ratoon crops of sugarcane (TUC-CP 77-42) under field conditions without water limitations. Data were derived from 10 similar and successive planting (plant cane) and harvesting (first ratoon) times from June to November, under optimal growth conditions in a subtropical location (Las Talitas, Tucumán, Argentina; 26°48’ S, 65°12’ W). Analysis showed that the effects caused by planting and harvesting dates were mainly explained by thermal behaviour, with temperature being the most influencing factor on emergence and early growth dynamics in plant and ratoon cane crops. Thermal factor showed a close relationship with final emergence and average emergence rate, stem elongation and leaf appearance. Highly significant inverse relations with emergence, elongation duration, as well as expanded leaf appearance were established. Under a similar thermal regime, emergence percentages for plant and ratoon cane crops did not differ, but because of the larger number of buds available on the first ratoon stubble, a significantly higher number of primary stalks per row metre was established. Emergence, elongation and leaf appearance rates were higher with first ratoon crops than those observed for plant cane because of duration reductions, which allowed an important phenological advance.

Introduction

Sugarcane is grown as a perennial crop in tropical and subtropical regions, where climate plays an important role in determining the length of the growing season and the duration of crop cycles. In subtropical regions, the crop is usually harvested every nine to 18 months, through periods of the year in which temperature limits regrowth of subsequent ratoon crops. Primary shoots emerge from buds on planted stem pieces or from the underground portions of the stem remaining after harvesting. The first crop to emerge and be harvested after the replanting of a field is called the plant-cane crop and in succeeding years, ratoon cane crops are harvested from the regrowth.

Sugarcane emergence and initial growth represent a critical phenological phase in the annual production cycle, which is affected by several internal and external factors, with temperature playing an important role in the fulfillment of this phase (Diliewijn, 1952). Rapid emergence and initial growth of primary shoots is important for early beginning of tillering and active stalk growth, thus building a maximum stalk volume for future sugar storage.

Temperature has important effects on growth, development rates and the duration of the phenological phases because of its major effects on the rates of emergence, shoot and leaf appearance, and stalk elongation. Other biochemical processes controlling meristematic activity of leaf and bud development are also influenced by temperature (Kingston, 2000; Ferraris and Chapman, 1991; Kapur and Kanwar, 1985).

Since sugarcane is grown both as a plant and ratoon crop, it is very important to know if there is a differential response of crop age to temperature. A better understanding of temperature effects on emergence and initial growth of plant and ratoon cane crops under field conditions is needed for the
development of crop management strategies. Different authors report that ratoon crops usually grow faster than plant crops and that leaf canopy closure occurs much earlier in ratoon cane under similar environmental conditions (Inman-Bamber, 1994; Fogliata, 1995), even though, comparative studies on temperature effects on the emergence phase and initial growth dynamics in plant and ratoon cane crops are scarce. The objective of this study was to evaluate the effects of temperature on emergence and early growth of plant and ratoon cane crops of TUC-CP 77-42 under field conditions, without water limitations. TUC-CP 77-42 is one of the three commercial cultivars of major importance in Tucumán, with almost 27% of the sugarcane cultivation area planted to this variety (Jerez et al., 2002).

Materials and methods

Field studies were carried out under irrigated conditions at the Estación Experimental Obispo Colombes (EEAOC) research station located in Las Talitas, Tucumán, Argentina (26° 48' S, 65° 12' W), on a loamy sand soil (USDA soil taxonomy: Typic Argiudoll) with the following properties: pH 6.3–6.7, organic matter content 2.5–2.8%, phosphorus availability 40 ppm (Bray II), potassium availability 1.0 K Cmol+/kg, available water content 150 mm/m and no drainage limitations.

During 1995, 10 similar and successive planting (plant cane) and harvesting (first ratoon) dates were carried out for the TUC-CP 77-42 variety in order to generate different thermal scenarios to make comparative evaluations (Table 1). Temperature information was obtained from a weather station located near the trial site and daily records were used to calculate average air temperature.

| Table 1—Planting and harvesting dates for plant cane and first-ratoon crops and average temperature from the planting/harvesting date until the end of emergence. |
|---------------------------------|---------------------------------|
| Planting/harvesting date       | Average temperature (°C)        |
|                                | Plant cane | First ratoon                |
| 28–6–1995                      | 16.2       | 14.9                        |
| 12–7–1995                      | 16.1       | 15.4                        |
| 08–8–1995                      | 18.1       | 17.1                        |
| 22–8–1995                      | 20.3       | 18.2                        |
| 11–9–1995                      | 20.8       | 18.8                        |
| 28–9–1995                      | 22.2       | 20.9                        |
| 11–10–1995                     | 23.4       | 22.0                        |
| 26–10–1995                     | 23.8       | 23.5                        |
| 8–11–1995                      | 24.8       | 23.1                        |
| 15–11–1995                     | 25.4       | 24.8                        |

The treatments, crop age (plant and ratoon cane) and planting/harvesting dates followed a factorial arrangement with a randomised complete block experimental design. There were three replicates of each treatment. Plots consisted of one row 3 m long with a row spacing of 1 m, for each planting date. The planting density used was 15 buds/m.

The trial for first-ratoon emergence evaluations was planted on September, 1994, using the previously specified design and additional plots to make complementary determinations. Seedcane for this trial was obtained from the EEAOC multiplication plots.

During the plant-cane growing season, steps were taken to insure optimum levels of chemical weed control, irrigation, and fertilisation in order to obtain excellent stubble for future first-ratoon sprouting studies and supply high quality seedcane for the plant-cane emergence experiment.

The soil N, P and K availability was adequate for optimum plant-cane emergence, but in order to insure the best growth and development of stubble for future first-ratoon sprouting, 90 kg N/ha was applied at the end of plant-cane emergence of the first trial (November 1994).

All plots, for both trials, were irrigated and the frequency was determined by a water balance (Class A pan evaporation rate). The total amount of water applied was variable for each case, depending on rain and environmental conditions.

Seed cane for both trials (plant cane and first ratoon) was prepared by selecting well-developed stalks (internodes longer than 150 mm and thicker than 20 mm) containing normally developed buds. The 3–4 upper and 4–5 basal internodes and foliage were removed from the stalks before cutting them into 2–3 eyed sets.
In the first ratoon trial, the number of millable stalks was determined before the first harvesting date (May 1995). Excavations were made in five complementary plots in order to determine bud numbers per metre and per millable stalk that were potentially available for the first-ratoon emergence. This information was used as a reference value to evaluate emergence percentage in the first-ratoon crop.

The number of primary shoots emerged (having at least one green leaf with visible dewlap) was measured twice a week for each replicate on all treatments (crop age and planting/harvesting time). Emergence was characterised by fitting cumulative emergence, expressed on shoot number and percentage, as a function of time using the Single Logistical model (symmetrical and sigmoidal function):

\[ Y = \frac{A}{1 + \exp(b - c \cdot t)} \]

where:

\( Y \) = cumulative emergence; \( A \) = final emergence, \( b \) and \( c \) are constants, and \( t \) = time in days.

Fitted functions with \( R^2 \) higher than 0.93 and significant F test (\( P < 0.05 \)) were chosen, supported by visual comparisons of observed and calculated data. The following variables were derived from the fitted functions: \( A \): Maximum emergence and \( t_{50} \): days required for appearance of 50% of final shoot numbers. A simple factorial ANOVA model was used to evaluate the relative contribution of the principal factors analysed on total variance for the different growth and development crop variables. Relationships between emergence and initial growth parameters with temperature were evaluated with regression techniques.

**Results and discussion**

The emergence dynamics of the plant-cane and first-ratoon crops are presented in Figure 1 for three contrasting planting/harvesting dates. Noticeable differences were found between plant-cane and first-ratoon crops when their performance was compared at similar planting/harvesting times. First-ratoon emergence started and finished earlier and the final primary shoot density was higher in every compared situation.

The relative contribution of the evaluated factors to the total variance of initial growth and development variables studied is presented in Table 2. Planting/harvesting date was the main factor affecting emergence and early growth of plant and ratoon cane and this factor explained between 18.3% and 96.5% of the total variance associated with the evaluated variables and showed significant effects in most of them. Crop age also had significant effects, but its contribution was lower than the previous factor with crop age explaining between 0.1% and 72.8% of the total variance of the evaluated variables. However, crop age had a significant effect on several of the variables.

![Comparative emergence dynamics for plant and first ratoon crops of TUC-CP 77-42, at three different planting/harvesting dates (June, September and November).](image)
Table 2—Relative contribution of the principal factors analysed in the total variance of different growth and development crop variables.

<table>
<thead>
<tr>
<th>Emergence and growth variables</th>
<th>Percentage of total variance</th>
<th>Sources of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crop age</td>
<td>Planting/harvesting date (Thermal Scenarios)</td>
</tr>
<tr>
<td>Final primary shoot no.</td>
<td>72.6***</td>
<td>18.3*</td>
</tr>
<tr>
<td>Final emergence (%)</td>
<td>2.5</td>
<td>88.2***</td>
</tr>
<tr>
<td>Mean emergence rate</td>
<td>29.5*</td>
<td>47.2*</td>
</tr>
<tr>
<td>t50</td>
<td>20*</td>
<td>78.4***</td>
</tr>
<tr>
<td>Primary shoot height at end of emergence</td>
<td>0.1</td>
<td>34.8</td>
</tr>
<tr>
<td>Elongation rate of primary shoots</td>
<td>0.4</td>
<td>96.5***</td>
</tr>
<tr>
<td>Nº. of expanded green leaves / primary shoot at end of emergence</td>
<td>21.5</td>
<td>22.8</td>
</tr>
<tr>
<td>Leaf appearance rate per primary shoot</td>
<td>18.3*</td>
<td>75.0***</td>
</tr>
<tr>
<td>t50 leaf appearance</td>
<td>19.8*</td>
<td>77.7**</td>
</tr>
</tbody>
</table>

**P<0.001; **P<0.01; *P<0.05

Differences between replicates were not significant for any of the dependent variables evaluated. The non-significant crop age (ca) x planting/harvesting (p/hd) date interaction for all of the variables evaluated is evidence that the influence of the date factor was similar for both plant and ratoon cane.

Planting and harvesting times were the management factor that defined the thermal regime in which initial phases of plant and ratoon cane growth took place under field conditions (with no other limiting factors, i.e. water constraints or agronomic management). Sugarcane crop type modified crop behaviour in each thermal scenario.

The height of the primary shoot and number of expanded green leaves on the primary shoot at the end of the emergence period were not significantly affected (P>0.05) by the main factors analysed (Table 2) and these two initial growth variables in both plant and ratoon crops were not affected significantly by temperature variations. These results show that values of each variable at the end of the emergence phase were similar in the 10 planting/harvesting dates for the two crop ages, showing great independence from thermal variations.

All of the evaluated emergence and initial growth variables, except shoot height and green leaf number per primary shoot, showed non-linear relationships with temperature, with different response rates according to crop type.

In general, response rates showed a change of intensity when temperature is over 19–20°C, that was most evident in the plant-cane crops. The differential behavior is summarised in Figures 2, 3 and 4.

Final emergence in both plant and ratoon crops showed a significant response (P<0.05) to mean day temperature, registering an increase of almost twice as much when comparing lower and higher temperature levels (Figure 2).

Significant differences between plant-cane and first-ratoon crops were obtained for final emergence values when expressed in terms of primary shoot number per row metre, but no differences were found when it was expressed as emergence percentages (Table 2 and Figure 2).

Under a similar thermal regime, emergence percentages for plant and ratoon crops did not differ significantly, but because of the large number of buds available on the stubble, a significantly higher number of primary stalks per metre row (P<0.001) were established in ratoon crops.

Similarly, there was a significant difference in emergence rate of primary shoots between the plant-cane and first-ratoon crops at similar temperature levels (P<0.05), where emergence rates for the first ratoon crops showed a higher temperature response (Figure 3a), because of the larger initial bud density than for an establishing plant-cane crop.
Fig. 2—Effect of average temperature on final emergence of plant-cane and first-ratoon shoots for TUC-CP 77-42. (a) final emergence, expressed as primary shoot numbers; (b) final emergence expressed as percentages.

Total viable bud number on plant-cane stubble varied between 32/m and 43/m of row, according to millable stalk number.

This implied an average of three viable buds per millable stalk harvested in the preceding plant cane. Bezuidenhout et al. (2003) estimated under well-watered experimental conditions that an average ratio of 1.62 buds would germinate and form primary tillers for every mature tiller that was harvested in the preceding ratoon. They did not report the behavior of plant crops.

Fig. 3—Effects of temperature on mean emergence, elongation and leaf appearance rates per primary shoot for plant-cane and first-ratoon crops of TUC-CP 77-42. (a) mean emergence rate; (b) mean elongation rate of primary shoot; (c) mean leaf appearance rate per primary shoot.
Kapur and Kanwar (1985) found between 10 and 25 buds per stool for different varieties in plant cane and reported that about 50% of buds on the underground stubble did not possess the capacity to germinate. In all varieties, buds that were dormant and swollen at low temperature were able to emerge when temperatures increased.

Ferraris and Chapman (1991) analysed plant-cane stubble of seven Australian cultivars, and showed large variations in total bud number per stool. These authors reported a compensatory mechanism that insures adequate shoot development for good regrowth recording higher percentages of active buds in varieties with less tillering development. There are a lower number of stem pieces in the stubble; however, compensation is improved by increased bud activity.

In this research, primary shoot elongation rates did not show significant differences between plant and ratoon crops but, in both types of crop, important intensity changes when temperature was above 20–21°C were noted, especially in plant cane (Figure 3b).

Significant differences (P<0.05) in leaf appearance rates per primary shoot were observed between the various crops (Table 2), especially when temperatures exceeded 18–19°C (Figure 3c), and the leaf appearance rate in the first ratoon showed a higher temperature response. Rates of emergence and leaf appearance showed a close response to temperature for both crop types (Figure 3a, c); however, first ratoon crops required less time to complete the phase under similar thermal conditions (Figure 4).

This characteristic in ratoon crops is associated with the greater number of primary shoots produced and the reduction in the duration of the emergence phase, that allows an early establishment of a high number of expanded leaves per metre of row resulting in an advance of the next stages of growth and canopy closure.

A range between 27–32°C is reported as an optimum temperature for emergence and tillering, with tillering being delayed by temperatures below 21°C (Cassalet Dávila et al., 1995; Perumal, 1989). The minimum for emergence of sugarcane in subtropical climates varies between 12 and 16°C (Dillewijn, 1952). The optimum average temperature for sugarcane growth has been reported to vary between 26 and 30°C (Cassalet Dávila et al., 1995; Liu et al., 1998) with growth slowing at temperatures below 21°C (Kingston, 2000).

Although the range of temperatures studied in this research (between 14.5–25.5°C) is representative of thermal conditions during autumn, winter, spring and the beginning of summer in Tucumán, the highest thermal values recorded did not reach the optimal thermal range reported in different studies for emergence under subtropical field conditions.

These results clearly show that modifications of planting or harvesting date, associated with thermal conditions, causes important changes in sugarcane phenological development. When planting or harvesting is carried out under appropriate thermal conditions, it causes an acceleration of crop development, thus allowing an advance of emergence and subsequent vegetative growth and development.
Conclusions

Planting or harvesting dates define the thermal regime in which initial sugarcane crop establishment takes place. With no other limiting factors, temperature is the most influencing factor on the emergence and early growth dynamics in both plant and first ratoon cane crops. Temperatures showed a close relationship with final and average emergence rates, and stem elongation and leaf appearance rates. Highly significant inverse relationships were established between temperature and emergence and elongation duration, as well as the appearance of expanded leaves. These variables showed non-linear relationships with temperature and different responses according to crop age and temperature range. Under similar thermal regimes, emergence percentage for plant cane and ratoon crops did not differ, but because of the large number of buds available on the stubble, a significantly higher number of primary stalks per row metre were established in first ratoon crops. Emergence and leaf appearance rates registered for the first ratoon were higher than those observed for plant cane; hence, crop establishment and development were more advanced in the first ratoon crop.

REFERENCES


GERMINATION ET CROISSANCE INITIALE DE LA CANNE EN VIERGE
ET EN REPUSSE A DIFFERENTS REGIMES DE TEMPERATURE
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MOTS-CLES: Phase de Germination, Première Repousse,
Canne Vierge, Canne a Sucre, Température.

Résumé
Le but de cette recherche était d'évaluer les effets de la température sur la germination et la croissance initiale de la canne à sucre (variété TUC-CP 77-42) en vierge et en repousse, au champ, en l'absence de stress hydrique. Des données ont été dérivées de dix plantations à des dates similaires et successives de plantation (canne vierge) et de récolte (première repousse) entre juin et novembre, dans des conditions optimales de croissance dans une localité subtropicale (Las Talitas, Tucumán, Argentine - 26° 48’ S, 65° 12’ O). L'analyse a démontré que les effets dus aux dates de plantation et de récolte étaient principalement liés aux conditions thermiques, la température étant le facteur influençant le plus la germination et la croissance initiale de la canne en vierge comme en repousse. Un rapport établi a été noté entre le facteur thermique et le taux moyen et final de germination, l'allongement des tiges et le développement des feuilles. Des relations inverses fortement significatives ont été établies avec la germination, la durée de l'allongement, aussi bien que le développement de la feuille. Sous un régime thermique semblable, les pourcentages de germination chez la canne vierge et en repousse ne différaient pas, mais en raison du nombre plus grand de bourgeons dans la première repousse, un nombre sensiblement plus élevé de tiges primaires par mètre de ligne a été établi. La germination, l'allongement et la production de feuilles étaient plus élevées dans la canne en première repousse que chez la canne vierge en raison des réductions de durée qui ont permis une avance phénologique importante.

EMERGENCIA Y CRECIMIENTO INICIAL DE CAÑA PLANTA Y PRIMERA
SOCA BAJO DIFERENTES REGIMENES TÉRMICOS
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Resumen
El propósito de esta investigación fue evaluar, en condiciones de campo y sin limitaciones hídricas, los efectos de la temperatura en la emergencia y en el crecimiento inical en caña planta y primera soca de la variedad TUCCP 77-42. La información analizada derivó de la evaluación de 10 fechas similares y sucesivas de plantación (caña planta) y de cosecha (caña soca) efectuadas en campo entre junio y noviembre (otoño-invierno y primavera) bajo condiciones óptimas de manejo en una localidad subtropical (Las Talitas, Tucumán, Argentina; 26° 48’ Sur - 65° 12’ Oeste). El análisis mostró que los efectos causados por la época de plantación y cosecha resultaron prácticamente explicados por el comportamiento del régimen térmico, constituyendo el factor de máxima influencia en la dinámica de la emergencia y crecimiento inicial de la caña planta y de la primera soca. La temperatura mostró una estrecha relación con la emergencia final y con las tasas medias de emergencia, alargamiento caulinar y aparición de hojas. Relaciones inversas significativas fueron establecidas entre la temperatura y la duración de la emergencia, del alargamiento de los tallos primarios y de la aparición de hojas. Bajo condiciones térmicas similares, los porcentajes de emergencia de la caña planta y soca no disfrieron significativamente, pero debido a la mayor cantidad de yemas disponibles para el rebrote de la primera soca, se estableció un número significativamente mayor de tallos primarios por metro de surco. Las tasas de emergencia de aparición foliar de la caña soca fueron mayores y asociadas con la significativa reducción registrada en la duración de la fase, le permitieron alcanzar, respecto de la caña planta, un adelanto fenológico importante.