EFFECT OF SOIL MOISTURE CONTENT AND THE IRRIGATION FREQUENCYON THE SUGARCANE GERMINATION[1]

DIVINO RODRIGUES MOREIRA[2] and VICTOR JOSÉ MENDES CARDOSO[3]

ABSTRACT - The aim of this work was to observe the interaction between soil moisture and irrigation time intervals on the germination of sugarcane cv. RB785148 sets in semi-controlled conditions. One-bud sets of the variety RB785148 were germinated in ceramic pots filled with soil under a transparent PVC cover using soil humidity levels of 22, 25 and 30%, that were restored at intervals of 7, 14 and 21 days. The experiment was carried out at three different periods of the year: May-June/94; Oct.-Nov./94; and Mar.-Apr./95. The results indicate that the germination decreased mainly in function of the decrease in soil humidity, whereas irrigation interval have no statistical effect on germination. An interaction between humidity level and irrigation interval was observed. A variation of the timecourse of the germination could be observed when the results of the experiments installed at different dates were compared.

Index terms: development, *Saccharum*, water potential.

EFEITO DA UMIDADE DO SOLO E FREQÜÊNCIA DE IRRIGAÇÕES SOBRE A GERMINAÇÃO DE CANA-DE-AÇÚCAR

RESUMO - O objetivo deste trabalho foi investigar a interação entre umidade do solo e intervalos de irrigação sobre a germinação de toletes de cana-de-açúcar cv. RB785148. Toletes de uma gema da variedade RB785148 foram plantados em solo contido em vasos cerâmicos mantidos sob uma cobertura transparente de PVC. Foram utilizados os níveis de umidade do solo de 22, 25 e 30%, restabelecidos em intervalos de 7, 14 e 21 dias. O experimento foi montado em três diferentes épocas do ano: maio-jun./94; out.-nov./94, e mar.-abr./95. Os resultados mostram que houve um decréscimo da germinabilidade em decorrência do teor de água no solo, e observou-se também uma interação entre umidade e o intervalo de irrigação. O fator intervalo não apresentou, isoladamente, efeito significativo sobre a germinação. Observou-se que as curvas de germinação apresentaram diferenças, dependendo da época em que o experimento foi realizado.

Termos para indexação: desenvolvimento, potencial da água, *Sacccharum*.

[1] Accepted for publication on December 17, 1997.

[2] Biologista, M.Sc., DRN/ UFSCar, Campus de Araras, CEP 13600-000 Araras, SP, Brasil.

[3] Biólogo, Dr., Dep. de Botânica, IB, UNESP, CEP 13506-900 Rio Claro, SP, Brasil. E-mail: victorjc@life.ibrc.unesp.br

INTRODUCTION

According to Gascho & Shih (1983), “modern sugarcane cultivars are trispecies hybrids” of *Saccharum officinarum*, *S. spontaneum*, and *S. robustum*”, that vary widely depending on the particular local growing conditions. There are more than 11 millions ha of land in the world dedicated to sugarcane growing, where it has been used primarily as source of crystalline sugar. In Brazil the search for “renewable” fuels lead to the development of a programme for production of ethanol from the sugarcane fermentable sugars.

The crop is produced from stalk cuttings denominated sets that contain one or more axillary buds. Annual growth of sugarcane can be divided into the following development phases: germination and tillering; stalk growth; and maturation (Ellis & Lankford, 1990). The germination (shoot emergence from soil) is a critical event in the plant life to assure a good harvest (Tomer, 1969). The germinating bud is initially dependent on the set nutrients and water, developing its own root system after about three weeks under proper conditions (Bull & Glasziou, 1975). The initial growth of sugarcane is influenced by several internal and exogenous factors such as set age, cultivar, set nutrients, temperature, soil aeration; set position on stalk and humidity (Dillewijn, 1952; Gascho et al., 1973; Souza, 1976; Hayamichi, 1988). Some reports have shown an inverse relationship between set size (number of buds per set) and germinability (Clements, 1940; Dillewijn, 1952).

One-bud sets have been shown to germinate better than either whole stalks or three-bud sets (Segovia, 1974; Nath, 1978).

Sugarcane has shown to be relatively sensitive to soil water content, although the response to moisture stress is affected to an extent that varied with cultivar (Phogat et al., 1987; Sheu et al., 1992). The soil water retention curve is a tool for evaluating the amount of water retained in the soil as well as the available water for plants as related to its energy status. Thus it has been shown that "sandy" soils present more water availability at lower tensions than "clay"soils (Souza, 1976). Besides its water requirements a strong influence of the set moisture has been observed on the germination of sugarcane up to 28 days after planting (Verma & Sudama, 1965). Yang & Chen (1979) observed the germination of sugarcane in containers filled in with clay soil with different humidity levels, and concluded that -30 kPa soil water potential was optimum for germination and initial growth. These authors reported a decrease of the shoot emergence at potentials of -300, -1500 and zero kPa, the latter result being attributed to a reduction of the oxygen availability to germinating buds in response to soil waterlogging. The germinability decreased as the soil moisture was reduced, although a dependence of the response to cultivars was observed; thus, at -1500 kPa the variety F178 germinated 95% whereas the germination of other varieties ranged from 10 to 59% (Yang & Chen, 1980).

Calma (1933) designed a factorial assay to test the interaction between soil moisture and set position in the stem upon the sugarcane germination in plastic containers. At 15% moisture, sets germinated better if taken from the apical portion of the stem rather than basal portion; at 20% moisture, sets developed well irrespective of the portion of the stem they were taken from; and at 25% humidity the highest germinability was scored and no differences were observed among the set provenance treatments.

Most of the reports on the germination and development of sugarcane, as related to soil moisture, have been obtained from assays carried out in greenhouses or laboratory under controlled conditions of air temperature and relative humidity. Furthermore almost all the reports deal with varieties not cultivated for commercial use nowadays, and sugarcane cultivars have been shown to respond differently to soil moisture. Recent paper on germination of sugarcane sets report on its response to saline conditions (Kumar & Naidu, 1993). On the other hand, a lack of reports in the recent specialized literature has been observed concerning to the set emergence response to soil moisture content.

The objetive of this research was to investigate the influence of both soil moisture and irrigation time intervals on the germination of sugarcane cv. RB785148 sets in semi-controlled conditions, exposed to the natural fluctuations of the environment, at three planting periods.

MATERIAL AND METHODS

The assays were carried out at the Centro de Ciências Agrárias (CCA) of the Universidade Federal de São Carlos, Araras (SP, Brazil), with coordinates 22°18'S; 47°23'W and climate CWA (according to Köppen international system), that is, mesotermic with dry winter and mean temperature below 18°C at the coldest period and above 22°C at the hottest period of the year.

The cultivar RB785148 covers approximately 10% of the area cultivated in the State of São Paulo, germinate well, produces good agricultural yields, it is intermediate to late in maturation and not much demanding as for soil fertility.

Three experiments were carried out: a) assay 1, started at May 17, 1994, and performed with sets from 8 months old explants; b) assay 2, initiated at October 7, 1994, and carried out with sets from twelve-month old explants; and c) assay 3, sowed at February 17, 1995 with sets from ten-month old explants. The different age of the explants were due to their availability at the planting time and because the cuttings are usually taken from plant canes eight to twelve-month old. The planting times were selected as related to water demand periods, that is, a high (February), a mean (October) and a low (May) evaporation rate (Oliveira & Rota, 1973; Moreira, 1996).

One-bud sets obtained from the middle portion of the stalk were used, each one cut on the middle of the internode. The sets were treated with "Bayfidan" 5% fungicide and sowed at the same day they were harvested.

A movable PVC transparent film covering was used only at night and during rainy days. This covering allowed a good irrigation control and avoided high temperatures observed inside glass greenhouses in warm days, that could affect sugarcane development.

The sets (ten per pot) were planted at 40 mm deep, with the buds in lateral position, in 0.43 m (internal upper diameter) x 0.45 m height ceramic pots with 32 liters of capacity, internally impermeabilized to water with a betuminous paint ("Neutrol") and filled in with red latossol, whose physical-chemical characteristics are presented in the Tables 1-3.

Three moisture levels were tested: a) 30% (-33 kPa), corresponding to field capacity (FC) measured in the pots; b) 25% (-300 kPa), an intermediate level from which sugarcane need irrigation; and c) 22% (-1500 kPa), corresponding to permanent wilting point (PWP). These data were obtained from a soil water retention assay carried out by submitting soil samples to Richards pressure plates (Souza, 1976), at 0 to -10 and -100 to -1500 kPa intervals. Soil samples were taken from the whole 0.40 m soil profile in the pots with the aid of a 20 mm diameter spiral auger and put in aluminum containers for water content determination by gravimetric method (Kramer, 1969; Souza, 1976). Irrigations were made with watering can by pouring a water volume just to bring up to their respective initial moisture level, according to Moreira (1996).

TABLE 1. Mechanical characteristics of the soil used in the assays.

Depth (m)	Clay (%)	Silt (%)	Sand (%)[1]					Texture
			VF	F	M	RO	VR	class
0.0-0.2	44.18	37.77	6.59	7.03	2.97	1.01	0.45	Clay
0.2-0.4	62.46	24.79	4.50	4.94	2.10	1.06	0.19	Clay
0.4-0.6	54.22	31.74	5.04	6.06	2.23	0.61	0.10	Clay

[1] VF = very fine; F = fine; M = median; RO = rough; VR = very rough.

TABLE 2. Apparent specific mass (γ_s); actual specific mass (σ); total porosity (P) of the soil; and average water percent in dry soil mass (%) at three soil moisture levels.

Depth	γ_s	σ	P	-33 kPa	-300 kPa	-1500 kPa
(m)	(kg/dm^3)	(kg/dm^3)	(v/v)	(%)	(%)	(%)
0.0-0.2	1.26	2.97	0.56	30.93	25.10	21.34
0.2-0.4	1.20	2.99	0.60	30.25	25.80	22.16
0.4-0.6	1.09	3.04	0.64	32.04	26.20	22.76
0.6-0.8	1.11	3.06	0.64	-	-	-
0.8-1.0	1.07	3.06	0.65	-	-	-

TABLE 3. Chemical analysis of the soil used in the assays.

Depth	pH		OC[1]	Changeable content (me/100 g of soil).						
(cm)	Water	KCl	(%)	PO_4^{3-}	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	CEC[2]
0-25	5.5	5.0	1.89	0.01	0.07	3.57	0.75	0.13	4.59	9.11
25-70	5.9	5.6	0.94	0.01	0.04	1.31	0.45	0.09	3.05	4.94
70-160	6.1	6.1	0.76	-	0.03	0.77	-	0.10	2.30	3.20

[1] OC= organic carbon.
[2] CEC= cation exchange capacity.

The treatments followed a factorial arrangement with completely ramdomized plots, with three levels of moisture (22, 25 and 30%) and intervals of 7, 14 and 21 days between irrigations. Six replicates per treatment were used.

Germinations (sprout emergence from soil) were scored at two-day intervals until 45 days after planting. Data were converted to the respective angular values and submitted to factorial analysis of variance according to Snedecor & Cochran (1967), and $LSD_{5\%}$ was determined for significative F values. Germination rate was calculated according to the formulae: **V**= 1/**t**, where **V**= average germination rate; **t**= average germination time= (Σ**ni**.**ti**)/Σ**ni**; **ni**= number of germinated buds; **ti**= time interval (Labouriau & Agudo, 1987). The comparison of the rates was performed by two tailed Mann-Whitney test (Sokal & Rohlf, 1969).

RESULTS AND DISCUSSION

Soil moisture level was the main factor affecting set germinability in assay I started on May 17th, and an interaction was observed between moisture and irrigation time (**T**). At 7-day irrigation intervals no difference could be observed among 22, 25 and 30% humidity levels, whereas at 14 and 21-day intervals the germinability was higher at 30% moisture than at 22% (Table 4). A 30% moisture level (equivalent to a -30 kPa matric potential) has been reported to be optimum for sugarcane germinability (Yang & Chen, 1979), although Calma (1933) related high germinations of sugarcane sets in soils with 25% moisture. Thus the cultivar RB785148 could germinate likely under 25 and 30% soil humidity in the assay I.

TABLE 4. Germinability of sugarcane sets as influenced by soil moisture and irrigation time. Data in percentagem.

Assays	Irrigations (days)	Soil moisture[1]		
		22%	25%	30%
May/94	7	34Aa	78Aa	69Aa
	14	34Ba	78ABa	97Aa
	21	27Ba	71ABa	95Aa
October/94	7	60Aa	74Aa	89Aa
	14	48Ba	67Ba	99Aa
	21	35Ca	65Ba	97Aa
February/95	7	69Ba	90ABa	98Aa
	14	66Ba	84ABa	96Aa
	21	52Ba	86Aa	98Aa

[1] Capital letters indicate horizontal comparisons; small letters indicate vertical comparisons, within each assay ($LSD_{5\%}$).

Under 22% moisture (equivalent to PWP) no significative difference is showed by comparing this treatment with 25% moisture (Table 4). The germination values obtained in such a treatment were similar to the data obtained by Yang & Chen (1980) with different sugarcane cultivars, germinated under-1500 kPa matric potential (22% humidity). Yang & Chen (1979) reported no development of most of the sugarcane buds at PWP, whereas a decrease of the matric potential from -30 to -300 kPa caused a great number of budded but not emerged buds. Many buds were observed to germinate underground without emerging from the soil, although such an observation has not been recorded in this work.

The time course of the germination in the assay I (Fig. 1) is presented as noncumulative daily curves, showing that most of the germination events occurred between 13 and 23 days after planting, in addition to a tail extending to right representing a group of slow sprouting buds. A relationship between time of the first germinations and moisture level was observed, with the buds sprouting first in the highest matric potential and late in the lowest one (Fig. 1). Unlike the germinations in the 25 and 30% moisture treatments, bud emergence in the lowest matric potential lasted until 45 days after planting, in the 14 and 21-day irrigation intervals. This suggests that a decrease of the water potential can cause not only a low germinability but also a more irregular distribution in the time of the germinating buds.

The mean air temperature during assay I was below 20°C, thus lower than that temperature considered to be optimum for sugarcane germination according to Whitman et al. (1963) and Gascho et al. (1973), who reported that 30°C was the most favourable temperature. In general, no statistical differences are observed among the average germination time of the several humidity/irrigation time treatments, except for 30%/14 and 30%/21 day treatments, that were shown to be different to each other (Table 5). This result is probably due to the relatively high heterogeneity of the variances of the germination rate observed in the assay I.

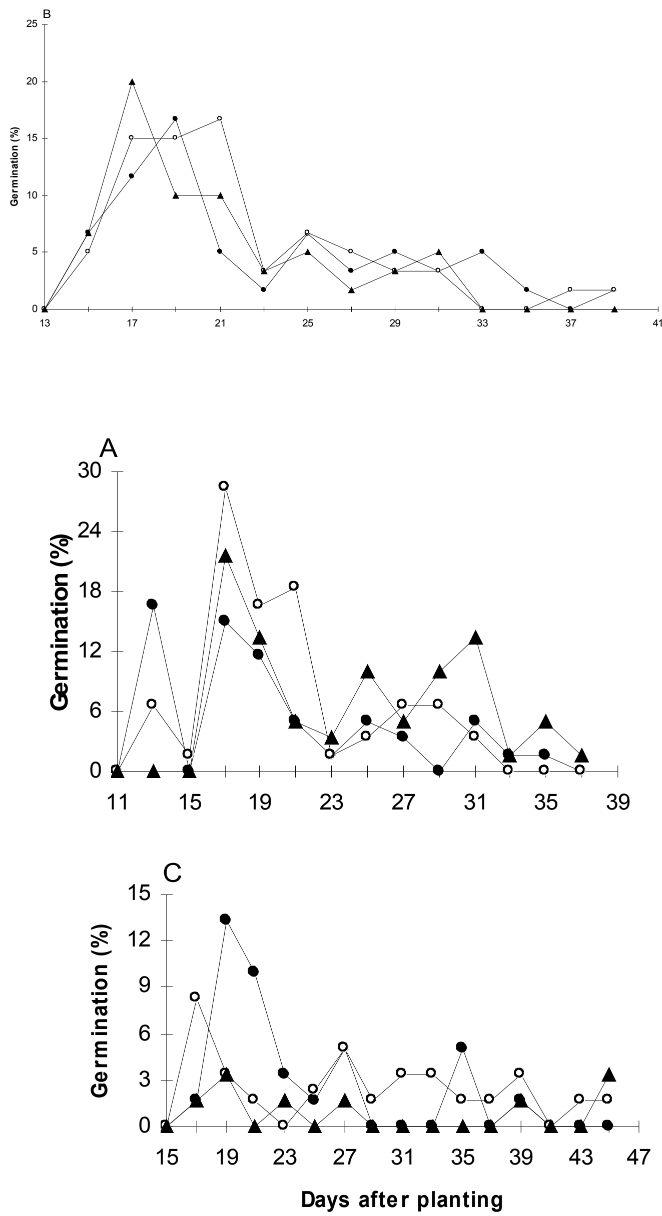

FIG. 1. Daily germination of sugarcane sets in 30 (A), 25 (B) and 22% (C) moisture levels, with 7 (dark circles), 14 (open circles) and 21 (dark triangles) days intervals between irrigations. Assay I, planted at May 17, 1994.

The main features of the assay I are observed again in the assay II, started in October 7, 1994, although both the mean temperature and evaporation were higher in the latter (Fig. 2). In the 14 and 21-day irrigation intervals, a more pronounced effect of the 30% soil moisture treatment in relation to the 25% and 22% soil moisture content is observed (Table 4). The germinability is indifferent to soil moisture level at 7-day intervals between irrigations, and promoted by a moisture level attaining the field capacity at 14 and 21 days. In the 21-day treatment, the most distinct difference among the three soil moisture levels is observed, with 25% being intermediate between 30%, that induces the highest germinability, and 22% that causes the lowest germination. The relatively high germinability of cultivar RB785148 in the -1500 kPa matric potential, as compared to another report (Yang & Chen, 1979) with different sugarcane cultivars, shows that such a variety is tolerant to water deficits during the germination process.

The distribution of germination curves (Fig. 3) shows that most of the buddings occurr between 10 and 16 days after planting in the 30% moisture treatment, that exhibited a more aggregated pattern of distribution as compared to assay I (Fig. 1). This result may be due to a more favourable climatic conditions present during assay II. In the treatments with 25% and 22% moisture the germinations exhibited an irregular pattern, with two or more "peaks", all along the germinative period (Fig. 3). The onset of germination was delayed in the assay I as compared to assay II, probably due to the fact that assay II was carried out under warmer mean temperatures than assay I. Temperature has a considerable influence on the germination of sugarcane (Chen & Yang, 1977/78; Yang & Chen, 1980).

TABLE 5. Effect of irrigation time and soil moisture on the germination rate of sugarcane sets. Data expressed as (1/t) x 100, where t = average germination time. Letters compare treatments within assays.

Soil moisture (%)	Irrigation time (days)	Assay May 94	Assay October/94	Assay February/95
30	7	5.05ab	6.03ab	7.73ab
30	14	5.07a	7.03b	7.26ab
30	21	4.26b	6.31ab	9.32b
25	7	4.43ab	5.85ab	8.59b
25	14	3.64ab	5.60ab	6.93a
25	21	3.85ab	6.77b	8.15b
22	7	2.93ab	5.31ab	7.96ab
22	14	2.91ab	5.09a	7.57ab
22	21	2.71ab	6.59ab	7.86ab

The germination rate is not much affected by moisture treatments, as observed in the assay I (Table 5). Ferraris & Chapman (1991) designed an experiment to find the effect of soil water regime on emergence of ratoon buds of some sugarcane cultivars in Australia. They reported that the germination rate varied as related to cultivar and soil moisture content, and early emergence was favoured by -10 kPa matric potential. According to these authors, the shoot emergence tended to be lower under low soil water regimes (-2000 and -5000 kPa) and high with high soil water potential (-10 and -100 kPa).

In the assay III, planted on February 17, 1995, an interaction between soil moisture and irrigation interval on the germinability of sugarcane sets was observed. This assay was performed under a mean temperature (23.2°C) similar to previous assay, and a mean evaporation lower than in assay II (Fig. 2). The differences between 30 and 25% soil moisture levels were nullified in this assay as compared to assay II, thus exhibiting a similar response to assay I (Table 4). The germination was more grouped in this assay than in assays I and II, with no "tails" extending from the mode (Fig. 4). The germinations started earlier as compared to previous assays, and the germinative period lasted from the 7^{th}-9^{th} until the 15^{th}-17^{th} day, exhibiting a unimodal figure in all the treatments. This result may be due to the low evaporation measured during the assay III, and a high relative humidity associated to prolonged rainfalls in February, 1995.

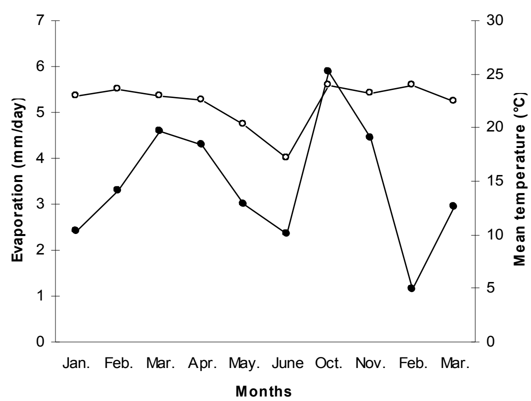

FIG. 2. Evaporation (dark circles) and mean temperature (open circles) in the experimental site at the time of the assays.

Significant germination rate differences are observed among the different irrigation intervals of the 25% soil moisture treatment, where a 14-day interval treatment delay set emergence (Table 5). A difference is also observed between the treatments 25%/14 and 30%/21-days as for average time of germination. No differences are observed among the treatments when other comparisons are made (Table 5). One can conclude from the germination rate data that such a parameter appears to be not much influenced by water stress in the cultivar RB785148, at least under the present experimental conditions.

The irrigation interval had no effect on germinability, as observed in the two previous experiments. In this work, the first irrigations were carried out at planting. Abayomi et al. (1990), working with two commercial sugarcane cultivars in Nigeria, reported that the date of first irrigation after planting significantly affected sprouting percentage, and the best sprouting was obtained when sets were irrigated at planting. Minhas et al. (1992), working in Pakistan, observed a decreased germination percentage as irrigation after planting was delayed, with the lowest yield obtained from delaying irrigation by 10 days. The results suggest that sugarcane appears to be more sensitive to delaying first irrigation than to a delay of the intervals between irrigations.

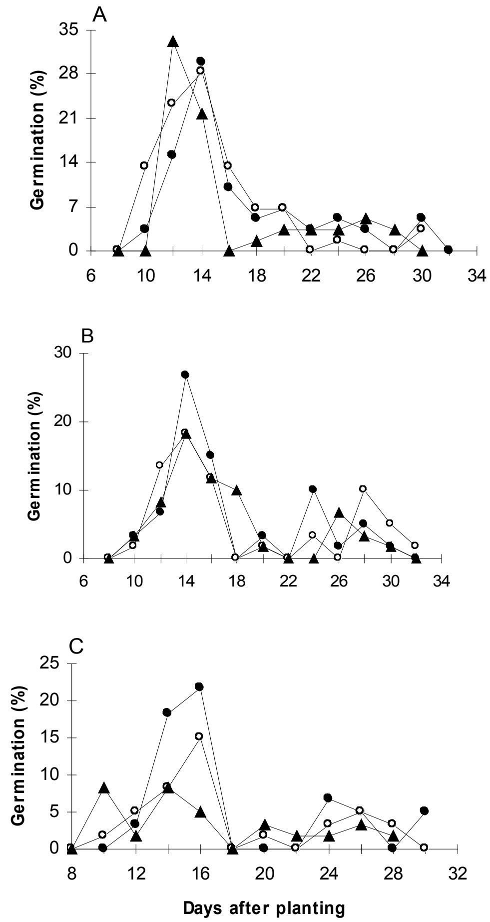

FIG. 3. Non-cumulative germination of sugarcane sets planted at October 7, 1994 (Assay II) in 30 (A), 25 (B) and 22% (C) soil moisture levels, with 7 (dark circles), 14 (open circles) and 21 (dark triangles) days intervals between irrigations.

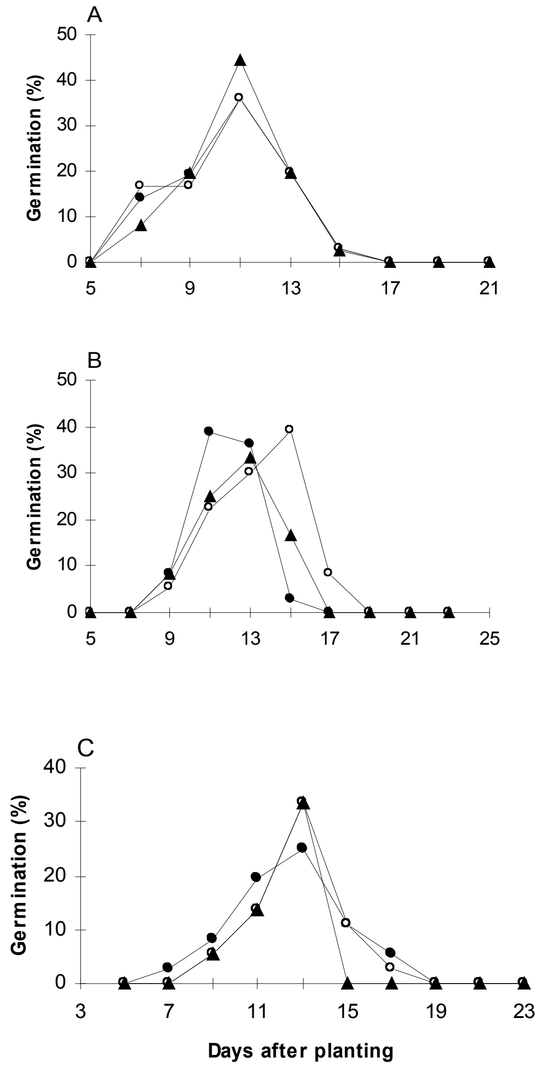

FIG. 4. **Non-cumulative germination of sugarcane sets planted at February 17, 1995 (Assay III) in 30 (A), 25 (B) and 22% (C) moisture levels, with 7 (dark circles), 14 (open circles) and 21 (dark triangles) days intervals between irrigations.**

CONCLUSIONS

1. The cultivar RB785148 is relatively resistant to water deficits in terms of germination.
2. A relatively low soil moisture content (22%) can inhibits the germinability of the sets.
3. The germination decreases mainly in function of the decrease in soil humidity.
4. The irrigation intervals have no significant effect on the germination of the sets.
5. A minimum variation can be observed when the results of the experiments installed at different dates are compared.

REFERENCES

ABAYOMI, Y.A.; ETEJERE, E.O.; FADAYOMI, O. Effect of stalk section, coverage depth and date of first irrigation on seedcane germination of two commercial sugarcane cultivars in Nigeria. **Turrialba,** San Jose, v.40, n.1, p.58-62, 1990.

BULL, T.A.; GLASZIOU, K.T. Sugarcane. In: EVANS, L.T. (Ed.). **Crop Physiology**. Cambridge: Cambridge University Press, 1975. 350p.

CALMA, V.C. Studies on germination degree of tillering and vigour of top and cut-back seed pieces of POJ-78 sugarcane (*Saccharum officinarum*). **Phillipine Agriculturist,** Laguna, v.21, p.585-612, 1933.

CHEN. J.B.; YANG, S.J. Effect temperature on sugarcane germination. **Annual Report Taiwan Sugar Experiment Station,** Tainan, v.22, p.23-35, 1977/78.

CLEMENTS, H.F. Factor affecting the germination of sugarcane. **Hawaiian Planter's Record,** Aiea, v.44, p.117-146, 1940.

DILLEWIJN, C. Van. **Botany of Sugarcane.** Waltham: The Chronica Botanica Co., 1952. 371p.

ELLIS, R.D.; LANKFORD, B.A. The tolerance of sugarcane to water stress during its main development phases. **Agricultural Water Management***,* Amsterdam, v.17, p.117-128, 1990.

FERRARIS, R.; CHAPMAN, L.S. Effect of moisture regime on early development of ratoon buds. **Proceedings of the Australian Society of Sugarcane Technologists,** Brisbane, v.13, p.172-178, 1991.

GASCHO, G.J.; RUELKE, O.C.; WEST, S.H. Residual effect of germination temperature in sugarcane. **Crop Science,** Madison, v.13, n.2, p.274-276, 1973.

GASCHO, G.J.; SHIH, S.F. Sugarcane. In: TEARE, I.D.; PEET, M.M. (Eds.). **Crop-Water Relations.** New York : John Wiley & Sons, 1983. p.445-479.

HAYAMICHI, Y. Studies on the germination of sugarcane seed pieces. Part 1: On the characteristics of the germination of buds and seed pieces from different nodes of sugarcane stalks. **Journal of Agricultural Science**, Cambridge, v.33, n.2, p.139-148, 1988.

KRAMER, P.J. **Plant and Soil Water Relationships:** a modern synthesis. New York: McGraw-Hill, 1969. 482p.

KUMAR, S.; NAIDU, K.M. Germination of sugarcane sets under saline conditions. **Sugarcane,** Karnal, v.4, p.2-5, 1993.

LABOURIAU, L.; AGUDO, M. On the physiology of seed germination in *Salvia hispanica* L. I. Temperature effects. **Anais da Academia Brasileira de Ciências**, Rio de Janeiro, v.59, n.1, p.37-56, 1987.

MINHAS. Y.J.; KHANZADA, A.G.; MEMON, M.I. Effect of delaying first irrigation after planting in sugarcane crop. **Pakistan Sugar Journal**, Pakistan, v.6, n.2, p.21-23, 1992.

MOREIRA, D.R. **Efeito da umidade do solo na germinação de toletes de cana-de-açúcar**. Rio Claro: UNESP, 1996. 116p. Dissertação de Mestrado.

NATH, M.N. A new sugarcane planting technique. **Sugar Journal**, New Orleans, v.40, n.12, p.20-21, 1978.

OLIVEIRA, J.B.; ROTA, C.L. Levantamento pedológico detalhado da Estação Experimental de Limeira, SP. **Bragantia**, Campinas, v.32, p.1-60, 1973.

PHOGAT, B.S.; SINGH, V.R.; VERMA, R.S. Response of sugarcane varieties to irrigation. **Indian Journal of Agronomy**, New Delhi, v.32, n.1, p.77-79, 1987.

SEGOVIA, A. Efecto del tamaño, posición del esqueje en la germinación de la caña de azúcar. **Revista de la Facultad de Agronomía,** Buenos Aires, v.7, n.4, p.21-35, 1974.

SHEU, Y.S.; YANG, P.C.; LI, S.W. Effects of soil moisture on the growth and maturity of recent sugarcane varieties in Taiwan. **Taiwan Sugar**, Tainan, v.39, n.3, p.12-16, 1992

SNEDECOR, G.W.; COCHRAN, W. **Statistical Methods**. Iowa: The Iowa State University Press, 1967. 240p.

SOKAL, R.R.; ROHLF, F.J. **Biometry**. San Francisco: W.H. Freeman & Co., 1969. 776p.

SOUZA, J.A.G.C. **Estudo do consumo de água pela cultura de cana-de-açúcar (*Saccharum* spp.)**. Piracicaba: ESALQ, 1976. 82p. Dissertação de Mestrado.

TOMER, R.P.S. Better germination of cane and high yeld. **Indian Sugar**, New Delhi, v.18, n.10, p.765-766, 1969.

VERMA, H.P.; SUDAMA, S. Studies in cane set germination under varying soil moisture status. **Indian Sugarcane Journal,** New Delhi, v.9, p.157-160, 1965.

WHITMAN, P.C.; BULL, T.A.; GLASZIOU, K.T. The physiology of sugarcane. VI: Effects of temperature, light and water on set germination and early growth. **Australian Journal of Biological Science,** East Melbourne, v.12, n.2, p.415-428, 1963.

YANG, S.J.; CHEN. J. Germination response of sugarcane cultivars to soil moisture and temperature. In: CONGRESS INTERNATIONAL SOCIETY OF SUGARCANE TECHNOLOGISTS, 17., 1980 Manila. **Proceedings**... Manila: ISSCT, 1980. v.1, p.30-37.

YANG, S.J.; CHEN, J. Influence of soil moisture on germination of four sugarcane varieties. **Report of Taiwan Sugar Research Institute,** Tainan, v.83, p.25-33, 1979.