AGROCLIMATIC ZONATION FOR VINE GROWING IN MARANHÃO STATE, BRAZIL

ZONAGE VITICOLE AGROCLIMATIQUE DANS L'ÉTAT DU MARANHÃO, BRÉSIL

A. H. de C. TEIXEIRA.[1]; P. H. B. RIBEIRO[2]; V. C. da S. REIS[3]; M. das G. L. dos SANTOS[4]

[1]Researcher of Embrapa Semi-Árido, CP 23, CEP 56300-970, Petrolina-PE, Brazil.

E-mail: heribert@cpatsa.embrapa.br

[2] Civil Engineer, Embrapa Semi-Árido, CP 23, CEP 56300-970, Petrolina-PE, Brazil.

[3]Agronomist, Embrapa Semi-Árido, C. P. 23, CEP 56300-970, Petrolina-PE, Brazil.

[4]Traineer, Embrapa Semi-Árido, C. P. 23, CEP 56300-970, Petrolina-PE, Brazil.

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ABSTRACT

The use of agroclimatic indexes based on water balance and air temperature means, allowed the characterisation of areas with different aptitude for grape (*Vitis vinifera L.*) crop growth in Maranhão State, Brazil. THORNTHWAITE and MATHER (1955) water balance for a 120 mm soil moisture capacity, of the regions of natural dispersion and of areas of commercial crop production was used to determine the annual hydric index of THORNTHWAITE (I_h) in the characterisation of ideal hydric conditions of climate for crop growth. Monthly climatic values of temperature and rainfall were used to obtain the water balance for the same soil moisture capacity for 88 locations of Maranhão State. It was observed that the State has no thermal limitation for grape growing. The hydric zones resulted in three classes of agroclimatic aptitude: Full aptitude ($I_h < -20$); Regular aptitude ($-20 < I_h < 60$) and Inaptitude ($I_h > 60$). Under irrigated conditions, the vine crop in Maranhão state may be encouraged mainly in the municipal districts of São Félix de Balsas, Loreto, Benedito Leite, Nova York, Pastos Bons, Buriti Bravo, Fortuna, Governador Luiz Rocha, Jatobá, São Domingos do Maranhão and Graça Aranha.

RESUME

Les indices agroclimatiques concernant le bilan hydrique et la température moyenne de l'air, ont été utilisés pour la caractérisation des zones avec différentes aptitudes pour la viticulture de vin (*Vitis vinifera* L.) dans l'état du Maranhão, Brésil. Le bilan hydrique de THORNTHWAITE et MATHER (1955), pour une réserve hydrique utile du sol de 120 mm, a été utilisé pour la détermination d'un «Indice Hydrique Annuel de THORNTHWAITE» (I_h),

capable de caractériser les conditions hydriques idéales pour la viticulture, pour les régions de dispersion naturelle et également pour les régions de production commerciale. Les valeurs climatiques mensuelles de température et pluie ont été utilisées pour le calcul du bilan hydrique I_h sur 88 emplacements dans l'état du Maranhão. Les résultats ont permis de constater que l'état n'a aucune limitation thermique pour le développement de la vigne. L'indice I_h à permis la classification des régions dans trois différentes zones agroclimatiques, qui correspondent à trois classes d'aptitude viticole : pleine aptitude (I_h < -20) ; aptitude régulière (-20 < I_h < 60) et inaptitude (I_h > 60). L'étude à permis de conclure que, sous conditions irriguées dans l'état du Maranhão, la viticulture pour la production de raisin et vin pourra être recommandée surtout dans les communes de São Félix de Balsas, Loreto, Benedito Leite, Nova York, Pastos Bons, Buriti Bravo, Fortuna, Governador Luiz Rocha, Jatobá, São Domingos do Maranhão et Graça Aranha.

INTRODUCTION

Genus *Vitis* belongs to the *Vitaceae* family, which comprises more than 90 species. Those of American (*Vitis labrusca L.*) and European origins have higher economic value. The cultivation of the European grape started in Minor Asia, which is considered the origin of the species. Later it was diffused to Europe and America (WEAVER, 1976).

The grape has too distinct markets: wine and other distilled alcohol; table fruit and natural juice. The characteristics of each are different, without resemblance concerning aroma, colour, flavour, etc. The Brazilian wine market, with consumption of 9 to 10 million boxes per year, reached a 35% export figure in 1995, falling to 27% in 1997. Regarding the table grape market, seedless grapes have increased at a fast rate. In England, supermarkets already reduced the purchase of seeded grapes. The international market for seedless table grapes is very attractive. Wine and table grapes are produced in more than 40 countries. Brazil is in the 17th position in terms of production (DUTRUC-ROSSET, 1998).

Solar radiation plays a role in photo-energy (photosynthesis) and in photo-stimulus (formation and translocation) processes. The absorption of photosynthetic active radiation (400nm to 700nm) by the grapevine depends on conduction and cultivation practices (SMART, 1985). The evapotranspiration process of the vine is determined by the availability of energy for the vaporisation of water. Solar radiation is the most important source of this energy. Because of the inclination of the sun, the radiation intensity depends on the atmospheric turbidity and on clouds that reflect and absorb a large fraction of this radiation (ALLEN *et al.*, 1998).

Air temperature plays a role in photosynthetic activity, because this process involve biochemical reactions of which the enzymes are dependent on temperature for maximum activity. Photosynthetic reactions are less intense when temperatures are lower than 20ºC, it reaches maximum activity at 25ºC to 30ºC, and decreases at temperatures above 35ºC. Yield potential is related to plant phenology. Temperatures lower than -15ºC result in the death of plants. The damage caused by high temperatures is a function of several factors, being the resistance limit variables between 38ºC and 50ºC. A temperature range of 20ºC to 30ºC is considered ideal for vine growing (COSTACURTA & ROSELLI, 1980). Temperatures lower than 10ºC limit the development of shoots and induce dormancy in temperate climates. This period is necessary for the formation of fruiting hormones, which transforms vegetative shoots into fertile shoots (WINKLER *et al.*, 1974). The flowers start to appear when the mean daily temperature reaches 18ºC. In tropical climates, the dormancy period is regulated by water management, it being possible to obtain a yield at any time during the year.

However, the yield is small when the crop is produced in colder months (ARAUJO, 1994). In the absence of excess precipitation, higher temperatures, within the critical limits, will contribute to higher sugar and lower malic acid concentration in the berries, favouring table grape, raisin and sweet wine production (WINKLER *et al.*, 1974; COOMBE, 1987).

The air humidity during the phenological phases is very important, because high values cause fungal diseases, particularly when associated with high air temperature. This may have a high economic impact.

The vapour pressure deficit between the grape canopy and ambient air, is the determining factor for vapour removal. Grapevines that are well irrigated in arid regions consume high quantities of water, because of the high availability of solar energy and concomitant atmospheric dryness (ALLEN *et al.*, 1998). The grapevine is largely resistant to dryness because of its root system being able to penetrate deeply (COSTACURTA & ROSELLI, 1980). The cultivated regions include areas with low precipitation and high evaporative demand. Water is supplied by irrigation. A deficit and excess of water affect the phenology of the grapevine, compromising productivity and quality of the grapes. When the deficit occurs during the initial period of fruit development, it leads to a reduction in berry size, whereas when it occurs during the ripening period, ripening is delayed, sunburn occurs and the colour and flavour of the grapes are affected. On the other hand, excessive availability of water associated with high temperatures leads to a high susceptibility to diseases. For better productivity, it is recommended that the grapevine grows under conditions of low precipitation, and that the water requirements are met by irrigation (TEIXEIRA & AZEVEDO, 1976).

The objective of this research was to determine the climatic aptitude of different regions in Maranhão State, Brazil, for irrigated vines, both for wine and for table grapes, as a basis for expanding commercial cultivation.

EQUIPMENT AND METHODS

Average monthly totals of precipitation in 88 locations in Maranhão State and the corresponding values of air temperature observed or estimated were used. Concerning the last parameter, in locations with precipitation data only, this was obtained by the following equation (CAVALCANTI & ILVA, 1994):

$$T=A_0+A_1\lambda+A_2\Phi+A_3h+A_4\lambda^2+A_5\Phi^2+A_6h^2+A_7\lambda\Phi+A_8\lambda h+A_9\Phi h \qquad (1)$$

where T is the monthly mean air temperature, λ the longitude, Φ the latitude, h the altitude and $A_0, A_1,..., A_9$ were obtained by the square minimum method.

The mean temperature data and precipitation totals of locations situated in regions of natural dispersion and crop commercial introduction were obtained from RUDLOFF (1981). With these data were calculated the water balance by THORNTHWAITE and MATHER (1955) for a 120mm soil moisture capacity.

For the water balance, the monthly reference evapotranspiration ($ET0_j$) was calculated, using the THORNTHWAITE method. According to this method, for the month j ($j = 1, 2, 3, \ldots, 12$), this evapotranspiration can be estimated by the following expression:

$$ET0_j = F_j . E_j \tag{2}$$

where E_j is the reference evapotranspiration not adjusted for day length and Julian day of the month, being obtained in the following manner:

- When the monthly temperature (T_j) is 26.5°C or higher, E_j is independent of the annual heat index (I) and we used the table of THORNTHWAITE (1948) for obtaining E_j.

- When the monthly temperature (T_j) is smaller than 26.5°C, we used the following expression:

$$E_j = 0.5333(10T_j/I)^a \tag{3}$$

where I is annual heat index, given by the sum of the 12 monthly indexes (i_j):

$$I = (i_1+i_2+\ldots+i_{12}) \tag{4}$$

where:

$$i_j = (T_j/5)^{1.514} \tag{5}$$

The exponent ***a*** in equation (2) is calculated by the following expression:

$$a = 6.75\ 10^{-7} - 7.71\ 10^{-5}\ I^2 + 1.79\ I + 0.49 \tag{6}$$

The symbol F_j in equation (1) is the correction factor that considers the mean day length and the number of days of the month. This correction is given by:

$$F_j = D_j N_j/12 \tag{7}$$

where D_j the number of days of the month j and N_j represent day length of day 15 of the month j, considered representative of mean day length of that same month . If Ø is the latitude and δ_j the Sun declination for day 15 of the month j, so:

$$N_j = 2\{arccos(tg Ø\, tg\, \delta_j)\}/15 \tag{8}$$

After calculating the precipitation and the reference evapotranspiration we estimated the hydric deficit (*DEF*) and the hydric excess (*EXC*) for each year. With these last two elements and the reference evapotranspiration, we obtained the humidity index (*IH*) and the hydric index (*IH*) by the following expressions:

$$IH = (100EXC)/ET0 \quad (9)$$

$$IA = (100DEF)/ET0 \quad (10)$$

$$IH = IH - IA \quad (11)$$

With data available in literature and water balance of origin and commercial regions of the species, we obtained climatic-limit indexes (TEIXEIRA & AZEVEDO, 1996) for the tillage of the specie. These indexes were the basis for the classification of the agroclimatic aptitude of several regions in the state.

With a Geographic Information System, we made first, the basic map with temperatures of the hottest (T_h) and coldest (T_c) months of the year and of the annual hydric index (I_h), considered as elements more important in determination of agroclimatic aptitude of the vine crop. With the maps of I_h we defined the limits for the different zones of agroclimatic aptitude for the grapevine.

DISCUSSION

The averages of air temperature of regions of natural dispersion and of commercial cultivation of the vine (Table 1), and the spatial distribution of this climatic element for the hottest (T_h) and coldest (T_c) months in Maranhão State were considered (Fig. 1). Regarding the thermal aspect, it was observed that there are no limitations for commercial cultivation of the species in the State.

The most regions where vines are commercially cultivated, show the I_h changing from -60 (maximum climatic aptitude and less problems with diseases) through 60 (above which there is no possibility of commercial cultivation).

For Maranhão state, we considered three ranges of aptitude with values of I_h lesser than - 20, I_h between -20 and 60, where in extent of humidity raised, the number of cycles per year are reduced, decreasing the annual production. The locations with I_h higher than 60 were classified as not suited for grape growing. With the map of the annual hydric index, the agroclimatic zonation for grapevines in Maranhão State was obtained, using the Geographic Information System (Fig. 2).

Under irrigated conditions, the cultivation of grapevines in Maranhão State can be expanded, mainly in the municipal districts of São Félix de Balsas, Loreto, Benedito Leite, Nova York, Pastos Bons, Buriti Bravo, Fortuna, Governador Luiz Rocha, Jatobá, São Domingos do Maranhão and Graça Aranha. These areas showed less humidity, resulting in less diseases problems as well as a reduction in the negative effects of excess precipitation on fruit size and quality. These municipal districts show bigger climatic potential for table grape production and for sweet wines.

The regions here classified as unsuitable must be zoned according to other environmental characteristics. It provided knowledge of the potential of the physical medium in Maranhão State for commercial grapevine growing.

CONCLUSION

Mapping of the THORNTHWAITE hydric index allowed the delimitation of zones with different agroclimatic aptitude and together with other ecological characteristics contributed to a rational planning for the expansion of grapevine growing in Maranhão State.

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Table 1. Mean annual air temperature of the hottest (T_h) and coldest months (T_c), pluvial precipitation (P), reference evapotranspiration (ET_0) and hydric index by "THORNTHWAITE & MATHER-1955" method (I_h) (120mm) of representative locations of several continents.

PARÂMETROS	*PHENIX (USA)*	*MENDOZA (ARGENTINA)*	*ANKARA (TURKEY)*	*VARNA (BULGARIA)*	*ALGER (ARGERIA)*
T_q (ºC)	32.9	23.6	22.8	1.2	25.2
T_c (ºC)	10.4	7.6	-0.3	22.9	12.2
P (mm)	184	197	344	474	691
ET_0 (mm)	1172	813	696	714	894
I_h	-84.3	-75.8	-50.6	-33.6	-32.8

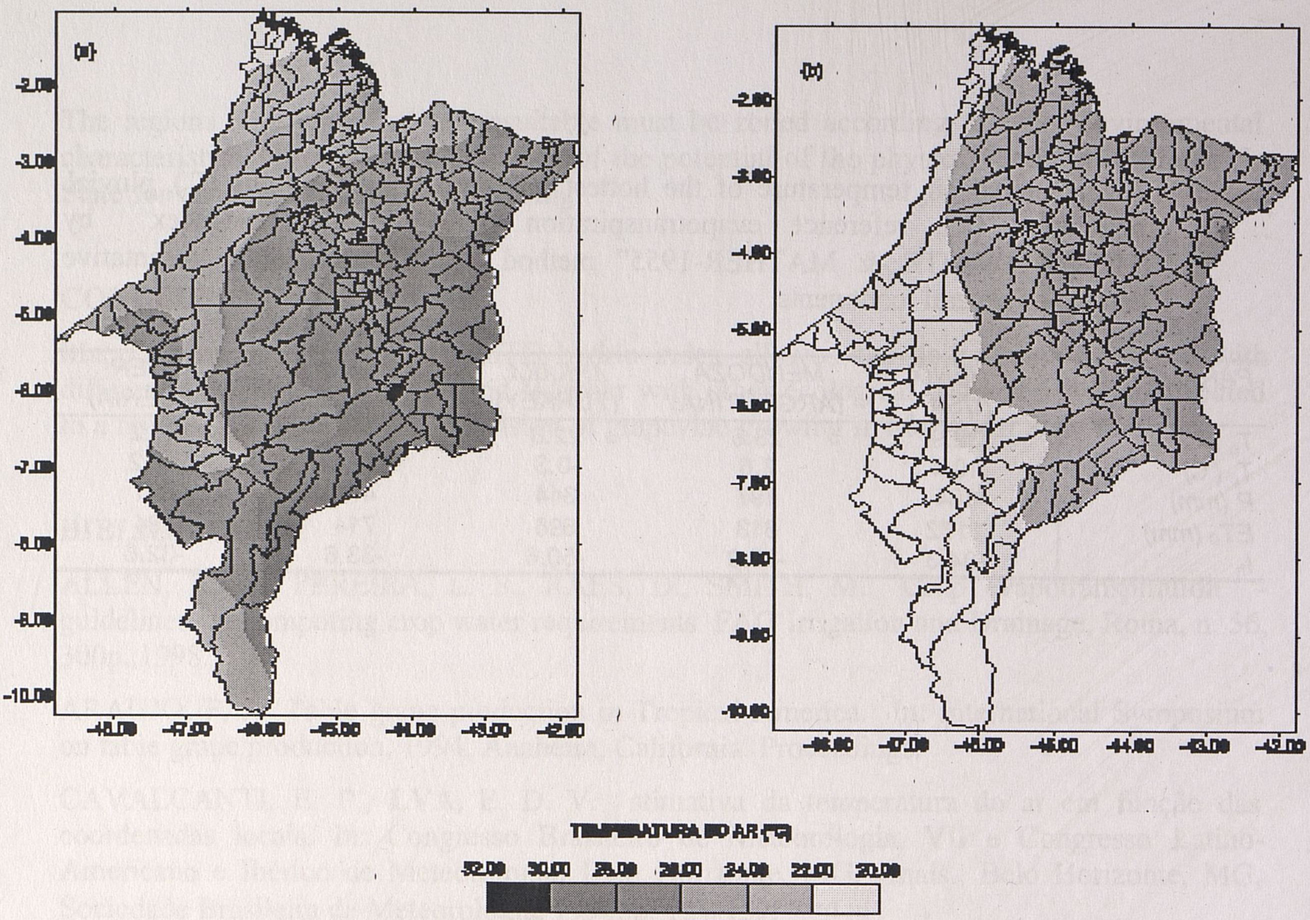

Figure 1. The hottest (a) and coldest (b) mean air temperatures of Maranhão State.

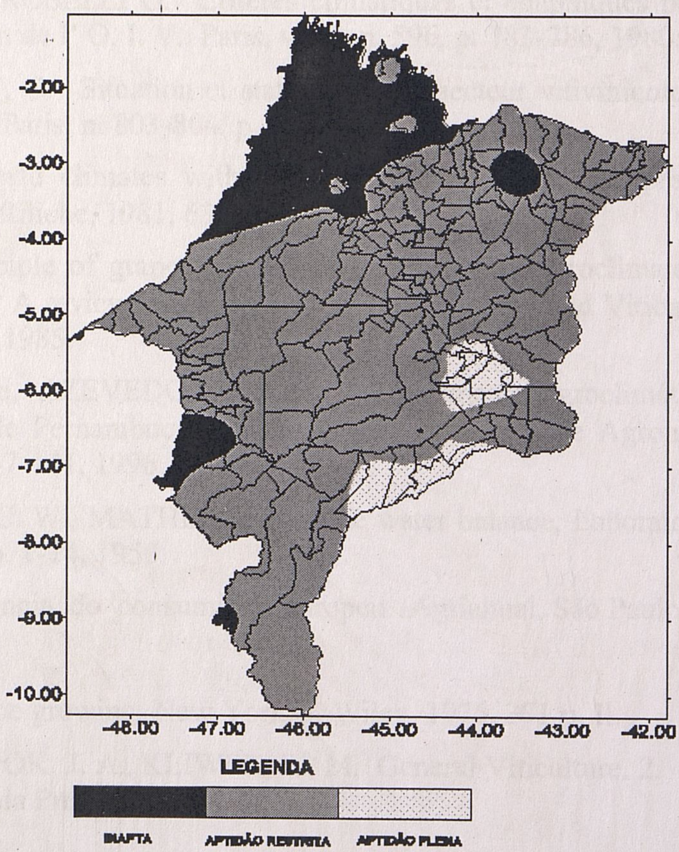

Figure 2. Agroclimatic zonation of vine crop in Maranhão State.