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Climatic Aptitude Evaluation for Grapevine Cultivation in Pão de Açúcar, Alagoas

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ABSTRACT

The grapes production in Brazil is comprised in southeastern and southern regions and also in the semi-arid Pernambuco. Environmental, climatic and even human factors influence on quality of grape production, which are sensitive to weather changes. In Alagoas State, a pilot project was carried out for Municipalities of Rio Largo, Pão de Açúcar and Delmiro Gouveia between 2013 to 2015 years; but the results were incipient. This work evaluated the climatic aptitude for grapevine cultivation for municipality of Pão de Açúcar. For climate characterization, three indices of the Geoviticure Multicriteria Climatic Classification System (MCC) were adopted: Heliothermic (HI), Cold Night (CI) and Dryness (DI), considering different cycles during the year. The Zuluaga Index (IZ) was also used to evaluate the risk of incidence of fungal diseases of the vine, especially in relation at mildew incidence (Plasmoparaviticola), a major disease in humid regions. According on CI, DI and ZI indices, the municipality of Pão de Açúcar presented climatic aptitude for vines production with highest quality potential between August to January months, classified as preferential for all indexes analyzed.

Keywords: Grapevine, Climatic Zoning, Viniculture

Introduction

The production of grapes and wine is comprised of at least 40 countries in the world and the quality and types of wine are associated with environmental and human factors (TONIETTO; CARBONNEAU, 2004).

The first grapevines were introduced were brought to São Paulo State, Brazil on the arrival of Portuguese colony in 1532 (DEBASTIANI et al., 2016), while on south of Brazil, only in middle of the 18th century by the Jesuits (WURZ et al., 2017).

In 1875, the arrival of the Italian and German settlers began the exploitation of grapes production and wine for domestic consumption in several cities situated in the Serra Gaúcha, (DEBASTIANI et al., 2016), boosting this socioeconomic activity on region.

Throughout the years, the grapevine cultivation in Brazil has been concentrated on south and southeast regions (BORGHEZAN et al., 2014; RICCE et al., 2014; MALINOVSKI et al., 2016), due to specific crop conditions for temperate climates, which after the harvest the vine would enter into hibernation during winter (DEBASTIANI et al., 2016).

In mid 1960's, due improvement in grape cultivation of Italian type was started in the Northeast Brazil (BASSOI, 2014; SANTOS LIMA et al., 2015), especially in semiarid region of the São Francisco Sub-Middle valley (DEMIR, 2014; ANDRADE et al., 2016; DA SILVA et al., 2016b; LEÃO et al., 2016), marking the beginning of viticulture in tropical Brazil (WURZ et al., 2017). This region presents predominantly hot climate and dry during greater part of the year, the irrigation infrastructure and the available workforce provide the favorable conditions for the development of this crop (FACHINELLO et al., 2011).

The Alagoas State does not have the tradition of grapevines cultivation; there was just one pilot project during 2013 to 2015 years in three municipalities: Rio Largo, Pão de Açúcar and Delmiro Gouveia. The varieties of the

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species/cultivar were: Niágara Rosada, Itália Melhorada and Isabel Precoce.

The objective of this work was to evaluate the climatic aptitude of grapevines cultivation for Municipality of Pão de Açúcar - Alagoas, based on six indices of production over the year with different scenarios.

Material and Methods

For climatic aptitude for grapevine cultivation for municipality of Pão de Açúcar, Alagoas, were needed data from local meteorological station (Latitude 9.75° S; Longitude 37.43° W; and Altitude 19.1m).

The period used correspond between January 1981 to December 2010, from monthly averages of air temperature (maximum, mean and minimum) and monthly amount of precipitation supplied by the Instituto Nacional de Meteorologia (INMET, 2017).

These data allow us to characterize the pattern climate in Pão de Açúcar (Figure 1), verifying its suitability, and so the Geoviticulture Multicriteria Climatic (MCC) classification system developed by Tonietto and Carbonneau (2004) was taken as the basis.

This MCC system evaluates the intra-annual climatic variability conditions of the region, detecting viable possibility for grapevine cultivation for commercial purposes.

This system adopted recommendations based on classifications determined by outcome of three indices: Heliothermic Index (HI), Cold Night Index (CI) and Drought Index (DI). The result obtained from each index will indicate that the region has suitable characteristics for viticulture installation.

The first index, Heliothermic Index (HI), developed by Huglin (1978), consists on thermal sum throughout all the crop cycle, which use monthly averages mean (Tmed) and maximum (Tmax) air temperatures, respectively, both in °C. That index is commonly used for regions with latitudes less than 40°, obtained from the calculation of the expression below:

$$\mathrm{HI} = \sum_{Mi}^{Mf} \frac{[(Tmed - 10) + (Tmax - 10]}{2} \quad (1)$$

HI is the Heliothermic Index; ∑ is summation of initial (Mi) and final (Mf) months of the crop cycle; Tmed and Tmax correspond to the average monthly of mean and maximum air temperatures (°C), respectively. The interpretation of HI values is described in Table 1.

The second index, Cold Night Index (CI) corresponds to the mean value of the minimum air temperature (Tmin) on last month of the crop cycle, corresponding at grapes maturation period, which evaluates the improvement of potential quality of the wine growing regions. The classes related to CI index are represented in Table 2. This index can to influence on grape quality, color of wine and flavors (scent) (KLIEWER; TORRES, 1972; KLIEWER, 1973).

The third, Drought Index (DI, Table 3), developed by Riou et al. (1994), evaluates the adaptation of a potential water reserve in the soil. This index was developed specifically for wine-growing areas (TONIETTO; CARBONNEAU, 2004). This index is obtained for following expression:

$$\mathrm{DI} = \sum_{\mathrm{Mi}}^{\mathrm{Mf}} \mathrm{Wo} + \mathrm{P} - \mathrm{Tv} - \mathrm{Se} \quad (2)$$

∑ is summation of initial (Mi) and final (Mf) months of each crop cycle; Wo corresponds the initial soil water reserve; P is monthly precipitation; Tv is monthly potential vineyard transpiration; Se is monthly soil evaporation.

To obtain the monthly potential vineyard transpiration (Tv), it is necessary to calculate the expression below:

$$\mathrm{Tv} = \mathrm{PET} \,.\, \mathrm{k} \quad (3)$$

PET is the potential evapotranspiration (mm); and k is the radiation absorption coefficient for grapevines cultivation.

According to Conceição et al. (2013), the k value will be equal to 0.1 for first month of the crop vegetative cycle, 0.5 for the remaining months of cycle. The monthly potential evapotranspiration (PET) values were obtained based on the Penman-Monteith method.

The monthly soil evapotranspiration (Se) is obtained by the estimation from the following expression:

$$\mathrm{Se} = \left(\frac{\mathrm{ETP}}{\mathrm{N}}\right) . (1 - \mathrm{k}). \mathrm{JPm} \quad (4)$$

N is number of days per month and JPm is the number of days per month of effective soil evaporation, obtained by dividing P by 5, this value has to be equal or less than N.

The criteria results following the grapevine production cycle with estimated time in four months, however, it is added more two months, one before for pruning and after for harvest, totaling six months for each crop cycle.

These indices are good indicators for viticulture implementation based on surrounding characteristics. However, a biological observation is also necessary, given that this cultivation is extremely vulnerable to weather inherent diseases. Thus, it is used the Zuluaga Index (ZI) (WESTPHALEN, 1977; CONCEIÇÃO et al., 2013; SHIMANO; SENTELHAS, 2013). This method was developed by Westphalen (1977) to evaluate the susceptibility of eventual problems with fungal diseases on grapevine cultivation from environmental characteristics during the grapevine cycle.

Besides ZI, there are two other indices that also will be evaluated: Zip (for pruning month) and ZIh (for harvest month). The indices results are very important, because will assess the possibility of fungal diseases outbreak.

The indices can be classified as preferred (present favorable conditions for possibility of occurrence); or restricted (little chance of occurrence), the grapevines cultivation are very sensitive excess water. ZI, ZIh and ZIp indices are based on criteria show on Table 4.

The equations for determining ZI, ZIp and ZIh indices are:

$$ZI = \sum_{Mi}^{Mf}\left[\frac{T.P}{N}\right] \qquad (5)$$

$$ZIp = \frac{Tp\,.\,Pp}{Np} \qquad (6)$$

$$ZIh = \frac{Th\,.\,Ph}{Nh} \qquad (7)$$

∑ is summation of initial (Mi) and final (Mf) months of each crop cycle of the grapevine cycle inside the six months; T, Tp and Th are monthly average temperature (°C) of the crop cycle, after pruning and before harvest months, respectively; P, Pp and Ph are average monthly rainfall (mm) of the crop cycle, after pruning and before harvest months, respectively; N, Np and Nh are number of days of grapevine cycle, after pruning (initial month) and before harvest months (final month).

The ZI, ZIp and ZIh classes were adopted based on those recommended by Westphalen (1977) as can be observed in Table 4.

Figure 1 - Climate Zoning for Alagoas State, highlighting the municipality of Pão de Açúcar, extracted of Martins et al. (2012).

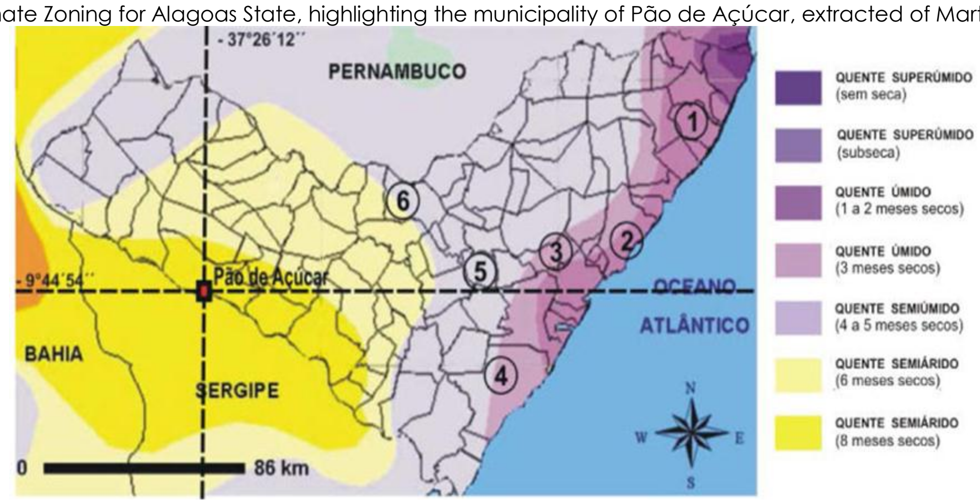

Table 1- Class, acronym and class interval for the Heliothermic Index (HI) (CONCEIÇÃO et al., 2013).

Class	Acronym	Class interval
Very cold	HI_{-3}	HI ≤ 1500
Cold	HI_{-2}	1500 < HI ≤ 1800
Temperate climate	HI_{-1}	1800 < HI ≤ 2100
Warm temperate climate	HI_{+1}	2100 < HI ≤ 2400
Warm	HI_{+2}	2400 < HI ≤ 3000
Very warm	HI_{+3}	> 3000

Table 2 - Class, acronym and class interval for the Cold Night Index (CI) (CONCEIÇÃO et al., 2013).

Class	Acronym	Class Interval (°C)
Hot nights	CI_{-2}	CI > 18
Temperate nights	CI_{-1}	14 < CI ≤ 18
Cold nights	CI_{+1}	12 < CI ≤ 14
Very cold nights	CI_{+2}	CI ≤ 12

Table 3 - Class, acronym and class interval for the Drought Index (DI) (CONCEIÇÃO et al., 2013).

Class	Acronym	Class Interval (mm)
Wet	DI_{-2}	DI > 150
Subhumid	DI_{-1}	150 ≥ DI > 50
Moderate drought	DI_{+1}	50 ≥ DI > -100
Strong dry	DI_{+2}	DI ≤ -100

Table 4 - Suitability class, acronym and interval for the Zuluaga index considering the crop cycle (ZI), after pruning month (ZIp) and before harvest month (ZIh) (CONCEIÇÃO et al., 2013).

Class	Interval	Class
Preferential	ZI, ZIp e ZIh< 70	Preferential
Intermediate	70 ≤ ZI, ZIp and ZIh < 80	Intermediate
Marginal	80 ≤ ZI, ZIp and ZIh < 90	Marginal
Limited	ZI, ZIp and ZIh ≥ 90	Limited

Results and Discussion

In this work evaluated the climatic aptitude for grapevines cultivation for municipality of Pão de Açúcar, Alagoas, during the 1981 to 2010 years, using six indices commonly used for grapevine cultivation.

Initially, Figures 2 and 3 exhibit the climatological normals of rainfall and temperature for the period of study, respectively. The rainfall behavior presents a distinct pattern between the dry and rainy periods (Figure 2).

The minimum values occur between October to December months, less than 20 mm/month. Already during the rainy period, comprised between May to July months, the accumulated monthly of rainfall varied between 56 mm (March) and 83 mm (June), with annual average accumulated of rainfall 549.8 mm.

The air temperature behavior (maximum, mean, minimum) present high temperatures throughout the year, however, during rainy season (between May to July months) there is a reduction in the monthly average values. The maximum temperature remains above 29° C, during January month. According with three temperatures analyzed, the minimum temperature represents at least seasonal thermal amplitude in the order of 3.2 °C with values less than 20.1 °C.

The following results of the climatic aptitude indices for grapevine cultivation, initially the HI (Table 5). The simulations carried out correspond to six months of crop cycle for all projected scenarios.

The HI values are greater than 3,000. This result is associated with high temperatures attributed to regional pattern and that according to Table 1. So, the municipality of Pão de Açúcar is classified as very hot region, the maximum temperature values greater than 30 °C.

It does not prevent the grapevine cultivation. Even with lack of rainfall and water shortage, this problem with respect to availability of soil water can be solved by efficient irrigation system (EDWARDS et al., 2011) such as occurred in Petrolina (FANCHINELLO et al., 2011; NUNES et al., 2016; DA SILVA et al., 2016a).

With these extreme conditions, it is important that the choice of scions be taken into consideration, since certain vine species are not temperature resistant, mainly in the preparation of fine wines. Species like Isabel, Petit Verdot e Tempranillo, have shown promise in the São Francisco Sub-Middle Valley region (CAMARGO et al., 2011; NUNES et al., 2016).

The CI results shows similar weather behavior of the wineries situated in the Petrolina (PE) region, being classified as very hot region and warm nights for all seasons of the year, confirming the results presented by Tonietto et al. (2012). The CI values vary between 20.1 °C during March to August months, and 23.8 °C during November to April, respectively.

In relation to DI results, it is verified that all the projected scenarios of grapevine cultivation cycle, Pão de Açúcar is classified as moderate drought with maximum values between August and January.

This index shows that water shortage occurs in the region throughout the year due for high monthly soil evaporation values (Es).

Besides, the rainfall cannot restore these losses stemming from long periods of drought resulting in DI negative values, found in Figure 5. During twelve simulated scenarios, none classified the region as strong drought, similar to the results obtained by Tonietto et al. (2012), which shows various periods of drought in the semi-arid region of Petrolina (PE).

The Zuluaga Index (ZI) results indicate limited class conditions in ten of the twelve simulated cycles; this is due to the high temperatures during the better part of the year.

In the July to December cycle, Pão de Açúcar is classified as marginal, while in the August and January cycle classified as preferential. Therefore, the region is less prone to the fungal disease outbreak. This same cycle was classified as of moderate drought by DI.

The DI and ZI values reflect the conditions of one period of vine cycle, while the ZIp and ZIh indicate the critical crop phases, regarding the possibility of fungal diseases incidence.

It is observed that in the cycle between June and November, the ZIp is classified as intermediary due at rainy period (March and July months); the other eleven simulated cycles are classified as preferential.

Just like the ZIp, the ZIh index has just one cycle classified as intermediary, between January to June months arising from the rainy period.

The simulations generated simultaneously therein on rainy period was classified as limited, corroborating to Angelotti et al. (2017), this condition favor on increase of fungal diseases probability on cultivation.

Figure 2 - Climatological Normal of rainfall of Pão de Açúcar, Alagoas, corresponding to the period from 1981 to 2010, created by author (INMET, 2017).

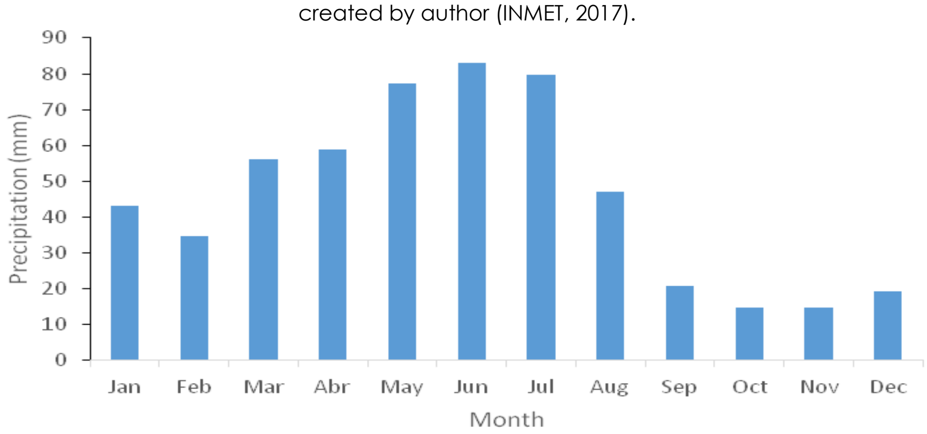

Figure 3 - Climatological Normal of air temperature (maximum, average and minimum) of Pão de Açúcar, Alagoas, corresponding to the period from 1981 to 2010, created by author (INMET, 2017).

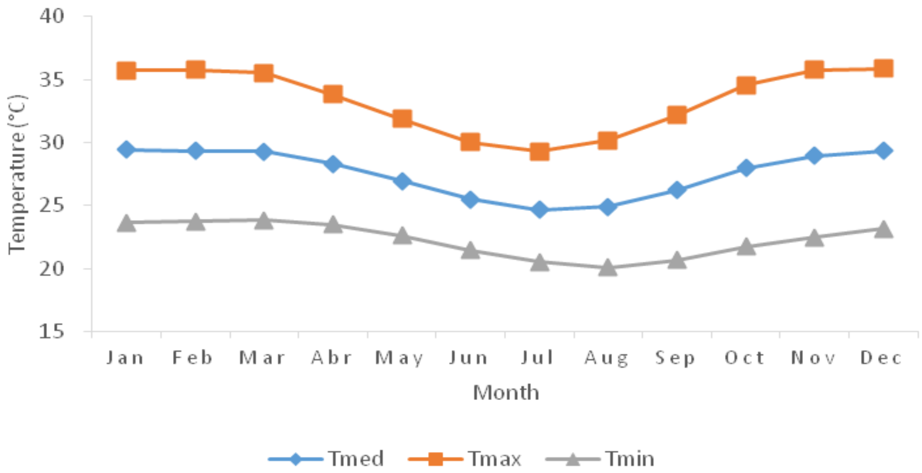

Table 5 - Heliothermic Index (HI), Night Cold Index (CI) and Drought Index (DI) for municipality of Pão de Açúcar, AL. (Author, 2017).

Period	HI	HI Class	CI	CI Class	DI	DI Class
JAN-JUN	3,721. 8	Very hot	22.6	Hot nights	-71.1	Moderate drought
FEB-JUL	3,643. 3	Very hot	21.4	Hot nights	-31.1	Moderate drought
MAR-AUG	3,474. 8	Very hot	20.5	Hot nights	6.3	Moderate drought
APR-SEP	3,396. 4	Very hot	20.1	Hot nights	17.1	Moderate drought
MAY-OCT	3,360. 9	Very hot	20.7	Hot nights	0.2	Moderate drought
JUN-NOV	3,497. 1	Very hot	21.7	Hot nights	-38.7	Moderate drought
JUL-DEC	3,631. 7	Very hot	22.5	Hot nights	-51.1	Moderate drought
AUG-JAN	3,788. 4	Very hot	23.2	Hot nights	-66.3	Moderate drought
SEP-FEB	3,922. 5	Very hot	23.7	Hot nights	-62.6	Moderate drought
OCT-MAR	3,864. 9	Very hot	23.7	Hot nights	-55.0	Moderate drought
NOV-APR	3,898. 8	Very hot	23.8	Hot nights	-51.6	Moderate drought
DEC-MAY	3,820. 5	Very hot	23.5	Hot nights	-40.3	Moderate drought

Table 6 - Zuluaga indices for grapevine cycle (ZI), after pruning month (ZIp) and before harvest month (ZIh) for municipality of Pão de Açúcar, Alagoas (Author, 2017).

Period	ZI	ZI Class	ZIp	ZIp Class	ZIh	ZIh Class
JAN-JUN	212.4	Limited	40.9	Preferential	70.6	Intermediate
FEB-JUL	246.7	Limited	36.2	Preferential	63.5	Preferential
MAR-AUG	257.1	Limited	53.2	Preferential	37.8	Preferential
APR-SEP	239.2	Limited	55.7	Preferential	18.2	Preferential
MAY-OCT	190.2	Limited	67.2	Preferential	13.2	Preferential
JUN-NOV	132.8	Limited	70.6	Intermediate	14.3	Preferential
JUL-DEC	83.6	Marginal	63.5	Preferential	18.1	Preferential
AUG-JAN	64.0	Preferential	37.8	Preferential	40.9	Preferential
SEP-FEB	86.7	Marginal	18.2	Preferential	36.2	Preferential
OCT-MAR	109.7	Limited	13.2	Preferential	53.2	Preferential
NOV-APR	148.6	Limited	14.3	Preferential	55.7	Preferential
DEC-MAY	186.1	Limited	18.1	Preferential	67.2	Preferential

Conclusions

The municipality of Pão de Açúcar, Alagoas exhibited weather suitable for the production of grapes with high quality potential between the months of August to January. This period was classified as preferential for all the analyzed indices. Therefore, the period mentioned above exhibits more favorable water conditions for vine cultivation installations. Thus, the DI and ZI results should be primarily considered, both reflect conditions a six-month period, while ZIp and ZIh indicate critical crop phases with possibility of fungal diseases incidence.

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