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Water demand for rice (*Oryza sativa* L.) in a Dark Plastic Gleyed soil

Demanda de agua para el arroz (Oryza sativa L.) en un suelo Oscuro Plástico Gleysado

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ABSTRACT: With the aim of determine the irrigation requirements of rice planted in a Dark Plastic Gley soil, a research was carried out in areas of the "Fernando Echenique" Agroindustrial Company located in the province of Granma, Cuba. To this end, a study was carried out of the 2008-2020 rainfall series from the rain gauge located in the study area, where the wet, medium, and dry hydrological years were defined. The climatic variables for determining the reference evapotranspiration were taken from the National Agrometeorological Bulletin issued by the Meteorology Institute. Using the CropWat program, the total net requirements for rice were estimated at different planting seasons and crop cycle durations. The results shows that for a dry year in the May-December period the water consumption is 9 110,4 $m^3 \cdot ha^{-1}$, in the May-September period the rice needs 7913,0 $m^3 \cdot ha^{-1}$ and for the July-October period it is 6 596,0 $m^3 \cdot ha^{-1}$ for to life cycle of 130 days. For to life cycle of 140 days the requirements plows ace follows: May-December 9654,0 $m^3 \cdot ha^{-1}$, May-September 4399,0 $m^3 \cdot ha^{-1}$ and for the July-October period it is 7072,0 $m^3 \cdot ha^{-1}$. When comparing the total net standards proposed by the Resolution 17/2020 for an average cycle of 140 days and to year with to 75 % probability of rainfall, the irrigation requirements obtained in this study are between 19,3 and 42,5 % higher depending on the planting season.
Keywords: effective rainfall, irrigation needs, planting seasons, crop cycle.

RESUMEN: Con el objetivo de conocer las necesidades de riego del arroz sembrado en un suelo Oscuro Plástico Gleysado, se desarrolló una investigación en áreas de las Empresa Agroindustrial de Granos “Fernando Echenique” ubicado en la provincia de Granma, Cuba. Para ello se realizó un estudio de las precipitaciones de la serie 2008-2020 del pluviómetro ubicado en la zona de estudio, donde se definen los años hidrológicos húmedo, medio y seco. Las variables climáticas para la determinación de la evapotranspiración de referencia fueron tomadas del Boletín Agrometeorológico Nacional emitido por el Instituto de Meteorología. Con el uso del programa CropWat se estiman las necesidades netas totales para el arroz en diferentes épocas de siembra y duración del ciclo del cultivo. Como resultados se tienen que para un año seco en la época mayo-diciembre el consumo de agua es de 9 110,4 m^3 ha^{-1}, en la época mayo-septiembre el arroz necesita 7 913,0 m^3 ha^{-1} y para la época julio-octubre de 6 596,0 m^3 ha^{-1} para un ciclo de vida de 130 días. Para un ciclo de vida de 140 días las necesidades son las siguientes mayo-diciembre 9 654,0 m^3 ha^{-1}, mayo-septiembre 4 399,0 m^3 ha^{-1} y para la época julio-octubre es de 7 072,0 m^3 ha^{-1}. Al comparar las normas netas totales que propone la Resolución 17/2020 para un ciclo medio de 140 días y un año de 75% de probabilidad de ocurrencia de las precipitaciones con las obtenidas en el presente estudio son superiores entre un 19,3 y 42,5% en función de la época de siembra.
Palabras clave: Precipitación efectiva, necesidades de riego, épocas de siembra, duración del ciclo del cultivo.

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INTRODUCTION

The rice (*Oryza sativa* L.) it is one of the main foods to world level together with the wheat and the corn, with a production of 509,2 million tons (FAO, 2020), that come, for the most part, of Asian countries as China and India.

According to Díaz *et al.* (2021), Cuba is one of the countries that registers high values of consumption of rice with 72 kg per capita in a year, for that it is important to increase the national production of this grain to small and medium scale, since currently it satisfies only the 50 % of the necessities.

As any crop, the rice has stages during the cycle of growth that are more sensitive to the lack of humidity in the soil, mainly after the transplant, during the tillering stage, during the initiation and at the floral primordium development, in the blossoming and during the development of the panicles, up to two weeks before the crop.

The irrigation is necessary to supply the deficiencies in water of the crop, and when water is not available for irrigation it is better than the farmer planted other crops, due to the economic losses that can be caused planting rice without supplementary irrigation (Reyes, 2003).

In this context, the water plays an important role in the grain production. Now the 80 % of the surface planted of rice is cultivated under conditions of continuous flooding from the transplant until the physiologic maturity, and the remaining 20 % using the method of direct sowing. In both cases big volumes of water are used surpassing the 14 000 $m^3 \cdot ha^-$ (Hernaiz y Alvarado, 2007). In the cultivation of the rice should be considered the losses of water due to the evapotranspiration of the plant, infiltration and percolation in the soil, being necessary to practice an specific of handling of the water (for example, drainage before the application of agrochemicals), and also a good initial soil farming and the drainage of the area before the tillering stage (Bouman *et al.*, 2007). This way, the rice is a high demander of the water resources.

The expression of the final result of the balance of water needs for rice cropping during all its cycle is the net irrigation standard, that is to say the quantity of total water to be planned (without keeping in mind the losses in the conduction system, distribution and application) to obtain the wanted yield.

According to Herrera *et al.* (2020), the parameters percolation and evapotranspiration occupy among the 80 % to 90 % of the water applied, of there the importance of the determination of the characteristics of the infiltration into the soil (it determines the percolation) and of the consumption of water by the crop, which is a function of the variety, of the duration of the cycle and of the climatic demand, in relationship this last one with the time of the crop's development.

The present work was carried out with the objective of knowing the necessities of irrigation of the rice sowed in a Plastic Dark Gleyed soil.

MATERIALS AND METHODS

The work was carried out in the Agroindustrial Company of Grains (EAG) "Fernando Echenique", province of Granma, Cuba, taking like base the information of the available climatic variables in the National Agrometeorological Bulletin of the National Meteorological Institute INSMET-Cuba (2024).

For the selection of the hydrological years was carried out the study of a series of 13 years (2008 - 2020) of the pluviometer located in "Veguita", province Granma, with geographic coordinates of 20°13´38,59" N and 76°57´3,40" W to a height of 41 m.o.s.l where the empiric probability was determined starting from the following expression:

$$P = \left(\frac{m - 0{,}3}{n + 0{,}4}\right)100 \qquad (1)$$

Where:
m: order number.
n: number of members of the series.

Each one of the years of the series was classified in function of their probability and for each time of sowing of the crop. The 25 % of probability denotes a humid scenario, 50 % medium and 75 % dry, according to Pérez & Álvarez (2005), with the program WINKOL.exe.

For the estimate of the ET_0 was started of the definition of the sowing dates more common in Cuba (Table 1) according to IIG-Cuba (2020) which are the following:

Table 1. Sowing dates and duration of the vegetative cycle

No.	Sowing dates	Duration, days
1	December - May	
2	May - September	130 y 140
3	July - October	

Were taken like reference for the determination of the net and total irrigation requirements the results of Maqueira (2014) & Herrera *et al.* (2020), where they defined four stages of vegetative development: initial, development, medium and end of the season, with crop coefficients (K_c) for the stages initial, medium and final. The K_c are shown in the Table 2.

Table 2. Coefficients of crop of the rice adjusted according to Herrera *et al.* (2020)

Development phases	K_c
Initial (GDCA 505 ±5)	0.8
Vegetative (GDA 1299 ±21)	1.2
Reproductive (GDCA 2136 ±98)	1.4
Final (GDCA 2555±168)	1.3

In the table 3, are summarized the parameters of entrance of the soil module using the program CropWat in function of the soil type defined by GOC-Cuba (2020).

Table 3. Parameters for a plastic dark gleyd soil

Parameter	Group I
Available total humidity in the soil (DC-CM, mm/m)	270
Highest rate of infiltration of the rain (mm/day)	17
Highest depth of the crop's roots (cm)	50
Initial exhaustion of the humidity of the soil (as % of ADT) (%)	100
Humidity of the soil initially available (mm/m)	0
Drainable porosity (SAT-DC) (%)	5
Critical exhaustion by cracks in the soil remaining after mudding (fraction)	0.6
Highest percolation rates after the mudding (mm/day)	2.6
Availability of water for the sowing (% saturation)	0
Highest height of the sheet of water (mm)	100

For the estimation of the total net water requirements the tool CropWat version 8.0 was used. This software allows to negotiate irrigation programs so much under unirrigated land conditions as of irrigation, for what it was used to determine the reference evapotranspiration since it uses the Penman-Monteith method of the FAO.

For the calculation of the total net water requirements were used the following approaches:

Moment of the irrigation: To water when the level 50 mm high of the water is reached.

Application of the irrigation: To apply water to reach the level of 100 mm high.

Fraction of permissible exhaustion: p = 50 %.

Efficiency of the irrigation (Field eff.) 60%: Surface irrigation of the rice, according to Resolution 17/2020 of INRH.

Once obtained the total net water requirements of the rice for the three sowing times and a medium cycle of the crop (140 days) they were compared with the ones that establishes the Resolution 17/2020 for the study region (Herrera *et al.*, 2019).

RESULTS AND DISCUSSION

Hydrological study of the years for each sowing time

Of the hydrological study of the work place was possible to define the humid, medium and dry years, of which were processed the climatic variables that intervene in the determination of the reference evapotranspiration and the effective rainfall for their later running in the programming tool CropWat. In the Figure 1 (A, B and C), are shown the studies of the rainfalls by sowing periods.

The table 4 show the hydrological years for the sowing times and the effective rainfalls in millimeters.

In the figure 2 (A, B and C) the balance of water availability is shown for the study area in the three sowing periods for a dry year. Can be appreciated that in the period December-May the reference evapotranspiration (ET_0) surpasses the effective rainfalls during the whole cycle of life of the crop. In the period May-September only in the month of September the accumulated effective rainfalls surpasses the ET_0. In the period July-October equally in the month of September the accumulated rainfalls surpasses the ET_0. This all indicates it that the irrigation is indispensable to satisfy the water requirements of the crop.

Similar results to those obtained, are informed by Herrera *et al.* (2019) in the work "Studies about the water availability of the rice in Cuba" and more recent for Herrera et al. (2020) in "Determination of the crop coefficient

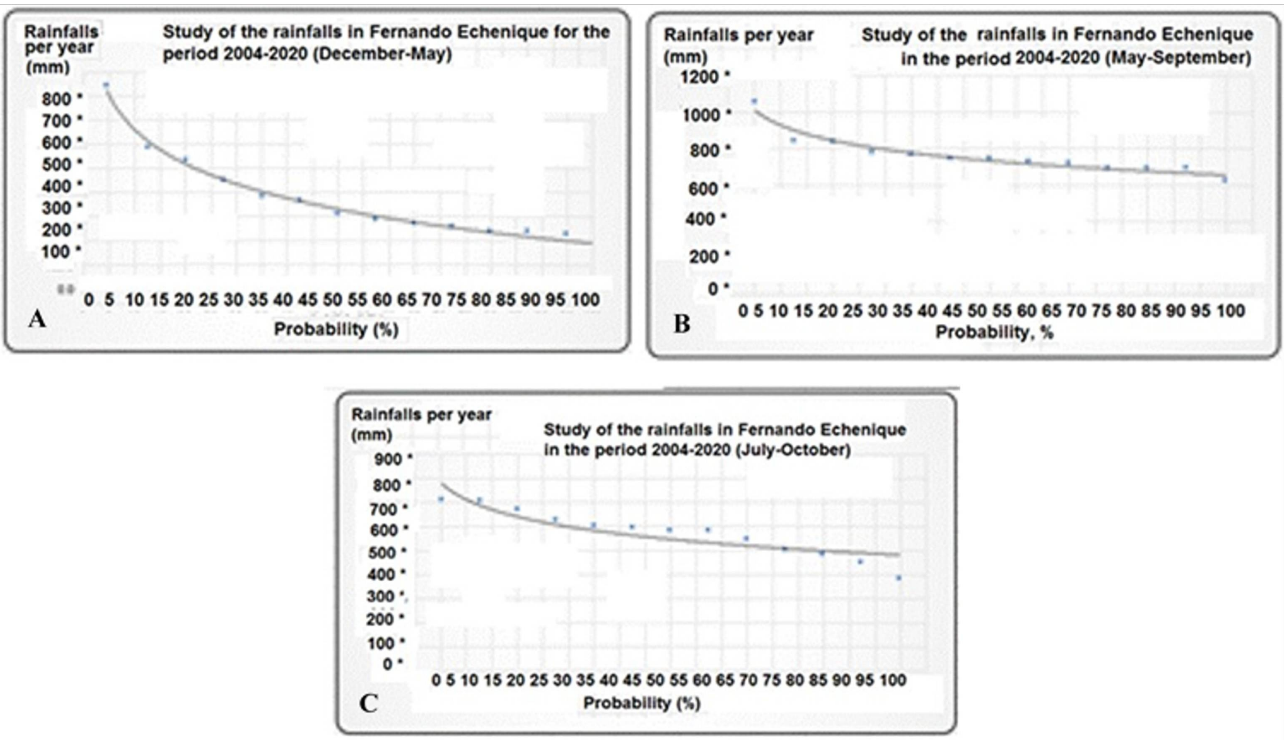

Figure 1. Graph of probabilities: A (period december-may), B (period may-september) and C (period july-october).

Table 4. Distribution of the hydrological years for sowing times

Site	December - May			May - September			July - October		
	H	M	S	H	M	S	H	M	S
EAG	2012	2010	2017	2019	2015	2010	2010	2012	2009
"Fernando Echenique"	281.4	267.5	203.7	568.5	540.4	501.7	442.4	425.6	352.5

Legend: H: humid (25 %), M; medium (50 %); S: dry (75 %).

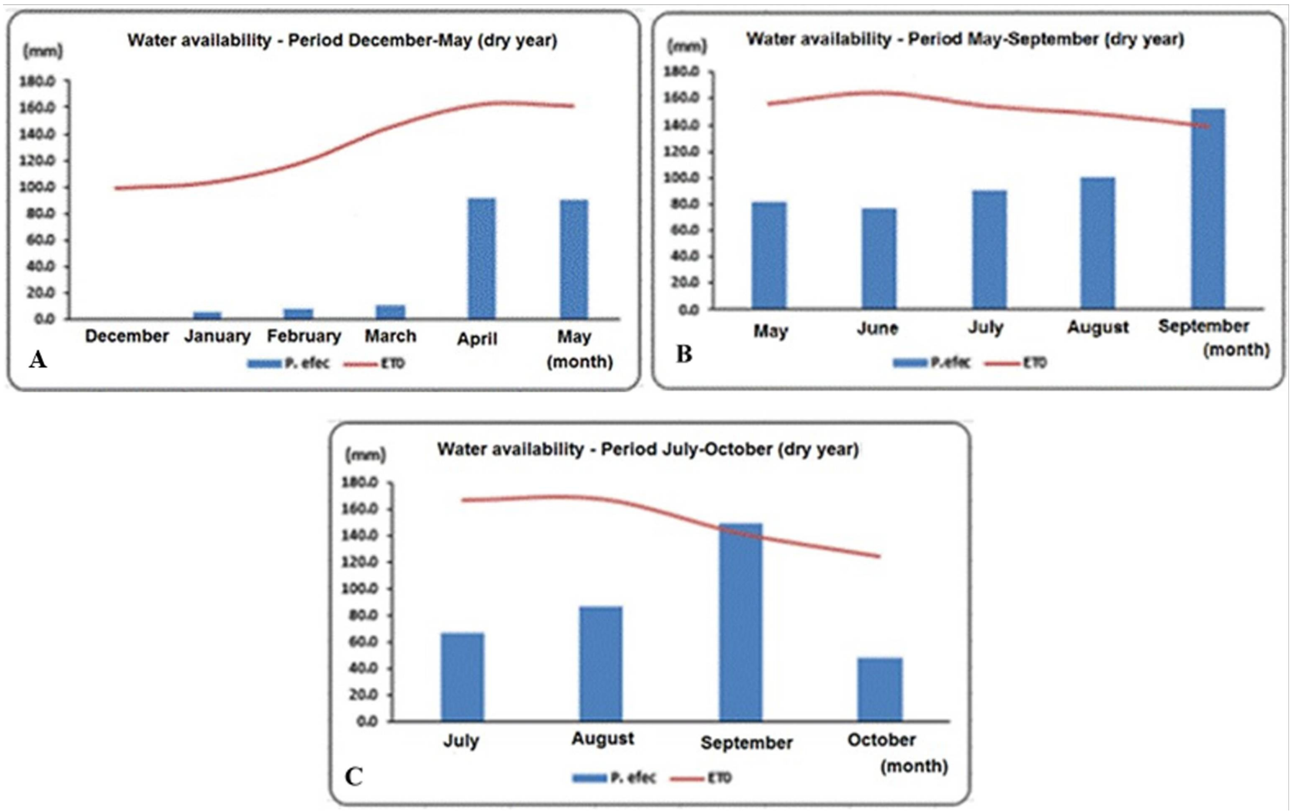

Figure 2. Water availability for the three sowing periods: A (december-may), B (may-september) and C (july-october) in the eag "Fernando Echenique", province Granma, Cuba.

for the estimate of the evapotranspiration of the rice in Cuba", in which a reference is made to the deficit of rainfalls in the three sowing periods of the rice, and where in general sense for most of the months, the reference evapotranspiration is higher than the volume of rainfalls.

Net total irrigation requirements estimated for different periods of sowing and probability of occurrence of the 75 % of the rainfalls (dry year)

In the Table 5 are shown the net total requirements estimated for the sowing period December-May for the cycles of life of the rice of 130 and 140 days for a dry year. The water requirements varied among 9 110,4 $m^3 \cdot ha^{-1}$ for 130 days and 9 654,0 $m^3 \cdot ha^{-1}$ for 140 days. Similar results were informed by Camejo *et al.* (2017) an study carried out on the irrigation of the rice in dark plastics soils when comparing a handling system allowed to diminish the sheet of water in the terrace up to 3 cm and restoring it later on up to 10 cm until the 50 % of panicles formation with the traditional system of permanent flooding, obtaining a decrease in 50 % of the irrigation needs without affectations in the yielding.

Table 5. Estimated water needs of the rice in the eag "Fernando Echenique", for a dry year (75 % of probability) in the sowing period (december-may).

Probability of rainfalls (%)	Effective rainfalls (mm)	ET_c (mm)	Net water requirement (mm)	Total losses by percolation (mm)
130 days				
75	118.2	747.1	911.04	157.8
140 days				
75	157.6	761.1	965.4	183.5

The evapotranspiration of the crop (E_{tc}) in this time it was of 5.75 $mm^3 \cdot day^{-1}$ for 130 days and of 5.44 $mm \cdot day^{-1}$ for 140 days. Similar results were informed by Ruiz (2014) in a work carried out on requirements of water in the cropping of the rice using the program CropWat 8.0 FAO (2009) and (Steduto *et al.*, 2012) with the coefficients (K_c) proposed by Allen *et al.* (2006).

For the period May-September the estimated total net water requirements varied between 7 913,0 and 4 399,0 $m^3 \cdot ha^{-1}$ for the cycles of life of 130 and 140 days as appears in the Table 6. The evapotranspiration of the crop (ET_c) is increased in 6 % when the cycle varied from 130 to 140 days.

Table 6. Estimated requirements of water of the rice in the eag "Fernando Echenique", for a dry year (75 % of probability) in the sowing season (may-september)

Probability of rainfalls (%)	Effective rainfalls (mm)	ET_c (mm)	Total net water requirements (mm)	Total losses by percolation (mm)
130 days				
75	637.2	865.2	791.3	233.8
140 days				
75	650.6	921.6	439.9	295.5

In a work carried out by Bouman *et al.* (2012), they refer that in the middle of the crop's cycle, when there are a complete covering of the crop, the rice evapontranspire to a rate lightly higher to the reference evapotranspiration (ET_0), with averages daily rates of ET_c of 4-5 mm·day^{-1} in tropical humid season and 6-7 mm·day $^{-1}$ in tropical dry season, but they can arrive up to 10-11 mm·day $^{-1}$ in the arid regions.

In the period July-October (Table 7), the estimated total net water requirements varied between the 8078,0 and 7072,0 m^3·ha^{-1} for the cycles of life 130 and 140 days. The evapotranspiration of the crop (ET_c) increases in 5,2 % when the cycle varied from 130 to 140 days.

Table 7. Estimated water requirements of the rice in the EAG "Fernando Echenique", for a dry year (75 % probability) in the sowing period (July-October)

Probability of rainfalls (%)	Effective rainfalls (mm)	ET_c (mm)	Total net water requirements (mm)	Total losses by percolation (mm)
130 days				
75	394.7	807.8	659.6	224.0
140 days				
75	402.9	852.3	707.2	249.7

The results shown coincide with the ones informed by Reyes (2003) in a work on the management of the irrigation where it outlines that a minimum supply of 1 liter of water per second per hectare during 24 hours in the parcel is enough for a crop of rice under irrigation, provided that the evaporation, infiltration and filtration indexes stay to the minimum with a good management of the irrigation in the plantation. The above-mentioned is approximately equal to about 26-30 gallons/minute during 10 hours daily per hectare. That is to say, that requires having a minimum of 300 gallons/minute during 10 hours per day for a project of some 10 hectares. The previous supply is in a consumption of approximately of 6 000 to 7 000 m^3 of water for hectare, in approximately 100 days of permanent or continuous irrigation during the cycle of the crop (Pérez & Álvarez, 2005).

Comparison of the total net water requirements obtained with the programming of the irrigation by means of the program CropWat and the Resolution 17/2020 of the INRH

The table 8 shows the total net water requirements approved by the INRH in the Resolution 17/2020 GOC-Cuba (2020) for an average cycle (140 days) and different sowing periods and the estimated using the program CropWat. When comparing the figures approved in the Resolution for the province of Granma in the Agroindustrial Company of Grains "Fernando Echenique" they are superior in the range of 19,3 and 42,5 % for the three sowing periods.

Similar results to those obtained have been informed by Camejo *et al.* (2017), who when comparing a management system where allowed to diminish the sheet of water in the terrace up to 3 cm and restoring it later on up to 10 cm, also until 50 % the formation of the panicles with the traditional system of permanent flooding, they obtained a decrease in 50 % of water needs for the irrigation without affectations in the yield.

In a study carried out by Herrera *et al.* (2019) about the balance of water requirements for the rice in Cuba, they informs that the demands of water in the rice are carried out on the basis of a gross norm of 17 400 m^3·ha^{-1}, and is calculated a global efficiency of the system that fluctuates among 0,68 for the western and central region and 0,70 for the Westerner Polon (2003). This should indicate a net water requirements of 11 832 and 12 180 m^3·ha^{-1} for the eastern, central and western regions, respectively. The same author refers that the intense droughts of the years 2014 - 2015, forced to the reduction of these norms with a view to maintaining the area sowed at a fixed level of 14 000 m^3·ha^{-1}. This reduction was not based on studies of the balance of water requirements of the crop, but rather in the historical averages of the real consumptions of water for irrigation.

Table 8. Comparison among the total net water requirements estimated for a dry year (75 % probability) and the ones approved in the resolution 17/2020 GOC-Cuba (2020)

Place	Sowing period	Total net water requirements estimated using CropWat (mm)		Total net water requirements (INRH) (mm)	Difference	% of increment
		130 days	140 days	140 days		
Agroindustrial grains company "Fernando Echenique", province Granma	Dic-May	911.04	965.4	1184.9	219.5	19.3
	May-Sept	791.3	439.9	1034.0	594.1	42.5
	Jul-Oct	659.6	707.2	940.0	232.8	24.7

CONCLUSIONS

For a dry year of 75 % of probability of occurrence of rainfalls in the period May-December the consumption of water is of 9 110,4 $m^3 \cdot ha^{-1}$, in the period May-September the rice needs 7913,0 $m^3 \cdot ha^{-1}$ and for the period July-October of 6596,0 $m^3 \cdot ha^{-1}$ for a cycle of life of 130 days.

For a cycle of life of 140 days and 75 % of probability the total net requirements are the following: May-December 9 654,0 $m^3 \cdot ha^{-1}$, May-September 4 399,0 $m^3 \cdot ha^{-1}$ and for the period July-October is of 7072,0 $m^3 \cdot ha^{-1}$.

The evapotranspiration of the crop (ET_c) for the study area stayed in the range of 5,4 and 6,21 $mm \cdot day^{-1}$ in dependence of the sowing period and the cycle of life of the rice.

When comparing the total net requirements that roposes the Resolution 17/2020 for a average cycle of 140 days and a year of 75 % of probability of occurrence of rainfalls, with those obtained in this study they are higher between a 19,3 and 42,5 % in function of the sowing period.

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