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Irrigation and drainage in pineapple crop (cultivar MD-2) in Ciego de Ávila province

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Abstract: The pineapple cultivar MD-2 was introduced in Cuba at the end of the year 2009 and the results obtained in the irrigation in Ceballos Agroindustrial Enterprise have not been satisfactory, being presented manifestations of excess of humidity with the affectation to the crop. With a view to value the conditions of management of the water under the given conditions and to propose the corresponding measures, a study of the irrigation and drainage conditions was carried out in the areas studied and the evaluation of the exploitation of the central pivot machine was carried out according to the NC 11545:2004 and the diagnosis of the problem of the drainage. The results indicate low quality of the irrigation with values of coefficient of uniformity of 66 % and of efficiency of discharge of 71 %. The irrigation system was calculated obtaining for the critical stage with a net norm of 152 m^3 /ha and a frequency of irrigation of 7 days, being concluded with the presentation of the technical chart for the adjustment of the module of nozzles and the calculation of the regulation of the machine. It was determined that the hardening of the soil is the main factor that impacts the present drainage problems. There are indicated recommendations on the irrigation technologies, which can be used to develop the crop and solve the current drainage problems.

Key words: efficiency water use; relationship; water-soil-crop

1 Introduction

Agriculture is the activity that uses the largest amount of water. Its scale accounts for more than two thirds of the earth's rivers, lakes and aquifers, and this proportion must increase in the next few years, because the irrigation area will naturally expand due to the increase in food demand, which urges people to use strategies to increase savings in this important sector (Puebla et al., 2011, cited by Lopez et al., 2017).

According to Paretas (2005) and Planos et al. (2013), efforts are being made to use irrigation water more effectively around the world, so that more food can be obtained with each drop of water used. In the last 20 years of the 20th century, the use of efficient irrigation technology has achieved significant growth, mainly due to the incorporation of high profitability crops generally associated to export activities.

The techniques for the evaluation and improvement of irrigation systems make it possible to know the parameters involved in the application of water based on field tests carried out under normal working conditions and to determine the necessary changes to improve the irrigation process; with these changes it is possible to achieve savings in water, labour, energy, soil protection, etc., as well as an improvement in crop yields (Tarjuelo, 1995).

According to Fernández (2003) and Dominguez et al. (2005), on the central and horizontal fulcrums that move automatically, it is relatively easy to properly manage the irrigation level. Almost all crops can and have been successfully irrigated through fulcrums under a wide range of conditions. In some cases, special cultural practices are required to facilitate infiltration and prevent surface runoff.

It has been reported by Rohrbach (1997) and Malézieux (1997) cited by Bonet and Guerrero (2016), that the characteristics of pineapple with respect to the water use have led to the fact that the irrigation has not become one of the most studied problems by researchers worldwide. However, the main pineapple-producing countries use irrigation to make up for the deficit in water use.

Different irrigation technologies have been used in the world for pineapple irrigation, but the general opinion among growers and researchers today is that localised and low and medium pressure sprinkler irrigation technologies are the best for pineapple irrigation. (Bartholomew et al., 2003, cited by Bonet and Guerrero (2016).

The MD-2 pineapple cultivar was introduced in Cuba at the end of 2009 at the Ceballos Agroindustrial Company with seedlings imported from Costa Rica. There are no studies on its water requirements in our conditions, but from the information available on its behavior in other conditions, it is known that its requirements are higher than those of the Española Roja cultivar, and the crop is irrigated with pivot irrigation machines.

In the process of irrigation, there are difficulties, mainly due to the rotten performance caused by excessive humidity, which affects the production. According to the situation, this study was carried out to evaluate the soil fertility of pineapple (planting MD-2), as well as the causes of poor overflow drainage, and put forward necessary suggestions to improve water management based on the results.

2 Methods

This study was conducted in the UBE pineapple production of Ceballos Agricultural Industry Company, and the research objects are typical red ferruginous soil and compacted red ferruginous soil (Table 1).

Table 1. Hydrophysical properties of soil

Soil	Field capacity (CC) (% b.s.s.)	Apparent density (da) (g cm^{-3})	Stable infiltration rate (mm · h^{-1})
Typical ferrallitic red	30.74	1.20	85.20
Compacted ferrallitic red	31.07	1.22	66.00

Source: Soil Research Institute. Minag. Ciego de Á vila (2009), cited by Bonet (2016)

The available irrigation technology comes from the pivot machine of the power plant (Fig. 1).

Fig.1. Irrigation and drainage of Ciego de Á vila pineapple (planting MD-2).

There are four machines, and their general characteristics are shown in Table 2.

Table 2. Information on available pivot machines

Machine	Q (L/s)	Ab (ha)	Length (m)	No. nozzles
1	66	66.1	459	219
2	60	66.1	459	219
3	80	48.4	392.5	187
4	66	65.9	458.4	220

Machine number 2 was selected for the study, and the typical red iron soil was dominant (76%). Initially, a diagnosis of the situation of the irrigation and drainage system was carried out based on the field investigation and the communication with the workers, technicians and officials of the production unit. In order to evaluate the irrigation and drainage system, the No. 2 machine was selected and the following parameters were determined:

• Uniformity coefficient according to ISO NC 11545:2007 (CEN, 2014)

• Discharge efficiency (Tarjuelo, 2005)

• Soil moisture (gravimetric method)

The irrigation regime of exploitation was studied for the given soil and climatic conditions and the available information on the crop's water requirements. Finally, the working parameters of farmland organization are calculated by using the super spray nozzle module calculation software. The performance of the drainage network used in the irrigation area was evaluated.

3 Results and discussion

3.1 Diagnostic results

Technical defects, such as the lack of a pressure gauge and inability to control working pressure, are decisive factors to achieve proper irrigation quality.

• The pivot mechanism does not conform to the original design, but have been converted, so there is no operation diagram under current conditions.

• Many diffuser nozzles are in poor condition because they operate under inappropriate conditions, such as towing or incorrectly positioned according to the regulation.

• Irrigation planning is not based on technical assessment of soil and crop conditions, but on actual experience.

• Irrigation or excessive rainfall is affecting crops, mainly in the area near the machine tower.

• The size of the machine allows the seeding process to take place over a long period of time, so the crops are irrigated at different stages of development.

• There is a waterproof layer at the depth of 15 to 20 cm, which limits the water penetration, thus causing artificial drainage conditions poor drainage.

• The dominant slope is 0.3%, but the slope in some areas is larger and undulating, resulting in water shortage within the field.

3.2 Irrigation quality

Table 3 summarizes the parameters obtained from the evaluation. The results confirmed that the irrigation quality was low, with CU and Ed values around 70%. The low evaluation was conducted using the criteria of Christiansen (1942) and Keller and Bliesner (1990) quoted by Tarjuelo et al. (2000) and Tarjuelo (2005), who consider a well irrigated plot when it reaches CU values above 80%, observing the greatest problems in the extreme sections, which must be influenced by a poor distribution of pressures, although this author states that it is common to find the greatest uniformity problems at the end of the pivot; these results together with an inefficient irrigation schedule are reflected in the soil moisture, far from the desired parameters of 80% and 100% CC before and after irrigation, respectively.

ED is seriously affected by the prevailing winds that remain above 4m s^{-1} for most of the day. Another option to reduce the water loss caused by evaporation and resistance is to put the nozzle close to the soil, which can be studied according to the specific conditions of crops and sites. However, attention should be paid to evaluating the possible increase of surface runoff in areas with slopes, which are very common in the areas under study.

Table 3. The coefficient of uniformity (%), the efficiency of discharge (%) and humidity before and after irrigation (% CC)

Tramo	Line 1		Line 2		Average value		Humidity	
	CU	Ed	CU	Ed	CU	Ed	AR	DR
Pivot - Torre 1	44	59	38	47	41	53	66	80
Torre 1 – Torre 2	69	71	76	76	72	73	70	85
Torre 2 – Torre 3	66	74	60	74	63	74	75	91
Torre 3 – Torre 4	69	69	69	71	69	70	63	79
Torre 4 – Torre 5	68	77	73	78	70	77	84	99
Torre 5 – Torre 6	72	73	67	72	69	72	82	94
Torre 6 – Torre 7	76	68	73	70	74	69	88	104
Torre 7 – Torre 8	74	76	77	74	75	75	78	92
Torre 8 - Consola	56	63	58	65	57	64	72	86
Total Machine	66	71	66	71	66	71	75	90

CU: the coefficient of uniformity; Ed: the efficiency of discharge; AR and DR: humidity before and after irrigation

3.3 Irrigation system

Bonet and Guerrero (2016a, 2016b) assumed the evapotranspiration value of the Spanish red crop study as a reference, since there are no studies in Cuba for the cultivar MD-2, and from the available information on soils and climate in the region, a farm irrigation regime was calculated (Table 4).

In practice, the existing irrigation technology cannot establish differences between different stages of crop development, so it is necessary to apply the rules and frequency calculated for the maximum demand stage in the whole cycle.

Table 4. Irrigation schedule parameters calculated in one year

Distance	Nn	Nb	Reg.	Tv	F	Tr		NR	Nbt
	(m^3 ha^{-1})	(m^3 ha^{-1})	(%)	(h)	(d)	(h d^{-1})	(d)		(m^3 ha^{-1})
Establishment	76	101	60	24	5	8	3	9	909
Vegetative growth	114	152	40	36	6	8	4.5	17	2584
Floration	152	202	30	48	7	8	6	8	1616
Des. of fruit	152	202	30	48	6	8	6	12	2424
Harvest									
Total								46	7533

Nn: Normal net; Nb: General standard; Reg: Regulation; Tv: Time to complete irrigation; F: Frequency of irrigation; Tr: Irrigation time; NR: Number of risks; Nbt: Total gross standard

3.4 Irrigation system operation

Tarjuelo (2005) pointed out that the most important factor to achieve good water distribution uniformity is the correct design of the issuer's articles of association.

According to the characteristics of the machine, the appropriate nozzle module and adjustment diagram are calculated, which will make it possible to organize the operation of irrigation technology (Pérez and Sabatier, 2015).

The regulation chart (Table 5) includes the applicable rules and turning time under different operating conditions. When selecting appropriate regulation according to the working conditions and wind speed of the machine, the emission efficiency should be considered.

Table 5. Operating parameters

Timer (%)	Standard applied (m^3 ha^{-1})	Time of turn (h)	Timer (%)	Application standard (m^3 ha^{-1})	Time of turn (h)
10	376	143.85	60	63	23.98
15	251	95.90	65	58	22.13
20	188	71.93	70	54	20.55
25	150	57.54	75	50	19.18
30	125	47.95	80	47	17.98
35	107	41.10	85	44	16.92
40	94	35.96	90	42	15.98
45	84	31.97	95	40	15.14
50	75	28.77	100	37.58	14.39
55	68	26.16			

3.5 Drainage

The nutrient development of crops depends directly on the air-water-soil interaction. Although drought or soil water deficit hinder the survival of plants, continuous excessive water will hinder the nutritional development of plants until they disappear (El-Nashar, 2013; Herrera et al., 2016).

In order to solve the problem of poor drainage, it is necessary to find out the causes of these problems (Vigoa, 2000; Méndez, 2010). The dominant soil in the study area usually does not have internal drainage problems, because their infiltration rate is very fast. But in this case, it can be seen that there is an impermeable layer at the depth of 15 to 20 cm, which is not the characteristics of the soil, but is caused by the large-scale use of heavy soil preparation equipment under the action of human beings. This factor is related to the structure of farmland. In the seeding direction, there is a 3m wide fence every 15m, which is responsible for the application of plant quarantine and the circulation of fumigants using flowering inducing products, herbicides, etc. in the fence. The passing frequency of equipment is very high, resulting in higher compactness of these guardrails. It is also necessary to consider the highly compacted dedicated area for irrigation machine parking lot, all of which will increase the loss of surface water.

The existing irrigation technology poses an additional obstacle to the normal operation of the drainage network, because the passage of the tower wheel gradually deforms the drainage channel, making it difficult to operate normally.

The current drainage system has the following disadvantages:

• The fishbone scheme is widely used. There is a drainage ditch in the center of each plot, which means that the drainage ditch is located at the lowest point of the plot, but this does not always happen.

• The drainage ditch in the center of the plot is built in the whole field. Assuming that the slope in the field is unidirectional, this is usually inconsistent.

• There is no final destination for drainage.

• Reaching the speed of water in some places will lead to serious erosion problems.

The solution to the current problem is to change the soil preparation technology, strive to reduce the use of heavy equipment, and adopt other technologies such as tillering to avoid soil compaction and promote water infiltration into the soil, and adopt drainage schemes suitable for specific slope and terrain characteristics of different crop areas to minimize soil erosion, and achieve a final destination for the drained water.

In the case of more regular areas, different types of drainage channels may be more separated. In this case, because the area to be drained will be larger, the part of these channels must also be larger. In areas with very irregular slopes, the situation is just the opposite. Another factor to be considered when defining the river section is the water flow speed. The water flow speed must be fast enough to promote water discharge, and it must also be slow enough to avoid accelerating soil erosion. In any case, this means that it is not recommended to follow a single plan when determining the depth of the drainage channel.

In the process of irrigation, it can be found that even if the minimum standard of dry soil is applied, surface water and surface runoff will occur in places with slopes, which shows the limit of water infiltration into the soil. This is crucial to the effective use of water and good agricultural results.

In the assessed machine cultivated land, the possible water storage in the 0.15 m soil layer is 110 m^3/ha. If we can decompose the soil to a depth of 0.40 m, the water storage will reach 295 m^3/ha, which will significantly reduce the amount of surface runoff.

Table 6 presents a comparison of the runoff volume that can be expected under different rainfall or irrigation values in the current situation considering the characteristics of the typical red ferruginous soils that dominate the selected machines.

Table 6. Expected runoff under two soil preparation conditions

Rain or irrigation (mm)	Water volume in turbine area (m^3)	Estimated runoff (m^3) Decomposition depth of soil (m) difference		
		0.15	0.40	
5	2500	0	0	0
10	5000	0	0	0
15	7500	2302	0	2302
20	10000	4802	0	4802
25	12500	7302	0	7302
30	15000	9802	1108	8694

It is worth noting that in the first case, the soil layer is only 0.15 m, and the surface runoff starts from 15 mm of rainfall, while when the available depth reaches 0.40 m, the surface runoff only starts from 30 mm of rainfall. These values are obviously not absolute values, but trend, and will be affected by various factors: initial soil moisture, rainfall intensity and slope during rainfall.

4 Conclusion

• The current irrigation quality is poor, because the nozzle module needs to be changed according to the characteristics of the existing machines, and the irrigation system taking into account the soil, crop and climate conditions is implemented.

• Due to excessive mechanization and poor surface drainage caused by soil compaction, the drainage variants used cannot solve the current problem.

• The hub mechanical irrigation technology is not suitable for the development of pineapple (MD-2) crop irrigation.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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