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AN EXPERIMENT ON DRAINAGE BY MEANS OF PUMPS

IN THE CANE PLOTS "MANUEL MOLINA",[1] "FABRICA PAJAS 1ª.",[2] AND "FABRICA PAJAS 2ª.",[3] OF THE GIORGETTI COMPANY, IN THE MUNICIPALITY OF BARCELONETA, YEARS 1923–1925

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TOPOGRAPHY

The 43.50 acres to which this experiment refers lie at a little over one kilometer to the west of the town of Barceloneta and of the Plazuela Sugar Factory. They comprise three distinct fields which stretch from south to north in the order "Manuel Molina," "Fábrica Pajas 1ª.," and "Fábrica Pajas 2ª". The last two fields are named after the old "Pajas" mill built at the foot of the calcareous knoll which rises close by, the oldest factory known in the surroundings, the ruins of which may still be seen there. The east end of the knoll slopes and gradually merges into the lots "Manuel Molina" and "Fábrica Pajas 1ª.," for a short distance, forming the higher part of the 43.5 acres. The rest of the land is low, marshy, clearly muck-like at intervals, where the dark color of the wet soil becomes deeper. These characteristics become less pronounced in other neighboring fields toward the east, as the relatively higher levels of the valley of the Manatí river are approached; on the other hand, they are more noticeable as we travel in the opposite direction toward the muck soil and *blanquizales*[4] of the Tiburones marsh lands. So, then, these lots occupy an intermediate position representing a transition between the predominantly organic soils of the Tiburones basin and the predominantly mineral soils of the banks of the Manatí river. In the topographical chart drawn by the engineers J. D. Schuyler and J. M. Howells in the course of their studies for an irrigation project of the Plazuela holdings, these plots are

[1] Previous estimate, 18 acres: actual measurement in 1925, 17.5 acres.

[2] Sixteen acres.

[3] Ten acres.

[4] "*Blanquizales*" is the local name for patches of the marsh lands, which present an ash-like, whitish color on the surface.

traversed by the contour lines of 3, 4 and 5 feet of elevation above mean high tide. At present the land measures lower than this at various places if computed on the basis of the mean high tide. This might be explained by the fact that the tide records taken by these gentlemen were obtained during the months of March to September, thus leaving out of their observations, other months when very high tides occur. The calcareous strata of the neighboring hills affect visibly the chemical composition and the physical structure of the soil in inverse proportion to the depth at which they lie under the more recent deposits which constitute the soil. These strata are also responsible for the springs locally called *cáncaras,* common to this region, which come to the surface when the underground currents flowing between the strata of the tertiary calcareous rocks are for one cause or another interrupted in their course.

CONDITION OF THE LOTS

At the time when this experiment was planned, the lots referred to were covered by a net of water-furrows, quarter-drains, lateral and main-ditches common to the "grand-bank" system used in Porto Rico under these extreme conditions of soil moisture. This situation was further aggravated by the continuous use and cleaning of the ditches, which had made them larger than they were originally intended to be. The water level in this net of ditches oscillated with the rainfall and with the tide, which had full access to them, while the outflow was never enough to drain them completely. At the lowest places the water level rose to the surface of the soil when the tides coincided with heavy rains. Springs were more abundant in the fields nearer the Pajas knoll. Some of the *cáncaras* furnished mildly brackish water, often used for domestic purposes in times of drought. In their surroundings the muck-like condition of the soil was extraordinarily accentuated. When dry, a fine white eflorescence appeared on its surface. The almost constant saturation of the wet, soft subsoil, riddled often by large-size and small-size crab holes was apparent by inspection of the inside perimeter of the ditches.

The newly extracted clay subsoil was bluish white. The cane plants growing on this land were of yellowish foliage; they exhibited prematurely dried leaves, adhering close to the stalk, and showed a very poor stand. The Para grass languished at intervals, in the ten acres given up to pasture, overcrowded by vegetation more resistant to excessive moisture and salts, such as lichens, algae, eneas, (*Typha angustifolia*) arrocillo, (*Paspalum paniculatum*) salvia,

(*Salvia oficinalis*) and various reeds. It was impossible to mistake the fundamental cause of the low production, heavy annual replantings, and the relatively short duration of the plantings. There were also other contributing causes, almost as apparent as the fundamental cause; such as excessive distance between stools and between rows, and the salt concentration on the surface due to surface evaporation.

PREVIOUS PRODUCTION AND COSTS

The available data cover the year 1912 to 1923, when these fields were plowed and planted as *gran cultura*, as will be explained further on.

TABLE NO. I

YIELD IN HUNDREDWEIGHTS PER ACRE

	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Average	Average Yield of the 3 lots
M. Molina 18,00 acres	Fall Planting (Gran Cultura) 352	1st. Stubble 279	2nd. Stubble 199	....	....	Fall Planting (Gran Cultura) 584	1st. Stubble 383	2nd Stubble 225	3rd. Stubble 392	4th. Stubble 270	5th. Stubble 220	6th. Stubble 208	311 (8)	316
Fábrica Pajas 1, 16,00 acres	2nd. Stubble 296	3rd. Stubble 386	4th. Stubble 290	5th. Stubble 305	6th. Stubble 366 (4)	....	Fall Planting (Gran Cultura) 500	1st. Stubble 225	2nd. Stubble 391	3rd. Stubble 270	4th. Stubble 200	5th. Stubble 298	321	
Fábrica Pajas 2, 10,00 acre4	....	....	Spring Planting (Primavera) 492	1st. Stubble 222	2nd. Stubble (4)	3rd. Stubble 153	4th. Stubble 200	....	Fall Planting (Gran Cultura) 400 (5)	1st. Stubble 264 (6)	2nd. Stubble (7)	....	280	

(1) The crops of both lots were counted together in this year, 1916.
(2) Five acres were cut for seed; no record of their yield is available.
(3) Ten acres were cut for seed; no record of their yield is available.
(4) The lot was surveyed in 1925, and the area was found to be 17.5 acres. This would bring up the yield to 320 *quintales*.

We have available only the cultivation costs for some of these years from 1912 to 1923. The costs of planting and cultivation for the *gran cultura* in "Manuel Molina" in 1917 reached, with the wages prevalent at that time, $4.69 per ton of cane; those for the *gran cultura* in "Fábrica Pajas 1ª." were, in 1918, $5.41 per ton; and those of *gran cultura* in "Fábrica Pajas 2ª." in 1920 (taking the mean cost of plant cane for that year, which tended to be lower, as there were no specific data for this field), $5.56.

Evidently this land required closer attention.

PREVIOUS STUDIES

Fortunately we had in our local literature the valuable work by Dr. Zerban, "The Marsh Lands of the North Coast of Porto Rico," Bulletin No. 4 of the Experiment Station of the Sugar Producers' Association of Porto Rico,[1] published in April 1913. The land to which this paper refers, is part of the "Hacienda Pajas" mentioned in his report, the only difference being that he operated a little farther to the northwest, in "Tablón 3," which at present is included in the field "Terrón," of the Giorgetti Company.

Dr. Zerban recognized drainage as the first necessity of the lands he was investigating.[2] He noticed the saline incrustations on the surface of the soil, and determined their percentage composition in Pajas[3] as follows:

Carbonic acid	0.00
Bicarbonic acid	7.08
Chlorine	50.36
Sulphuric acid	5.17
Calcium	3.90
Magnesium	1.37
Potassium	2.51
Sodium	29.59

He made determinations of the water-soluble salts in samples of soil and subsoil of the same locality and obtained the following results:[4]

	Bicarbonates	Chlorine	Sulphates
No. 10, Soil	.097%	.164%	.042%
No. 10, Subsoil	.090%	.212%	.047%

He also determined the salt concentration in the water of the

[1] Now the Insular Experiment Station.
[2] *Loc. cit.*, p. 40.
[3] *Loc. cit.*, p. 22.
[4] *Loc. cit.*, p. 25.

ditches near the places where he had taken his soil samples, and found:[1]

Parts per Million

	Total solids	Chlorine	Sulphates	Total acid radicals
No. 10	2,353.6	1,010	107.1	3,260

and he called attention to the influence of the springs of less salty water on the diminution of the salt concentration found in the water of the ditches which drained them.

With the help of Dr. Johnston, he correlated the vigor of the cane cultivated in the salty lands with the salt content of the soil, and concluded that there was a very close relation, stating that the cane did not present a normal aspect when the clorine in the soil exceeded 0.114 per cent equivalent to 0.198 per cent total acid radicals.[2] As there was no instance in which figures between 0.643 and 0.114 per cent chlorine were obtained, he could not determine the effect of these intermediate amounts on the growth of the cane. The mean between these figures would be 0.0785 per cent, which is not very far from that of 0.09 per cent and 0.06 per cent fixed by Maxwell and Eckart in Hawaii.

He attributed the poor appearance of the cane in Plot 3 of Pajas, to the high salt content of the soil, expressing the opinion that the bad effects of the salt would be even more pronounced, but for the attenuating effect of the high nitrogen and lime contents. The results of his analyses made according to the official methods (14) were as follows: (15)

Sample	Nitrogen	Phosphoric Acid	Lime	Potash
No. 10	0.38%	0.17%	1.51%	0.42%

In 1921 two samples of soil from Pajas were analysed Mr. F. A. López Domínguez, then Chief Chemist of the Insular Experiment Station. The samples were taken in the forty-three and a half acres under discussion, and the results were as follows:

Sample	No. 272	No. 276
Moisture	5.47	7.95
Volatile matter	18.70	22.21
Insoluble residue	56.01	54.98
Iron and Al oxides	20.22	19.60
Nitrogen	0.537	0.633
P_2O_5	0.105	0.180
K_2O	0.821	0.612
Lime	1.276	1.687

[1] *Loc. cit.*, pp. 26 and 27.

[2] *Loc. cit.*, p. 30.

In the Agricultural laboratory of the Giorgetti Company, samples of soil and subsoil from this same field were analyzed in 1922 by the analysts Mr. R. Fernández García and Mr. José E. Berrocal, using official methods (16) (Hydrochloric acid of specific gravity 1.115 as solvent), and the French method[1] in the determinations of alkaline salts. The results obtained were as follows:

Soil Samples

	Fábrica Pajas No. 2 By R. F. G.	Fábrica Pajas No. 1 By J. E. B.	Manuel Molina By R. F. G.
Reaction	Neutral	Alkaline	Alkaline
Moisture	7.715	7.092	7.442
Volatile matter	13.470 / 11.900 (18)	12.80 / 16.23 (18)	12.640
Humus	5.27 / 6.77 (18)	7.44	6.549
Nitrogen	0.236	0.2255 / 0.237 / 0.216	0.417 / 0.353 (18)
P_2O_5	0.213	0.293	0.318
K_2O	0.267	0.311	0.233
Carbonates	0.842	1.271	1.551
Bicarbonates	0.196	0.037	0.092
Chlorides	0.060	0.002	0.042
Sulphates	0.187	Traces	0.127

Subsoil Samples

Reaction	Alkaline	Alkaline	Alkaline
Moisture	9.265	7.850	7.462
Volatile matter	11.290	13.020 / 12.640 (18)	10.248
Humus	4.27 / 4.25 (18)	5.661	4.911
Nitrogen in humus		0.1044	
Nitrogen, total	0.064	0.135	0.230
P_2O_5	0.176	0.298	0.272
K_2O	0.267	0.311	0.233
Carbonates	1.077	1.758	1.304
Bicarbonates	0.253	0.028	0.057
Chlorides	0.081	0.002	0.055
Sulphates	0.269	Traces	0.105

These analyses were followed by determinations of the weight of the soil per cubic foot to the depth of 24 inches, obtaining:

Manuel Molina	69.00 pounds
Fábrica Pajas 1ª.	58.00 pounds
Fábrica Pajas 2ª.	60.20 pounds

The following calculations were made on the same samples:

Weight per Cubic Foot

	In the field on the recently drawn samples	In the laboratory, on the air-dried samples	In the laboratory, on soil dried at 100° C.
Fábrica Pajas 1ª.	100.2 / 97.9 (18)	62.8 / 59.2 (18)	58.0 / 55.2 (18)
Fábrica Pajas 2ª.	94.2	64.0	60.2
Manuel Molina	112.1	71.4	69.00
Averages	101.1	64.3	60.60

The samples were taken in July and August 1923 and in March and October 1924, so that the moisture retained by the soil and subsoil in the open air during these drier months would be approximately 36.8 pounds per each 101.1 pounds total weight, or 36.4 per cent.

Although obtained much later than the chemical data given above, we are giving below the results of analyses of samples from these fields made according to the Dyer method as modified by the chemists of the Hawaiian Sugar Producers' Experiment Station (20), using a 1 per cent citric acid solution.

		Manuel Molina	Fábrica Pajas 1ª.	Fábrica Pajas 2ª.
Soil	P_2O_5	0.0182	0.01252	0.01149
	K_2O	0.01499	0.01884	0.01875
	CaO	0.8595	1.2780	0.8570
	SiO_2	0.2258	0.1252	0.1847
Subsoil	P_2O_5	0.0134	0.00502	0.00926
	K_2O	0.0133	0.01656	0.01263
	CaO	0.7035	0.8991	1.509
	SiO_2	0.2938	0.0625 (21)	0.1424

In a neighboring field, separated from the one under discussion by only a passage way (*callejón*), strong indications of the presence of ferrous salts in the subsoil were obtained, as well as unmistakable proofs of the presence of hydrogen sulphide. A silver coin was tarnished when placed in contact with the subsoil, in a hole recently made and the odor of hydrogen sulphide was distinguishable. Also, a light precipitate of ferrous ferricyanide, or Turnbull's blue, was obtained on a filter paper. The bluish white color of the fresh subsoil has been already mentioned. The water, leaking out of the walls of the ditches, leave on the subsoil tracks of a reddish-brown color, which stand out on the black color of the ground. All these were evidences of lack of ventilation.

COMMENTS ON THE FOREGOING CHEMICAL DATA

In the interpretation of results of chemical analyses of soils made by different analysts, as in the present case, experience shows that general results rather than any particular specific figure should be considered, as variations are bound to occur, even in one and the same sample, due to differences in the methods chosen, to details of manipulation, to the laboratory equipment, and to the personality of the analyst. In the data given by Dr. Zerban, sample number 10, taken from the ditches, seem to show rather high results in acid radicals as compared with the figure for total solids. The figure obtained for chlorides by Berrocal in Fábrica Pajas 1 would seem to be in error when compared with the others; and these latter show considerable variations amongst themselves. The variations introduced by the washing of the soils by rainfall, and by the salt concentrations brought about by evaporation, should, however, be borne in mind, as well as the fact that until 1920 no official methods were given for the determination of alcaline salts in soils, thus giving rise to the use of different methods by different chemists, according to the necessities and personal preferences of the analysts. The determinations made on extraction's with HCl of specific gravity 1.115 by Dr. Zerban, by Mr. López Domínguez, and by Messrs. Fernández García and Berrocal differ considerably when compared figure for figure; but they agree as to the mediate fertility of those soils as shown by total nutritive ingredientes. With this point cleared, it is well to compare our analytical data with the standards used in other cases to judge the fertility of a soil.

For mixed soils in which clay predominates, Hilgard considers sufficient the following amounts, provided they contain a fair amount of lime, as in the present case: Nitrogen, 0.1 per cent; phosphoric acid, 0.1 per cent; potash, 0.45—0.85 per cent. Wolltman, in Tropical Africa, considers good soils those which, having 0.4 per cent lime, contain: Nitrogen, 0.12 per cent; phosphoric acid, 0.1 per cent; potash 0.2 per cent.

The foregoing standards for mineral nutrients refer to similar soil extractions with strong acids. According to them, our soils show up to be very rich.

As regards extractions with weak acids, such as citric, let us consider the following standards:

Harrison, in Demerara, fixed the following percentages as sufficient for sugar-cane raising: Phosphoric acid, 0.007 per cent; potash, 0.008 per cent; lime, 0.006 per cent.

Dyer had already fixed in a general way, a content of 0.01 per cent of P_2O_5 or K_2O as the lowest limit, at which fertilizers should be applied.

Maxwell in Hawaii considered as good soil for cane, the low lands which contained: P_2O_5, 0.0023 per cent; K_2O, 0.019 per cent; lime, 0.067 per cent.

And McGeorge, lately in Hawaii, considers as fair soils for sugar cane those containing: P_2O_5, 0.004 per cent; K_2O, 0.03 per cent; lime, 0.314 per cent.

The tendency in these standards has been to increase rather than to decrease, from Dyer on, with the exception of the figure for phosphoric acid. According to the highest standards the soils under discussion would be deficient only in available potash, a point which will be verified in due time.

THE SITUATION

This could be now stated concretely: We had a plot which was not yielding properly, almost nothing in the 10-acre lot, and at a loss in the remaining 33½ acres.

The soil was not a normal mineral soil, as was shown by the muck soil still apparent in places, similar to that of the marshes to the west, the low weight per cubic foot, its high moisture-holding capacity, the low figures for "insoluble residue" and "silicates," and its high content of volatile matter, humus, and total nitrogen.

We have already seen that the potential fertility of these soils as shown by their content of phosphoric acid, potash, and lime, soluble in hydrochloric acid of specific gravity 1.115, was remarkable. And the deficiencies shown by their 1 per cent citric acid extraction, depended on the standards adopted for the interpretation of the figures obtained. These deficiencies, in any case would be shown only by the percentages for "silicates" and "potash," if the standards of McGeorge, in Hawaii, were used as basis of comparison. The high percentages of lime gave hopes of improvement, as soon as proper ventilation of the arable layers of the soil was obtained.

On the other hand, there were present dangerous amounts of salts, the concentration of which would increase with improved ventilation, unless the source of the salts, was cut off, by preventing the tides from getting into the plot, and the bad effects of evaporation were counteracted by washing accomplished by rainfall. There was, besides, one other hope of compensation in the constant flow of almost fresh water derived from the springs above described, which might at any time be used to advantage for their amelioration.

As the ditches across the plot did not drain completely in many cases even in times of low tide and the water level came up flush with the soil surface in several places in times of high tides, it was decided to carry out a drainage experiment providing for the exclusion of the tide waters and pumping out the water from the springs, seepage, and rainfall, using the least possible number of ditches, in order to compensate for the extra expense required by the operation of the pump.

EXECUTION OF THE PLAN

As a preliminary test, four acres of the higher ground of the lot Manuel Molina were planted during dry weather, in the Spring of 1923. The old canals, too wide and deep already, were filled and new shallow ditches opened. The planting was done on banks of two rows each. The banks were made with implements on the furrow made when breaking up the old stubbles just harvested. The seed used was partly of Egyptian cane (P. O. J. 105) (4½ acres) and partly of Striped Cane (Striped Cheribon) (½ acre), and the planting was done toward the end of April. The yield was about 680 quintals (34 tons) per acre, harvested in May, 1924. The pump did not affect this field until the third week of November.

Encouraged by the good growth of this Spring planting, we began to prepare for *gran cultura* planting the remaining 38½ acres. In the Summer of 1923, all the old ditches were filled with dirt, ash, bagasse, and trash. Of the old ditches, only the one dividing the lot Manuel Molina in two plots (one of 5 acres, and the other of 12½ acres), was kept; so also the ditches around the perimeter of the 43½ acres, and a canal 3 to 4 feet deep in Fábrica Pajas 2ª, which, stretching from east to west along very low land, could be used to great advantage for collecting the water to be pumped.

Although after filling the ditches the land was rather soft, we were able to plow and cross-plow with bulls, using a moulboard plow Wiard No. 90; then the tooth-harrow and the disk harrow were used. Furrows five feet apart were then opened with a 16-inch double moulboard plow (*fullosa*), and on the one-row banks thus formed, furrows were made with a Wiard plow No. 62. This furrow was then cleaned with a small, adjustable double-moulboard plow of

German make, or with a celery hiller. The subsoil plow was then run along both, the planting furrow and the water furrow.

Then the ditching was done. We cut two main ditches, 4 feet wide, and from 2 to 4 feet deep, perpendicular to the collecting ditch, discharging in the latter. The ordinary quarter drains (*cruceros*) 3 × 2, were opened. Ditches were further made to drain the springs (*cáncaras*) of greatest flow.

The planting was then done, in a single continuous row. The variety planted was the Egyptian (P. O. J. 105), as it was desired to find out whether it would repeat in Plazuela the good results in tonnage and quality of juices reported from Aguadilla, although about one-forth acre of this cane had, however, been destroyed the year before, for its bad growth, in a different type of soil. The planting was finished in October 26, 1923.

Meanwhile, the installation of the pump was begun in the beginning of October, placing it at the outflow end of the collecting ditch. The ditches within the 43½ acres were isolated from any outside ditches. The pump was ready to work on the third week of November.

THE PUMP

We had available the daily precipitation for 1922, measured in the water-gage at Central Plazuela. The maximum in 24 hours had been, in that year, 3.62 inches on December 1, and 5.74 inches in the 48 hours of December 1 and 2.

The yearly precipitation in Barceloneta, according to the records of Weather Bureau at San Juan, P. R., varied during the years 1915 to 1922 from 45.04 inches to 74.13 inches, with an average annual fall of 59.93 inches, the most frequent and heaviest rains falling usually during the months of October to January.

In Holland, in the region around Lake Haarlem, with an annual precipitation of 27 to 40 inches, and drainage accomplished by open ditches and pumps, it has been necessary to pump up to three-eighths inch in 24 hours (21). In western England, with an annual precipitation of 50 inches, calculations for drainage are based on three-fourths of an inch in 24 hours. The records for June to October 1909 at the Willswood plantation, of the County of St. Charles in Louisiana, the precipitation and lands of which are similar to ours, and where the system of open ditches and pumps was also used for drainage, show that in two instances they had to pump 1.4 and 1.03 inches in 24 hours, after a rainfall of four inches; the ordinary pumping required is, however, of 0.7 to 0.8 inch in 24 hours. Referring to this case, Elliot considers as probably sufficient, a rate of 0.75 inch. Basing his calculations on a maximum precipitation of 24 inches, during the months of July and August (23), J. O. Wright estimated the rate of drainage for the Florida marshes, at 0.87 inch. Wiley determined the moisture-absorbing capacity of these soils, and fixed it at 128.75 per cent, as an average of nine samples.

None of these calculations, could, however, be properly applied to our case, not even the highest, obtained for places with precipitation similar to ours, for the following reason:

1. The small area of our field, 43½ acres, compared with the thousands of acres for which the run-off in the cases cited had been calculated.

2. The low elevation of the land on the mean sea level, which gives rise to a high water level, thus diminishing the depth of soil for rainfall absorption.

3. The springs, which overflowing into the plot, increase by additional amount of water they contribute, the rate of drainage that could be otherwise obtained.

More similar than any that we know of have seemed to us the conditions described by Jones, Schlick and Ramser in the basin of the rivers Black and Pearl, in Mississippi (23). Their measurements of the run-off to drain gave 1.00, 1.17, and even 3.48 inches in 24 hours; that is, about 60 per cent of the rainfall in 24 hours.

Accepting the run-off at 60 per cent of the precipitation, we would have for the 24 hours, a maximum amount of water to pump, in 1922, of $3.62 \times 0.60 = 2.172$ inches, not counting the water contributed by springs and seepage, which vary with differences in level of the water table.

That we are not far from the truth in adopting 60 per cent as the proportion of the rainfall to drain, is shown by the following calculations, based on the water-holding capacity of the soil under consideration:

3.62 inches of rainfall in 24 hours over 44 acres (25)	= 36,067,034.08 pounds (1)
Average moisture contained by the soil in months of scanty rainfall, 36.4 per cent on the weight of the soil *in situ*.	
Ditto, to complete saturation, according to Crawley, 44 per cent.	
Surplus capacity for use in times of rainfall, 7.6 per cent, which on 43½ acres	= 14,400,936.00 pounds (2)
Difference that must be drained in 24 hours	= 21,666,098.08 pounds (3)
Ratio (3) to (1)	= 60%

To drain this amount of water in 24 hours, we would have to pump at the rate of 1,805 gallons per minute.

Bearing in mind the unknown amount of water that might be supplied by the spring and seepage, it was decided to install a pump of greater capacity, (2,100–5,000 gallons per minute) operated by an oil motor, type Y, Semi-Diesel, of 15 H. P. According to the manufacturers, such a pump should be capable, under a head not to exceed 10 feet, of draining 4 inches of rainfall from 61 acres in 36 hours. As a matter of fact, there have been instances when we have had to pump consecutively during one day and night and the following day, in order to remove the water fallen. In times of drouth and no trouble in the motor we have pumped from one-half to 1 hour daily, to remove the water from springs and seepage.

To test roughly the efficiency of the installation the following calculations were made, based on data obtained on May 29th, when 4.14 inches of rain fell in the course of a few hours, filling all the ditches, and flooding the lower parts of the plot.

The pump operated normally, and the water was removed in 32½ hours (1,950 minutes).

$$\frac{4.14 \text{ inches} \times 43.5 \text{ acres} \times 1,000,000}{12 \times 3.0689} = 4,890,188 \text{ gallons.}$$

$$\frac{4,890,188}{1950} = 2,507 \text{ gallons per minute.}$$

60 % of 2,507 = 1,504.2 gallons.

The efficiency of the plant then resulted too low, estimating run-off at 60% of the rainfall-probably too low for this particular case.

THE PLANTATION

After replanting and fertilizing, the cane grew without interruption and exhuberantly, an unfamiliar occurrence in these fields, the planting of a part of which at least had always been considered a waste ot time and money.

Several analyses were made of the water on samples taken at the intake of the pump, and from the outflow canal outside the lot, to compare their chlorine content. The results were unexpected. The water from the inside ditch showed a higher percentage of chlorine than that of the outside canal, as may be seen from the following figures.

Date	Number of determinations average	Parts of chlorine per million average	
		Inside	Outside
From December 20, 1923, to February 19, 1925	35	696.54	549.28

The last two weeks during which samples of water were analyzed (February 8 and 19, 1925) a mean concentration of 675 parts of chlorine per million was found, as compared with 769 parts per million found for the first two weeks (December 20 and 28, 1924). This seemed to indicate a slow washing by the fresh rainfall water.

In March, 1924, there was a severe drought. The plantation was beginning to show its effects. As a test, we decided to irrigate five acres of Fábrica Pajas 2ª. with same water that was pumped from the plot. This was done, conveying the water from the discharge of the pump to the land by means of wooden conduits. The plantation improved visibly by the weekly irrigations given on the 21st and 28th of March and 4th of April. Then the rainfall made it unnecessary to continue the test.

In August, 1924, it was easy to foresee that the yield would not be less than 800 quintals per acre.

The harvesting began on January 5th, 1925, and by February 18th the 38½ acres of plant cane and the 5 acres of first ratoons had all been cut and hauled to Central Plazuela. The results were as follows:

Gran Cultura 14 months	Quintals Yielded	
	Total	Per acre
Fábrica Pajas 1.	16,880.60	1,055.00
Fábrica Pajas 2.	8,984.80	898.48
Manuel Molina	11,849.70	971.97
Average	37,715.10	979.61

The ratoon cane in the 5 acres flowered at 10 months. It gave 2,421.90 quintals, or at the rate of 484.38 quintals per acre.

The stubble, in general, has required very little replanting, and at the time of writing (May 1925) it is growing very well and promises to give a fair crop for 1926, with reasonable expenses for cultivation.

The results obtained have surpassed our greatest hopes. It is possible that they may be duplicated in many parts of Porto Rico.

Costs

1. Installation of pump and motor, with shed, full expense	$3,546.21	
Amortization in five years, annual charge		$709.24
2. Materials for repairs and for pumping (petroleum, gasoline, oil)		461.46
3. Wages, pumping and repairs		276.57
4. Cost, planting and cultivation, 38½ acres plant cane and 5 acres first stubble		4,731.90
Total cost		$6,179.17
5. Tons of cane produced		2,006.85
6. Cost per ton of cane, counting amortization		$3.07
7. Cost per ton of cane, not counting amortization		$2.72