(English Edition)

EXPERIMENT STATION

of the

SUGAR PRODUCERS' ASSOCIATION OF PORTO RICO.

RIO PIEDRAS, P. R.

IRRIGATION

(Proceedings of a Meeting of Sugar Planters, Held at Central Fajardo, August 15, 1912),

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INTRODUCTION.

The papers which are herewith published were prepared for presentation at meetings of sugar planters called at Central Fajardo on August the 15th and at Arecibo on August the 25th. The meeting at Fajardo was well attended and the interest shown in the procceedings by all those present was an indication of the importance of the subject chosen for discussion. As will be seen by reading these reports, there has been an almost unprecedented drouth in many parts of the island which in some parts began last year and with but few exceptions has continued until the present time. The object of the meetings was to confer with the planters and discuss the possibility and practicability of installing cheap but efficient irrigation plants that would assist in the future in diminishing the disastrous effects of drouths. The Commissioner of the Interior recognized the importance of the matter and at our request sent Mr. W. W. Schlecht, a practical irrigation engineer of the Irrigation Service, to Fajardo to look over the situation and be present at the conference.

At the same time it was considered a very opportune occasion to discuss the methods of conserving soil moisture by methods of preparation and cultivation of the soil as it is believed that proper methods of cultivation will tend greatly to mitigate the bad effects of seasons of drouth. The statistics of rainfall do not extend over a period sufficiently long to enable one to speak with confidence, and yet a careful consideration of all data available leads one to believe that in many places drouths are of frequent recurrence, so frequent as to make irrigation and moisture conservation of great practical importance. My own impression is that so much attention has been paid to the drainage of cultivated fields, (in fact the systems of preparation of the land and planting seem to be with that chief end in view) that the planters have forgotten that as much harm may be done to cane by having too little water as by having too much.

Unfortunately no meeting was held at Arecibo, owing to the fact that preparations for a meeting place were not made until it was too late.

The Experiment Station has been very desirous of getting the people generally interested in holding meetings and discussing with them practical plantation problems. There are some subjects of a more or less scientific aspect, such as injurious insects and cane diseases, fertilization, etc., in the discussion of which the staff of this Station should be leaders and teachers, but there are many practical details of plantation work and plantation problems that the planters alone understand. There is such a close relation between the scientific and practical aspects of these subjects that meetings of all parties should result in much mutual benefit. In most cane-growing countries such meetings are held periodically, and all the more important questions are discussed, but in Porto Rico, it seemed best to hold a number of conferences in the various sections, rather than to depend on having one large meeting where all the sections would be represented. Meetings have thus been held at Ponce, Rio Piedras, San German and Fajardo and the intelligent interest on the part of the planters encourages us to hope that they have been of some value. They at least tend to foster a spirit of inquiry and cooperation that is essential in building up and maintaining any large and commanding industry.

J. T. CRAWLEY,
Director.

IRRIGATION

By J. T. Crawley.

The subject of irrigation has hitherto received but little attention on the part of the sugar planters of the north and east coasts, partly owing to the fact that drouths are rare, and the rainfall is sufficient for securing large crops of cane. The extended drouth of the past two years, however, has done so much damage that I think you will agree with me that the subject is of sufficient importance to be seriously and carefully considered.

The sugar cane is a plant that requires a great deal of water, in fact it is one that responds very quickly to water whether this be from rainfall or irrigation. Although normally the rainfall is sufficient for large crops I believe there are many years when irrigation would pay, and in times of drouth like the present, a few thousand dollars spent on pumps and ditches would save hundreds of thousands. While it is not necessary to the maintenance of the sugar business in this vicinity to establish irrigation, yet it would be an insurance. You spend thousands of dollars in insuring against fire, in insuring against accident, and loss of life, in insuring against cyclones, and insuring your sugar on its way to market. But the basis of all of this, of all of your wealth, of your living itself, is the crop of cane. In the final analysis it is the cane itself that gives work to your laborers, work to your Centrals, and wealth to the country, and it is not insured. In times like the present this necessity of insuring against drouth forcibly presents itself, and I believe that irrigation in the valleys of the north and east coasts could be very cheaply and effectively introduced. You have large streams of pure water very near the surface of the ground, and the cost of pumping this on to the land would be very small. Again the ground water is near the surface and is apparently abundant. There are three principal ways of securing the water, first by intercepting the streams at an elevated point, and bringing the water to the plantations by gravity, second by pumping direct from the streams to the land, and third, by digging wells and pumping. The first would in most cases probably be the most expensive as it would necessitate long lines of ditches, but after these are established the cost of upkeep should be very small, and you would never have the cost of fuel, pumps and repairs to the same, ditches, etc.

In Bulletin No. 17 of the Estación Agronómica of Cuba, there is a record of some results of irrigating in Hawaii.

As an average of 28 tests, 46 inches of rainfall produced 1,600 lbs. of sugar per acre, while 48 inches of irrigation applied at proper times, in addition to this 46 inches of rainfall produced 12 tons of sugar per acre.

During a period of three years beginning in 1898 and ending in 1900, the following crops were produced:

TABLE SHOWING AMOUNT OF WATER USED AND SUGAR PRODUCED.

Year	Water used per acre	Sugar produced.	
1898	2.5 millon gals.	14.5 tons	
1899	2.8 " "	17 "	
1900	3. " "	20 "	ratoon crop.
1900	3.3 " "	18 "	plant "
1900	5.5 " "	27 "	" " 1 plot only

These figures are very instructive and show that the yield of sugar was almost proportional to the amount of water applied to the cane, and illustrates what wonderful results are possible with good soil, plenty of fertilizer, and plenty of water.

You have in Fajardo a very great advantage in that your soils are heavy and hold the water for a long time. Frequent irrigations then, even in times of drouth would not be necessary. In fact I believe that a very few irrigations per year would be sufficient in most years to maintain the proper amount of moisture in the soil for good crops of cane. Your method of planting cane would have to be changed, but this would also be a benefit rather than a detriment. Where irrigation is practiced the cane is placed in deep furrows, "chorro", and water is run directly in these furrows. For ratoons you would either run the water in the cane row, or hill up the ratoons, making a depression between the rows into which the water is run. Whenever irrigation is adopted you use more fertilizers, for fertilizers pay best where there is an ample supply of water.

The following table gives the rainfall at Fajardo for the past 13 years the same having been furnished by the U. S. Weater Bureau at San Juan:

Table I.—Rainfall at Fajardo.

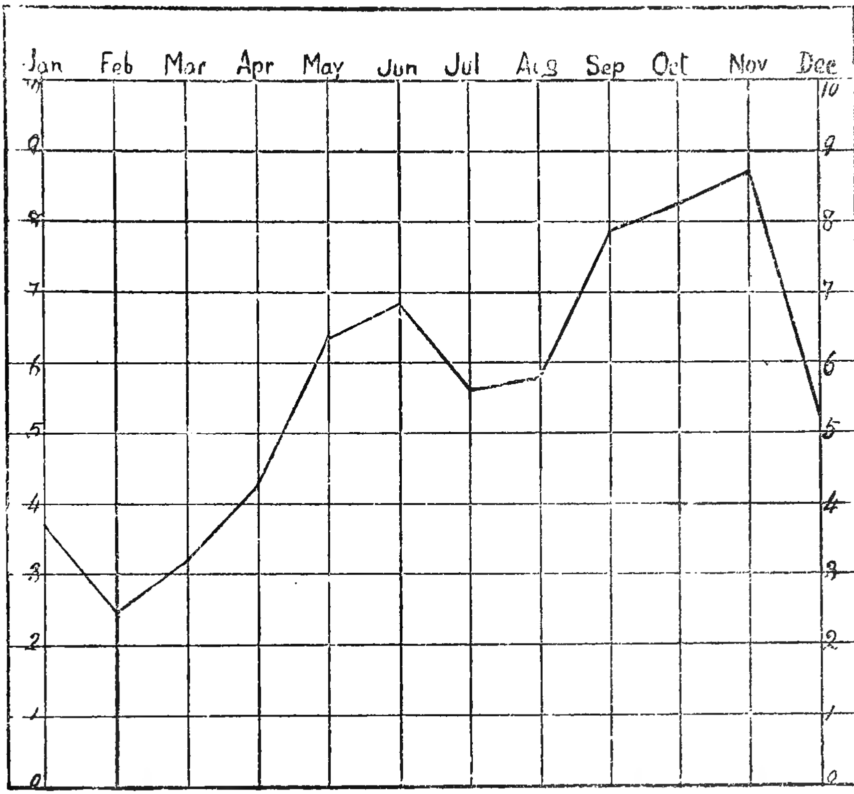
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
1899	4.53	1.20	2.26	8.00	6.00	5.88	5.58	6.21	6.13	17.07	17.80	3.50
1900	4.44	.65	2.15	13.77	2.94	14.35	5.43	8.25	10.00	7.62	3.42	3 44
1901	6.07	1.34	3.90	3.03	7.13	8.16	16.01	2.90	9.03	8.81	14.87	6.71
1902	5.56	.10	2.60	3.92	8.04	16.29	4.28	3.24	5.49	3.21	8.67	4.47
1903	1.33	.90	2.24	2.98	5.90	3 45	8.83	9.44	3 42	9.87	5.87	6.43
1904	1.93	3.80	4.96	4.57	3.26	3.03	4.41	4.25	9.64	13.55	10.93	2.73
1905	6.65	2.12	4.76	2.00	8 97	3.43	3 44	7.75	7.30	13.43	9.26	3.85
1906	1.30	2.00	3.94	1.95	3.58	7.21	8.08	1.81	14.04	3.21	5.04	7.65
1907	2.48	3.09	2.66	1.33	5.27	4.36	5.07	3.06	4.97	7.02	5.85	10.42
1908	5.02	3.59	3.95	1.16	5.50	4.50	2.82	3.99	9.63	4.57	7.73	5.57
1909	1.55	5.89	3.59	2.56	3.59	8.83	3.04	14.63	4.27	8.00	16.23	2.03
1910	5 28	2 39	5.36	3.09	6.57	1.27	4.00	4.87	12.92	4.94	4 63	6.49
1911	4.34	5.52	0.93	3.52	8.85	1.94	6.18	[illegible].27	5.92	5.[illegible]5	3.05	14.54
1912	1.14	1.94	2.31	5.51	3.42	3.04	1 78	—	—	—	—	—
Means	3.68	2.47	3.26	4.24	6.34	6.85	5.62	5.82	7.90	8.24	8.72	5.22

For our purpose we should have the rainfall for a great number of years so as to be able to predict the frequency and probable severity of drouths. Any month with less than five inches of rain, unless preceeded by heavy rainfall, may be considered as a dry month. Cane should have 5 inches to insure a good growth. Taking this as our basis let us see how often you have drouths in this neighborhood and how long they last.

The years 1899, 1900, 1901 and 1902 were practically without drouths except for periods of two or three months that did little harm to the cane. The first recorded drouth was that of 1903 which began in January and ended in July. This was almost as severe as the present drouth, but it was broken earlier. In 1904 there was a still longer period of drouth, which ended only in September. 1905 was a good year, as also 1906, except for a long spring drouth. 1907 was another dry year, the drouth beginning in January and ending in October. 1908 was dry from February until September, or throughout the principal growing period. Both 1910 and 1911 had dry springs and comparatively dry in midsummer but on the whole the rainfall was fairly satisfactory. The drouth of the present year began in January, and has not yet ended, with but 19.14 inches for the first seven months of the year.

Figure I gives the mean monthly rainfall at Fajardo for the period covered by our statistics.

FIGURE I.—RAINFALL AT FAJARDO.
(The numbers indicate inches of rainfall).



Taking the average of 13 years, the spring drouth begins in December and ends in May, followed in many cases by shorter periods of small rainfall in June and July. October and November are almost always wet, and September is usually so

It is fortunate that the drouth in the spring comes at the time when the cane is being harvested, otherwise harvesting would be difficult, but fall plant cane gets a check to its growth from which it is often difficult to recover. With a convenient system of irrigation this cane could be kept growing until the summer rains come. With irrigation one could also give a quicker start to the ratoons in the spring. But to my mind the greatest damage is done in the years of summer drouths, and especially those, as in 1904, 1907, 1908 and 1912, which are preceeded by dry spring months.

This is a period when the cane should be in full growth, fall plant as well as spring plant and ratoons. It is the hottest time of the year, plant growth is most active, evaporation from the plant and from the soil is the greatest, in fact the time when the greatest drain is made on the soil moisture.

You might say that this is the critical period of the year, which in a large measure determines what the next crop shall be.

Method of irrigation of cane.—Various methods of supplying the water to the cane will suggest themselves to the planter, and methods have to be devised to suit the circumstances. Fig. 2 will illustrate one system where the land is comparatively level and where, as is often the case in Porto Rico, drainage has to be carefully provided for. *A* is the ditch carrying the water; *B* and *D* are small ditches passing through the field at right angles to the rows of cane, *a*, *b*, *c*, *d*, etc., and *C*, *E* are drainage ditches. The water is brought down the ditch and into the cane rows, one at a time, on either side, and is allowed to run until it reaches the drainage ditches, which are parallel to the irrigation ditches, when it is cut off and run into the next row. This will be seen by reference to the figure, the water is run into *D* and from there into row *a* until it reaches drainage ditch *C* on one side and *E* on the other, it is then stopped and turned into row *b*, and so on for the whole field. Where the field is not level, it would probably be more convenient to run the irrigating ditches parallel to the drainage ditches, and at a distance of two or three feet. The water is run into the cane rows on one side only and allowed to flow until it reaches the next drainage ditch. Suppose the fall of the land in the figure is from *A* to *H* and *B*, *C*, *D*, and *E*, are the drainage ditches, then the water is run in shallow furrows on the lower side of each one of these, and led successively into the cane rows. The appearance of the rows is as represented in the figure, *l*, *m*, *n*, etc., being the bottom of the furrows where the cane is planted and into which water is run.

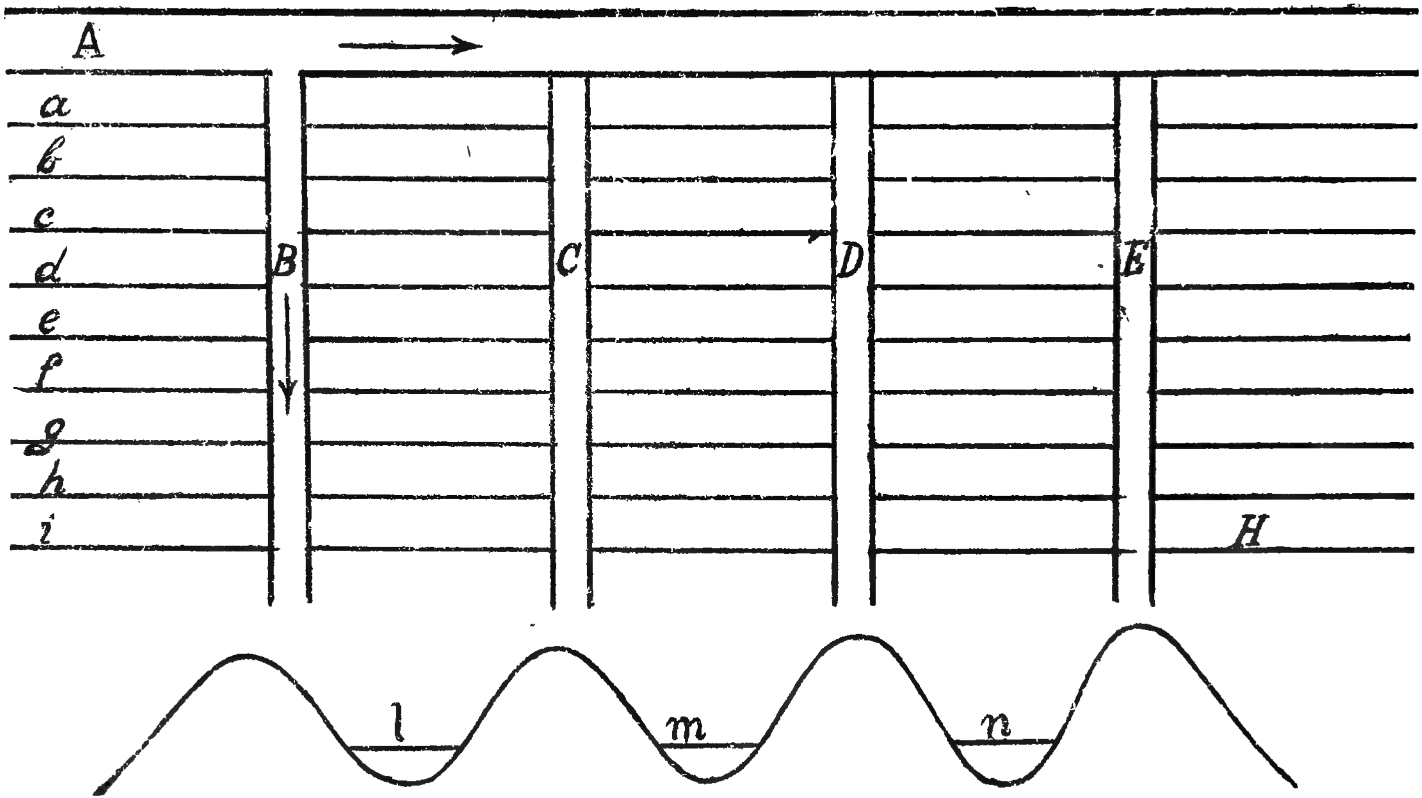


Fig. 2.—Irrigation and Drainage of the Cane.

DISCUSSION ON IRRIGATION AT A MEETING OF THE PLANTERS AT FAJARDO ON AUGUST 15, 19 2.

By W. W. SCHLECHT.

Irrigation was first introduced in regions were the rainfall was deficient for the growing of any crops, but it is now being rapidly extended to regions where, although crops may be grown, the rainfall at times, especially during the growing season, is too scant to produce the best and largest yields. In order best to satisfy the conditions of plant growth, the moisture should never fail from the time of planting until the crop is fully matured, and there are certain times when the cessation of the supply will do more harm than at others. This applies to sugar-cane, for which a drought during February or March is not very harmful, but should a similar drought occur during the growing season, from June to November, the yield is decreased by a large percentage. Irrigation by supplementing the rainfall does away with the element of chance, makes the crop larger and better and eliminates failures.

In order to determine the extent to which this region (Fajardo) requires irrigation, the same table of duty of water which was assumed by the Porto Rico Irrigation Service has been used. It is assumed that sugar-cane requires 72 inches of moisture during a year. This may be rainfall or irrigation water. This gives an average of 6 inches per month, but it is furthermore assumed that shortly after cutting or planting and also while maturing and also during the 20 weeks of harvesting the needs are not as great as during the growing season, and based on these assumptions, a table of monthly requirements of moisture or "duty of water" has been compiled. This it is assumed will, *in a general way*, apply to this region.

DUTY OF WATER.

January,	6.0 inches	July,	6.1 inches
February,	5.3 "	August,	6.5 "
March,	4.5 "	September,	7.0 "
April,	4.0 "	October,	7.6 "
May,	4.6 "	November,	7.8 "
June	5.7 "	December,	6.9 "

Total, 72.0 inches.

Combining these requirements of moisture with the rainfall record observed at the Station at Fajardo gives the amount of irrigation water that should be applied to the land to obtain the best results.

The table shows that during the past three months, from May 15th to August 15th, which are in the growing season, there was a deficiency of 12 inches of moisture. This, as can be seen by passing through the cane fields, has seriously stunted the growth. Now in studying the table we find that practically each year has a month during the growing season in which the moisture is deficient, although there are only two seasons, i. e., from July to October, 1912, and from October 1906 to January 1907, in which the drought was almost as serious as this year's. The table furthermore shows that, in addition to the rainfall, the land requires an average of 25 inches of moisture, *to produce the best results*, the maximum being about 30 inches, and the minimum about 15 inches. This compares favorably with the cane fields along the south side of the island, where the irrigation requirements are from 30 to 60 inches, and where the irrigation is of vital importance. Due to this fact, you must not expect to pay as much for irrigation as the people on the south side.

Although it is assumed that the land requires an addition of 25 inches of moisture during an average year, the amount to be provided by irrigation must be greater, thidiue to the losses in the canal and laterals and in the fields themselvs. These losses in a new system before the canals and laterals are primed, are rarely less than 50%, and in an old and well built system are rarely under 20%.

It is now assumed that this region (Fajardo) needs irrigation, although intermittent, and that the sources of supply are next to be discussed. The first and generally the cheapest source of supply is a perennial stream, and after the natural flow of this is developed, a reservoir to hold back the flow for use in the periods of drought, can generally be built cheaper that a pumping plant, deriving its supply from wells driven into the underground reservoir, giving due consideration to operating and maintenance charges.

At present you have a large and undeveloped flow in the Fajardo, Mameyes, Blanco and the small streams of this vicinity, which can be utilized for irrigation very cheaply, but it is apparent that there is more land to be irrigated during the periods of drought than can be supplied by the natural flow of these streams, and that sooner or later additional development will be desired. Now surveys of land can always be made in a short space of time, but due to the ever-varying flow of a river from day to day, from month to month from season to season and from year to year, it is necessary to have a consecutive record of the height and discharge of a stream extending over several years before any plans can be drawn for the complete utilization of the water furnished by these streams. For a partial development such as you are making now, such a record is not very important, but the time will come when it will be desired to irrigate additional lands that such a record will be very valuable.

Yesterday morning (August 14th) the Fajardo River was discharging 1,250 liters per second, or about 29 million gallons per day, but at that time it was not at its lowest stage, and since no record is available, low flow of more than 550 liters per second cannot be assumed with safety for a period of drought. This would irrigate approximately 1,500 acres, provided irrigation was carried on through out the 24 hours of the day, and leave an ample margin for losses in the irrigation system of evaporation and seepage. In addition to this land irrigated by the Fajardo River, a large area can also be irrigated by the other streams of this vicinity.

In order to irrigate land by gravity, the following structures are generally needed:

1. Diversion works.
2. The main canal, with its structures, such as tunnels, siphons, flumes, spillways, bridges, culverts, etc. Tunnels and siphons are the most expensive structures, but the number of these for this region appears to be small, consequently the cost of the canal should not be high.
3. The field laterals.
4. The preparation of the irrigated area to receive water, such as leveling, furrowing or checking.

The major portion of the losses in an irrigation system occurs in the small laterals and in the irrigated field, generally due to the fact that the carrying capacity of the field laterals is too small and that consequently the water, instead of covering the area which it is intended to irrigate, sinks into the ground at the upper end of the lateral and leaves the lower end with a deficient supply. Furthermore, the land must be prepared very carefully for irrigation. A little time and money devoted in the beginning to a proper preparation of the land will be more than repaid in the saving of the water and the ease and cheapness with which it can be applied. Land once properly prepared can always be cheaply and easily maintained in the best condition. Where land is properly prepared one man can quickly and thoroughly handle water on 10 acres; whereas, two or three men will not produce as satisfactory results on the same area poorly graded and prepared.

Where water is to be applied by the flooding method great care should be taken to produce a perfectly uniform slope and surface. This should be done by the use of some of the grading tools which are now on the market, in connection with levels taken to determine within an inch or two as maximum limits the slope of the land. If the surface is particularly uniform, deep ploughing followed by harrowing and then dragging over the surface a heavy log or beam or some other device for leveling the land will suffice. At other times the slope may be too great to permit of irrigation by flooding, because it would produce such a velocity as to cause erosion of the soil. This is to be corrected by grading the soil so as to form checks or in extreme cases by terracing, which is but an exaggerated form of check. If the surface is uneven the water will stand about in pools, so that certain portions of the land will receive too much and become supersaturated while other places will be high and dry. It is only, therefore, by the creation of a uniform surface that water can be satisfactorily applied by the flooding method.

Where the soil is to be prepared for irrigation by furrows, and especially where these furrows are to be small and narrow, even greater care must be taken than in the flooding method in producing the proper slope and surface level. If the slope of the land is too steep the furrows will, because of the velocity of the water, be rapidly eroded. If the slope is too slight the water may take so long in flowing across the fields as to be all evaporated or absorbed before it reaches the further end. Too steep slopes may be rectified by running small ditches or flumes down the slope of the ground and inserting falls in them to overcome excess of slope, and by turning the water from these into lateral furrows and drills which run at such an angle as procures the proper fall.

The moistening of the roots by sidewise percolation from shallow furrows is not nearly so complete as generally supposed, the general movement of the water being downward, therefore, in conclusion, it it may be stated that many field laterals are built too deep in the ground.

Fajardo, August 15, 1912.

PREPARATION AND CULTIVATION OF THE SOIL FOR THE PURPOSE OF CONSERVING MOISTURE

By J. T. CRAWLEY.

You are all agreed as to the important role played by water in the production of all crops, and especially in that of sugar cane. Without an ample supply of water whether from irrigation or rainfall it is impossible to grow satisfactory crops of cane, and it is quite important to know how to preserve the moisture in the soil after it has been secured. Eighty inches of rainfall is sufficient to produce good crops, providing all, or the greatest part is utilized—that is, providing it falls with comparative regularity, and that your methods of cultivation are such as to preserve it for the uses of the crop. If these eighty inches fall irregularly, that is in heavy storms, with long periods of drouth intervening, it may be insufficient. When drouths come, as the present one, long continued and severe, it emphasizes the fact that every means possible should be used to mitigate its evils. After the drouth has come and the cane is dying there is but little in the way of cultivation that can be done. But systems of preparation of soil and cultivation can and should be adopted that will tend to make drouths less severe.

What I am going to say is at the very foundation of agricultural science, facts and principles so well established as to seem elementary and simple.

It is much more important that the water coming as rainfall, that costs nothing, neither for the supply nor for the application of it, be utilized, than that you should provide expensive systems of irrigation. There are two distinct questions, first, how shall we secure the absorption of the water by the soil and second, how shall we prevent its being evaporated from the soil after it has been absorbed.

Absorption of water by soils.—The amount of water that a soil can absorb depends on two principal factors. In the first place, it depends on the size and nature of the particles composing the soil, and in the second place on the arrangement of these particles. The water is taken up in the spaces betwen the particles, and the greater the space between these particles, the greater will be the amount of water absorbed.

Assuming that all soil particles are spherical, it has been calculated that with the closest possible arrangement of the particles with reference to each other, there would be a pore space between these particles of 25.95 per cent of the volume of the soil, and a soil of this kind could take up 25.95% of water. If however, these particles be arranged so as to give the greatest pore space, the soil could absorb 74.05% of water. Now on standing unmoved for a long time the soli particles become packed together with but little pore space, and in this condition can absorb but little water. But on being loosened up whether by the plow or hoe, the particles assume a more open position, the pore space is therefore enlarged, as well as the capacity of the soil to absorb water.

One method then of promoting the absorption of water by the soil, is to break up the soil thus increasing its volume and pore space. You are familiar with the fact that when you plow four inches deep, measured along the cut surface of the unplowed land, the loose soil is at least 6 or 8 inches in depth. Deep and thorough plowing in the preparation for planting cane is then of the greatest importance. It not only gives a loose soil for the growing of the roots but it enables the soil to take up water for the future uses of the growing plant.

After a crop of cane has beeen taken off, the soil is hard packed and in this condition it cannot absorb much water nor can the roots of the young plants penetrate it sufficiently to give the greatest vigor to the cane. This soil should be broken up as well as possible with the plow. Subsequent rains will penetrate and be absorbed by the soil, and by subsequent shallow cultivation the soil will be in a much better condition to withstand a drouth.

It is easily seen that where one has left ratoons to grow without plowing, but has made clean smooth ditches every 11 feet, as is the present custom, much of the rain that falls will run off. This might happen at a time like the present when it would be very desirable that all the water falling on the land should be caught and preserved by it.

Another factor that is of the very greatest importance in absorption of water is *organic matter* or *humus*.

Every one knows that a rich virgin soil absorbs more water and stays wet a longer time than one that is old and exhausted of its organic matter. You are also familiar with the fact that the soil in a cane field is always more moist under the trash than that exposed to the sun.

The following table showing the total absorptive and retentive power of soils very well illustrates these facts.

Soil No.	1	2	3	4	5	6
Water absorbed	86.9%	73.7%	86.4%	44.3%	4.63%	45.2%
" retained after one month	51.9%	45.9%	52.4%	14.8%	16.8%	18.2%

The first three soils contain much organic matter, while the last three contain but little.

Following are the amounts of water which were found in three types of soil when they were saturated under field condition:

Sandy loam	17%
Clay loam	22%
Humus soil	44%

These facts and figures suggest that the saving of the cane trash and plowing it into the soil where it will assist in taking up and retaining water is of the greatest consequence in warding off the disastrous effects of a drouth. But it is just as important that the water be retained in the soil as that it be absorbed, and we shall now take up the means of preventing the loss by evaporation from the soils.

Conservation of Soil Moisture.—If a clean glass tube be stuck in water, the water will rise in the tube to a height depending on the diameter of the tube. In a tube 1 inch in diameter the water rises $^1/_{20}$ inch; in a tube $^1/_{10}$ in. diameter, the water rises ½ inch; in a tube $^1/_{100}$ in. diameter, the water rises 5 inches; and in a tube $^1/_{1000}$ in. diameter, the water will rise 54 inches. Now in a soil at rest there are fine tubes or spaces between the soil grains themselves, through which the water rises and passes into the air. After a hard rain these tubes become smaller since the soil is closely packed, and in this condition they are very effective in bringing up water. These tubes bring up an enormous amount of water which is absolutely lost. Now plowing or cultivating 2 or 3 inches deep breaks up these tubes and prevents the escape of the water.

Following is the result of an experiment to determine the effects of cultivating on the moisture content of the soil, as reported by Snyder in "Soils and Fertilizers":

	Per cent of water in corn field.	
	With shallow surface cultivating	Without shallow surface cultivating
Soil depth 3 to 9 inches..........	14.12	8.02
Soil depth 9 to 15 inches.... ...	17.21	12.38

Ordinarily one thinks of cultivation as a process for the purpose of killing weeds and grasses, and therefore when these are killed cultivating stops. But this is a great mistake and during dry spells, cultivation should be kept up for the purpose of maintaining a covering of loose soil of 2 or 3 inches in order not to lose the little water that you already have in the ground. This is especially needed after a hard, packing shower. A hard shower of short duration may actually do more harm than good during a drouth. The water does not enter the soil to a sufficient depth to be of benefit to the roots, the sun dries out the surface which becomes baked and cracked in consequence, and, what is worse, they open up communication with the moisture already in the soil, causing that to be drawn to the surface and lost.

In an example mentioned by Snyder. tests, were made of the amount of water in the soil before and after a shower, with the following results:

	Per cent of water		
	Surface soil 1 to 3 inches		Subsoil 6 to 12 inches
Before the shower..............	9.77		18.22
After " "	22.11		16.70
Gain..	12.34	Loss .	1.52

Now there was but enough water to raise the percentage in the surface 11%, therefore the 1.34% extra that it contained came from the subsoil, which itself had lost one and a half per cent. This is just what has happened in this neighborhood. The drouth began in January, after a very heavy rainfall in December. At Santa Rita there have been 20 weeks with showers from .04 in. to. 83 in These showers have not only been of little use to the growing crops, but in many cases have doubtless done damage in the way already indicated.

From the foregoing we see that:

In order that the soil shall take up a large quantity of water, preparation of soil must be deep and thorough, and the trash plowed into the soil, and to conserve moisture after it has been absorbed by the soil frequent and shallow cultivation should be practiced.

I venture to say that those in this community who have followed these practices are suffering less from the present drouth than those who have not practiced them.

DISCUSSION

It is to be regretted that no stenographic notes of the discussions were made. The general opinion seemed to be that furrow planting could be adopted in many parts of Fajardo and that this would simplify irrigation should that be necessary. The water could thus be brought to the cane along these furrows. However, in places where the soils are very wet and heavy the present system of "banco" and "gran banco" will have to be continued, owing to the heavy and continued rainfall that may be expected at certain seasons of the year. Deep plowing for the purpose of conserving moisture and subsoiling as an aid to drainage were advocated, but it was maintained by some of those present that owing to the difficulty of plowing the heavy lands of Fajardo, thorough preparation could not be secured unless the acreage was reduced; in other words that it was a question between extensive and intensive planting. So long as large areas are planted to cane neither thorough preparation of the soil nor adequate subsequent cultivation could be secured, and it was a question if a reduction of the planted area would be compensated for by the increased yield that might be secured. The question therefore becomes an industrial as well as an agricultural one.

The subject of the cultivation of ratoons was considered of great importance as bearing on possible drouths. Trash should be saved and incorporated with the soil, and never burned, unless there were special and urgent reasons for this course—should insects become very numerous and work much damage to the cane it might be necessary to burn the trash in order to check the insects, but it was agreed that in most other cases burning of the trash is a mistake. The ratoons should be kept cultivated—this was considered essential to retain moisture, and especially in those soils that tend to bake and crack on drying.

RAINFALL AT ARECIBO.

By J. T. CRAWLEY.

The following table gives the rainfall at Arecibo since January 1st, 1900, except the latter half of 1905 and all of 1906 and 1907.

TABLE II. RAINFALL AT ARECIBO.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1900	2.50	.87	1.55	5.38	3.16	7.43	4.84	4.25	3.59	4.79	6.28	5.89
1901	3.04	1.40	7.59	7.68	8.25	4.25	5.62	2.72	6.05	11.74	16.36	8.15
1902	10.47	.15	5.01	4.84	9.63	4.60	7.67	7.54	3.26	3.38	6.09	5.50
1903	1.53	1.25	4.74	3.[illegible]7	8.43	3.10	5.15	4.87	5.73	5.29	5.05	7.90
1904	2.00	8.53	4.15	4.30	3.17	2.82	2.77	4.43	7.15	3.87	1.13	2.65
1905	3.72	2.85	2.80	1.85	4.88							
1906												
1907												
1908	2.00	5.00	5.00	3.28	3.27	3.20	3.27	2.56	5.65	4.87	7.89	8.77
1909	1.64	4.60	1.69	1.21	3.14	4.15	4.92	11.12	2.80	4.10	13.80	4.50
1910	7.61	2.70	2.75	1.85	2.75	2.87	4.90	5.25	5.80	3.25	2.00	7.88
1911	12.20	1.85	1.65	5.75	5.25	.30	3.55	2.55	3.30	3.95	1.20	7.65
1912	.85	1.15	1.80	3.80	2.60	.75	6.19					
Means	4.32	2.72	2.52	3.91	4.96	3.35	4.89	5.03	4.91	5.03	6.64	6.54

The record covers a very short period, but it is nevertheless interesting and valuable.

In 1900 there was a drouth of medium severity beginning in January and ending in June, but if you had been prepared to irrigate, you would have irrigated practically the whole year except June, July, November and December.

1901—was dry in January and February, and again for a short time in mid-summer.

1902—was practically without drouth, though water could have been applied with advantage to the September and October planting.

1903—A drouth began in January and ended in May.

1904—A drouth began in April and lasted throughout the summer.

1905—The whole time up to the end of May was dry. No further records.

1908—Five months of spring and summer were dry.

1909—Drouth lasted until the end of June.

1910—Drouth began in February and ended in August, though October and November were also dry.

In 1911 there were two dry periods, but the first did no damage since it occurred after the heavy rains of January, but a severe drouth began in June, and with the exception of December, when good rains fell, has lasted to the present time. Even July with 6.19 inches of rain can be considered as a part of the drouth period since 6 inches of rain after such a long drouth is not sufficient to bring the cane to a normal condition,

Taking the means of 10 years the drouth begins in January and ends only in July. During January, February and March it does little damage except as to retarding the spring plant, but the chief damage is done in the months of April, May and June.

During the past 10 years or 120 months, I should say that you have had 67 dry and 53 wet months.

Fig. III. gives the mean monthly rainfall at Arecibo during the time covered by the table, also the mean monthly rainfall at Manati beginning in January, 1899 and ending July 31, 1912. It will be seen that the rainfall at Manati is uniformly higher than that at Arecibo, and it is probable that the curve of rainfall in the large sugar belt between the two places would fall between the curves given in fig. III though we have no data to support this assumption.

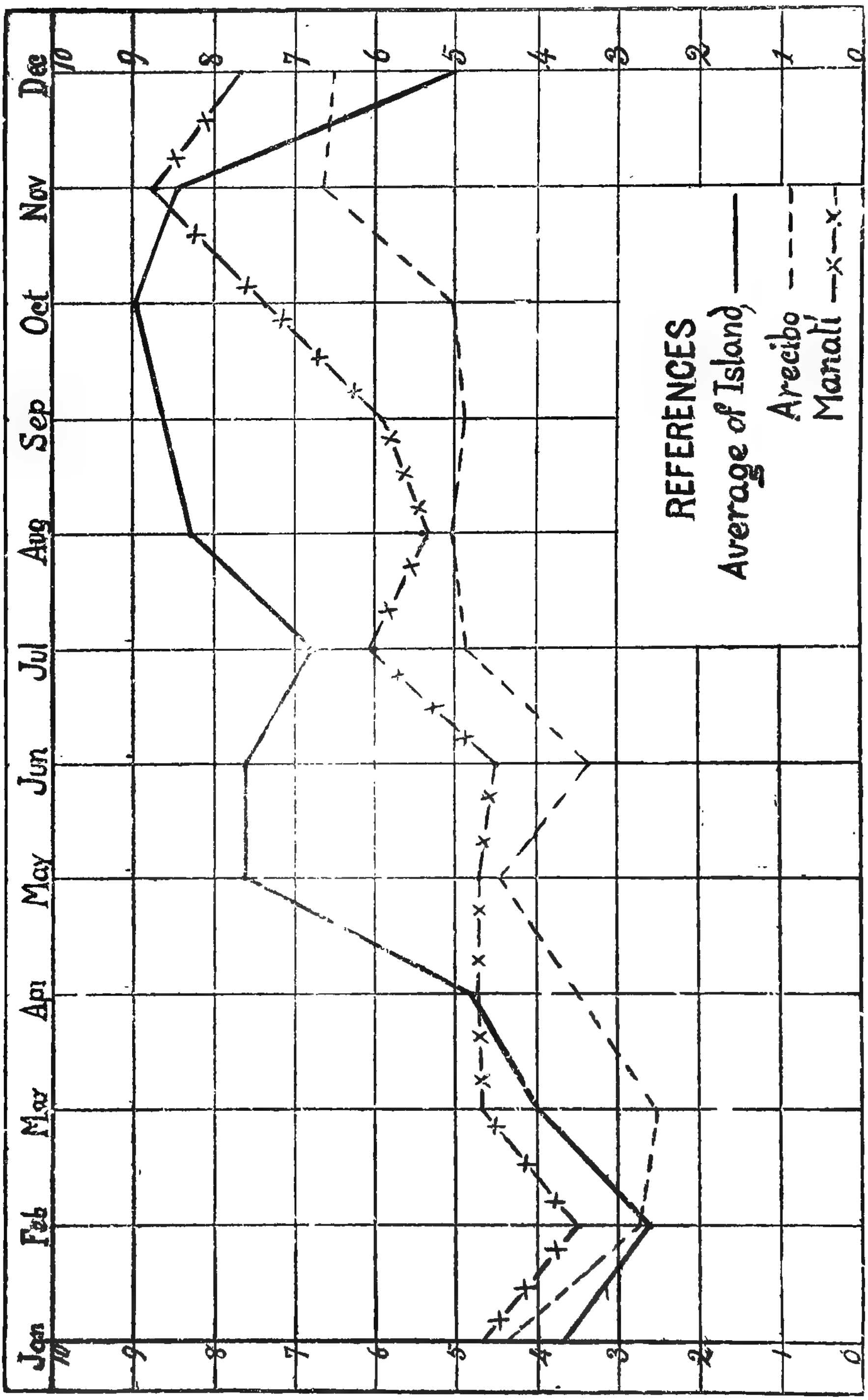
For comparison we give in the figure the average rainfall as recorded at all the Stations of the island by the U. S. Weather Bureau for the period 1899 to 1909.

It is a fact that will probably surprise the people of Arecibo that the rainfall at that place both in June and in October is the smallest of the whole island, as recorded at these 44 stations. In June the average rainfall was 4.24 inches, followed by Guanica with 4.37 and Santa Isabel with 4.40 inches, these three stations being the only ones in the sugar belt with a mean June rainfall of less than 5 inches. In October the mean rainfall was 5.43 the smallest of the island, being exceeded by all the stations on the southern part of the island where irrigation is looked upon as a necessity.

I have said that the summer is the critical period of the year, as the greatest growth takes place then. Now the mean rainfall of the summer months, June, July and August was 14.49 inches, and there are no other points of the island with less than 14 inches of rainfall during the summer, except Guanica with 10.39 and Santa Isabel with 11.89. This is exceeded by Guayama with 19.01, by Aguirre with 19.53, and by Yauco with 14.99 inches. I consider these facts of the greatest moment in the discussion of the irrigation of the lands in the vicinity of Arecibo.

FIG. III.—RAINFALL AT ARECIBO AND MANATÍ.

(Also average for the entire Island.)



IRRIGATION.

By E. E. OLDING.

Where the effective rainfall is deficient for the production of crops, an abundance of water available for irrigation is one of the most valuable assets a plantation can have.

Wherever water can be put on the land by gravity, this system is recommended, even if the cost of canals is much greater than the cost of pumping water, as the pumps, boilers and pipe lines necessitate a much greater expense for maintenance. Where canals are well constructed the cost of up-keep is very small.

In the Arecibo District the rainfall as shown by the following table is deficient during an average of five months in each year. The minimum quantity of water necessary to produce a fair growth of cane, (as determined by the Hawaiian Experiment Station in 1903) is taken at 1 inch per week. Taking this as a basis we get the following shortages of water for Arecibo (see also table of rainfall at Arecibo.)

TABLE No. III.

SHOWING MINIMUM SHORTAGE OF RAINFALL AT ARECIBO.

Year	1900	1901	1902	1903	1904	1908	1909	1910	1911	
January....	1.50	0.96	3.85	2.47	2.00	2.00	2.36	1.30	2.15	
February...	3.13	2.60	3.85	2.75	—	—	2.31	1.25	2.35	
March	2.45	—	—	—	—	0.72	2.79	2.15		
April.......				0.93		0.73	0.86	1 25		
May	0.84				0.83	0.80	—	1.13	3.70	
June.				0.90	1.18	0 73	—		0.45	
July.......					1.23	1.44			1.45	
August....	—	2.72								
September.	0.41	—	0.74				1.20			
October. ...			0.62		0.13			0.75	0.05	
November..					2.87			2.00	2.80	
December..					1.35					
Total	8.33	6.28	9.06	7.05	9.59	6.42	9.52	9.83	12 95	Inches
N. of months drouths	5	3	3	4	7	6	5	7	8	

Average of months of drouth, 5.33

The cost of pumping water as determined at the Ewa Plantation in Hawaii, where 64,750,000 gallons of water are pumped daily to an average height of 91 feet, maximum 205 feet, using oil as fuel, at the cost of $1.40 per barrel, four barrels of oil being equivalent to one ton of coal, (which formerly cost $8.00 per ton) cost 5½ cts. for lifting 1,000,000 gallons one foot, adding to the above interest on the plant and maintenance, the cost is increased to 8 cts. per million gallons lifted 1 foot

It may be of interest to mention that Reidler Pumps have been found the most satisfactory for pumping to high elevations, as the valves in these pumps are automatically closed, there is less loss of water from slip. They are usually driven by triple expansion condensing engines, steam being delivered at 225 lbs. pressure from water tube boilers, fitted with Green's economizer or other good system of feed water heater.

· As has been shown, elevating one million gallons of water one foot costs 8 cts., then to pump one million gallons to 100 feet elevation will cost $8.00, 200 feet $16.00, to 300 feet $24.00.

By carefully conducted experiments made at the Hawaiian Experiment Station, where the water used in irrigating was carefully measured, it was found that the amount of water required to produce 22,974 lbs. of available sugar, equalled 4,751,950 gallons, and to produce 20,900 lbs. of available sugar from the same area, 1,656,394 gallons of water were required. That is to say, that by the application of one inch of water per week only 2074 lbs. of sugar less, were produced, than where three inches of water were applied weekly. It was also found that 3 inches of water applied per week gave the maximum yield; but from the foregoing figures it is shown that the most profitable amount of water to be applied between one and three inches weekly will altogether depend on the cost of water delivered on the land.

In pumping water to the higher lands, these can stand a much greater reduction in the amount of water used than at the lower levels, and in taking water at a certain figure, say, from an irrigating company, the amount which can be profitably used may from the foregoing figures be closely calculated.

Cane makes the most rapid growth during the hot months or between May and November, where there is sufficient moisture in the soil. The difference in temperature during this period in Arecibo is about 4 degrees F. A saturation giving about 77% of the soil's capacity for water will give the best results. The maximum of water which can be profitably used in Porto Rico will probably not exceed two inches per week as against three inches in the Hawaiian Islands.

The average yield of sugar per acre will also fall off in about the same proportion and will not be more than about 4 tons per acre as against 6 tons average in Hawaii under the same growing period. And the maximum yield under the most favorable conditions in Porto Rico will not exceed 7 tons of sugar per acre as against 10 tons in Hawaii over any large area. This is due to climatic differences and also because the soil in Porto Rico contains more clay and is not so well drained, and consequently not so well aerated.

Rainfall is not to any extent affected by the removal of forests but is governed largely by the topography of the country and the direction of the prevailing winds.

In irrigating cane, water is conserved by having the cane rows not more than 30 feet long, filling these one at a time from the lateral ditch, then closing them off.

In making any permanent improvement, the cost, in its relation to the income it will bring, should always be carefully estimated, so the effectiveness of the different systems of delivering waters for irrigation either from streams or wells should be carefully studied. If pumps have to be used, their efficiency should be tested from time to time, or if the water is delivered by canals the leakage or seepage should be determined by measurement, as no good management can be had where the losses are not known, and knowing where losses occur is the first step towards preventing them. This is just as important in the fields as in the factory.