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EVAPORATION AND PLANT-TRANSPIRATION.

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THE data which largely compose this contribution were obtained in the course of observations bearing upon the factors which enter into a system of rational and economic irrigation, and in connection with the study of certain practical questions that relate to land irrigation on the Hawaiian Islands. These data, however, have also a more purely scientific value, and may have an interest for those who are more exclusively engaged in physiological investigations.

The actual purpose of the observations which these data represent was to try to determine: first, the loss of moisture due to direct evaporation from the soil; and secondly, the relative proportion that escapes by transpiration from the sugar-cane (*saccharum officinarum*) during different periods of growth, and to note the meteorological and other factors which appear to control these phenomena.

The observations on soil-evaporation and plant-transpiration were made as follows: A given weight of the particular soil was put into two tubs, exactly 125 pounds into each tub. The tubs had perforated bottoms, over which a piece of linen cloth was laid before putting in the soil, in order to prevent the soil dropping through, or blocking up the holes. When filled thus with soil, the tubs were each set into a galvanized iron pan containing water, the water being kept up to a given mark or level, which level was the point of contact between the soil in the tubs and the water in the pans. The pans were most carefully covered with moisture-proof glazed oilcloth, to prevent any evaporation from the pans except through the tubs containing the soil. When the tubs were set in place, water was added to each pan by means of a funnel that was inserted through the waterproof covers, and in sufficient volume to saturate the soil, whose absorptive power was 48.2 per cent. on its own weight. This was done on April 15, and on April 16 three pieces of seed-cane were planted in tub No. 2, whilst in tub No. 1 no cane was planted, the latter having to record the escape of water by means of the soil, and No. 2 tub the loss by means of the soil plus the growing cane.

The tubs were placed upon a veranda, having a south exposure and a strong light, but as they had to be protected against rainfall they were so located that no direct sunlight fell upon them. Near by the tubs, temperature readings were taken. The maximum and minimum thermometers gave the extremes of temperatures, and the dry-bulb and wet-bulb thermometers the indications of "humidity in the air."

It has commonly been claimed that temperature and the "relative humidity in the air" are controlling factors in evaporation. The writer, however, has believed not only that there is not necessarily a constant relation between temperature, atmospheric moisture, and the water given off from soil and water surfaces, but that there are other factors whose individual action exceeds the united influences of the factors already stated. For this reason we decided, at the time of taking the temperature and humidity readings, to determine the actual evaporation, by use of evaporators. The form of evaporator used was a small galvanized dish, one inch deep, and having a superficial area of 120 square inches. The evaporator was placed between the dry- and wet-bulb thermometers, thus having the same protection against the sun and exposure to the wind. At seven o'clock in the morning 500 grams of water were weighed into the evaporator, and at the end of twenty-four hours the weight was retaken and recorded. The water was made up again in weight to 500 grams, proceeding thus daily over the whole period of time included by the experiment. In addition to the evaporator described, a second one, in each item exactly identical with the former, was used. This second one was placed in a barn. The large doors of the barn were kept open day and night, thus providing an ample circulation of the outer air, but no violent wind disturbance or sudden movements of the air. The purpose in this case was to have the corresponding conditions of temperature and atmospheric humidity surrounding the former evaporator located thirty feet distant, with the exclusion of the factor of wind. The data furnished by the two evaporators were taken and recorded in the same way, with the corresponding thermometer readings. With this brief description of the mode of observation, the data are now given. These are numerous and occupy considerable space, but the full statement is necessary in order to observe the wide range of variations. Two statements could be made with some advantage, from the data. The soil-evaporation and the transpiration by the cane, however, are so bound up with the meteorological conditions that we present it as a whole:

Date, 1897.	Mean outdoor evaporation.	Outdoor evaporation.	Mean indoor temperature.	Indoor evaporation.	Humidity.	Direction of wind.	Evaporation of soil No. I. Saturated. cc.	Evaporation of soil and cane No. II. Cane planted. Saturated cc.
April 16	74	27.6	78	10.4	76.3		....	....
" 17	76	27.6	79	10.6	73.8		1000	1000
" 18	75	32.0	80	13.2	90.4		800	800
" 19	76	34.0	80	13.0	73.8		1000	1000
" 20	76	37.6	79	14.4	76.3		500	500
" 21	76	36.6	79	13.4	76.4		200	200
" 22	75	31.4	80	14.0	76.4		500	500
" 23	75	32.0	79	12.2	73.8		700	700
" 24	74	33.4	77	13.0	73.7		700	700
" 25	72	27.2	76	10.6	78.9		500	500
" 26	75	30.2	78	11.2	76.3		700	700
" 27	75	27.0	76	11.2	78.9		500	500
" 28	76	32.2	78	13.6	76.3		500	500
" 29	74	29.2	79	12.6	76.3		700	700
" 30	75	31.2	77	11.2	81.7		500	500
May 1	75	35.4	78	12.2	78.9		500	500
" 2	72	28.4	76	9.6	78.8		500	500

Date, 1897.		Mean outdoor evaporation.	Outdoor evaporation.	Mean indoor temperature.	Indoor evaporation.	Humidity.	Direction of wind.	Evaporation of soil No. I. Saturated. cc.	Evaporation of soil and cane No. II. Cane planted. Saturated. cc.
May	3	72	34.2	77	11.8	78.9		500	500
"	4	75	38.2	79	12.6	73.7		500	500
"	5	75	29.2	79	11.4	78.9		500	500
"	6	77	35.4	79	13.2	76.4		500	500
"	7	75	34.4	81	13.4	71.5		500	500
"	8	71	19.2	78	6.8	78.9		500	500
"	9	72	17.2	79	11.0	76.4		500	500[1]
"	10	73	25.6	80	10.0	81.8		300	300
"	11	75	27.2	83	12.6	79.1		300	300
"	12	73	22.2	79	10.6	76.4		300	300
"	13	75	25.8	80	12.2	71.5		300	300
"	14	76	22.2	80	10.8	79.0		300	300
"	15	74	23.0	77	9.0	84.5		300	300
"	16	73	11.0	78	4.2	87.4		300	320
"	17	73	11.0	78	6.0	84.6	S. E.	300	330
"	18	77	25.2	81	11.0	79.1	N. E.	300	350
"	19	77	32.8	80	12.6	79.1	"	180	200
"	20	77	31.3	82	13.2	76.6	"	220	250
"	21	75	33.6	80	13.0	76.5	"	180	200
"	22	75	29.0	79	10.6	93.5	"	220	250
"	23	75	30.6	78	11.6	78.9	"	300	310
"	24	76	26.2	81	12.0	76.5	"	300	310
"	25	76	27.0	80	11.6	79.1	"	340	350
"	26	73	27.2	80	12.2	76.7	"	350	360
"	27	71	15.6	79	9.6	81.8	S. E.	450	500
"	28	76	30.0	81	12.6	76.6	E.	500	550
"	29	79	31.6	80	12.6	79.1	S. E.	500	550
"	30	78	35.2	82	14.0	79.1	E.	300	310
"	31	78	30.2	82	14.2	76.6	"	300	410
June	1	78	34.6	83	14.6	76.6	"	400	450
"	2	78	30.2	82	12.0	87.6	S. E.	350	400
"	3	78	24.0	81	11.0	79.1	"	450	500
"	4	76	30.0	81	13.2	76.5	N. E.	550	600
"	5	75	21.0	79	9.2	81.8	S. E.	450	500
"	6	75	24.8	80	10.6	81.8	"	400	500
"	7	75	24.0	79	9.6	79.1	N. E.	400	500
"	8	76	24.6	80	10.0	81.9	"	400	500
"	9	77	26.2	80	10.8	79.1	"	400	500

[1] The cane began to come up and twelve stalks were up by May 21.

Date, 1897.		Mean outdoor evaporation.	Outdoor evaporation.	Mean indoor temperature.	Indoor evaporation.	Humidity.	Direction of wind.	Evaporation of soil No. I. Saturated. cc.	Evaporation of soil and cane No. II. Cane planted. Saturated. cc.
June	10	77	28.6	81	12.0	79.1	N. E.	400	500
"	11	76	23.0	80	9.2	79.1	"	450	500
"	12	77	27.6	79	10.0	81.8	"	400	500
"	13	77	36.6	82	14.0	76.6	"	400	500
"	14	76	27.2	81	11.2	81.8	"	400	550
"	15	78	29.0	80	11.0	81.8	S. E.	400	550
"	16	79	31.0	82	12.0	81.9	"	400	500
"	17	78	28.2	83	12.0	81.9	N. E.	450	550
"	18	78	30.0	83	12.2	79.2	"	400	550
"	19	78	26.0	81	12.2	81.9	"	400	550
"	20	76	22.2	82	10.6	81.9	"	400	500
"	21	76	16.2	81	8.2	84.7	S. E.	400	500
"	22	74	12.6	80	9.2	84.6	S.	400	500
"	23	75	9.2	79	6.0	87.5	"	400	500
"	24	73	6.0	78	4.2	96.7	S. W.	200	400
"	25	77	13.4	81	9.6	87.6	S. E.	100	300
"	26	75	5.6	78	4.4	93.5	S.	100	300
"	27	76	13.4	82	9.6	84.7	"	100	300
"	28	76	13.0	83	9.0	82.0	S. W.	100	400
"	29	74	13.0	81	8.0	84.7	"	200	400
"	30	80	31.0	83	10.0	79.3	S. E.	200	500
July	1	78	25.0	85	12.0	76.7	E.	200	500
"	2	77	23.0	80	9.0	87.5	S. E.	200	500
"	3	78	30.6	81	11.2	81.9	E.	200	500
"	4	80	32.0	81	11.2	81.9	"	300	500
"	5	80	31.6	85	12.6	74.3	"	400	600
"	6	78	23.0	80	9.8	84.7	"	400	600
"	7	78	27.6	83	11.2	84.7	"	500	700
"	8	77	23.6	80	9.6	84.7	S. E.	500	700
"	9	77	25.6	79	10.2	84.6	E.	400	700
"	10	77	27.2	82	11.2	79.1	"	400	700
"	11	78	25.2	81	11.0	81.9	"	400	600
"	12	79	27.6	83	12.0	84.7	"	400	700
"	13	79	29.6	82	13.0	79.2	"	300	600
"	14	78	26.0	80	11.0	84.6	"	300	600
"	15	76	27.2	81	12.0	87.7	"	400	600
"	16	76	21.8	82	10.2	87.5	"	400	600
"	17	77	28.0	80	12.0	84.7	"	400	700
"	18	78	26.2	83	11.8	81.9	"	400	700

Date, 1897.		Mean outdoor evaporation.	Outdoor evaporation.	Mean indoor temperature.	Indoor evaporation.	Humidity.	Direction of wind.	Evaporation of soil No. I.	Evaporation of soil and cane No. II.
									Cane planted.
								Saturated. cc.	Saturated. cc.
July	19	78	23.0	81	10.6	81.9	E.	400	700
"	20	76	23.0	81	10.0	81.9	N. E.	400	700
"	21	79	27.6	83	13.0	74.1	E.	400	700
"	22	78	25.4	82	12.0	74.0	"	400	700
"	23	79	29.0	82	12.0	76.6	"	400	700
"	24	79	29.0	84	14.0	71.7	"	400	700
"	25	79	20.6	84	11.2	71.7	"	400	700
"	26	80	28.0	83	12.2	74.2	"	400	700
"	27	79	28.8	83	13.2	74.1	"	400	700
"	28	79	32.2	84	15.2	76.7	"	400	800
"	29	78	25.2	83	12.0	76.7	"	400	800
"	30	77	26.0	84	12.8	76.7	E. S. E.	400	800
"	31	78	31.0	84	14.0	76.7	E.	400	800
Aug.	1	77	24.2	84	12.0	76.7	"	400	800
"	2	76	17.6	83	11.6	79.1	S. E.	400	800
"	3	79	18.2	85	11.0	76.7	"	400	800
"	4	80	23.0	86	12.0	76.8	E.	400	800
"	5	78	23.6	83	11.2	79.2	"	400	800
"	6	78	32.6	83	13.8	76.7	"	300	700
"	7	77	31.0	81	12.2	81.8	"	400	700
"	8	78	30.2	81	12.6	76.5	N. E.	400	800
"	9	79	31.6	84	14.0	71.7	"	400	800
"	10	79	26.2	84	13.0	71.7	E.	400	800
"	11	78	27.2	83	12.2	71.7	"	400	800
"	12	79	23.0	83	10.8	79.1	"	400	800
"	13	80	15.0	83	7.6	84.8	"	400	800
"	14	80	25.4	84	11.2	82.1	"	400	800
"	15	79	26.6	82	12.2	71.6	"	400	800
"	16	77	31.2	83	13.4	71.7	"	400	800
"	17	78	26.2	81	12.0	74.0	"	400	800
"	18	79	32.2	84	12.4	71.7	"	400	800
"	19	80	33.0	83	13.2	74.1	"	400	900
"	20	79	26.0	83	13.2	71.6	"	400	900
"	21	78	26.0	81	13.0	74.0	"	400	1000
"	22	78	26.0	82	12.0	74.0	"	400	1000
"	23	81	33.4	84	15.8	69.3	"	400	1000
"	24	80	29.6	84	14.4	74.2	N. E.	400	1000

[1] One stalk of cane died.

Date, 1897.		Mean outdoor evaporation.	Outdoor evaporation.	Mean indoor temperature.	Indoor evaporation.	Humidity.	Direction of wind.	Evaporation of soil No. I. Saturated. cc.	Evaporation of soil and cane No. II. Cane planted. Saturated. cc.
Aug.	25	79	30.6	83	14.0	74.1	E.	400	1000
"	26	79	26.4	80	12.6	76.6	"	400	1000
"	27	80	25.6	83	13.0	74.2	"	400	1000
"	28	80	26.0	83	12.0	76.7	"	400	1000
"	29	79	31.6	83	14.2	71.7	"	400	1000
"	30	79	32.6	83	13.6	71.6	"	400	1100
"	31	79	35.2	83	14.0	67.0	"	400	1100
Sept.	1	78	29.0	82	12.0	74.0	N. E.	400	1200
"	2	78	32.6	81	11.6	84.6	"	400	1200
"	3	79	32.0	84	13.6	69.3	"	400	1200
"	4	78	34.0	82	13.0	74.0	"	400	1200
"	5	79	35.0	83	13.0	71.6	"	400	1200
"	6	79	27.4	82	11.2	74.1	"	400	1200
"	7	79	31.8	83	12.0	76.6	"	400	1100
"	8	79	32.8	83	11.6	71.6	"	400	1100
"	9	79	26.2	84	9.0	72.2	"	400	1000
"	10	80	23.0	82	10.6	84.7	"	400	1000
"	11	79	39.0	83	14.6	71.6	E.	400	1000
"	12	78	31.0	83	12.0	69.3	N. E.	400	1000
"	13	77	28.2	79	10.2	79.0	"	400	1000
"	14	77	30.2	79	10.0	76.5	"	400	1000
"	15	76	28.2	81	11.8	71.5	"	400	1000
"	16	75	25.0	81	11.4	71.6	"	400	1000
"	17	74	21.0	78	9.6	78.9	S. v. N. E.	400	1000
"	18	74	11.4	78	7.0	81.7	S.	400	1000
"	19	73	8.2	76	5.0	90.4	S. v. W.	400	1000
"	20	77	23.2	79	8.6	81.8	N. E.	300	800
"	21	78	29.0	81	10.6	79.1	"	300	800
"	22	78	31.8	82	12.0	74.0	"	300	800
"	23	78	31.6	80	10.6	76.6	"	300	800

At this date, and for reasons to be explained later, nitrogen was applied in the form of sodium nitrate, the application being made by putting 100 grams of the salt into the water in the pan, which was taken up by the cane. The effect of this application of nitrogen is seen in the increased activity of the cane, whereby a greater transpiration resulted, the evaporation in tub No. 1 remaining constant.

Date, 1897.		Mean outdoor evaporation.	Outdoor evaporation.	Mean indoor temperature.	Indoor evaporation.	Humidity.	Direction of wind.	Evaporation of soil No. I. Saturated. cc.	Evaporation of soil and cane No. II. Cane planted. Saturated. cc.
Sept.	24	78	32.2	81	11.2	74.0	N. E.	300	800
"	25	77	34.2	81	12.0	73.9	"	300	900
"	26	78	29.2	82	11.4	74.0	"	300	900
"	27	76	22.6	81	10.0	79.1	"	300	1000
"	28	80	26.6	82	11.2	79.2	S. v. N. E.	300	1200
"	29	80	34.2	82	12.6	76.6	"	300	1500
"	30	78	31.6	82	12.0	76.6	N. E.	300	1400
Oct.	1	78	32.6	81	11.0	76.6	"	300	1200
"	2	74	30.2	81	11.6	76.6	"	300	1200
"	3	76	23.6	82	11.0	74.1	"	300	1200
"	4	75	14.6	80	8.2	76.5	S. v. E.	300	1000
"	5	76	14.0	80	9.0	81.8	S.	300	1000
"	6	74	15.8	80	8.0	79.1	"	300	1000
"	7	79	25.2	81	10.2	76.6	S. v. N. E.	300	1000
"	8	79	24.0	84	10.2	74.3	N. E.	300	1000
"	9	78	14.0	83	8.0	82.1	"	300	1000
"	10	76	13.0	81	8.2	79.1	S.	300	1000[1]
"	11	77	11.0	81	4.2	81.9	"	300	1000
"	12	77	25.2	79	9.0	81.9	S. v. N. E.	300	1000
"	13	78	31.2	80	11.2	79.1	N. E.	300	1000
"	14	77	29.8	81	13.0	79.1	"	300	1000
"	15	75	32.6	79	11.4	76.5	"	300	950[2]
"	16	75	25.6	79	10.0	76.5	"	300	950
"	17	76	19.6	79	8.2	76.5	"	300	950
"	18	76	22.2	79	9.0	79.0	"	300	1000
"	19	76	16.6	80	8.6	79.1	"	300	1000
"	20	79	27.0	80	10.0	79.1	"	350	1000
"	21	79	31.0	80	10.4	79.1	"	350	1000
"	22	78	35.6	80	12.0	74.0	"	350	1100
"	23	75	20.0	80	7.6	81.9	"	350	1200
"	24	76	10.6	79	6.6	87.5	S.	400	1200
"	25	75	8.4	79	5.6	87.5	"	350	1000
"	26	76	9.6	80	6.6	87.6	N. W. v. S.	350	1000
"	27	75	8.6	80	6.6	87.5	S.	300	900
"	28	76	15.6	79	7.0	84.6	S. v. N. E.	300	800
"	29	76	17.0	79	8.0	81.8	N. E.	300	700
"	30	78	26.0	80	10.2	76.5	"	300	600

[1] Second stalk of cane died.
[2] Third stalk of cane died.

At this date a second application of 100 grams of sodium nitrate was made, it being observed that the vitality of the growing cane was decreasing, which was indicated by its yellowish appearance and by a falling off in transpiration. The evaporation from the soil in tub No. 1 still remained the same.

Date, 1897.		Mean outdoor evaporation.	Outdoor evaporation.	Mean indoor temperature.	Indoor evaporation.	Humidity.	Direction of wind.	Evaporation of soil No. I. Saturated. cc.	Evaporation of soil and cane No. II. Cane planted. Saturated. cc.
Oct.	31	75	24.8	81	10.0	76.5	N. E.	300	700
Nov.	1	77	29.6	79	11.0	76.4	"	300	900
"	2	72	30.0	78	10.0	78.9	"	300	1000
"	3	68	32.4	74	9.0	81.6	"	300	1000
"	4	76	31.0	78	10.6	78.9	"	300	1000
"	5	77	32.0	79	10.0	76.5	"	300	1100
"	6	78	37.0	79	12.0	76.4	E.	300	1100
"	7	78	38.0	81	11.6	74.0	N. E.	300	1100
"	8	77	41.2	78	12.4	78.9	"	300	1100
"	9	76	41.0	79	12.6	76.4	"	300	1100
"	10	74	25.0	79	10.0	76.4	"	300	1100
"	11	73	16.0	77	7.4	78.9	W. v. S.	300	1200
"	12	72	15.6	78	8.6	81.7	S.	300	1100
"	13	72	14.2	77	8.0	84.5	"	300	1000
"	14	73	14.0	77	8.0	84.5	S. v. E.	300	1000
"	15	72	12.2	77	6.2	84.6	"	300	1000
"	16	72	12.6	76	7.2	81.6	S.	300	1000
"	17	74	13.0	78	8.0	87.5	"	300	1000
"	18	73	8.0	77	5.4	93.5	"	300	900
"	19	76	22.2	72	8.0	84.3	S. v. E.	300	800
"	20	68	24.0	74	9.0	76.1	N. E.	300	800
"	21	69	12.2	73	5.6	87.2	"	300	700
"	22	70	26.6	71	9.2	81.3	"	300	600
"	23	68	25.2	73	9.2	73.5	"	300	500
"	24	69	12.0	73	6.2	84.4	S.	300	500

These data were taken with the assistance of our field assistant, E. G. Clarke.

November 24, or seven and one-fourth months from the date of planting the cane, the experiment was stopped. The growth was no longer normal, due possibly to the want of room for extension of the root system, and also in part to the moistness of the soil, which was kept at the point of saturation. At this place, we shall remark that, while tub experiments afford the most exact mode of controlling certain observations, other observations which require a continuance up to actual maturity, cannot be carried out in such restricted conditions. In no case have we found a mature and normal development of the cane when grown in tubs. In normal growth in the field, the roots of the cane are found very many feet away from the stock in their search for food and water.

Before considering further the data bearing on transpiration from the sugar-cane, we shall refer to the comparative proportions of water that were actually dissipated by the "evaporators," and the apparent relation of this evaporation to the "humidity in the air." In order to do this with convenience we shall gather the total data together in a table of averages, bringing them more easily within view:

Memoranda.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	General average.
Mean outdoor temperature..	74.4	76.0	77.0	78.3	78.7	76.8	75.3	71.0	75.9
Mean outdoor evaporation ..	28.5	27.2	22.5	25.8	30.0	24.3	23.5	17.3	24.8
Mean indoor temperature ..	78.7	80.3	81.3	83.0	82.4	80.6	78.8	74.1	79.9
Mean indoor evaporation...	11.7	11.3	10.1	12.1	12.5	10.0	9.2	7.5	10.5
Mean humidity in the air ...	77.4	80.2	83.6	77.3	73.8	80.4	80.1	83.2	79.5

If the "mean indoor evaporation" is considered with the "mean humidity in the air" it is apparent that there is a very clear and strong relationship, although this relationship is not always in a proportional ratio. The relationship is not so definite between the "humidity of the air" and the "mean outdoor evaporation." A corresponding relation is seen between the "mean indoor temperature" and the "indoor evaporation," which is as definite, and equally constant, as the connection between the evaporation and the humidity of the air, indoors. Notwithstanding these relations of the humidity in the air, and of the temperature, to the evaporation, the great difference between the "indoor" and the "outdoor" evaporation indicates that there is some other cause of evaporation whose potency supercedes the combined controlling actions of temperature and atmospheric humidity. This is set forth more strikingly by the following table:

Evaporators.	Number of days.	Mean temperature.	Humidity of the air.	Water evaporated. cc.
"Outdoor" or wind exposure	270	75.9	79.5	33,480
"Indoor" or no wind	270	79.9	79.5	14,175

From this table it is seen that the "outdoor" evaporator, which was carefully protected against the sun, yet fully exposed to the wind, evaporated 136 per cent. more water than the "indoor" evaporator, and yet the mean temperature indoors was 4° higher than the outdoor temperature, whilst the humidity was the same. These data confirm a statement made by us in a previous publication, that the "direction and force of the wind is a more potent factor in increasing or arresting growth and in controlling evaporation, than small variations in temperature."

It is further shown that there is not necessarily anything like a proportional ratio between the "humidity in the air," as shown by the dry- and wet-bulb readings, and "actual evaporation." The factor of "wind" dominates the combined influences of atmospheric moisture and temperature. In the location of meteorological instruments for recording climatic data, this has to be borne in mind.

Moreover, in the matter of practical irrigation, it is seen that not only temperature and the relative state of moistness of the air, but mainly the exposure to wind, are controlling factors in the rate of evaporation, and the proportion of water to be used. Consequently for these reasons alone, and apart from the nature of the soil, more or less water of irrigation should be applied in certain localities than in others. On the leeward sides of these islands the temperature is several degrees higher than on the windward exposures. The winds from the south, however, are little more than prolonged calms, excepting when a sudden storm occurs, while the north or northeast winds have a high mean velocity, which causes a high evaporation. A recurrence to the detailed data already given will furnish ample illustrations of these facts.

Returning to the experiment on evaporation from the soil, and transpiration from the cane, in the tubs, we first bring the data together in a table of averages. At the head of the table we repeat the daily average for each month of the evaporation from the "indoor" evaporator, in order to note any relation between the variations of evaporations from the soil and from the evaporator. The data furnished by the "indoor" evaporator are selected for this purpose because the tubs were placed so as to be protected from the wind, thus corresponding to the exclusion of the wind from the barn where the evaporator was placed :

Time.	Indoor evaporation.	No. 1 tub. Evaporation from the soil.	No. 2 tub. Transpiration by cane and soil.
	Per cent.	Grams.	Grams.
April	11.7	15,000	15,100
May	11.3	12,290	13,150
June	10.1	9,350	15,850
July	12.1	12,300	23,300
August	12.5	12,200	31,800
September	10.0	9,400	30,450
October	9.2	9,700	30,800

Between the "indoor evaporation" and the "evaporation from the soil" a relation in behavior is clearly noted.

During the month of April the two tubs evaporated exactly the same volume of water. When the cane began to grow, transpiration supplemented the evaporation from the soil, and No. 2 tub commenced to dissipate more water, increasing the proportion in ratio with the development of the cane.

A decrease in evaporation from the soil, as in June and again in September, has not, during any period, been accompanied by a decrease in transpiration by the cane. Indeed, it has operated in the opposite direction. In September, it is seen, the evaporation from the soil in tub No. 1 was 2,900 grams less than during August; the total transpiration from tub No. 2, however, was only 1,350 grams less in September than in August. As the evaporation from the soil in the two tubs was the same, it then appears that the cane transpired 1,550 grams more in September than in August, although the total loss of water in tub No. 2 was less in September than in the preceding month. This result is quite understandable. During warm, calm, sultry weather, when the moisture in the air is relatively high, plant-growth proceeds rapidly ; and as the transpiration is a result of, and in proportion to, the rate of growth, more water can be dissipated by the plant under the particular atmospheric conditions which cause a decrease in evaporation from the soil.

We now call attention to one other factor over whose influence on plant-transpiration we can have a control. On September 20, the cane in tub No. 2 was losing its appearance of health and vigor; the leaves began to yellow and to curl up, as if in the first stage of withering. Of course there was no question of want of water, neither of the need of potash, phosphoric acid, or lime, since the soil is very rich in these elements. The soil, however, is very low in nitrogen, and it occurred to the writer that the growth, and consequently the transpiration, were being checked by the dearth of that element. Therefore, on September 24, 100 grams of sodium nitrate (Chili saltpeter) were dissolved in the water in the pan under tub No. 2, containing the growing cane. This was repeated on October 31st, the growth and transpiration having suffered a second depression at that time. The apparent results of the action of nitrogen are seen as follows:

First application of nitrogen.			Second application of nitrogen.		
Date.	Evaporation from soil.	Transpiration from soil and cane.	Date.	Evaporation from soil.	Transpiration from soil and cane.
	Grams.	Grams.		Grams.	Grams.
Sept. 24	300	800	Oct. 31	300	700
" 25	300	900	Nov. 1	300	900
" 26	300	900	" 2	300	1000
" 27	300	1000	" 3	300	1000
" 28	300	1200	" 4	300	1000
" 29	300	1500	" 5	300	1100
" 30	300	1400	" 6	300	1100
Oct. 1	300	1200	" 7	300	1100
" 2	300	1200	" 8	300	1100
" 3	300	1200	" 9	300	1100

A third application of nitrogen was made on November 25th, the result of which corresponded with the former, but, as the growth of the cane was now being affected by the crowding of the root system in the tub, further data did not appear reliable enough for use.

It is seen that six days after the first application of nitrogen the transpiration was increased from 800 grams to 1500 grams, or nearly 100 per cent. A corresponding effect is noted after the second application. In looking back over the data in detail it will be seen that these increases in transpiration are greater, and more sudden and marked, than any such that resulted from variations in the effects of atmospheric influences. Also, that no appreciable increase in the transpiration occurred without an accompanying increase in evaporation from the soil in tub No. 1.

These observations upon the action of nitrogen in plant-transpiration appear to amply support our practical advices sent out to the managers of sugar plantations during the period of great drought last year. We advised that sodium nitrate should not be applied until after rain came, giving as our reason that the nitrogen would stimulate growth and cause increased transpiration, which would result in the rapid and greater exhaustion of the soil moisture, and a subsequent collapse of the crop, if the drought continued, which experience has shown to be liable in districts upon these islands, and for a period of six to twelve months.

Further, these observations appear to support our view, which is in opposition to the views of distinguished observers; *viz.*, that nitrogen (and not potash or phosphoric acid) is the vital and controlling element in the life and growth of plants. All constituent elements are necessary to this growth, but nitrogen seems to be supremely so. Our view in this matter rested upon the consideration, that nitrogen is a vital and essential constituent of protoplasm; that protoplasm is a component substance of all structural cells, whose development and increase are the explanation of plant-growth. All vegetable organisms contain protoplasm. The higher forms have this nitrogenous, fundamental substance admixed with large proportions of non-nitrogenous matters; but the incipient forms of life have been regarded as little more than drops of the protoplasmic fluid.

At the end of seven and one-fourth months the cane in tub No. 2 was taken up and divided into roots, stems, and leaves, whose proportions of water-free material were as follows:

Roots. Grams.	Stems. Grams.	Leaves. Grams.	Total weight. Grams.
31.8	53.9	483.2	568.9

The water evaporated from the soil in tub No. 1, during seven and one-fourth months, was 83,140 grams. The water evaporated by the soil, and transpired by the cane in tub No. 2, during the same period, was 167,250 grams, thus showing that the cane transpired, during the period between the dates of planting and cessation of growth, 84,110 grams of water. As the total amount of the dry material produced during the period of growth was 568.9 grams, it is thus shown that for each gram of water-free sugar-cane material produced, 147.8 grams of water were transpired.

It is understood that this experiment is not intended to represent what actually takes place when a crop is grown in exposure to sun and wind. In the field, evaporation decreases as the crop protects the ground from the sun and wind. In these observations the soil in each tub was kept in the same state of exposure, the cane in tub No. 2 being tied up in order not to shade the soil. As the evaporation from the growing crop increases, this increased transpiration is in greater proportion than the decrease in the soil evaporation. The actual evaporation from the cane growing in tub No. 2, during the several months, was as follows:

Month.	Age. Months.	Transpiration. Grams.
April	..	....
May	1	860
June	2	6,500
July	3	11,000
August	4	19,800
September	5	20,050
October	6	21,100

From these data we obtain guidance in practical field irrigation. We note the relative proportions of water that the cane can make use of at different stages in its development. To apply the same volume of water at the time of planting, and during the early period of growth, that is required by the cane of increased bulk and development, incurs a great loss of water and of the soil constituents that water removes. The transpiration-equivalent of other plants differs very greatly from that of the sugar-cane.

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