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Experiment Station Report.

The printed report of the "Work of the Experiment Station and Laboratories of the Hawaiian Sugar Planters' Association," has recently been issued by C. F. Eckart, Director, and will be published in serial form for the benefit of those who may not have received a copy thereof.

Cost of Irrigation

The report as a whole is valuable and interesting. The conclusions adduced under the heading "Yield of Sugar in five irrigation experiments," will be of particular interest to plantations relying upon high lift pumps to obtain water above sea level for irrigation purposes, as showing that beyond a certain limit the increased large production of sugar per acre is clearly obtained at such an increase of expense as to entail a considerable loss.

It has lately been shown (Vid. Vol. XXII, p. 541) that increased yields of sugar from extensive fertilization are not commensurate with the quantity of material applied beyond a certain point, and beyond this point the yield of sugar decreases proportionately as the quantity of fertilizer applied is increased; and we are now told, and it is demonstrated, that while the application of large volumes of water give an increased production of sugar, such increase would, under certain conditions existing on some irrigated plantations, relying upon expensive pumping plants for the water supply, be obtained at an unwarrantable cost.

While all of this is true, the meat of the matter is, of course, what will be done. We presume that it is the natural desire of all plantation managements to harvest large crops, to show an increased tonnage; and while this, no doubt, is a laudable desire, sufficient consideration is not always given to the vital question, does it pay?

Mr. Kennedy at the annual meeting pointed out that little or nothing is being done towards obtaining devices to lessen the cost of field work; Mr. Ekart showed that the use of too much expensive fertilizer works no benefit; Mr. Goodale showed where a saving could be effected in the use of molasses as stock food. But we fail to see the value of such suggestions unless followed by intelligent investigation and action. The suggestions made are all in the line of greater economy in the practical administration of plantation affairs. When sugar is high and other conditions affecting the industry are favorable, leaks of this kind are likely to escape detection; but there is at present certainly nothing particularly encouraging in the condition of the sugar market which would lead us to have very great hopes of good prices. What was prophesied prior to the passage of the Cuban Reciproity treaty relative to the prices which would be realized by the Cuban planter for his sugar has come true, and no one now seriously believes that any benefit will be derived by Cuba from reciprocity; but on the other hand it is painfully apparent that American sugar is contributing just .337c. for every pound of sugar manufactured, as its share in the advantages of Cuban reciprocity.

However that is now a dead issue and is merely referred to as illustrating the assertion that to produce sugar at a profit advantage must be taken of every possible opportunity to effect a saving. Therefore we say that there is *now* special need that the suggestions of the men named should be given careful consideration.

As a whole the Hawaiian plantation managers are as strong and efficient a body of men in their line as you may be able to find anywhere, and we certainly believe it is for them to say collectively whether or not sugar can be raised in these Islands at a profit. Statistics of the plantations will show that the profit realized during ten years past has not exceeded two per centum on the capital invested. Large profits can not be expected, but a reasonable one certainly ought to be obtained if the most is made of our opportunities.

And right here we want to urge the managers in the various districts and Islands of the group to stand together for the common good in all matters of plantation administration. It has been fully demonstrated that if the plantations of each Island will effect an organization or association for their mutual protection and benefit, much good will result from the harmonious action which will surely follow. As practical men, interested in the welfare of the sugar industry, they certainly ought to realize the advantages resulting in combining forces and working together. If they have differences, and strong men always do have differences, they should be laid aside for the good of the cause, and incidentally, of course, for the distinct pecuniary benefit of their respective shareholders.

Increase in the Consumption of Molasses for Cattle Feeding. In the report of the committee on utilization of by-products, presented to the last annual meeting of the Hawaiian Sugar Planters' Association, it is said: "To run molasses into the sea or waste ditches is criminally wasteful," and that there seem to be three methods only by which this valuable by-product may be made fully profitable: * * * "By its use for feeding working horses and mules, and for fattening cattle and hogs."

Yet we venture to say that the use of molasses for stock-feeding is not generally practiced among the planters themselves, much less among the stockmen; and this in the face of ample proof that a considerable saving can be effected in the hay and grain bills.

Molascuit, a combination of waste molasses and fine bagasse, was first introduced in Demerara or Barbados, and exploited as an economical and nutritious food for cattle, sheep, etc. It is mixed and dried for transportation, and this or similar preparations of beet pulp and molasses, has rapidly grown in favor, especially in the European countries. It is being largely used for feeding horses in the armies of the European powers, and in Germany and Austria the consumption of residuary molasses for cattle feeding grew from 60 tons in 1901 to about 5,000 tons in 1902.

In England it has been found that molasses for feeding live stock during certain portions of the year has become well-nigh indispensable. There molasses is purchased in casks, and is fed with hay and grain.

The article quoted from the "Saturday Evening Post" in the Report of the Committee (P. M., Vol. XXI, p. 571) clearly shows the value of molasses as a substitute for oats and other feedstuffs, and that while the molasses is both a tonic and health food, it also is valuable from an economic standpoint in that it reduces the cost of maintenance at least 25 per cent.

In the Southern States the planters are realizing the value of this important product, and the stockmen and farmers are coming to rely upon it more and more, and it is stated that by actual test a saving of 50 per cent. in food bills has been effected.

All of this, of course, is not new, but if it opens the field for discussion we will have accomplished our purpose.

The three methods of utilizing the waste molasses suggested by the committee are:

1. By distillation by which means spirits can be made, and also a by-product of distillation—potash for fertilizer;

2. By burning in properly constructed furnaces, so that the full heat value may be obtained for producing steam, and all the ashes saved for potash-making;

3. By its use for feeding working horses and mules, and for fattening cattle and hogs.

The first method seems, for reasons stated in the report, to be out of the question; and there remains to be considered the second and third methods, both of which are more or less in use on our plantations.

To properly burn the molasses requires specially constructed furnaces, the erection of which would entail considerable expense, which most managements would hardly feel justified in incurring so long as the bagasse is of sufficient quantity to answer the requirements.

But certainly in the last method there is merit and economy. It has long since passed the experimental stage, and the results attained in other countries certainly justify us in paying more attention to this important subject.

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*MACERATION OF BAGASSE.**

In the February number of this Journal (page 54) we made some reference to Mr. Prinsen Geerligs' new process of total exhaustion of sugar cane bagasse. This consists in macerating the bagasse from the second mill in a series of vessels with water in such a way that the bagasse first comes into contact with an already concentrated solution, gradually with more diluted ones, and finally with water. The exhausted bagasse from the vessels passes through a mill in order to get rid of the superfluous water, and is used as fuel just as ordinary bagasse.

A special commission, consisting of managers and chemists of factories, and of machinery agents, recently examined the process and gave the following verdict of it, as published in the "Archief von de Java Suikerindustrie" of 1903, page 983:—

"We assisted at the experiments made with the Prinsen Geerligs-Hamakers method of sugar extraction from bagasse, made at the Wonopringgo factory, in the residency of Pekalongan, Java, from 11-14 September, 1903, and give here our opinion, based on the results obtained during these experiments and on other facts, derived from former experiments made during this grinding season, experiments extending over an amount of 2,000 tons of cane.

1. The condition which the bagasse must possess for being properly treated in the battery is that it ought to be fine

*(From International Sugar Journal as revised by E. E. Hartman for the Hawaiian Planters' Monthly.)

and regularly crushed, such as can be obtained by having been passed through a cane shredder or crusher and double crushing with mills.

2. The experiments were made in a diffusion battery, which was originally used for the diffusion of cane-chips, and had a capacity of 280-300 tons of cane per 24 hours. This battery proved to have a sufficient capacity for the maceration of the bagasse from 450 tons of cane per 24 hours, with a loss on extraction of 0.25 parts of sucrose on 100 parts of cane, and a dilution of 19.6 parts on 100 parts of normal juice.

3. The increased extraction brings along with it a dissolution of non-saccharine matter; whilst the quotient of the juice extracted from the bagasse by a third mill was six points inferior to that of the first mill's juice, the juice extracted from that same bagasse by the maceration process had a quotient of purity differing by from eight to eleven points from that of the same first mill's or normal juice. The clarified juice from the mixture of mill juice and maceration juice was 0.7 per cent. less in purity than the clarified juice from the same cane extracted by treble crushing.

4. The moist bagasse from the maceration vessels could easily be deprived of its superfluous water by one three-roller mill and then showed an amount of moisture ranging from 45-50 per cent., with an average of 48 per cent. It could very well be burnt in the furnaces without preliminary drying in the sun.

5. When using the existing diffusion plant, which was originally not destined for the purpose of macerating bagasse, it had already become evident last year that the transport of the fresh and the exhausted bagasse claimed other exigencies of the mechanical part of the battery than the transport of cane chips. Both difficulties were already overcome this year by changes made in the carriers and other conveyors. At the same time it became obvious that the existing diffusion vessels were not of the most appropriate design for proper filling and discharging, though this inconvenience is likewise remedied against to a large extent. The circulation in the battery encountered peculiar obstacles, which, however, can easily be avoided when constructing a new, judiciously arranged plant. The dilution is still rather high; yet we are convinced that a new battery, constructed with the aid of the now obtained experience, will reduce it.

6. From a chemical point of view, apart from the reduced quotient of the clarified juice, no difficulties were experienced with the process, as exhausted molasses (having a quotient of +30) were as well obtained from this juice as from juice extracted by mills. Only the second masse-cuites were stickier than usual.

7. For factories possessing a good milling plant, and

having sufficient fuel (trash) to feed another boiler of a size in proportion to the capacity of the factory (at Wonopringgo when making 530 tons of cane per 24 hours + 1500 square feet h.s.) our conclusions as to the usefulness of the process are as follows:—

(*a*) With an appropriate maceration plant and a sufficient boiler capacity the loss of sugar on extraction can be reduced to 0.20-0.25 per cent. on 100 cane (which results, as has been said above, are obtained at the Wonopringgo factory, when working up 470 tons of cane per 24 hours).

(*b*) The probable financial results for an estate of 2,000 acres and 80,000 tons of cane will be shown by the following calculation:

Under the favorable circumstances referred to above, one had an extraction of 98 per cent. when using the maceration process, while an extraction of 92.5 was obtained by treble crushing with mills only.

When starting from a first mill's juice of 84.24 quotient, one got a clarified juice of that same purity when using the mills only, and one of 83.53 quotient when the mixture of mill juice and maceration juice was clarified.

Suppose the sucrose content of the cane to be 13 per cent.; the polarization of the dry sugar equals 97.5, and admit further a loss of sucrose in filter-press cakes of 1 per cent. of the sucrose indicated in juice, whilst the juice is in both cases worked out to a waste molasses of 32.5 quotient of purity.

Now the yield of raw sugar (refining crystals) is for milling work.

$$\frac{13}{100} \times \frac{84.24-32.5}{97.5-32.5} \times \frac{100}{84.24} \times 0.99 \times 92.5 = 11.25\%$$

and with the maceration process

$$\frac{13}{100} \times \frac{83.53-32.5}{97.5-32.5} \times \frac{100}{83.53} \times 0.99 \times 98.0 = 11.85\%$$

giving an advantage of 0.6 per cent. sugar on 100 cane.

For a factory as under review working 86.700 tons of cane, as surplus yield of $867 \times .6 = 520$ tons of sugar, could be obtained.

The surplus cost of manufacture of these 520 tons are (apart from sinking fund and interest on the purchase of the plant and the expenses of up keep), as follows:

Coolie wages 150×60×.10	$ 900
Two overseers at $40 per month	960
Extra trash for boiler	2,520
Transportation bags, etc., at $3 per ton	1,560
	$5,940

which amount is to be deducted from the yield of the sugar, 520 tons at $36.00. Under the already mentioned favorable circumstances the profit is

(520×36)—5,940 or $12,780 per annum.

—International Sugar Journal, Nov., 1903.

This showing is certainly very much in favor of this process. That 60 extra men should be required, i. e., 30 for each shift, seems rather extraordinary. The item $2,520 for extra trash for boiler, must represent the cost of bringing in a sufficient amount of dead leaves, etc., from the field to evaporate the extra amount of water, a practice in more or less general use in Java.—H.

WORK OF THE EXPERIMENT STATION AND LABORATORIES.

(Charles F. Eckart, Director and Chief Chemist.)

To the Trustees and Members of the Hawaiian Sugar Planters' Association:

Gentlemen: In this report of the Experiment Station, I beg to present for your consideration, results from field tests in irrigation, fertilization, stripping, and varieties harvested during the year 1903.

IRRIGATION EXPERIMENTS.

These tests were started by Mr. R. E. Blouin in June, 1901, and comprise ten plats in all, five with Lahaina cane and five with Rose Bamboo. The volumes of irrigation water applied in the respective experiments were as follows:

One inch per week.
Two inches per week.
Three inches per week.
Two inches every two weeks.
Three inches every three weeks.

While the yield of sugar in the experiments harvested in 1903 can not afford a strict comparison with those reported in 1901, owing to a difference in the conditions under which the respective crops were grown, it may be of interest to bring them together and consider the causes which have had a determining influence on the results. The tests started by Dr.

Maxwell in 1899 and cropped in 1901, gave very high yields of sugar, 15 tons per acre being the smallest quantity produced on one plat, the plat in question receiving three inches of water every three weeks. The same plat in 1903 yielded 9½ tons of sugar (average of Lahaina and Rose Bamboo). Naturally, the heavy draught on the soil occasioned by the large tonnage of the 1901 crop would, to a certain extent, influence the yields of a succeeding crop on the same area and must be taken into account in any comparison that may be made. Again, the fertilization of the two crops was materially different, a fact which alone would be responsible for an apparent discrepancy in results. As will be noted in the Report for 1901, Dr. Maxwell's irrigation experiments received potash and nitrogen as nitrate of soda, phosphoric acid being omitted. In Mr. Blouin's experiments, 100 pounds of nitrogen as ammonium sulphate, 100 pounds of phosphoric acid as double superphosphate, and 100 pounds of potash as sulphate were applied per acre.

The most potent factors in determining difference in yields on the same soil from year to year are, without doubt, the irrigation and various weather conditions, and these will now be brought into comparison for the two periods. (See Table I.)

It is seen from the foregoing table that the mean temperatures for the periods during which the respective crops were grown were quite different, the 1903 cane growing under a lower temperature than the 1901 cane for the last fifteen months of its career. For the first eight months the temperature ran very much the same for two crops.

DISTRIBUTION OF RAINFALL WITH RELATION TO TEMPERATURE FOR TWO CROPS.

TEMPERATURE	RAINFALL				PERCENTAGE OF TOTAL RAINFALL	
	Crop Harvested in 19'1		Crop Harvested in 1903			
	Rain—Inches	Rain—Total for Specified and lower Temp.	Rain—Inches	Rain—Total for Specified and lower Temp.	Crof of 1901	Crop of 1903
67	——	0	5.00	5.00	0	7.09
68	7.38	7.38	——	5.00	12.51	7.09
69	——	7.38	4.54	9.54	12.51	13.53
70	1.64	9.02	20.26	29.80	15.28	42.26
71	5.78	14.80	2.63	32.43	25.08	45.99
72	9.79	24.59	9.16	41.59	41.68	58.98
73	3.04	27.63	12.76	54.35	46.83	77.08
74	12.43	40.06	——	54.35	67.89	77.08
75	3.62	43.68	7.17	61.52	74.03	87.25
76	6.99	50.67	——	61.52	85.88	87.25
77	2.82	53.49	6.61	68.13	90.66	96.62
78	3.83	57.32	2.38	70.51	97.15	100.00
79	1.68	59.0	——	——	100.00	——

While a large rainfall during warm weather is most favorable for cane, copious rains with low temperature have a retarding influence on its growth, and in this connection it is interesting to note the distribution of rainfall with relation to temperature for the two crops.

A great difference is manifested in the percentage of rain that fell under similar temperatures for like periods. The crop of 1903 received 42.26 per cent. of its rain at a temperature of 70° F. and below, while the 1901 crop received 15.28 per cent. Under 76° F. the 1903 cane received 87.25 per cent. of its total rain, and the 1901 cane, 74.03 per cent. When we consider that the total rainfall between June, 1901, and April, 1903, was 70.51 inches, and between June, 1899, and April, 1901, 59 inches, the figures in the preceding table are very significant.

The volume of irrigation water applied to the experiments harvested this year was modified in accordance with the rainfall, and during those weeks that copious rains fell, irrigation was discontinued. When it is stated, therefore, that to one plat, three inches of water were applied per week, such quantity is understood to be the maximum amount of irrigation received by the cane in that experiment.

The rainfall and volumes of irrigation applied in the various tests for the two crops are shown in Table II.

In looking over the above figures it will be observed that for the irrigation experiments started in 1899 and concluded in 1901, the volumes of water received at certain irrigations were considerably larger than the statement of the experiment would indicate. With the exception of the "one inch per week" plat, Dr. Maxwell's experiments show the *average* irrigation to be as indicated in the title of the test, although for the second "growing season" the volume of water was in many instances doubled. For the "one inch per week" test, 9.5 inches were applied in July, 1901, and for other months and in other experiments the quantities of water used were almost proportionately increasd during warm weather.

With Mr. Blouin's experiments, as previously stated, the *maximum* quantity of water applied was in accordance with the terms used in stating the tests, the quantities of water used being reduced in proportion to the rainfall. These explanations are necessary for properly understanding the marked difference in total amounts of water applied for the separate tests during two different periods. Dr. Maxwell found two inches of water per week to give the best results in the tests conducted by him, and with the experiments planned by Mr. Blouin, three inches per week gave the highest yields. In comparing the total quantity of water (irrigation and rainfall) received by the "two inch per week" plat harvested in

1901, and the "three inch per week" plat harvested in 1903, it will be found that the difference amounts to only 24.5 inches.

Before considering the yields of sugar on the respective plats, it may be well at this place to show the influence exerted by the different volumes of water applied on the percentage of moisture in the soil. The following table gives the percentages of moisture (figured on dry weight of soil and at a depth of one foot in the furrow) as they vary during the period between two irrigations in the several experiments. They represent the average results from daily readings of a soil pygrometer devised by the United States Department of Agriculture, the moisture having been calculated on the resistance of an electric current passed through the soil at a depth of one foot.

MOISTURE IN SOIL AT DEPTH OF ONE FOOT.— PER CENT.

Day	1 Inch per Week	2 Inches per Week	3 Inches per Week	2 Inches in Two Weeks	3 Inches in Three Weeks
1	30.84	30.62	35.90	29.11	32.74
2	30.57	29.51	34.24	29.93	31.35
3	29.46	29 05	33.64	29.63	30.68
4	28.05	28.48	33.19	29.39	29.78
5	26.20	27.97	32.40	28.79	29.32
6	24.42	27.37	31.81	27.81	28.74
7	23.87	26.83	31.81	27.12	28.20
8				25.75	27.36
9				24.95	26.90
10				24.16	25.52
11				23.31	24.61
12				22.58	23.14
13				21.82	21.47
14				21.90	20.08
15					18.68
16					18.51
17					18.46
18					17.96
19					17.76
20					16.96
21					16.73

After irrigating, the "one inch per week" plat contained 30.84 per cent. of water, and before the next irrigation 23.87

per cent. Where two inches of water were applied per week the moisture drops from 30.62 to 26.83 per cent., and with three inches per week from 35.90 to 31.81 per cent. The greatest drop in moisture content between two irrigations was with the "three inches in three weeks" plat, when the water steadily decreased from 32.74 per cent. to 16.73 per cent. These calculations are for periods when the rainfall was small.

The average percentage of moisure in the soil throughout a period of eleven months is shown by the following:

MOISTURE IN SOIL AT DEPTH OF ONE FOOT.—PER CENT.

(Average of Daily Readings.)

Month	Rainfall	1 Inch per Week	2 Inches per Week	3 Inches per Week	2 Inches in 2 Weeks	3 Inches in 3 Wks.
June, 1902	1.25	30.78	30.92	32.27	23.36	....
July	2.21	29.54	29.60	33.29	24.70	24.35
August	1.46	24.35	28.25	34.86	26.22	24.16
September	2.19	23.97	28.06	32.06	28.27	22.17
October	2.25	28.53	28.01	....	29.39	27.51
November	8.35	30.83	27.90	34.38	32.50	31.14
December	8.12	33.86	33.89	33.40	35.50	35.90
Jan'y, 1903	3.28	30.27	32.62	31.15	33.50	34.21
February	4.32	31.05	32.36	30.40	33.35	33.01
March	.68	22.36	26.39	26.58	28.58	23.30
April	1.19	20.75	22.50	25.45	23.32	18.60
Average		27.84	29.13	31.38	28.97	27.43

The largest percentage of moisture was maintained in the "three inches per week" plat, the average amount being 31.38 per cent. The lowest percentage, 27.43, was in the "three inches every three weeks" plat. The influence of rainfall on the moisture content of the soil is readily seen in the preceding tabulation, and is graphically shown in Plate II.

Having fully considered the conditions under which the cane was grown in the various tests, the weights of cane per acre in the several experiments are presented. It should be explained that these yields of cane do not represent the quantity harvested from an actual acre of ground. Owing to the limited area of the field, the experiment plats are necessarily small and the area from which the cane was harvested and weighed was 750 square feet, the yields being calculated for an acre from such basis. It is believed, however, that the figures given are fairly reliable, although they must be taken as close approximations rather than actual quantities.

WEIGHT OF CANE PER ACRE.

Experiment	Weight of Cane per Acre, 1903. Lbs.		Average Weight of Cane. Lbs.		Average of 1901 and 1903
	Lahaina	Rose Bamboo	1901	1903	
One inch per week....	146,362	118,425	308,805	132,393	220,599
Two inches per week..	152,866	130,157	390,080	141,511	265,795
Three inches per week	160,882	136,778	285,343	148,830	217,086
Two inches every two weeks.............	141,773	121,349	328,657	131,561	230,109
Three inches every three weeks.......	115,579	118,077	226,170	116,828	171,499

The "three inches per week" plat easily leads the others in the quantity of cane produced for the crop of 1903, with the "two inches per week" plat a close second. This is at variance with the results for 1901, when the "two inches per week" plat made the best showing by a wide margin. As previously stated, the quantity of water received per acre by the "two inch per week" plat for 1901 was very much the same as that received by the "three inch per week" plat in 1903. This fact must be borne in mind in any comparison of the two crops.

The analysis of the juices and the weights of sugar per acre were as follows:

ANALYSES OF JUICES, 1903.

Experiment	Brix		Sucrose		Glucose		Purity	
	Lahaina	Rose Bamboo	Lahaina	Rose Bamboo	Lahaina	Rose Bamboo	Lahaina	Rose Bamboo
One inch per w'k	19.88	20.08	18.45	18.55	.201	.103	92.80	92.38
Two inches per week........	19.2	20.0	17.5	18.75	.343	.105	91.15	93.28
Three inches per week........	19.8	19.2	18.4	17.55	.227	.197	92.92	91.40
Two inches every two weeks....	19.74	20.35	18.95	18.85	.270	.109	95.99	92.62
Three in. every three weeks..	20 22	19.35	18 8	17.90	.224	.102	92.97	92.50

AVERAGE QUALITY OF JUICES, 1901-1903.

Experiment	Brix 1901	Brix 1903	Sucrose 1901	Sucrose 1903	Glucose 1901	Glucose 1903	Purity 1901	Purity 1903
1 Inch per week ...	18.82	19.98	16.84	18.50	.465	.152	89.43	92 59
2 Inches per week...	17.77	19.60	15.60	18.12	.700	.224	87.78	92.21
3 Inches per week ..	17.87	19.50	15.75	17.97	.730	.212	88.13	92.16
2 Inches every 2 wks	16.70	20.04	16.70	18.95	.730	.189	86.22	94.3[illegible]
3 Inches every 3 wks	17.77	19.78	15.70	18 35	.690	.163	88.35	92.73

WEIGHT OF SUGAR PER ACRE.

Experiment	Weight of Sugar per Acre. Lbs. 1903		Average Weight of Sugar. Lbs.		Average of 1901 and 1903
	Lahaina	Rose Bamboo	1901	1903	Lbs.
One inch per week.........	24,164	19,658	46,424	21,911	34,167
Two inches per week.......	23,939	21,840	54,605	22,889	38,747
Three inches per week......	26,497	21,488	44.387	23,992	34,189
Two inches every two weeks.	24,045	20,472	42,505	22,258	32,381
Three inches every three wks.	19,452	18,916	31,890	19,184	25,537

With Lahaina cane, the best results were obtained where three inches of water were applied weekly; while with Rose Bamboo two inches of irrigation per week gave slightly superior yields. The variation in yields due to differences in irrigation is much less for the 1903 crop than for that of 1901.

The amounts of solid matter in the cane and leaves, and the quantities of water used per pound of sugar produced, are given in the following tables, which are self-explanatory and of some interest:

SOLID MATTER PRODUCED IN IRRIGATION EXPERIMENT.

LAHAINA.

Irrigation	Solid Matter in Leaves, Tops, etc. Lbs. per Acre.	Solid Matter in Canes. Lbs per Acre.	Total Solid Matter Produced. Lbs. per Acre.	Solid Matter per Pound of Sugar.
One inch per week........	49,244	41,406	90,650	3.75
Two inches per week......	48,376	42,313	90,689	3.78
Three inches per week....	49,018	45,401	94,419	3.56
Two inches every two weeks	46,612	39,923	86,535	3.59
Three in. every three weeks	43,672	33,044	76,716	3.94

ROSE BAMBOO.

Irrigation	Solid Matter in Leaves, Tops, etc. Lbs per Acre.	Solid Matter in Canes. Lbs. per Acre.	Total Solid Matter Produced. Lbs. per Acre.	Solid Matter per Pound of Sugar.
One inch per week........	52,013	33,715	85,728	4.47
Two inches per week......	48,597	36,964	85,561	3.91
Three inches per week....	53,935	37,860	91,795	4.27
Two inches every two weeks	55,757	34,839	90,596	4.42
Three in. every three weeks	51,087	32,837	83,924	4.43

GALLONS OF WATER USED PER ACRE.

Experiment	Rainfall. Gallons.	Irrigation Water. Gallons.	Total Water. Gallons.
One inch per week..........	1,914,628	1,656,394	3,571,022
Two inches per week........	1,914,628	3,204,172	5,118,800
Three inches per week......	1,914,628	4,751,950	6,666,578
Two inches every two weeks.	1,914,628	1,737,856	3,652,484
Three inches every three wks.	1,914,628	1,819,318	3,733,946

GALLONS OF WATER USED PER POUND OF SUGAR PRODUCED.

AVERAGE FOR LAHAINA AND ROSE BAMBOO.

Experiment	Gallons of Water Used per Acre.	Pounds of Sugar Produced per Acre	Gallons of Water Used per lb. of Sugar.	Gallons of Water per lb. of Solid Matter.
One inch per week........	3,571,022	21,911	163.9	39.9
Two inches per week......	5,118,800	22,889	223.6	58.2
Three inches per week....	6,666,578	23,992	277.8	71.0
Two inches every two weeks	3,652,484	22,258	164.1	41.0
Three in. every three weeks	3,733,946	19,184	194.6	46.5

The irrigation experiments, as outlined in the preceding pages, were carried out with the greatest exactitude that small areas would permit, and while conclusions should not be hastily drawn from the results obtained from one crop, the significance of the data obtained from the tests harvested in 1903 may be summed up as follows:

Yield of Sugar in Five Irrigation Experiments

	Irrigation.	Av. moisture in soil at one foot.	Sugar per acre.
(1)	......3 inches per week	31.38 per cent.	23,992 lbs.
(2)	......2 inches per week	29.13 "	22,889 "
(3)	......2 inches in two weeks	28.97 "	22,258 "
(4)	......1 inch per week	27.84 "	21,911 "
(5)	......3 inches in 3 weeks	27.43 "	19,184 "

The difference in irrigation between 3 inches per week and 2 inches per week amounted to 57 inches for the crop. The difference in yields amounted to 1,103 lbs. of sugar. The amount of water required for each additional pound of sugar gained by using three inches of water per week amounted to 1,403 gallons, equivalent to 11,687 lbs. or 5.8 tons.

The difference in irrigation between 3 inches per week and 1 inch per week amounted to 114 inches for the crop, and the difference in yields, 2,081 pounds of sugar. The quantity of water required for each additional pound of sugar gained by using 3 inches of water, instead of 1 inch per week, amounted to 1,487 gallons, equivalent to 12,387 lbs., or 6.2 tons.

The percentage of water at one foot in the soil that was most favorable to the cane in the various experiments was 31.38 per cent., which was the average percentage of moisture maintained where 3 inches of water were applied. With 1 inch of water per week, the average amount of moisture in the soil at one foot depth was 27.84 per cent. To raise the average content of moisture 3.54 per cent. at a depth of one foot in the soil, required 3,095,556 gallons, or 12,893 tons of water per acre for the crop.

The water absorptive power of the Experiment Station soil (in place and figured on water-free soil) is 40.74 per cent. At a depth of one foot, in experiments where 3 inches of water were applied weekly, there was contained on an average 77 per cent. of the amount that could be absorbed.

These experiments have a practical bearing on irrigation on plantations, as they show that while the larger volumes of water gave an increased production of sugar, such increase would, under some conditions, be obtained at a loss. For instance, if we were to take the average cost of lifting 1,000,000 gallons of water one foot, to be $.09, where 3 inches per week irrigation were applied it would cost $42.77 per acre at 100 feet elevation. One inch of water at the same elevation would cost $14.90. The additional cost of irrigation in increasing the yield of sugar 2,081 pounds would be $27.87, or 1.3 cents per pound. At 200 feet elevation the cost per pound of sugar gained by increased irrigation would be 2.6 cents, and at 300 feet elevation, 3.9 cents. Naturally, these calculations are for a soil similar to that at the Experiment Station and receiving about the same rainfall.

The statement that it required 3,095,556 gallons or 12,893 tons of water (for the crop) to raise the average content of moisture, 3.54 per cent. at a depth of one foot in the soil, is sufficient to indicate the large amount of water which must necessarily have been lost through the land in causing such an elevation of the soil moisture. If the applied water were all held in the first foot of soil, only 13,877 gallons would be necessary, at each irrigation, for a 3.54 per cent. increase in water content. As these figures appear rather startling, it may be well to give the average percentage of water held by the soil at various depths, as determined in an irrigation experiment to be harvested in 1904. The figures represent the averages for eighteen irrigations, one inch of water being applied (to young cane).

Depth.	Before Irrigating.	After Irrigating.
One foot	25.65 per cent.	28.61 per cent.
Two feet	29.67 "	31.99 "
Three feet	33.61 "	34.86 "

The downward movement of the water applied to the cane furrow is more rapid than its lateral distribution, and consequently the second foot of soil is receiving part of the applied irrigation when the first foot is far from containing the amount it is capable of obsorbing.

The amount of water which would be required to raise the percentage of soil moisture at one foot in the furrow would necessarily vary with different soils, those of lower absorptive power requiring more water than those of higher absorptive power.

IRRIGATION EXPERIMENTS WITH SALT WATER.

These experiments were started by Mr. R. E. Blouin in June, 1901, and were harvested in April, 1903. The objects of the tests were to determine the influence of saline irrigation on the quality of the juice, yields of sugar, and the amounts of the soil elements appropriated by the cane.

The experiments were four in number, and the respective plats were irrigated with water containing the following amounts of salt:

(1) 50 grains salt per U. S. gallon.
(2) 100 " "
(3) 150 " "
(4) 200 " "

The weights of cane and sugar per acre and the quality of the juices are given in the following tables:

IRRIGATION WITH SALT WATER.

CANE PER ACRE.

SALT PER GALLON OF IRRIGATION	Salt Added per Acre During Crop Growth	Cane per Acre
50 grains salt per gallon.....	14,159 lbs.	135,675 lbs.
100 " " "	28,318 "	92,754 "
150 " " "	42,477 "	102,744 "
200 " " "	56.636 "	79,860 "

ANALYSIS OF JUICES.

SALT PER GALLON OF IRRIGATION	Degree Brix	Sucrose, Per Cent.	Glucose, Per Cent.	Purity	Chlorine, Per Cent.	Chlorine, Grs. Per Gal.
50 grains salt per gallon..	19.79	18.1	.249	91.46	.0520	30.212
100 " " "	20.07	18.3	.219	91.18	.0758	44.04
150 " " "	18.89	17.0	.281	89.99	.0778	45.086
200 " " "	18.07	16.35	.534	90.42	.1010	58.681

SUGAR PER ACRE.

SALT PER GALLON OF IRRIGATION	Cane per Acre	Sucrose in Cane, Per Cent.	Sugar per Acre
50 grains salt per gallon....	135,675 lbs	16.2	21,979 lbs.
100 " " " "	92,754 "	16.38	15,193 "
150 " " " " ...	102,744 "	15.22	16,638 "
200 " " " "	79,860 "	14.63	11,684 "

As was to be expected, the highest yields of cane and sugar were obtained where the smallest quantity of salt was contained in the irrigation water, and the lowest yields where the largest amounts of salt were added. Cane receiving 150 grains of salt per gallon of irrigation gave somewhat better results than where 100 grains of salt were contained in a gallon of irrigation, a fact which cannot be satisfactorily explained and must be attributed to other influences than those exerted by the salt.

In comparing the juices in these plats it will be observed that the density and sucrose content are highest for 100 grains of salt per gallon of irrigation, and show a diminution for 150 and 200 grains. Fifty grains per gallon of water gave brix and sucrose readings slightly lower than for 100 grains. In regard to purity of the juices in the various experiments, we find a steady decline from the 50 grains to the 150 grains plat, and then a slight increase of the 200 grain test over that with 150 grains. While density, sucrose and purity showed a tendency to drop as the salt was increased, the amounts of glucose were materially raised (the 100 grain plat in this instance being somewhat out of conformity with the general results).

If the "working quality" of these juices were to be judged solely by their purities, an erroneous opinion would be formed as to their respective merits owing to their large content of chlorides. The juices show a material, though disproportionate, increase of chlorine as the salt in the irrigation was raised. The plat receiving 50 grains salt per gallon of irrigation contains in its juice 30.21 grains of chlorine, equivalent to 49.8 grains of salt per gallon; the juice of the "200 grain" plat contained 58.68 grains chlorine, equivalent to 96.82 grains salt per gallon. The average chlorine content of the juice of normal cane is about 12 grains per gallon.

These results indicate that not only the yields of sugar are materially reduced by excessive amounts of salt in the irrigation water, but also that the availability of the sugar is considerably lessened.

The composition of the leaves and cane, together with the amounts of the principal elements removed from the soil are presented in the following tables:

SOLID MATTER PRODUCED PER ACRE.

Salt per Gallon of Irrigation	Solid Matter Produced per Acre. Lbs.		Total Solid Matter per Acre. Lbs.
	In the Cane	In Tops, Leaves and Dead Canes	
50 grains...........	38,274	50,839	89,113
100 grains...........	26,397	43,444	69,841
150 grains...........	28,151	40,950	69,101
200 grains...........	21,298	33,362	54,660

COMPOSITION OF THE SOLID MATTER OF THE LEAVES, TOPS, ETC.

Salt per Gallon of Irrigation	Organic Matter		Mineral Matter	
	Per Cent	Pounds Per Acre	Per Cent	Pounds Per Acre
50 Grains	91.39	46,462	8.61	4377
100 Grains	92.10	40,012	7.90	3432
150 Grains............	92.39	37,834	7.61	3116
200 Grains............	92.41	30,830	7.59	2532

COMPOSITION OF THE SOLID MATTER OF THE CANE.

Salt per Gallon of Irrigation	Organic Matter		Mineral Matter	
	Per cent.	Pounds per acre	Per cent.	Pounds per acre
50 grains.......	97.12	37,172	2.88	1102
100 "	96.96	25,595	3.04	802
150 "	96.96	27,295	3.04	856
200 "	97.36	20,736	2.64	562

MINERAL MATTER USED PER ACRE.

Salt per Gallon of Irrigation	In Cane. Pounds	In Trash. Pounds	Total Pounds
50 grains..........	1102	4377	5479
100 "	802	3432	4234
150 "	856	3116	3972
200 "	562	2532	3094

COMPOSITION OF THE MINERAL MATTER OF THE CANE.

Salt per Gallon of Irrigation	Lime Per Cent	Phos. Acid Per Cent	Potash Per Cent
50 grains...........	3.23	8.34	32.21
100 "	3.49	7.46	30.16
150 "	3.66	8.18	29.01
200 "	3.10	10.20	30.30
Average.........	3.37	8.54	30.42

COMPOSITION OF THE MINERAL MATTER OF THE LEAVES, ETC.

Salt per Gallon of Irrigation	Lime Per Cent	Phos. Acid Per Cent	Potash Per Cent
50 grains...........	4.92	2.53	12.92
100 "	4.76	2.22	10.51
150 "	3.79	2.45	13.74
200 "	3.72	2.21	12.25
Average........	4.29	2.35	12.35

WEIGHT OF ELEMENTS REMOVED PER ACRE.

Salt per Gallon of Irrigation.	Lime. Pounds.		Phos. Acid. Pounds		Potash. Pounds	
	Cane	Trash	Cane	Trash	Cane	Trash
50 grains	36	215	92	111	355	566
100 grains	28	163	60	76	242	361
150 grains	31	118	70	76	248	428
200 grains	17	94	57	53	170	310

TOTAL WEIGHTS OF LIME, PHOS. ACID AND POTASH REMOVED.

Salt per Gallon of Irrigation	Lime, Pounds.	Phos. Acid Pounds	Potash Pounds
50 grains	251	203	921
100 grains	191	136	603
150 grains	149	146	676
200 grains	111	113	480

NITROGEN REMOVED IN THE EXPERIMENTS.

Salt per Gallon of Irrigation	In the solid matter of Cane.		In the Solid Matter of Trash.		Total Nitrogen Removed per Acre.
	Percent.	Removed per Acre	Percent.	Removed per Acre	
50 grains	.188	72 lbs	.333	169 lbs	241 lbs
100 grains	.156	41 "	.301	121 "	162 "
150 grains	.170	48 "	.382	156 "	204 "
200 grains	.179	38 "	.378	126 "	164 "

MINERAL MATTER USED PER TON OF SOLID MATTER AND SUGAR PRODUCED.

Salt per Gallon of Irrigation	Lime, Pounds		Phos. Acid, Pounds		Potash. Pounds	
	Per Ton Solid Matter	Per Ton Sugar	Per Ton Solid Matter	Per Ton Sugar	Per Ton Solid Matter	Per Ton Sugar
50 grains..........	5.6	22.8	4.5	18.4	20.6	83.9
100 grains..........	5.4	25.2	3.9	17.9	17.2	77.9
150 grains..........	4.3	17.9	4.2	17.5	19.5	81.2
200 grains..........	4.0	19.0	4.1	19.3	17.5	82.1
Average........	4.8	21.2	4.1	18.2	18.7	81.2

NITROGEN USED PER TON OF SOLID MATTER AND SUGAR PRODUCED.

Salt per Gallon of Irrigation	Per Ton Solid Matter	Per Ton Sugar
50 grains....................	5.4	21.9
100 grains....................	4.6	21.3
150 grains....................	5.9	24.2
200 grains....................	6.0	28.0
Average	5.5	23.8

Although the quantity of sugar produced and its availability are materially influenced by the amount of salt in the irrigation water, the data presented in the preceding tables, do not indicate that the composition of the cane and leaves, with regard to nitrogen, lime, phosphoric acid and potash, is modified to any appreciable extent by the varying amounts of salt applied to the land. The mineral matter of the cane stalk contains 10.20 per cent. of phosphoric acid in the plat receiving 200 grains of salt per gallon of irrigation, as compared with 8.34 per cent. in the plat receiving 50 grains salt per gallon of water; also the mineral matter of the leaves shows a steady, though immaterial, decrease in its percentage of lime as the salt in the irrigation was raised. Such differences in results, however, may be accidental, and no degree of importance can be attached to the same until they are confirmed through a repetition of the experiments.

STRIPPING EXPERIMENTS.

These tests comprised four plats of Lahaina cane, planted July 27th, 1901, and grown under identical conditions, except with regard to stripping. The plats may be designated as follows:

Plat 1.—No stripping.
" 2.—One stripping; June, 1902.
" 3.—Two strippings; March and October, 1902.
" 4.—Three strippings; March, August and November, 1902.

The cane in these experiments was harvested in April, 1903.

The yields of cane and sugar and the quality of the juices in the several tests were as follows:

WEIGHT OF CANE PER ACRE.

No. of Strippings	Weight of Cane per Acre, Pounds
No Stripping	150,950
One "	156,467
Two strippings	142,586
Three "	140,031

ANALYSIS OF JUICES.

No. of Strippings	Density (Brix)	Sucrose in Juice	Glucose in Juice	Purity
No stripping	20.62	19.15	.311	92.87
One "	20.78	19.00	.258	91.43
Two strippings....	21.18	19.50	.241	92.06
Three "	19.82	18.15	.369	91.57

YIELD OF SUGAR PER ACRE.

No. of Strippings	Cane per Acre Pounds	Sucrose in Cane Per Cent	Sugar per Acre Pounds
No stripping	150,950	17.14	25,873
One "	156,467	17.00	26,599
Two strippings.......	142,586	17.45	24,881
Three "	140,031	16.24	22,741

The yields of cane and sugar were highest for the plat which received one stripping, the unstripped plat standing second. Where the cane was stripped twice lower yields were obtained than where it was unstripped. Three strippings likewise gave lower yields than two strippings.

As regards the quality of the juices, a certain variation was manifested in the different experiments, although the differences were not uniform. The unstripped plat gave the highest purity and the plat stripped twice gave the highest percentage of sucrose in its juice.

While the results herein presented are somewhat in favor of one stripping, the experiment is purely a local one and cannot be used as a criterion for localities where the exposure and climatic conditions are radically different from those of the Experiment Station. It should be stated that the plats in question were located at the exposed end of a field, where they received the full force of the prevailing northeasterly winds. The data, while of value to plantations having irrigated fields similarly exposed, would not apply to such wet localities as are found in the Hilo district, and where the consensus of opinion is in favor of frequent stripping.

In dry districts the dead leaves not only protect the cane in some measure from sweeping winds, but by shading the soil diminish the amount of evaporation from its surface. In wet districts this shading is not desired and the removal of the dead leaves gives the sun's rays more play on the wet soil and assists in a beneficial drying.

VARIETIES OF CANE.

In the adjoining tables are given results with twenty-one varieties of cane harvested in April, 1903. The canes in question were grown under identical conditions as regards soil, cultivation, fertilization and irrigation, and although harvested from small areas, the results afford an indication of what may be expected from the respective canes when grown on a larger scale. A repetition of these experiments is being made on areas sufficiently large to afford a strict comparison of their merits under the given conditions, and the tests will be concluded in April or May, 1904.

RESULTS WITH VARIETIES.

Analysis of Juices.

Variety	Density (Brix)	Sucrose Per Cent.	Glucose Per Cent.	Purity
Queensland 1	14.20	11.3	1.58	79.57
Queensland 4	16.28	13.7	1.28	84.15
Queensland 7	20.19	17.8	.215	88.16
Queensland 8 A	18.69	17.1	.169	91.49
Yellow Bamboo	16.98	14.6	.413	85.98
Yellow Caledonia	20.45	18.4	.192	89.97
White Bamboo	20.47	18.1	.180	88.20
Big Ribbon	17.07	14.3	.676	83.77
Striped Singapore....	15.48	13.75	.522	88.82
La. Purple	15.90	14.15	.335	88.99
La. Striped	16.00	14.40	.483	90.00
Tiboo Merd	17.44	15.80	.330	90.59
Otaheite	16.33	14.00	.831	85.73
Sacuri	18.34	16.15	.607	88.05
Demerara No. 74	16.83	14.90	.216	88.53
Demerara No. 95	18.34	16.80	.178	91.60
Demerara No. 117....	16.60	14.40	.463	86.74
Bongau	16.73	14.50	.615	86.67
Badilla	20.52	19.15	.614	93.32
Gee Gow	18.79	17.10	.217	91.00
Cavengerie..........	15.58	12.90	1.078	82.79

SUGAR PER ACRE.

VARIETY	Cane Per Acre Lbs.	Sucrose in Cane. Per Cent.	Sugar Per Acre Lbs.
Queensland 1	154,362	10.11	15,606
Queensland 4	128,938	12.26	15,808
Queensland 7	200,376	15.93	31,920
Queensland 8A	186,237	15.30	28,494
Yellow Bamboo	175,982	13.07	23,001
Yellow Caledonia	241,322	16.46	39,722
White Bamboo	239,580	16.20	38,812
Big Ribbon	209,088	12.80	26,763
Striped Singapore	133,294	12.31	16,408
La Purple	65,390	12.66	8,272
La Striped	132,422	12.89	17,069
Tiboo Merd	164,657	14.14	23.282
Otaheite	134,165	12.53	16,811
Sacuri	80,150	14.45	11,582
Demerara No. 74	261,360	13.33	34,839
Demerara No. 95	94.090	15.04	14,151
Demerara No. 117	333,670	12.89	43,010
Bongan	119.354	12.98	15,492
Badilla	43,560	17.14	7,466
Gee Gow	91,476	15.30	13,996
Cavengerie	163,786	11.54	18,901

A wide difference is noted in regard to the quality of the juices, the density varying between 20.47 degrees and 14.20 degrees Brix; the sucrose between 19.15 and 11.3 per cent.; the glucose between 1.58 and 0.169 per cent., and the purity between 93.32 and 79.57.

The highest yield of sugar was obtained with Demerara No. 117, which gave approximately 333,670 pounds of cane and 43,010 pounds of sugar per acre. The lowest yield was obtained with a New Guinea variety, Badilla, which gave 43,560 pounds of cane and 7,466 pounds of sugar per acre.

The wide divergence in yields with the varieties enumerated indicates most forcibly the great difference in conditions required for the most satisfactory growth of the various canes. The varieties in question will not be discussed at further length, until after the crop of 1904 has been taken off, when their relative sugar-producing value and economy in the utilization of the soil elements will be considered.

BUD VARIATION WITH BIG RIBBON CANE.

Occasionally a stool of cane is observed to contain a stalk which bears little or no resemblance to the variety from which it originated. Such shoots, termed "sports," are noted more particularly among striped canes, although they are sometimes found among varieties with less variegated markings, as for instance, Yellow Caledonia. Mr. H. Deacon, of the Pepeekeo Sugar Co., noted several sticks in a field of the latter variety which bore no resemblance to the parent cane, the rind of the stalk being completely hidden by a mass of valvety fur.

The Experiment Station is indebted to Mr. J. T. Moir, manager of the Onomea Sugar Co., for a number of "sports" from Big Ribbon cane. This latter variety, as is well known, is characterized by a large, heavy stalk, marked with dark red and yellow stripes. The "sports" in question were marked in various ways, some having one-half of the stick yellow, the rest of the stalk being striped (similar to ordinary Big Ribbon); others had only one narrow, red stripe, and still others were pure light yellow. Seed cane from these "sports" were planted with the following results:

Planted	Character of Cane Obtained
Normal Big Ribbon....................	30 normal canes ; 3 "white" canes
Cane, one-half striped (from Big Ribbon)..	31 striped canes ; 30 "white" canes
Cane, one red stripe (from Big Ribbon)..	8 "white" canes ; 0 striped canes
"White" cane (from Big Ribbon)........	54 "white" canes ; 0 striped canes

The quality of the juices may be seen in the following table:

ANALYSIS OF JUICES.

Cane	Brix	Sucrose Per Cent.	Glucose Per Cent.	Purity
Striped Cane.....	19 07	16 00	.379	83.90
"White" Cane (from ½ striped)	21.27	18.35	.231	86.27
"White" Cane (from "white").	20 27	17.40	.426	85.84

The "white" cane obtained from Big Ribbon appears almost identical with Yellow Caledonia, and is characterized by a firmer and more erect stalk, and materially better juice than the striped parent cane. The "white" cane is at present being grown for seed to be used in more extensive tests which are necessary before it may be designated as a new and better variety.

[To be continued.]

CONDITIONS AFFECTING SUGAR-BEET CULTURE IN THE UNITED STATES.

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During the last thirty years, beet sugar production has become a very important industry in Germany. In 1872 Germany was a large importer of sugar, the excess of imports over exports amounting to more than thirty thousand metric tons. In 1898 she was the largest exporter of sugar in the world, the excess of exports being more than a million metric tons. This rapid development of the industry in Germany has led many to believe that the people of the United States may succeed in producing their own sugar supply.

This proposition led the writer to study the conditions under which sugar beets are produced in Germany and to compare the conditions there with those which exist in that portion of the United States which has been designated by the Department of Agriculture as "the probable areas suited to beet culture." The writer is in sympathy with the efforts which are being put forth to extend the beet-sugar industry, but feels that a careful study of the subject from the point of view of commercial agriculture may, to some extent at least, enable the promoters of this industry to avoid misdirecting their energy. It is believed that a comparative study of the crops and field systems of Europe and America will lead to the conclusion that any attempt to establish the beet-sugar industry where it must compete with Indian corn is likely to prove a failure ,and that, for this reason, our efforts to establish this industry should be restricted to that part of the beet region of the United States which lies outside of the corn belt.

It has been fairly well demonstrated that vast areas within our borders have the requisite soil and climate for producing beets with a sugar content as high as, if not higher than, those of the best beet regions of Germany; and perhaps it may be conceded that the advantages due to cheap labor in Europe will be balanced by greater skill and the more general use of machinery in the United States. It does not necessarily

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*Albrecht Thaer wrote extensively on agriculture during the first quarter of the nineteenth century and is remembered as Germany's greatest agriculturist.

follow, however, that it will be economical for us to produce our own sugar supply. Suppose that we are able to produce beet sugar at as low a cost in labor and capital as is possible in Germany, and yet in order to do so it is necessary to use land which would yield a larger net return when employed in some other way. Would it then pay to sacrifice the more profitable crop in order to produce sugar? The solution of this problem requires an understanding of the fundamental principles of commercial agriculture. Pliny wrote, that he was a poor husbandman indeed who would buy anything which he could produce on his own estate; but Thaer* taught his generation to produce nothing which could be procured more cheaply upon the market. Pliny was writing for a time when the self-sufficient economy of the villa prevailed and when the goal of the husbandman was the direct satisfaction of all the wants of his household. Thaer lived at a time when commerce had so developed and industry had become so diversified that farmers produced primarily for the market, and he stated the most fundamental principle of modern agriculture when he said that each farm should be operated in such manner as will yield the largest, long-time average net return, and only those crops which will add to the total net return should be included in the field system; all others should be excluded.

This economic principle, which underlies all commercial agriculture, is an important factor in determining the geographical distribution of farm crops in modern times. It is a commonplace fact that sunshine and rainfall determine in a general way which plants may thrive here and not there, or there and not here. Some plants require much heat, while others thrive best in a relatively cool climate. Some require a great deal of moisture, while others get on with a very little. But while all plants will not thrive under the same conditions, there are always several species present to compete for each piece of land. This is true on every farm, and the more favorable the soil and climate the greater the number of species which enter into this struggle. When nature is left to herself, the plants which are best fitted for this warfare survive and occupy the land; but when man intervenes plants are divided into two classes, those which are useful and those which are harmful or of no use. The harmful plants are destroyed, the useful ones are cultivated. Under the regime of the self-sufficient agriculture of Pliny's time all the useful plants which would thrive were cultivated on each farm. The greater the variety of crops which each husbandman could produce, the greater the degree of his well-being, for each household was a little economic world living unto itself. But under the regime of modern commercial agriculture, where each farmer produces primarily for the city, national or world markets and buys upon the same market nearly everything he consumes, his well-being no longer depends upon the variety of his own productions, but upon his power to command the desired commodities upon the market. This power does not depend upon the variety, but upon the cost, quantity and price of the articles he takes to the market. Cost, or cheapness of production, is not the one determining factor; neither is the quantity of the product. The selling price would also be a poor guide in itself. But when the cost of producing an article, the quantity which one man can produce upon a given area, the capacity of the crop to fit itself into the field system, and the farm price of the product, are all taken together, it will be found that, with prices as they are at a given time, some crops will net the farmer a handsome profit, while others can be grown only at a loss. The economic well-being of the modern farmer depends, then, upon his capacity to select and produce that crop or combination of crops which one year within another, will make his farm yield the largest net return. Hence, it is no longer natural fitness to win out in the struggle, nor simply some degree of utility to man, but it is fitness to increase the total profit of the farm that determines which of the plants suited to the soil and climate of a region should be allowed to occupy the land.

The largest net return being the economic ideal in modern agriculture, it is the purpose of this paper to point out that even though the conditions with respect to the demands upon soil, climate and labor be as satisfactory, yet the production of beet sugar may prove relatively unprofitable for the farmers of the corn belt while it is a profitable crop in other parts of the United States and in Germany. This conclusion has been reached by a comparative study of the available crops and of the systems of crop rotation in the two countries under consideration. In central and southern Germany, and in fact almost everywhere in Europe where the soil was not too sandy, a three-field system of crop rotation prevailed during the middle ages and down to the beginning of the present century. This system consisted of winter grain, summer grain and fallow. During the fallow year the land was cultivated carefully to clear the field of weeds and to bring the soil into good tilth. At the close of the eighteenth century the industrial and commercial population was making such demands for agricultural products that the more intelligent farmers began to think it too great a waste to cultivate a third of the arable land each year with nothing growing upon it. A general search was made for crops which could be grown in the place of the bare fallow and at the same time allow the soil to be cleaned of weeds and cultivated preparatory to sowing grain. Unfortunately Indian corn, the one grain crop which can be grown successfully under such conditions, was found to be ruled out by the climate; so potatoes, turnips and beets were resorted to. Besides the root crops, clover was introduced and the rotation changed into a four-course system in which roots, summer grain, clover and winter grain succeeded each other in the order given. During the last quarter of the eighteenth century and the first half of the nineteenth this four-course system gradually replaced the old three-field system with its bare fallow. The root crops came to be called "fallow crops" because they were looked upon as incidental to the fallowing of the land in preparation for the grains. The grains continued to be the most profitable crops.

The old three-field system was the rule in northwestern Europe during the first two centuries of American colonization, yet the bare fallow never became permanently established in the colonies. The colonies were, from the beginning, well provided with valuable crops which could be cultivated while growing. Corn and tobacco made the bare fallow unnecessary and practically unknown in this country long before "fallow crops" were introduced in Europe; and while our country has greatly expanded, cotton, corn and tobacco have continued to make fallowing unnecessary in most parts of the United States. Of these crops corn is the one which interests us especially in this paper, because of the relation which exists between the corn belt and the area suited to sugar-beet culture.

The beet region of the United States is described in the Year-book of the Department of Agriculture (1901, p. 501), as "a large strip of land reaching across the northern portion of the country. It starts at the Hudson, takes in the southern half of New York, the northern portions of Pennsylvania, Ohio, Indiana, Illinois, Iowa and Nebraska, the southern half of Michigan, Wisconsin and Minnesota, all of South Dakota, large sections of Colorado, Utah, Wyoming, Montana, Idaho, Washington and Oregon, and the coast side of California." By comparing a map of this beet region with one showing the corn belt, it will be seen at once that from the Hudson River to Central Nebraska, the southern half of the beet region passes through the very heart of the corn belt, and if sugar beets are to be generally introduced as a profitable crop in the possible beet areas east of the great plains, they must show as large a net return, on the long-time average, as corn. It seems to be true, however, that the beet region extends farther north in Michigan than does the area of very profitable corn production. Here we may expect beets to compete with corn more effectively than in the heart of the corn belt.

But why should we ask that beets be as profitable as corn before we introduce them in the corn belt? We grow oats without asking that they be equally profitable. Why not grow beets for what profit there is in them, even if the cultivation of this crop does prove less profitable than the growing of corn? Or again, it may be asked, why not compare the profit to be derived from the growing of oats and of beets instead of comparing that of corn and of beets? The answer to this question is made clear when we study those principles which underlie the organization of the farm economy. The intelligent farmer seeks to operate his farm in such a manner as will make it yield the largest net return. The organization of the farm is essentially different from that of the factory. In mechanical pursuits it is the common thing for each man to devote all of his time throughout the year to the production of that one article or class of articles which he can produce to best advantage. In agriculture, however, the production of any one crop requires the attention of the farmer for only a portion of the year, and various crops demand his attention at different seasons, so that his labor, horses and machines are usually employed more economically in a system of diversified farming than in a single crop system, even if the crop needing attention at one time is less profitable than that requiring attention at another time.

The crops which require attention at the same time of the year may be looked upon as a group of competing crops. Thus the crops which require cultivation for six or eight weeks during the early period of their growth, such as corn, cotton, tobacco, potatoes, sugar beets, etc., may be classed together as a group of competing crops, because they compete for the attention of the farmer—for his labor, his horses, his tools and machinery. The winter grains, rye and winter wheat, or the spring grains, oats, barley and spring wheat, may be given as other crops. We may call these separate groups non-competing groups, because the members of one group require the attention of the farmer at a different time than do the members of other groups. For example, corn, cotton, etc., do not compete with oats, barley, etc. The farmer who seeks to use his labor and capital to the best advantage should select from the best group of competing crops that one which will yield the largest net return and should introduce as many non-competing crops into the field system as will yield a profit. When this principle is followed it will often happen that of two non-competing crops in the field system, one will yield a larger net return than the other. Yet, when the year's accounts are balanced, it will be found that the net returns are greatest when both crops are cultivated, even if one is less profitable than the other, for each crop represents the most profitable use to which the labor, horses and machines can be put at the given time, and if not used in that way that must be put to a less productive use or to no use at all. But of two competing crops, only the more profitable one should be produced.

With this principle in mind, let us note that while oats and corn may be brought into rotation so as to supplement each other in the economy of the farm, beets and corn cannot be made to do so. Beets may be brought into a system of rotation with oats, but not with corn. In some places, as where the sugar-beet region crosses the corn belt, in the United States, the one may be made to replace the other, but corn and beets cannot be made to supplement each other. The time devoted to the culture of oats is not subtracted from the time which the farmer may devote to the corn crop. The oat crop is sown and harvested at just the time when the farmer is not needed in the corn-field, and hence oats fit naturally into a profitable rotation with corn. Beets, however, demand cultivation at the same time when the farmer is needed in the corn-field, and if the beet crop increases the corn crop must decrease. Again, the corn and the beets are both cultivated while growing, so that either one prepares the soil for the small grain and makes fallowing unnecessary. Thus we find that beets and corn are competitors, while oats and corn are not. Oats can be grown with profit even though they do not yield so large a net return as corn, but unless beets yield as large a net return as corn, they can be grown only at a loss. Hence the question arises, is beet culture and sugar production more profitable than corn growing and pork production? If so, there is reason for trying to introduce sugar beets in the corn belt. If pork and beef production and the other industries based upon corn are more profitable than sugar production, the profitable culture of the sugar beet must be found outside of the corn belt.

Corn is the one grain which can easily be cultivated while growing. Where corn will not thrive, as is the case in central and northern Europe, the small grains, wheat, rye, oats, and barley, are the most profitable crops. In parts of southern Europe where it will grow, corn has replaced the fallow, but in those districts where sugar beets are being grown the climate precludes the growing of corn; hence sugar beets have only to show themselves as profitable as turnips, potatoes and fodder beets in order to enter as a profitable element into the field system. Thus, while in Germany the sugar beet has to compete with a relatively unprofitable element in the system of crop rotation, in the corn belt of the United States it must replace corn, where corn is king. Hence, it may be true that were the industry once established in the corn belt, our farmers would be able to produce beet sugar at a lower cost in labor and capital than can the Germans, and yet if corn shows a larger average net return than beets, beets will prove unprofitable in the corn belt, while at the same time they may remain profitable in Germany, because no very valuable crop is present to compete with them for a place in the German field system. A high duty on sugar may stimulate the sugar-beet industry to expand within the limits of the corn belt, but from an economic standpoint it will not be profitable to the nation until the beet regions of the world, where corn cannot be grown, are so occupied with sugar beets and the cane sugar regions are so taken up that the price of sugar on the world market will rise to a level which will enable beets to show as large a net return as corn. Let us consider for a moment what is likely to happen in this regard.

In France, Germany, Austria-Hungary, Russia and the western and northern parts of the United States there still remain vast areas which could be devoted to sugar beets if the price of sugar were slightly higher. The sane-sugar industry is capable of very great expansion when stable government makes capital safe in all those countries where sugar cane can be grown. On the other hand, the corn lands of the world are pretty well occupied. The United States is, and will doubtless remain, the principal corn country of the world. The Mediterranean and the Himalayas occupy most of the surface of the Old World which might otherwise have provided the proper climate for corn. Only the narrow part of South America and small parts of South Africa and Australia have a corn climate.

As the population of the world increases, there is sure to be an increasing demand for pork and other articles of commerce which are most cheaply produced where corn is plentiful. The demand for sugar will also increase; but when we consider the chances for expanding the two industries, there is no reason for believing that the increasing demand will result in as great a rise in the price of sugar as in the price of corn products. In fact the price of sugar has been falling while the prices of corn products have been rising, and the chances are that the relation between the price of sugar, on the one hand, and that of corn products, on the other, will never be such as to enable sugar beets to compete successfully with corn where the climate is especially suited for corn production. If corn would thrive throughout the beet sugar region of the United States, the sensible thing would be to abandon the beet-sugar industry at once; for so long as we can get our sugar with less outlay of labor and capital by producing corn and hogs for the foreign market and buying sugar from abroad, it would not be economical to produce sugar beets. There might be political reasons, it is true, for desiring to produce our own sugar supply, in order that we may "be in a position to ignore the foreign product," as Secretary Wilson has said. In this case, however, would it not be wise to look rather to the promotion of the cane-sugar industry within the United States and her dependencies?

But the "probable areas fitted to beet culture," extend beyond the corn belt to the west and north. Parts of Colorado, New Mexico, Utah, Washington, Oregon and a narrow belt along the Pacific Coast from the north to the south of California, are included within its limits. Here corn will not thrive. Wheat and barley are the most important grain crops. As these States grow older the fallow becomes more and more essential to the successful growing of grains; and in the absence of corn as a competitor, sugar beets have only to prove more profitable than fodder-roots, or a bare fallow, in order to be introduced with profit into the field system. Thus so far as competing crops are concerned the conditions are nearly the same in these Western States as in the sugar-beet regions of Europe, and there is no reason for doubting that where the rainfall is sufficient the beet-sugar industry of the West will be able in time, without any form of government aid, to compete successfully with the Europeans. A very great deal of the probable beet areas of the West require irrigation, however, and it may well be questioned whether the farmers who must pay the costs of irrigation will ever be able to compete on an equal basis with the European producers in beet-sugar production. It may possibly be found that the humid region outside of the corn belt which is suited to beet culture is sufficient to supply our demand for sugar. But if it is not, and this is questionable, the economy of trying to supply the home demand for sugar by cultivating beets is certainly doubtful.

It may be possible for us to supply our home demand for sugar by developing the sugar industry in the ultra corn-belt areas of beet culture and in the cane-sugar regions of the United States and her dependencies. We find here a suggestion regarding the attitude the government should take in attempting to foster the sugar industry in this country. It is certainly in accordance with our infant-industry policy to encourage, in some way, the development of the sugar industry in the West or any place else where there is good reason for believing that it will be able to stand on its own merits when once established. On the other hand, it is contrary to the same policy to force a growth of the industry in those parts where it cannot be expected to prove profitable longer than while the external stimulus is being applied.